FACTORS AFFECTING POSSIBLE MANAGEMENT STRATEGIES FOR THE NAMIB FERAL HORSES

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"These creatures moved through life in a peaceful, balanced state accented by
moments of pleasure and pain, fear and elation, playfulness and repose
that came and went like clouds moving across a clear blue sky."

Linda Kohanov
(in The Tao of Equus)

ABSTRACT

Demographic, biological and behavioural knowledge, together with information on the ecological interactions and impact of a species is fundamental to effective management of most mammal species. In this study, these aspects were investigated for a population of feral horses in the Namib Naukluft Park of Namibia, which lies within a part of the Namib Desert. An attempt was made to evaluate the justification of the continued existence of this exotic species in a conservation area, as well as to provide baseline information and recommendations regarding management of these horses. The study investigated the botanical component and grazing capacity of the area inhabited by the horses, as well as the demography and quality of life of the horses. The study further examined the possible negative impact the horses may have on the natural biodiversity of the area. Finally, it looked at the historic, scientific, aesthetic and economic values of the horses. The collected data was then used as a technical basis for the development of a draft management plan during a stakeholder workshop. The study proposed a range of grazing capacity values related to the total rainfall of the preceding twelve months, based on grass production in response to rainfall in different plant communities. The horses, as well as the native large herbivores, utilized the study area according to the patchy rainfall patterns typically found in the Namib Desert. The population size of the horses fluctuated between 89 and 149 over a ten year period. The social structure of the population was more significantly influenced by artificial interference than natural disasters which had implications on natality, mortality and genetic viability. Termite activity, measured as utilization of grass provided in bait boxes, did not correlate with horse density and seems, instead, to be influenced by soil properties. The results of ant and tenebrionid beetle species composition surveys and analyses did not indicate a significant negative impact from the horses on the study area. No indication could be found that the horses threaten the survival of any native species in the area or that they change the vegetation structure. It appears as if the biodiversity of the area is subjected to large natural stresses due to the continued and frequent desiccation in the desert environment. The impact of the horses is therefore probably minor to that of the climatic stochasticity. It also became apparent that the horses have developed significant historical, scientific and tourism value. The general public opinion is that the horses should be managed as a wild population with minimal artificial interference.

Key words: Feral horses; Namib Desert; grazing capacity; demography; biodiversity; indicators; termites; Tenebrionidae; ants.

UITTREKSEL

Informasie met betrekking tot demografie, biologie, gedrag, ekologiese interaksies en impak van 'n spesie op sy omgewing is noodsaaklik vir die effektiewe bestuur van meeste soogdiere. Genoemde faktore was ondersoek gedurende hierdie studie aangaande 'n bevolking wilde perde in die Namib Naukluft Park in Namibië, wat deel is van die Namib Woestyn. Die doel van die studie was om die voortbestaan van die perde, 'n uitheemse spesie in 'n beskermde gebied, te evalueer en verder om basislyn inligting te verskaf vir aanbevelings rondom die bestuur van die perde. Hierdie studie het eerstens die plantegroei komponent en drakrag van die veld ondersoek asook die demografie van die perde en hulle lewenskwaliteit. Verder is die moontlike negatiewe impak van die perde op die natuurlike biodiversiteit van die omgewing bepaal. Laastens is die historiese, wetenskaplike, toerisme en ekonomiese waarde van die perde ondersoek. Hierdie data was vervolgens gebruik as 'n tegniese basis vir die ontwikkeling van 'n raamwerk vir 'n bestuursplan gedurende 'n werkswinkel met die deelname van verskeie belangegroepe. Die studie het 'n reeks drakrag waardes voorgestel gebaseer op die grasproduksie in verhouding tot die hoeveelheid reënval gedurende die voorafgaande twaalf maande in verskillende plant gemeenskappe. Die perde, asook die inheemse groot herbivore, het die studie gebied benut volgens die oneweredige verspreiding van reënval wat tipies is vir die Namib Woestyn. Gedurende 'n periode van tien jaar het die grootte van die populasie gewissel tussen 89 en 149 perde. Die sosiale struktuur van die perde bevolking is meer betekenisvol beïnvloed deur kunsmatige inmenging as natuurlike rampe wat weer implikasies op die geboortes, sterftes en genetiese lewensvatbaarheid van die populasie gehad het. Termiet aktiwiteit, gemeet deur middel van die hoeveelheid gras wat deur termiete uit grasgevulde bakkies verwyder is, was nie gekorreleer met die digtheid van die perde nie, maar was eerder deur die substraat eienskappe van die grond beïnvloed. Resultate wat verkry is uit die opnames en verwerking van mier en tenebrionid kewers se spesiesamestelling, het nie op 'n betekenisvolle negatiewe impak van die perde gedui nie. Geen tekens of bewyse kon gevind word dat die perde die oorlewing van enige inheemse spesie bedreig nie, of dat hulle die plantegroei struktuur verander nie. Dit wil eerder voorkom asof die gereelde en aanhoudende droogte en uitdroging in die woestyn groot natuurlike druk op die biodiversiteit van die area plaas. Die impak van die perde word dus verdwerg deur die klimaat stogastisiteit. Dit het egter duidelik na vore gekom dat die perde betekenisvolle historiese, wetenskaplike en toerisme waardes het. Die algemene opinie van die publiek blyk te wees dat die perde soos 'n wilde bevolking bestuur moet word met minimale kunsmatige inmenging.

Sleutel woorde: Wilde perde; Namib Woestyn; drakapasiteit; demografie; biodiversiteit; termiete; miere; Tenebrionidae.

LIST OF ABBREVIATIONS

CDM	-	Consolidated Diamond Mines
Ma	-	million years ago
m.a.s.l.	-	meters above sea level
MET	-	Ministry of Environment and Tourism (Namibia)
N_e	-	Genetic effective population size
NNP	-	Namib Naukluft Park
pers. comm.	-	personal communication
pers. obs.	-	personal observations
SAR	-	South African Railways
USA	-	United States of America
unpubl.	-	unpublished
WWI	-	World War I

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CHAPTER ONE: INTRODUCTION

Chauvet Cave wall painting dating back 30 000 years.

INTRODUCTION

Man has conquered the world. He has successfully over-populated and exploited the resources of earth to a point where the future is uncertain and the need for environmental management has become crucial. During his quest to conquer every continent and island, he made use of, and abused the Earth's natural resources, including animal populations. Of paramount importance was the horse (*Equus caballus*). The domestication of the horse was a milestone for humanity since it provided humans with speed and agility, which in turn changed the pace and scope of human advancement. The horse carried man across the world in exploration, colonization and the waging of centuries of wars. The courage, reliability and strength of the horse was admired and praised through the ages. It is perhaps for this reason that horses are still today often regarded as special animals and their plight initiates strong responses from the public anywhere in the world. No exception is the controversy excited from time to time regarding the feral horses in the Namib Desert.

This population of feral horses in Namibia likely originated from horses left or lost during colonization and First World War activities in the early 1900's, near a railway station named Garub, in the south-west of Namibia. Although the use of motor vehicles was growing, horses still maintained a vital role in the transport of humans and cargo throughout Africa. Shelling at Garub scattered the Allied troops' horses in 1915 and it is likely that some of them, as well as breeding stock from neighbouring farms, took refuge in this unlikely place for the survival of a domesticated animal. The area the horses inhabit is on the periphery of the Namib Desert, which has an arid to extreme-arid climate and is one of five west coast deserts within subtropical latitudes (Ward, Seely & Lancaster 1983). Such an environment would produce little fodder for grazing. However, studies indicate that the Namib horses could be a unique population due to their exposure to high selection pressure in an extreme environment. Among other traits, their blood typing revealed a new variant in the Pi system, called "q", which most likely is a mutation that became established in the population after their isolation (Cothran 1994) in the Namib Desert.

Being a domestic species introduced into an area where *E. caballus* did not previously occur, the Namib Desert's horses are regarded as feral, non-native and exotic. Controversy started to surround them when their habitat was included within the Namib Naukluft Park (NNP) in 1986. According to the Nature Conservation Ordinance (Ordinance 4 of 1975), national parks or game reserves are proclaimed as areas for the propagation, protection, study and preservation therein of wild animal and plant life, as well as objects of geological, ethnological, archaeological, historical and other scientific interest. The Ordinance further prohibits hunting in, removing animals or plants from, and introducing domestic animals into the confines of these protected areas, except by permission of Cabinet (Barnard 1998). Therefore, after the establishment of the NNP, a move was made to remove the horses from the NNP based on them being exotic. This decision was strongly opposed by many people from within the ministry and the public (J.H. Coetzer, pers. comm.). Thus, no action took place, but neither were the horses granted an exemption from exotic status. The matter was simply laid aside, not resolved and it is revisited every time reports appear about the horses being over-populated and perhaps suffering due to the scarcity of food and water needed to support their numbers.

Opinions varied greatly. From a purist point of view, the horses are perceived as an exotic species which has no right to exist in a national park or game reserve dedicated to protecting the native environment. From this argument came various accusations about the horses being a threat to the environment in general and in particular to the species that occur naturally in the area. Horse enthusiasts, on the other hand, admired the survival ability and freedom of the wild horses, while some animal rights activists felt the horses were suffering in their survival struggle under such harsh conditions. However, none of the proponents of these arguments had any scientific data available on which to base or contest any of these claims.

From their origin during the First World War until the 1980's the Namib Desert horses were fairly obscured from both public and scientific attention because they lived in an area restricted due to diamond mining. In 1980, J.H. Coetzer from Consolidated Diamond Mines brought the horses' existence and quality of breed under the attention of F.J. van der Merwe, then Director of Animal Production in South Africa (J.H. Coetzer, pers. comm.). Van der Merwe wrote the first report on the horses in 1984, which focused on the conformation and possible origin of the horses. This was followed by further reports and a few articles in popular magazines dealing with aspects of the horses' condition, ecology and physiology (Eyre 1985 as quoted by Meyer 1988; Meyer 1988; Mariner 1987; Sneddon 1990). In 1994, the author conducted a study on their behavioural ecology (Greyling 1994) and has continued to monitor the population since.

Other feral horse populations around the world have been studied and monitored for decades. Since the 1960's, research mainly concerned aspects of social structure, population growth rates, population control methods, etc. (Feist & McCullough 1976; Berger

1986; Garrott 1991; Turner, Liu & Kirkpatrick 1996; Gross 2000). Feral horse populations that occur on state land in some other countries are protected by law and are treated as "wild animals" and managed as such, even though they are not native to the environment. For example, horses and donkeys in the United States of America are protected by law and managed through the government's Bureau of Land Management (Public Law 92-195, December 15, 1971). However, many people are of the opinion that horses in general are destructive to the environment and are an economic loss because they are generally not used as a food source for humans and their role in the domestic world has been replaced by motorization. However, horses have been studied extensively and it has been found that, although they can be considered invasive in some habitat types, this is not necessarily the case in all habitats. Additionally, horses are revered by so many people they have an appeal for tourists and enthusiasts, creating avenues for economic gain. Each population of horses should therefore be studied individually to determine what their specific role/impact is in a given ecosystem and the socio-economic impact of the population on the surrounding environment.

This study attempts to evaluate the justification of the horses to remain inside the Namib Naukluft Park. As mentioned above, the Nature Conservation Ordinance provides not only for "wildlife" to be preserved but also for objects of historical and scientific interest. If these latter criteria could be applicable to the horses, thereby allowing for their protection, other criteria such as their impact on the environment should also be determined. Therefore, this study endeavors to determine if the horses have a significant negative impact on the naturally occurring biodiversity of the area, and to provide baseline information regarding the future management of the population whether it be within or outside the NNP. Baseline information includes aspects of demography, carrying capacity of the area, socio-economic impact as well as historical, tourism and scientific value of the horses. The study finally attempts to bring all these aspects into focus for the recommendation of practical, sustainable management strategies partly through the contribution of a stakeholder workshop.

CHAPTER TWO: THE STUDY AREA

Design based on Celtic art c. 600BC - 50AD, from "THE LORD OF THE RINGS" movie poster (2002).

LOCALITY

The study area is located in southwest Namibia, in the southern part of Africa, between 26° 25' to 26° 45' latitude South and 15° 55' to 16° 12' longitude East. It is 20 km west of the town of Aus and 80 km east of the seaport, Lüderitz (Fig. 2.1). The greater part of the area lies north of the B4 (T0402) trunk road between Aus and Lüderitz. This northern area forms part of the Namib Naukluft National Park (NNP) while the area south of the B4 was part of Restricted Diamond Area 1 which is in the process of being declared as a new national park. The focal study area or area mainly utilized by the horses cover 40 000 hectares (400 km²) or approximately 18 x 23 kilometers (Fig. 2.2). This area has a game proof fence on the southern and eastern boundary, bordered by commercial farms. Food availability and distance from the water trough determine how far the horses graze to the north and west, which is within the NNP.

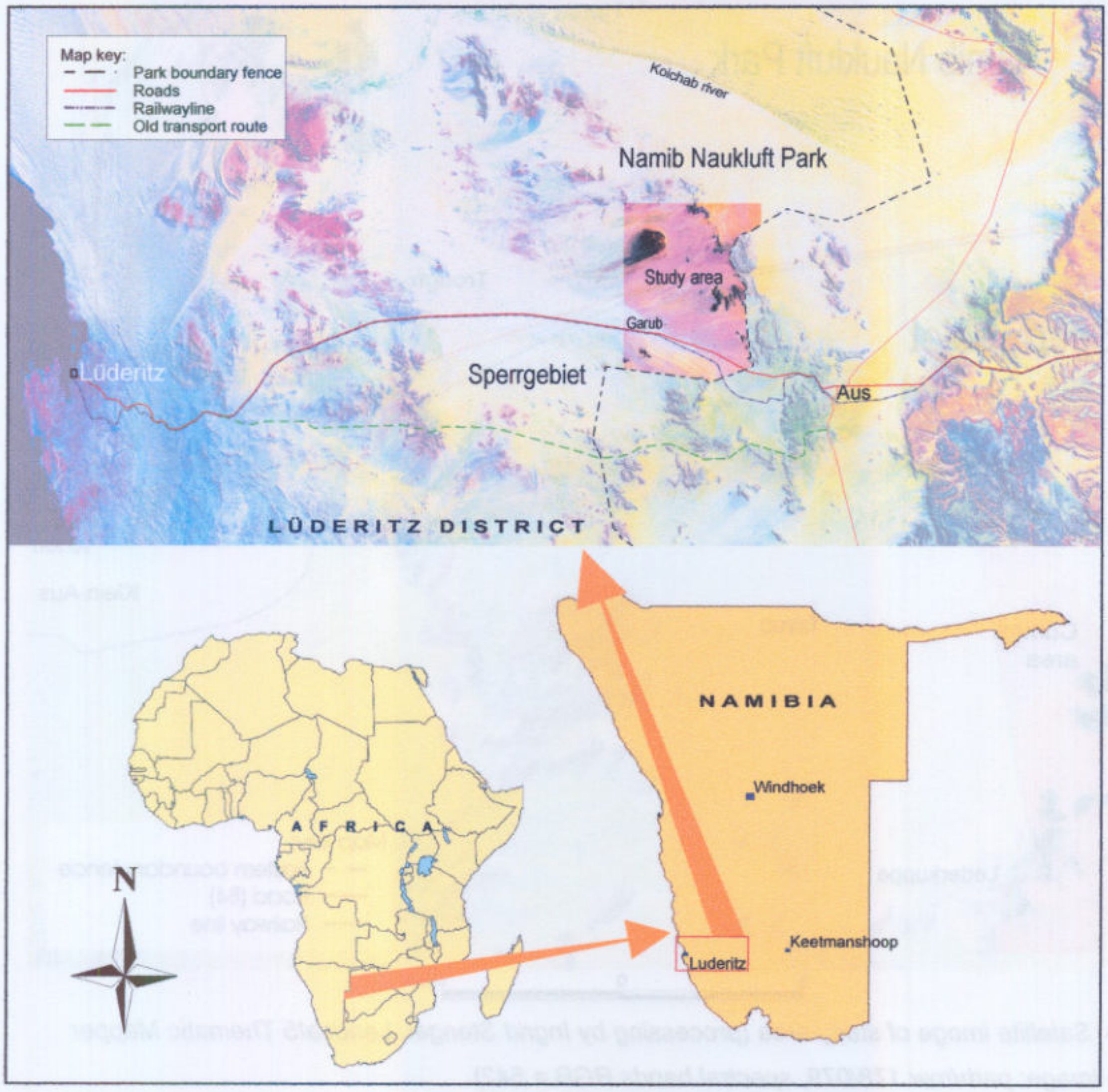


Fig. 2.1: Location of the study area.

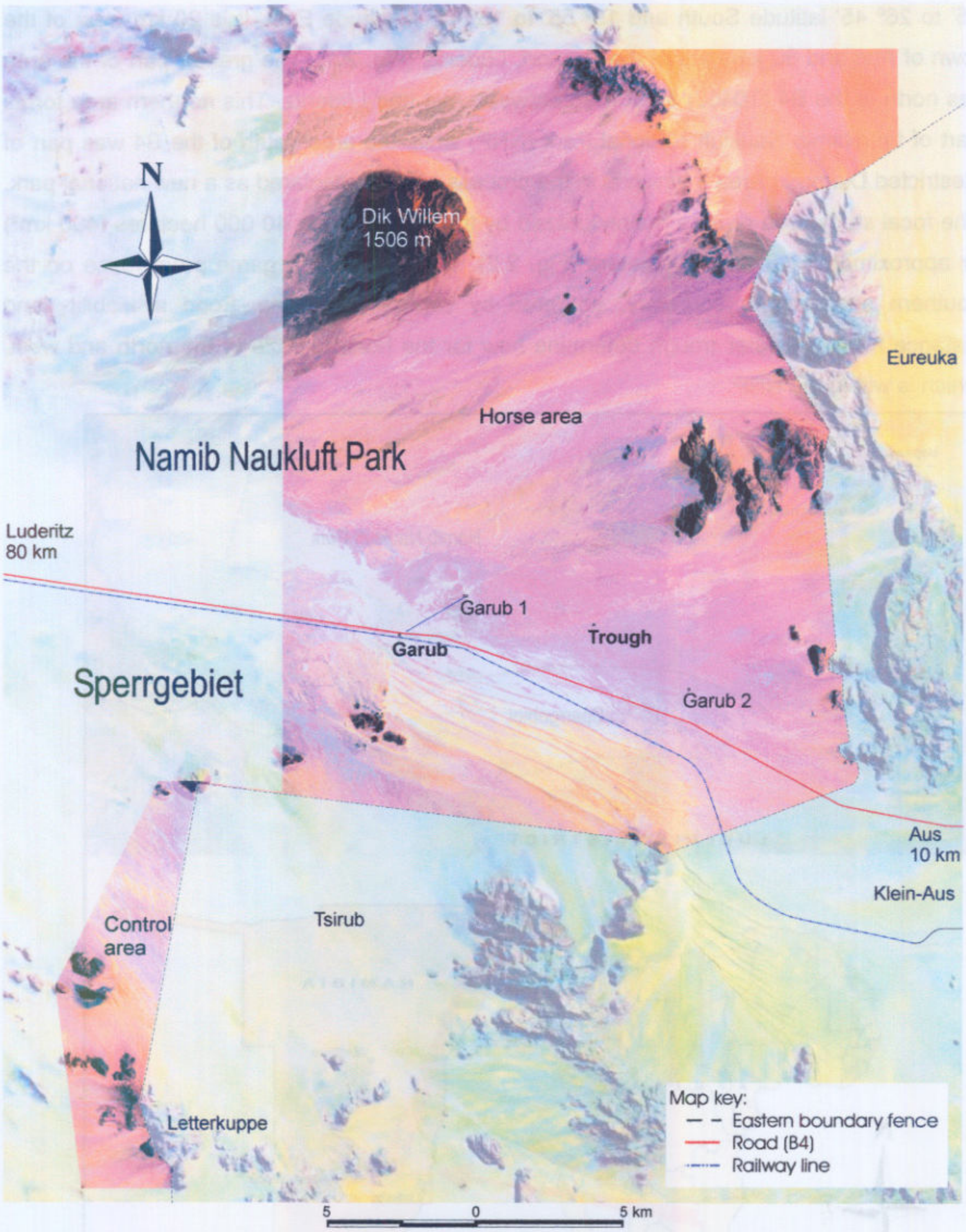


Fig. 2.2: Satellite image of study area (processing by Ingrid Stengel, Landsat5 Thematic Mapper Satellite Image: path/row 178/079, spectral bands RGB = 542)

TOPOGRAPHY

Landforms in the study area include the Namib Plains with the Great Escarpment on the eastern periphery and the Namib Sand Sea starting on the northern bank of the Koichab River, which is just north of the study area. The Namib Plains in the study area are covered with quartz gravel and thin layers of aeolian sand. Areas with exposed desert crust (calcrete) are common and many rocky outcrops and inselbergs (isolated mountains) protrude from the plains. The eastern part of the study area rises rapidly to the Great Escarpment from where shallow drainage lines originate. These drainage lines are eroded sporadically with the occurrence of thunderstorms. A patch of sand dunes, orientated in a northwest, southeast direction, occurs in the south of the study area. These dunes are typically longitudinal dunes with dune streets between them. The lowest altitude in the study area is 760 m above sea level at Garub 1 and it rises to 1 200 m.a.s.l. on the eastern boundary. The highest point in the study area is the summit of the mountain Dik Willem at 1506 m.a.s.l (Fig. 2.3).

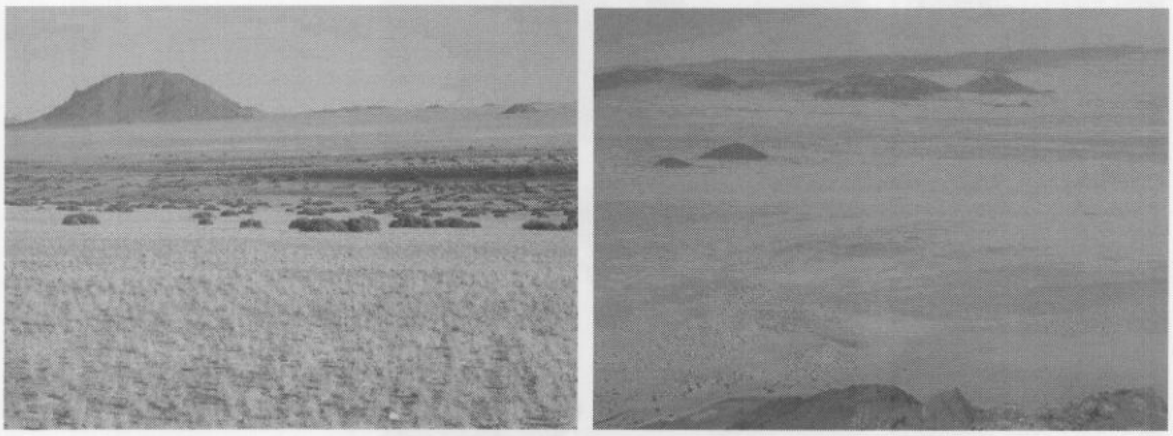


Fig. 2.3: Topography of the study area: left) dunes in foreground with Dik Willem on horizon; right) looking southeast towards Aus over the plains from the top of Dik Willem.

GEOLOGY & SOILS

The coastal plain which forms part of the Namib Desert, was formed by erosion of the continental edge which lifted up when South America and Africa moved apart about 128 Ma ago (Mendelsohn, Jarvis, Roberts & Robertson 2002). The study area is on the eastern edge of the Namib Desert. The geology of the area around Aus, including the study area, was described by Jackson (1976). According to this description, the rock formations in the study area are mainly from the Namaqua Metamorphic Complex and Garub sequence. However, Jackson (1976) focused on the inselbergs and underlying formations, he did not describe the younger calcrete formations or soils. He did, however, indicate these on a geological map for the area around Aus (Jackson 1975). This map is adapted and shown in Fig. 2.4. The mountain commonly known as Dik Willem is an exception in the environment because it is a diatreme-like, subvolcanic carbonatite complex that intruded the Precambrian basement of the Namaqua Metamorphic Complex possibly around 49 Ma ago (Cooper 1988). The Namaqua Metamorphic Complex was derived from the erosion material of the Congo and Kalahari Cratons and mountains of the Vaalian, which were transported towards the sea and welded onto the cratons in the Mokolian period. This metamorphic material consists of both granites and volcanics (Grünert 2003).

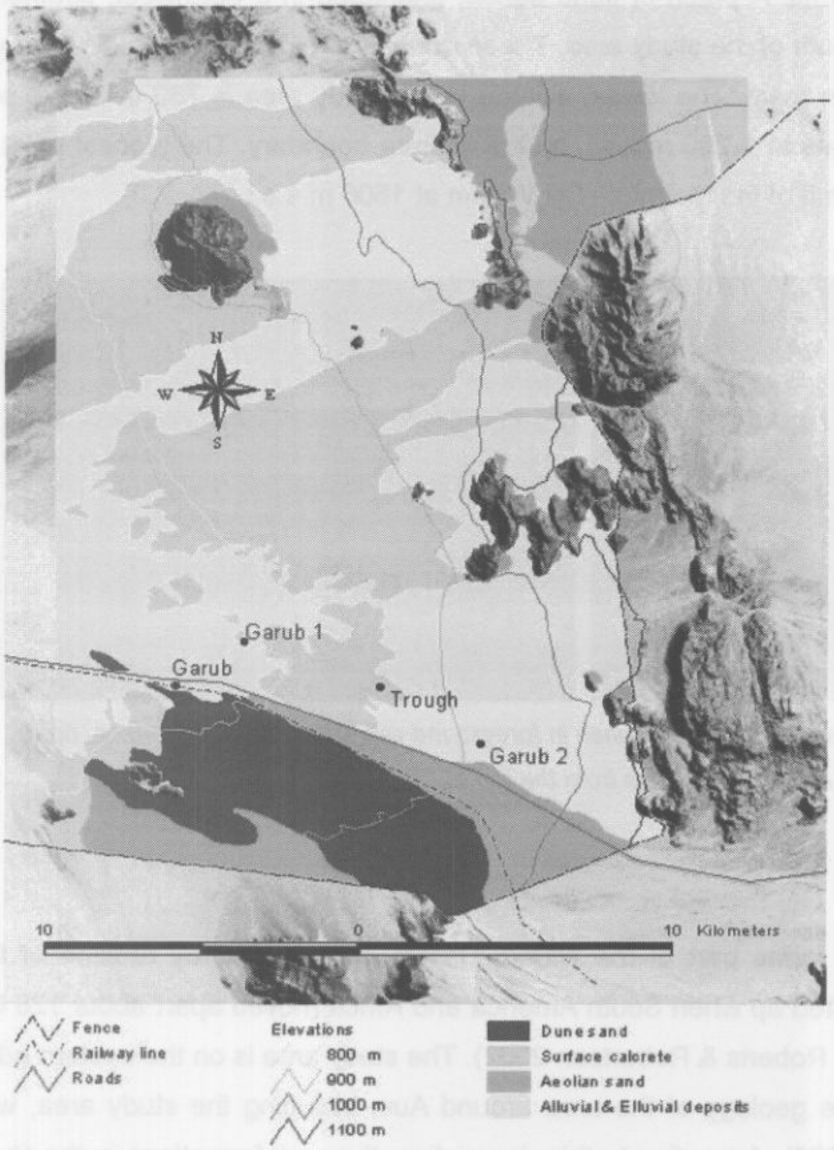


Fig. 2.4: Surface geology of the plains in the study area, adapted from the geological map by Jackson (1975). For detailed geology of the inselbergs and rock formations see Jackson (1975) and the Geological map of Namibia, sheet 2616 – Bethanien, 1999, Geological Survey of Namibia.

Dominant soils and surfaces in the study area are Lithic Leptosols, Eutric Regosols, Alluvium, sand, gravel and calcrete plains (Mendelsohn *et al.* 2002). These soils have a very low suitability for crop cultivation and lack characteristics, such as water-holding capacity, that is necessary for high soil fertility. Water-holding capacity in these soils is low due to the lack of sufficient amounts of clay and silt components and organic matter. Thus, they are also prone to erosion from sudden storms and constant wind. Leptosols are coarse-textured soils of limited depth, which often contain an abundance of gravel. Within 300 mm of the surface, a continuous highly calcareous or cemented layer of hard rock is usually found with Leptosols. Regosols are weakly developed medium- or fine-textured soils created in arid climates and which occur in actively eroding landscapes, usually not reaching depths of more than 500 mm. Vegetation cover on both types of soil is generally sparse because of their low water-holding capacity and nutrient deficiency (Mendelsohn *et al.* 2002). Alluvial deposits occur widely and consist of heavier, weather resistant material, which developed out of erosion. Calcretes are also common in the Namib and are formed by the penetration of dissolved lime ($CaCO_3$) into the upper soil layers. This lime either already exists in the rocks, or is a result of the weathering of carbonate rocks which produces dust containing lime. This dust is blown into the air where it is absorbed by rain or fog and reaches the ground with rainfall. Due to strong heating of the desert surface, the ground moisture often rises and evaporates, leaving the lime on the ground to cover and cement sediment and soil particles (Grünert 2003). The sand dunes in the southern part of the study area consists of fine quartz sand, red in colour, due to iron oxide which covers the sand grains as a thin coating. These red sands in the eastern Namib mainly originate from the interior (Kalahari) and are blown in by the very strong east winds (Grünert 2003).

SURFACE & GROUND WATER

No permanent surface water occurs in the study area. Rainwater collects in hollow weathered rocks and pans after significant rain and is available for a few days to a few weeks depending on the amount and frequency of rain. Historically, these basins of collected rainwater lasted longer in the mountains at Aus and on the farm Tsirub (east and south of the study area), and were called "fountains" during high rainfall years. These fountains have been mostly dry since the 1960's except for short periods after good rain. The closest source of surface water is the permanent fountain at Kaukausib approximately 60 km southwest of the study area.

The study area also has very little ground water with most boreholes in the vicinity supplying only 0 to 5 m^3/hour (Christelis & Struckmeier 2001). The first borehole in the study area was sunk at Garub 1 on 29 February 1908 to a depth of 68 m, the water rose to 54 m and supplied 4 m^3/hour (Bravenboer & Rusch 1997). This borehole was destroyed by the German military during the First World War in 1915. Subsequent boreholes were drilled at Garub 1 by the Allied Forces and later to provide water for steam locomotives. The sole remaining borehole at Garub 1 has fallen into disuse but can still be used when necessary. A borehole at Garub 2, which was originally drilled to provide water for livestock during the "emergency grazing years", has been used since 1992 to provide water for horses and game. This borehole is approximately 120 m deep with the water level currently around 100 m and supplies 2.7 m^3/hour. The quality of the water from this borehole is classified as Group A, which is excellent quality water, with corrosive properties that can dissolve calcium carbonate (Appendix A).

CLIMATE

Climate has a major influence on all aspects of life in Namibia. The climate in Namibia and specifically the Namib Desert has been dry for the past few million years. The reason for this arid climate over the Namib Desert is the presence of the cold Benguela Current and the South Atlantic Anti-cyclone. An anti-cyclone is a region of high pressure around which air flows anti-clockwise in the southern hemisphere. Areas experiencing high barometric pressures are indicated by clear skies. The Benguela Current, which is a cold ocean current in the Atlantic, cools the air so much that it cannot rise high enough to form rain bearing clouds that could move inland and rain. Therefore, it remains trapped at lower elevations and is seen as fog.

The Namib Desert thus receives little moisture from the Atlantic Ocean. In addition, moist tropical air from the north and east interior are often blocked by strong breezes from the sea (caused by the South Atlantic Anti-cyclone). On occasions when this moist air does reach over the escarpment into the hot desert it quickly warms and dries out (Louw & Seely 1982). Temperature, humidity, rainfall, barometric pressure, wind speed and direction have been measured in the study area from March 2003 to the present with a Davis Vantage Pro Weather Station (Davis Instruments, Hayward, California, USA). Additional rain gauges were placed at 12 locations to monitor rainfall in an east-west, north-south and altitude variation. The year is divided into winter and summer according to temperature averages. Summer begins in October and continues through April with winter occurring during the months of May through September.

Sunshine and cloud cover

The study area receives on average 9 to 10 hours of sunshine per day (Mendelsohn *et al.* 2002). During 2003 and 2004 there were annually approximately 45 days with high elevation cirrus clouds and 28 days with stratus and cumulus clouds.

Temperature

The average annual temperature in the study area for 2003 to 2005 was 24.4°C, the average maximum and minimum temperature in the hottest month (February) was 38.8°C and 24°C and the average maximum and minimum temperature in the coldest month (August) was 23.8°C and 13.7°C. The highest temperature recorded during the study period was 44.5°C on 6 Feb 2005 and the lowest temperature was 3.3°C on 20 Aug 2003 (Fig. 2.5 and 2.6). The only recorded temperature data existing for Aus covers the period of 1953 to 1961. During that period, the average annual temperature was 17.7°C, with the highest temperature recorded as 39°C on 12 Jan 1961 and the lowest temperature being recorded as -4°C on 19 July 1956 (National Weather Bureau, Namibia). Although the limited temperature information available for Aus makes certain assumptions regarding the differences in temperature between Aus and the study area somewhat less certain, the temperature seems to be generally about 2 to 10 °C warmer in the study area (at 950 m.a.s.l) than in Aus (1480 m.a.s.l) with some exceptions (Fig. 2.7).

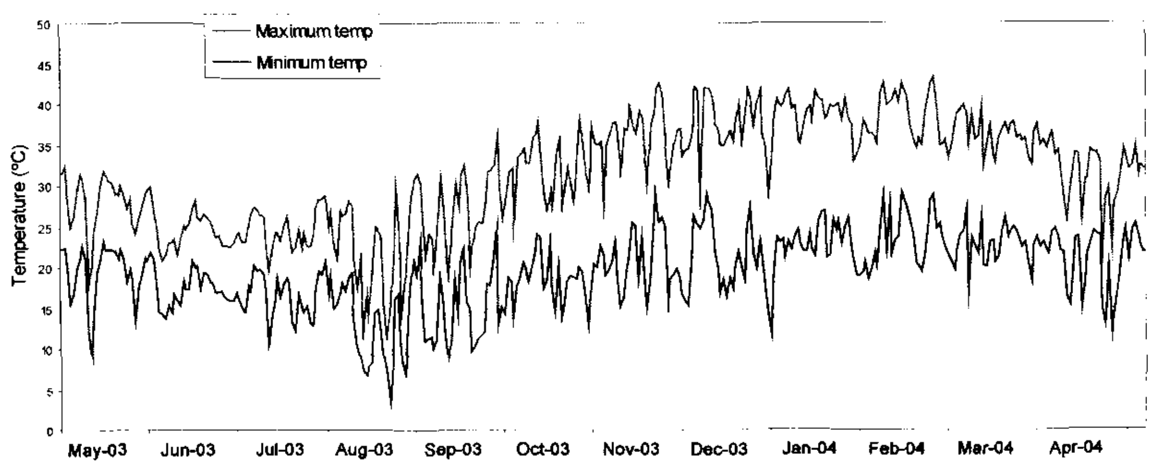


Fig. 2.5: The daily maximum and minimum temperatures from 1 May 2003 to 30 April 2004.

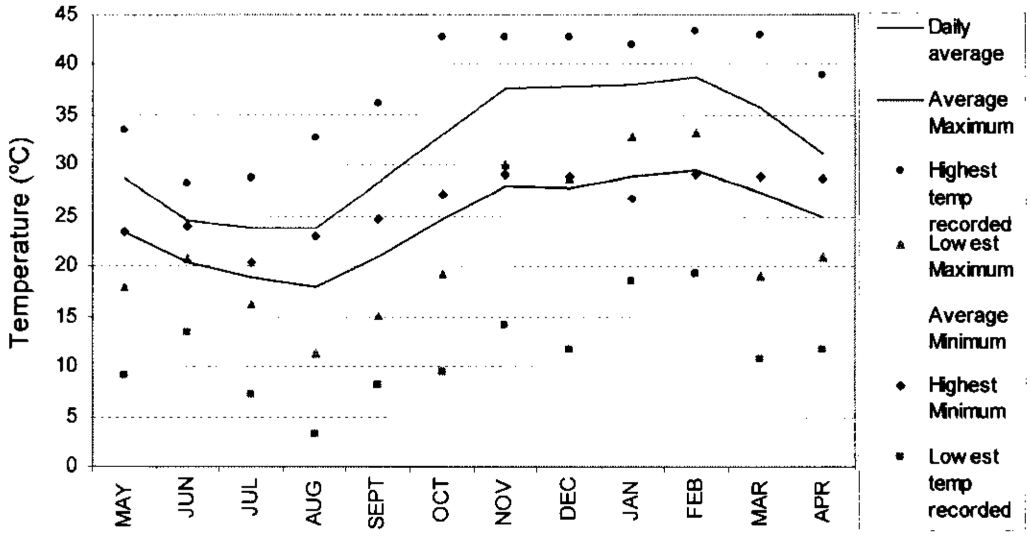


Fig. 2.6: Daily average, average maximum and average minimum temperatures with ranges for each month as recorded at Garub during 2003 to 2005.

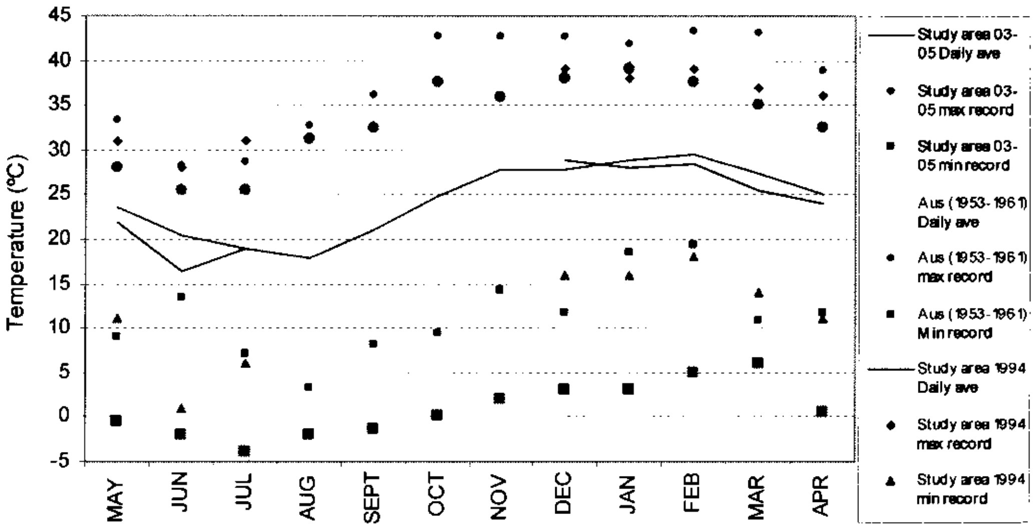


Fig. 2.7: Daily average, average maximum and minimum temperatures for each month as recorded at Garub during 1994 and 2003 to 2005 and at Aus during 1953 to 1961.

Humidity

Humidity is usually highest at 8h00 in the morning and lowest at 14h00 in the afternoon (Mendelsohn *et al.* 2002). The relative humidity in the study area was lower during winter months (defined above as May through September) with an average of 17 to 21% and higher during summer months (October through April) with an average of 21 to 29% (Fig. 2.8). The median for the annual humidity was 21%. The average annual relative humidity at 8h00 was 31% and at 14h00 was 17%. The average annual relative humidity at 20h00 was 30%.

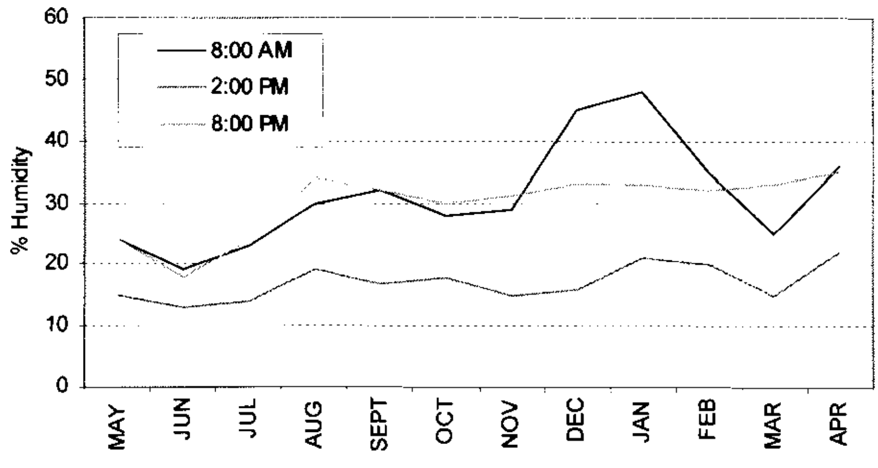


Fig. 2.8: The daily average humidity for each month at 8:00 a.m., 2:00 p.m. and 8:00 p.m.

Rainfall

Rainfall is probably the most important influence in the study area because it directly impacts the amount of food and water available for the horses. Rainfall occurs infrequently and unpredictably at any time during the year. The study area is considered to be in the "transitional zone" of summer and winter rainfall because the area receives 1 mm or more rain during 10 to 15 days per year and the coefficient of variation of rainfall is 60 to 80% (Mendelsohn *et al.* 2002). It is more appropriate to describe the average rainfall of the study area as a range rather than one value since amount and frequency of the rainfall varies considerably in the area (Fig. 2.12). Data from 2003 to 2005 indicates an annual rainfall average of 20 to 73 mm.

Rainfall in the study area is generally lower than the neighbouring escarpment community of Aus and farm Tsirub, both of which have rainfall data available from 1913 to the present. Figure 2.9 gives an indication of rainfall in the area during the past 90 years (unpubl. data: National Weather Bureau, Namibia; J.J. Bosman, farm Tsirub; S. Swiegers, farm Klein-Aus). The rainfall in the desert often differs from that in the interior, as shown in Fig. 2.10 (unpubl. data: M. Goldbeck, Karas region). Some suggest droughts can be defined as those years with rainfall less than a threshold value, which occurs only once every 14 years. This threshold value for the study area is 25 mm (Mendelsohn *et al.* 2002).

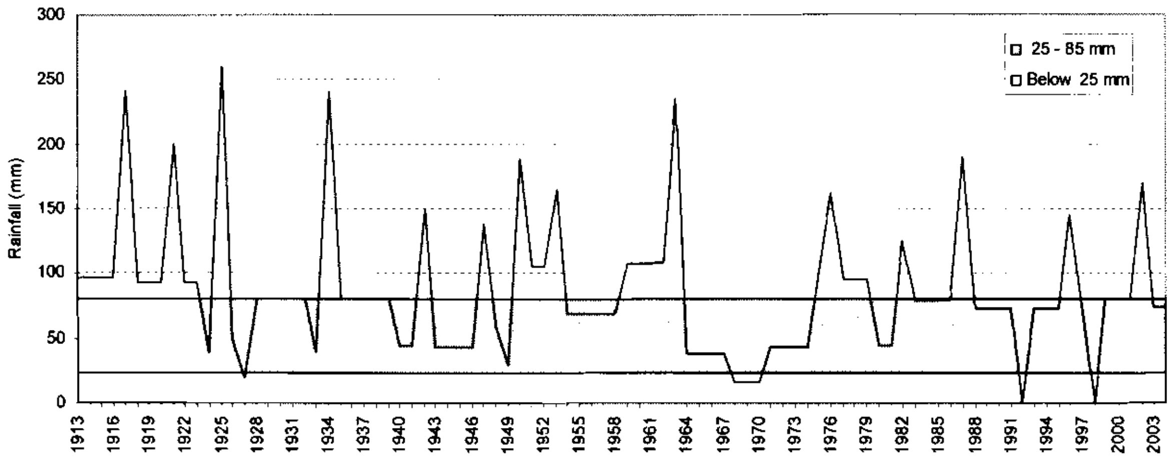


Fig. 2.9: Mean annual rainfall from 1913 to 2004 for Aus and Tsirub with similar years averaged and peak or very low years unchanged, the median is 85 mm and the drought threshold 25 mm.

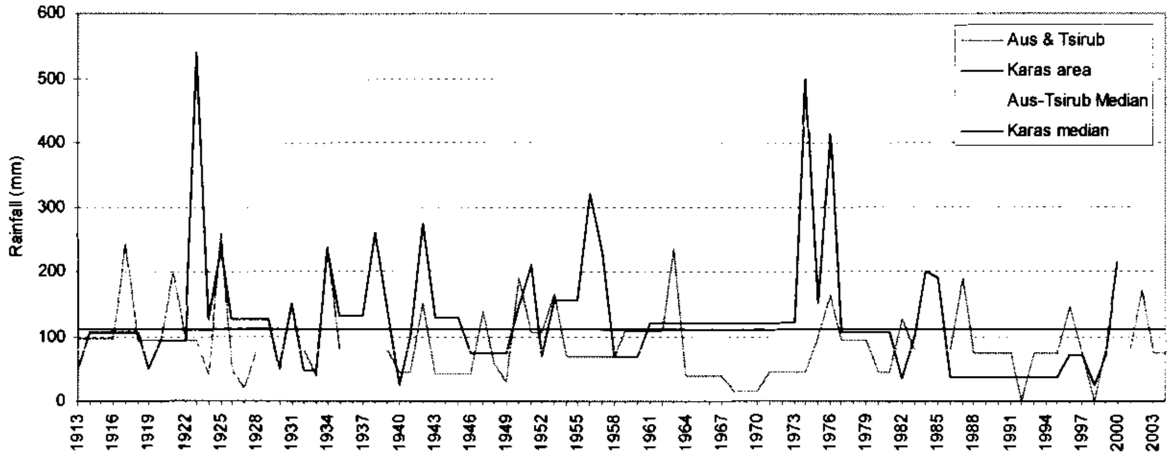


Fig. 2.10: Mean annual rainfall from 1913 to 2004, with similar years averaged and peak or very low years unchanged, for the Aus area (median: 85 mm) and the Karas region (median: 104 mm).

The monthly average rainfall for Tsirub and Aus (documented since 1913), and the study area is shown in Fig. 2.11 (data of the study area is limited to the rain gauge at Garub 2, documented during 1994 and from 2003 to 2005). The records appear to indicate that Tsirub, which is located approximately 40 km south-west of Aus, receives more winter rain while Aus receives more summer rain. The data from the study area is limited by the smaller number of years it has been documented, thereby making rainfall trends somewhat speculative. However, it appears as if the study area receives slightly more winter rain. The rain in summer falls in irregular and inconsistent patches, in contrast to the winter rainfall, which generally increases with increasing height above sea level (Fig. 2.12).

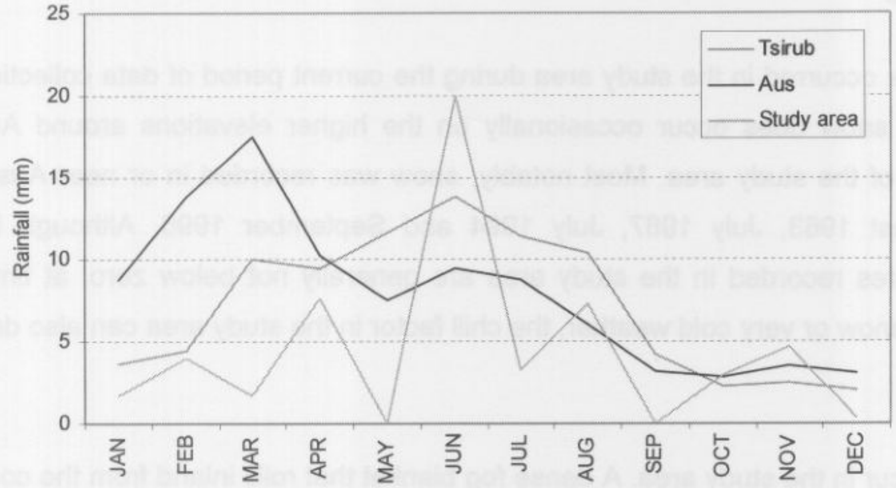


Fig. 2.11: The monthly average rainfall on the farm Tsirub (south of study area), Aus (east of the study area) and in the study area.

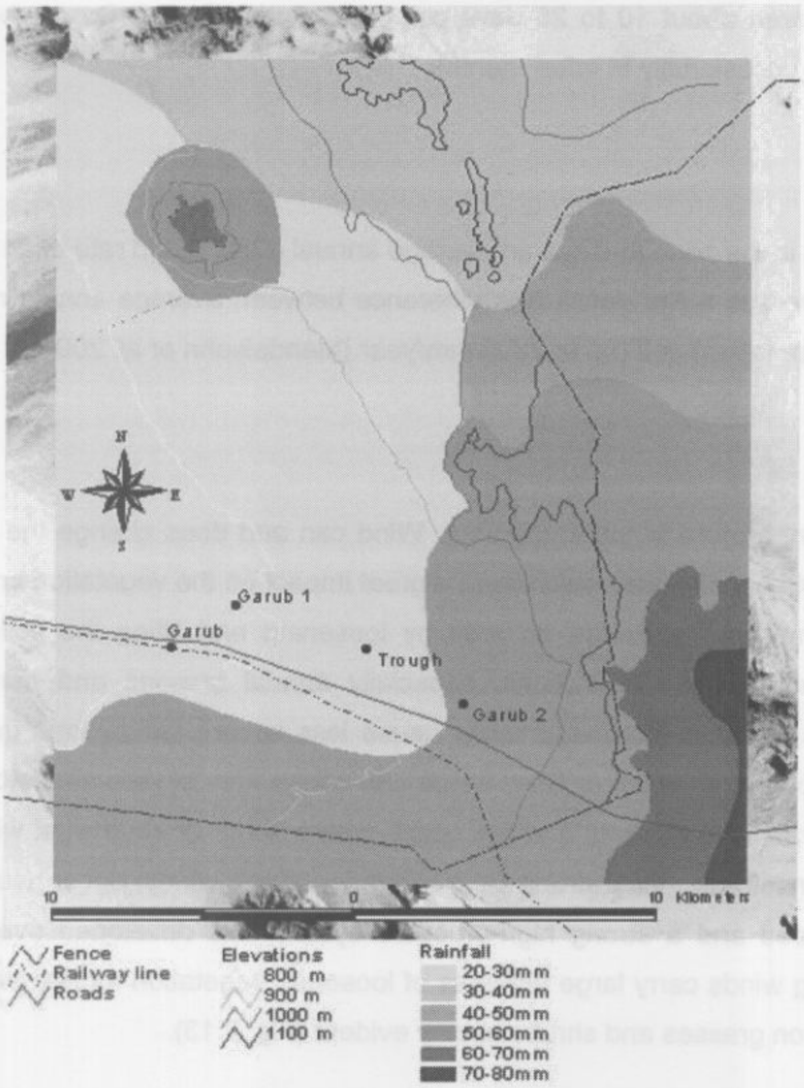


Fig. 2.12: Mean annual rainfall across the study area measured 2003 to 2005.

Frost, fog and snow

No frost or snow has occurred in the study area during the current period of data collection. However, frost and snow does occur occasionally on the higher elevations around Aus, which lies just east of the study area. Most notably, snow was recorded in or near Aus in August 1933, August 1963, July 1987, July 1994 and September 1996. Although the minimum temperatures recorded in the study area are generally not below zero, at times when Aus receives snow or very cold weather, the chill factor in the study area can also drop below zero.

Two kinds of fog occur in the study area. A dense fog blanket that rolls inland from the coast in the morning, reaches the study area (1000 m.a.s.l.) about 5 to 15 days per year. Morning fog from the coast can occur any time of the year, but occurs more frequently from August through November. Afternoon fog that moves in with a strong south or southwest wind reaches the study area about 10 to 25 days per year, usually during September through December, but also occasionally in other months.

Evaporation

The study area falls in the zone that has an average annual evaporation rate of 2100 to 2240 mm/year and an average water deficit (the difference between average annual rainfall and average rate of evaporation) of 2100 to 2300 mm/year (Mendelsohn *et al.* 2002).

Wind

Wind is an important feature in the study area. Wind can and does change the landscape from time to time with sandstorms, which have a great impact on the vegetation and fauna of the area. Sandstorms can obliterate an area by loosening and lifting the soils and any attendant vegetation from their positions, especially annual grasses and herbs. These sandstorms vary in strength. Southerly winds cause less severe sandstorms in the study area. However, strong east winds or Berg winds can cause very severe sandstorms in the study area, in contrast with Lüderitz and the coast, where south or southwest winds cause the most severe sandstorms. Very strong Berg winds (catabatic winds) occur usually after a cold front has passed and a strong high-pressure system has developed over southern Africa. These strong winds carry large amounts of loosened vegetation further west and the sandblasting effect on grasses and shrubs is very evident (Fig. 2.13).

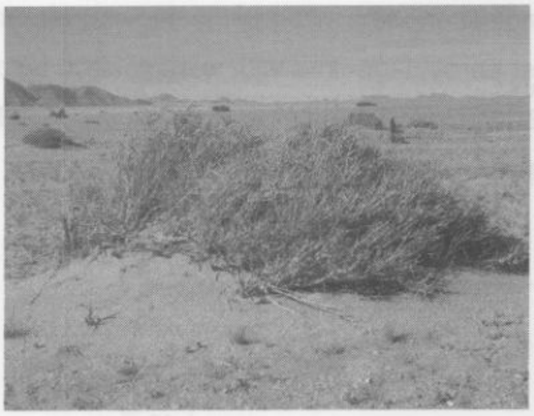


Fig. 2.13: left) Calicorema capitata shrub with bare sandblasted stems on the eastern side; right) sand deposited on western side of shrubs after a 5-day sandstorm in 1994; these hummocks were much smaller before this sandstorm.

Generally, the average wind speeds in the study area is around 10 to 30 km/h, but gusts often occur at around 40 km/h (Fig. 2.14). East winds are more dominant from approximately March to September, while west and southerly winds are more dominant in summer (Fig. 2.16). Obviously, since in the study area summer is defined as October through April, there is some overlap. On some days a strong east wind blows in the morning, followed by a strong west wind in the afternoon. The highest wind speed recorded in the study area during 2003 to 2005 was 122 km/h on 31 March 2003, which occurred during a thunderstorm. The highest wind speed recorded during a sandstorm was 119 km/h on 5 July 2004, and the average wind speed for that day was 72 km/h.

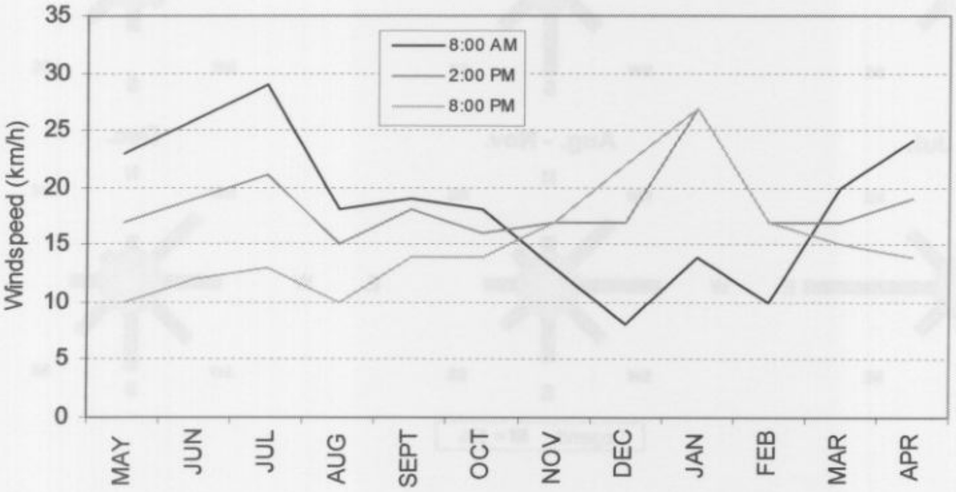


Fig. 2.14: The daily average wind speeds for each month at 8 am, 2 pm and 8 pm recorded at Garub during 2003 to 05.

April to July and January are typically the windiest months. August to November and February to March are the months with the highest percentage time with wind speeds below 5 km/h, in other words the calmest months (Fig. 2.15). June through October are the months where the highest wind speeds are reached and sandstorms occur.

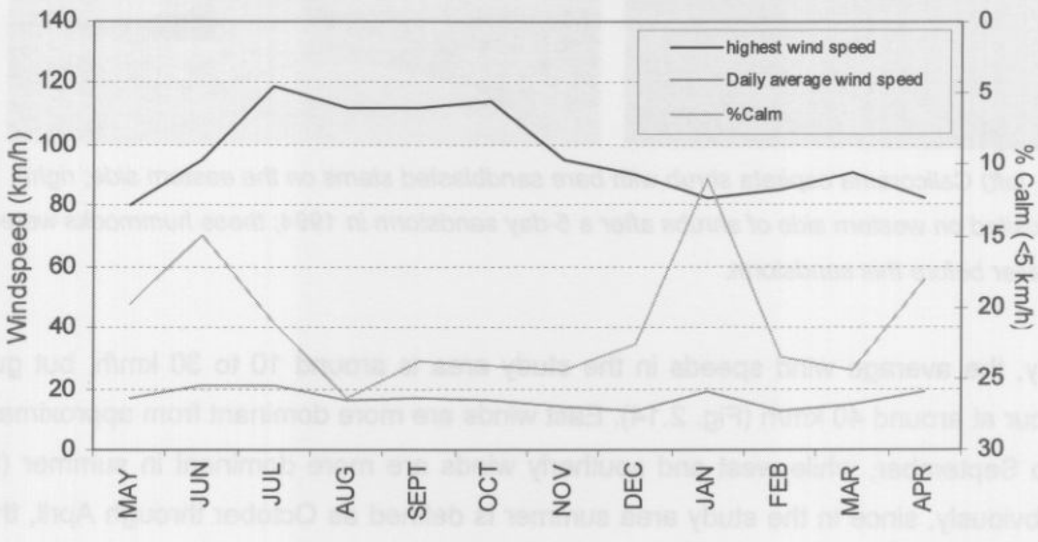


Fig. 2.15: The % calm and maximum wind speeds for each month recorded at Garub during 2003 to 2005.

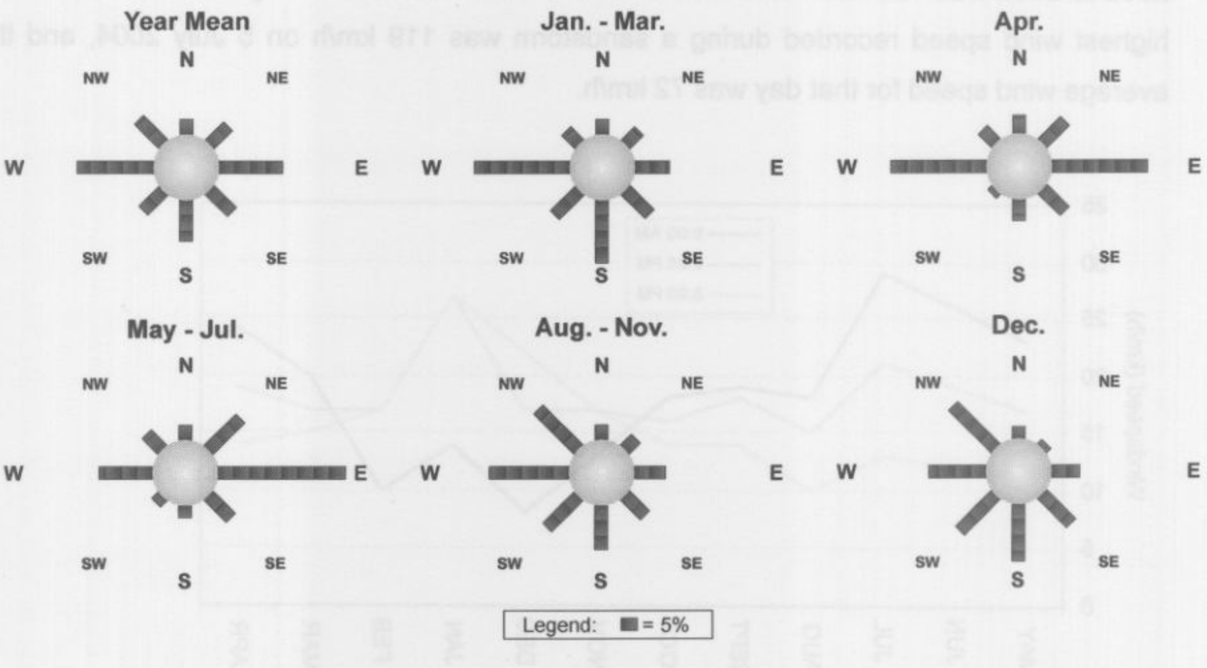


Fig. 2.16: Wind direction recorded at Garub during 2003 to 2005.

VEGETATION

The dry climate that prevails in the study area has resulted in the survival of those plant species that are adapted to the variable climatic conditions. Adaptations for survival include, for example, a wax containing epidermis, like the Bushmen candle (*Sarcocaulon* species), small leaves to minimize exposed surface area and succulent leave forms. One important strategy to ensure future existence of plant life is to concentrate growth and reproduction to periods after rain. Therefore the abundance and status of vegetation often varies a great deal from month to month and year to year depending on the amount and distribution of rainfall. Since plants are primary producers, this variation has a major influence on all other animals that depend upon plant production for food.

According to the original classification of vegetation types by Giess (1971), the study area falls in the Desert and Succulent Steppe. The most recent classification of vegetation types, as presented in Mendelsohn *et al.* (2002), provides a more detailed division of Namibia which places the study area in the Southern Desert, containing patches of Succulent Karoo vegetation. Landforms associated with these vegetation types are described as dune sand, gravel and calcrete plains, inselbergs, grassland with dwarf shrub lands and succulent shrubs. The Succulent Karoo is recognized as one of the world's 25 hotspots due to its great diversity of plants and animals. It is furthermore the only entirely arid hotspot in the world (van Wyk & Smith 2001). Namibia, as a whole, has a 17% plant endemism. The vegetation in the higher elevations around Aus, just east of the study area, includes of 50 to 60% of Namibia's endemic species (Barnard, 1998). Some plants occurring in the area are local endemics, occurring only in the Aus area.

The study area, excluding the mountains or inselbergs, was further divided into plant communities as described in Chapter 3 (Vegetation composition & grazing capacity). In general, it does not appear as if the plant community structure has changed much during the past 90 years and the growth of trees has been extremely slow (Fig 2.17). Trees are not common in the study area and only occur in drainage courses, on the inselbergs and on the dunes where more moisture is available for longer periods due to its protection against evaporation or the presence of underground drainage systems. The most common tree on the inselbergs is the exceptionally arid adapted Shepherd's tree (*Boscia albitrunca*) and the most common tree in the riverbeds and dunes is the Camel Thorn (*Acacia erioloba*).

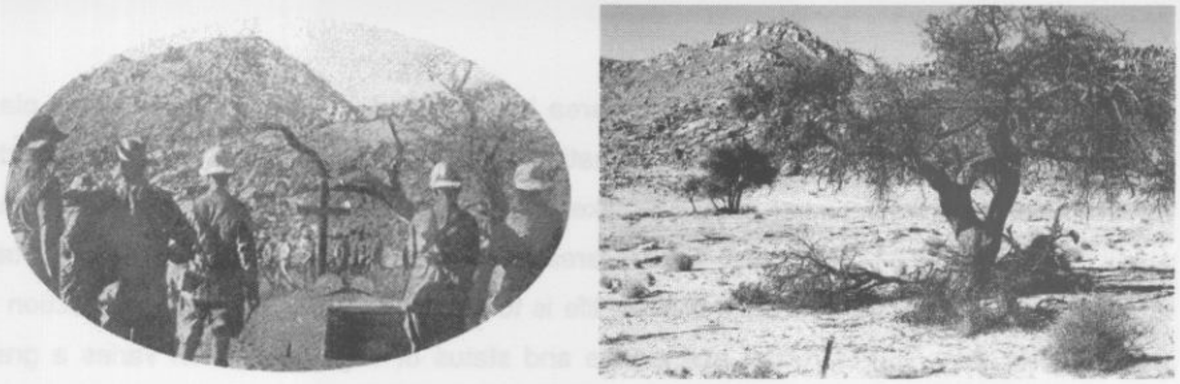


*Fig. 2.17: A Camel Thorn tree (*Acacia erioloba*) on the farm Klein-Aus behind the original grave of Captain de Million in left) 1915 (Rayner & O'Shaughnessy 1916) and right) in 2004.*

In general, the most common shrubs in the study area are *Calicorema capitata* and *Euphorbia gummifera*. The three main grass species are *Stipagrostis ciliata*, *Stipagrostis obtusa* and *Eragrostis nindensis*. There are also numerous specimens of *Sarcocaulon patersonii*, *Euphorbia namibensis* and *Euphorbia juttae*. After rain, several annual herb species appear, most frequently in August and September. Plant growth and production in the study area can vary significantly from time to time and locally, from patch to patch, due to varied and inconsistent rainfall patterns and amounts. The average standing biomass in the study area during 1994 and 2004 was 11 kg/ha and during 2002 it was 148 kg/ha (Fig. 2.18).

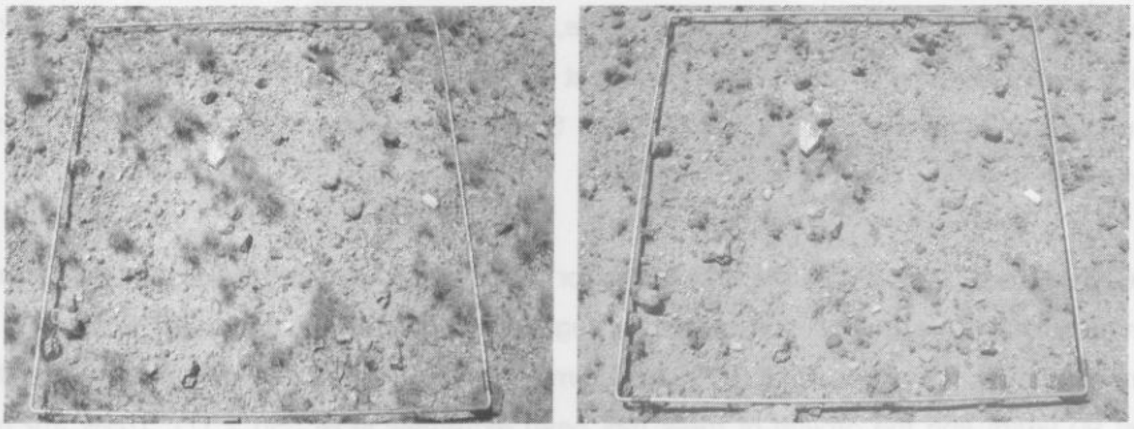


Fig. 2.18: A 1 m² quadrate showing the difference in vegetation cover between left) 2002 and right) 2004.

FAUNA

Similar to the relative low plant diversity in the Namib Desert, the faunal diversity is also relatively low due to the dry climate. However, endemism is high due to required specialization and adaptation to the arid conditions. Endemic fauna occurring in the study area includes 1 to 3 bird species; 13 to 16 kinds of reptiles; 3 to 4 varieties of scorpion and 3 to 6 mammal species (Mendelsohn *et al.* 2002). Biodiversity in the study area is further discussed in Chapter 6 (Impact on biodiversity).

It appears as if the faunal composition in the study area has not changed significantly over the past few hundred years. Plains game (other than oryx, springbok and ostriches) and their predators only utilized the area sporadically, when the area experienced abundant rain leading to more accessibility of drinking water and food for the herbivores (M. Griffin, pers. comm.). Zebra (*Equus zebra*) teeth were found in the Koichab riverbed (north of the study area) by J. Grobbelaar, a security officer from Consolidated Diamond Mines, in 1966. The find may indicate the occurrence of zebra in the area at times when open water was available, but unfortunately the age of these teeth is unknown. Since European colonization, man-made boreholes and water troughs made water more available, causing some species, such as the spotted hyena (*Crocuta crocuta*), to increase their historical range into the Namib Desert. However, many species, including large herbivores, were restricted by hunting and fences, causing migration to the area to be limited or completely curtailed. Some species, such as horses (*Equus caballus*) and the house sparrow (*Passer domesticus*), were introduced into the area by the activities of man.

At present the following mammalian orders are represented in the study area: Insectivora, Chiroptera, Primates, Carnivora, Lagomorpha, Rodentia, Perissodactyla and Artiodactyls. The mammals most often observed are horses, oryx (*Oryx gazella*), springbok (*Antidorcas marsupialis*) and jackals (*Canis mesomelas*). Not many birds occur on the plains areas. Most of the 50 to 80 bird species in the area are found along the eastern highland and mountainous areas where more food and shelter are available. Birds most often observed in the study area are ostriches (*Struthio camelus*), crows (*Corvus capensis*), chats and larks (various species). Reptiles are fairly common and well adapted to the arid environment, 40 to 50 species may occur in the study area. *Meroles* and *Pedioplanis* lizards are most commonly seen in the study area and *Ptenopus* spp. (barking geckos) are heard at dusk. Invertebrates most commonly observed are ants, termites and beetles, of which the tenebrionid beetles seem to be the most common; most insects on the gravel plains are very small and well-camouflaged.

HISTORY OF UTILIZATION

Pre-European colonization: before 1883

The archeological evidence uncovered thus far indicates that hunter-gatherers utilized the Koichab area of the southern Namib Desert, which includes the study area, in an opportunistic way during the course of the Holocene (Noli 1989). A few archeological sites in the study area, mainly on and around Dik Willem mountain, produced artifacts from hunter-gatherers which supports this theory (Noli 1989). According to Moritz (as quoted by Noli 1989) a Dutch ship, "De Bode", sent a party ashore in 1677, approximately 30 km south of Lüderitz, where they encountered local inhabitants. These people, presumably Namas or Hottentots, indicated they had livestock inland. This is the first documented report of nomadic pastoralists opportunistically utilizing the southern Namib Desert during favourable wet periods from the late 17th century onwards.

European colonization: 1883-1915

The first permanent European settler in Namibia was Guilliam Visagie who lived at what is now known as Keetmanshoop in 1785. From 1806, missionary stations were erected in Namibia. Among the first was the station at Bethany (Bethanien), approximately 80 km east of Aus, in 1814 by J.H. Schmelen (Dierks 1999). However, it was not until Heinrich Vogelsang, an employee of Adolf Lüderitz, bought the bay "Angra Pequena" (present day Lüderitz) on 1 May 1883 that colonization of the south really gained momentum. Less than four months later, Vogelsang acquired the entire coastal strip from the Orange River to the 26º latitude South, and from the coast to 20 geographical miles (148 km) inland, for a purchase price of 60 Wesley-Richard rifles and £500 in gold. The land was purchased on 25 August 1883 from the Nama Captain Joseph Fredericks II of Bethany whose family had lived there since 1804 (Mouton 1995). The study area falls within this "Lüderitz land", as it was known for a while.

After the establishment of a trading post in Lüderitz bay, a transport route between Lüderitz and Aus, which passes just south of the study area, was used regularly. Commercial production of livestock and fresh produce began on the first farm, named Kubub, in the area (Sycholt 1986). During 1904, traffic on the transport route between Aus and Lüderitz increased significantly to provide supplies to the German Schutztruppe. The Germans were fighting against the Namas in the south of Namibia during resistance movements of the Namas. An estimated 10 000 horses, mules, oxen and camels were used on the transport route (see Fig. 2.1 for location) during 1904 (Bravenboer & Rusch 1997). The first European activity at Garub came with the building of the railway line between Lüderitz and Aus that reached Garub station on 13 September 1906. The first boreholes were sunk 2 km northeast of the station on 29 February 1908 (Bravenboer & Rusch 1997) at what is today known as Garub 1. These boreholes at Garub were a breakthrough for the people in the area and also delivered water to Aus and Lüderitz.

On 14 April 1908 Zacharias Lewala found the first diamond near Kolmanskoppe, which he gave to his employer August Stauch. On 8 May 1908 August Stauch, Sönke-Nissan and Weidtmann made an agreement to reserve the mineral rights in the area (Bravenboer & Rusch 1997). On 22 September 1908 the new Colonial State Secretary, Bernhard Dernburg, ordered a 100 km wide area between the Orange River and the 26º latitude to be a restricted diamond area or "Sperrgebiet" (Sycholt 1986). Most of the German colonization took place from 1910 to 1915 (Dierks 1999) and several farms were established at that time around Aus, bordering the Sperrgebiet. It is possible that as early as 1908, horses from the mines or the Station Master ("Ploegbaas") at Garub could have been kept for extended periods in the Garub area, since there existed water and grazing, which were not as readily available at the coast.

Records and photographs was also recently found (private collection of Walter Rusch) of a large breeding herd of horses that were kept on the farm Kubub, 20 km from Garub. These horses belonged to the Mayor of Lüderitz, Mr. Kreplin, who rented the farm from around 1911 to 1919. The horses bred by Mr. Kreplin show (comparing the historical photographs with present horses) several conformation and marking characteristics similar to the present feral horses at Garub. Considering these morphological characteristics, it is likely that Kreplin's horses contributed to the gene pool represented in the present Namib horses.

World War I: 1914-1919

South Africa officially declared war against German South West Africa (now Namibia) on 9 September 1914 (Dierks 1999). This was primarily an extension of the war in Europe between Germany and Great Britain. On 19 September 1914, Allied Forces from South Africa, consisting of troops under the command of Great Britain, including, but not limited to South Africa and Rhodesia (now Zimbabwe), landed in Lüderitzbucht to confront the Germans. The town surrendered without resistance since the German troops had already retreated inland (Rayner & O'Shaughnessy 1916). The Allied Forces remained in Lüderitz for a few months and then proceeded slowly through the desert having to repair the railway line that was destroyed in places by the retreating German Forces. The first Allied troops eventually occupied Garub without opposition on 22 February 1915. This occupation was important to the Allied Forces since Garub had the best underground supply of potable water they had found thus far. The force stationed at Garub camped there for almost six weeks and numbered around 10 000 men and 6 000 animals. The area around the boreholes became a permanent dust cloud as the thousands of horses and mules watered there pounded the surface to powder. During those weeks, the German aircraft "Fritz" bombarded the camps at Garub on three occasions. The first sections of the Allied Force at Garub advanced to Aus on 30 March 1915 after the German force had evacuated two days earlier (Rayner & O'Shaughnessy 1916). Von Oelhafen (1923) mentions specifically the bombardment by a pilot officer named Fiedler, on 27 March 1915, of the camps at Garub. This bombardment were also specifically aimed at scattering about 1 700 cavalry horses grazing in the area.

The German Schutztruppe surrendered to the Union forces on 9 July 1915 and South West Africa then fell under South African Rule, which was ostensibly British Rule. The German soldiers were detained in prisoner of war camps until the end of WWI in April 1919. One of the detention camps was located on the plain, east of Aus, and housed 1 552 prisoners of war and about 600 officers (Bruwer 2003).

Sperrgebiet: 1919-1986

On 31 October 1919, Sir Ernest Oppenheimer from the Anglo-American Company acquired the remaining diamond mines around Lüderitz and amalgamated them as Consolidated Diamond Mines (CDM). He also acquired the rights to the Sperrgebiet and the entire area remained a restricted diamond area (Dierks 1999). The restricted nature of the area, of which the study area is a part, led to the population of feral horses present around Garub to remain there without too much human interference. During this period from 1919 to 1986, access to the Sperrgebiet, including the study area, was limited by the security regulations of CDM. The only section that allowed public movement was on the railway line and the road that followed the course of the present day B4, close to the railway line and also passing through the study area. The station at Garub was occupied by personnel from the South African Railways (SAR) who continued to pump water for the steam locomotives until December 1977, when diesel locomotives were mostly in use.

After finding the discontinuation of the water supply at Garub, J.H. Coetzer, security officer from CDM, who took an interest in the horses, applied to the SAR to continue the provision of water to the horses with a cost contribution from CDM. According to communication by J.H. Coetzer, after the SAR stopped pumping water for the steam locomotives, the horses went at least fourteen days without water, causing some horses to die of dehydration. Horses had also died of dehydration on other occasions, when the personnel responsible for the provision of water went on leave and there was no continuous water supply. Therefore, CDM funded the installation of holding tanks and a trough regulated with a ball valve in 1980.

It appeared that the horses did not always fare well with their interaction with humans. Coetzer, for example, observed pieces of rope around some horses' necks during the emergency grazing times. Presumably farmers were trying to catch some horses, as they would any wild animal for which they had a use. Additionally, some horses were found killed by bullets leading to the assumption that the horses were used for target practice on occasion.

The Sperrgebiet was "opened" at times of severe drought for emergency grazing to farmers that had insufficient or no grazing on their own farms. This happened periodically from the 1950's until 1983 (Williamson & Jacobson 1995) when large flocks of small livestock grazed the eastern grasslands of the Sperrgebiet, including the study area. There were no fences between the farms and the study area, which led to farm horses and livestock occasionally wandering into the Garub area, as well as the feral horses grazing and drinking on the neighboring farms, specifically Eureka, Klein-Aus and Tsirub (J.H Coetzer,. H. Steenkamp, A.F.B. Schlemmer, J.J. Bosman and W.P.J. Swiegers, pers. Comm.).

Namib Naukluft Park: 1986-2004

The Namib Naukluft Park has expanded over the years. In 1907, the area between the Swakop and Kuiseb Rivers was proclaimed Game Reserve No. 3 by the German Colonial Administration. In 1956, the area was enlarged to incorporate the Swakop River Valley, Welwitchia Plains, and the Kuiseb Canyon and became known as the Namib Desert Park (14 095 km²). In 1968, the Naukluft Mountain Zebra Park was proclaimed to protect the endangered Hartmann's mountain zebra in the Naukluft Mountains. Subsequently, more farms were purchased to form a corridor between the Naukluft Mountains and the Namib Desert. In 1979, a large portion of Diamond Area 2 was ceded to the government for nature conservation and this area, together with unoccupied State Land, the Namib Desert Park and the Naukluft Mountain Zebra Park were consolidated to form the Namib Naukluft Park of 23 340 km² (Nel 1983). On 15 August 1986, the remainder of Diamond Area 2 and a part of

Diamond Area 1, up to the Aus – Lüderitz trunk road was also included into the Namib Naukluft Park to enlarge it to a total size of 49 768 km².

This last addition in 1986 to the Namib Naukluft Park included the largest portion of the horses' habitat, including the water points and began a new phase in the existence of the horse population, since they now resided in a national park. By 1986, the first investigation of the study area was done in 1985 by Chris Eyre, then Senior Nature Conservation Officer at the regional office in Keetmanshoop. In his 1985 study, Chris Eyre attempted to determine the population size and physical condition of the horses, as well as the influence of sheep utilizing the pasturage (Meyer 1988). Since the horses were regarded as an alien or exotic species in the NNP, the newly created authority over the area, Directorate of Nature Conservation, wanted to remove the horses from the NNP in 1986. This decision was strongly opposed by various people, including J.H. Coetzer, from CDM who had worked to ensure the horses continued existence up to that point. Other supporters urging the protection of the horses included people within the Directorate, the general public and Dr. F.J. van der Merwe, then Director of Animal Production in South Africa, who wrote the first report on the horses in 1984. Due to the strong outcry, no action was taken and the horses remained at Garub.

Van der Merwe obtained permission from the Directorate of Nature Conservation in 1987 to capture 10 of the horses for research purposes. These horses were taken to the Veterinary Institute at Onderstepoort, Pretoria, South Africa. Eight additional horses were captured and taken to Etosha National Park to be used by the Directorate of Nature Conservation as patrol horses, apparently without much success (Van der Merwe 2005). The first relatively extensive study of the ecology of the horses was done by T.C. Meyer in 1988, who compiled a report for the Directorate of Nature Conservation. In 1989 to 1990, the entire eastern boundary of Diamond Area 1 and the Namib Naukluft Park from the Orange River to the Kuiseb River was fenced off with a game-proof fence. This measure prevented poaching, but also prevented migration of game and the horses from grazing on the neighboring farms and the Aus municipal "Town land". Another change occurred at the end of 1991, when new water troughs were built about 4 km east of the original trough at Garub 1. The new troughs received water from a borehole (Garub 2) about 4 km further south east. This move had the advantage of using a borehole that belonged to the Ministry of Environment and Tourism (MET). However, the primary advantage was the proximity of the water troughs to the eastern areas which were more utilized by the horses due to more grazing being available there. The new troughs reduced the distance the horses had to travel to and from the water to the better grazing areas.

In 1992, after Namibia became independent, and during a devastating drought over most of southern Africa, the MET approved a decision to reduce the number of horses then estimated at 276. On 1 June 1992, 104 horses were captured at Garub and sold to interested buyers at a cost of Namibian $120 per horse regardless their age, sex or condition. Several buyers came to collect the horses with their own transport, mostly livestock trucks. There was no selection of horses during the capturing process. A canvas enclosure was erected around the water troughs and the water was closed for 48 hours to keep the horses nearby. Those horses which entered the enclosure after the water was opened were enclosed and herded onto the trucks. Unfortunately these captured horses had difficulties adapting to their new environments (different climates, domestic restrictions, etc.) and as far as could be traced, at least half of them died by 1997.

Public interest continued to grow. In November 1993, a look-out shelter was erected 100 m from the horses' trough, which was opened to allow the public to be able to view the horses. During 1994, a study on the behavioural ecology of the horses was done by the author and records of the population have been kept since. In 1997, another decision to reduce the number of horses at Garub (149 horses) was approved by the MET and a game capture team selected 35 horses according to age, sex, relatedness and group composition. The game capture team removed these horses, utilizing immobilization drugs, to a holding facility at Hardap Dam (350 km north-east of Garub) in October 1997, where the horses were kept for six weeks. The horses were to be sold at a public auction, but this auction was cancelled and the horses released back to Garub in November 1997 due to political reasons. During the six weeks the horses were kept in the holding facility, their behaviour changed significantly. Most notably, the stallions became very aggressive in the confined space, unfamiliar to them, of the holding facilities and had to be separated from their breeding groups.

November 1997 was the last time it rained in the study area until March 1999. This extended period with no rain caused a severe drought at the end of 1998. Several horses, mostly in the older age classes, died during the period from October 1998 to January 1999, even though supplementary hay (lucerne) was provided from November 1998 to May 1999. This drought and the resultant public outcry about "starving horses" rekindled talks about removing the horses from the desert. The present project was initiated by this renewed interest in the horses and the uncertainty of their future. The desert experienced an exceptionally good year with increased and sustained rainfall in 2002 and the horses have maintained mostly good condition since 2002. The horses have also become a popular tourist attraction, which brings an economic benefit to all of Namibia and in particular, to the area adjacent to the horses' habitat. An area, including the study area, was opened as a concession to a neighboring tourist operation in 2000 for a five year period. The concession holders are allowed to do guided excursions with tourists into the study area and the adjoining Koichab River area.

CHAPTER THREE: VEGETATION COMPOSITION & GRAZING CAPACITY

Bronze horses (Saint Marks Square) Venice, Italy.

INTRODUCTION

An integral part of management of large herbivores is knowledge regarding the vegetation component and estimated carrying capacity of their habitat. The concept of carrying capacity (*K*) defined as the maximum population size that can be supported indefinitely by a given environment, is true for hypothetical populations but is much more complicated in natural ecosystems (Begon, Harper & Townsend 1996). Due to extensive environmental variation it is almost impossible to determine an accurate fixed figure for the carrying capacity of any specific area. For agricultural purposes the term grazing capacity is generally used for the productivity of the grazable portion of a homogeneous vegetation unit in relation to the area required to support a single animal unit at a specified stage without causing deterioration to either vegetation or soil. A number of methods to determine grazing capacity have been used, most of which need controlled experimental camps or plots where vegetation and animal production can be measured and monitored (Stuart-Hill & Aucamp 1993). An important part of determining grazing capacity is the division of the area under investigation into plant communities, since the productivity and thus grazing capacity of the different communities most likely varies. Such an approach was followed by Nel (1983), who described plant communities for the Kuiseb area (Central Namib Desert, Namibia) and measured the herbaceous production in "exclusion camps" as above ground biomass. These quantities, per surface area of vegetation biomass, were then used to determine the number of animal units that could utilize it. Both of the above approaches resulted in minimum and maximum figures for grazing capacity, which also depended on rainfall and veld condition.

The study area falls within the Southern Namib Desert which has a coefficient of variation in rainfall of more than 70 to 80% (Mendelsohn *et al.* 2002). This high variability, together with very low and unpredictable rainfall, extensively complicates any attempt to determine long term figures for grazing capacity. It does, however, result in a vegetation production curve which is directly and strongly related to rainfall (Seely 1978). For arid to hyper-arid regions, Brown (2005) suggested relating grazing capacity to the percentage of the median rainfall. Specifically, Brown proposed that the advised grazing capacity (e.g. 6.5 kg/ha) is viable at a three year running mean which is equal to the median rainfall. Thereafter, Brown suggested, the grazing capacity should be adjusted to the percentage of the three year running mean compared to the median (e.g. three year running mean at 60% of median, grazing capacity = 4.3 kg/ha). For this study, a similar concept was followed where vegetation production and thus grazing capacity was correlated to rainfall. Controlled experiments, such as using exclusion camps to measure gross production or controlled grazing camps, were not possible in the study area. It was determined that any type of fencing proved potentially lethal to the animals, as well as creating attraction points, which had severe impacts around these fenced plots. However, in any attempt to calculate grazing capacity there are many uncertainties and unforeseen aspects, which could influence the accuracy of finite figures, and therefore such figures are merely a guideline, which should be reviewed and adapted continually according to prevailing circumstantial and environmental conditions.

The objectives of this chapter were to: (1) investigate the floral composition and vegetation structure of the area and identify plant communities to use as basis for grazing capacity calculation; (2) measure standing vegetation biomass and determine the correlation between plant productivity and rainfall; and, (3) develop a grazing capacity scale which is correlated to plant productivity and rainfall.

MATERIAL & METHODS

3.1 Plant communities

Plant communities in the study area were identified and classified according to the Braun-Blanquet method (Mueller-Dombois & Ellenberg 1974). During September 2002, 61 relevés were subjectively chosen based on experience in the area and knowledge from previous wheel-point surveys (Greyling 1994). The condition of the veld was excellent in 2002 with many annual herbs following two seasons of above average rainfall. Size of relevés was determined as 10 x 10 = 100 m^2 using species area curves (Kent & Coker 1996). In each relevé the total plant species composition was recorded and vegetation cover was estimated according to Braun-Blanquet cover-abundance scales (Mueller-Dombois & Ellenberg 1974). Specimens of unknown plants were collected and deposited at the National Herbarium of Namibia where the specimens were identified. In addition, notes were taken to describe properties of each relev é regarding: the soil type, topography, aspect, slope (angle in degrees), trampling (low, moderate, heavy), number of ant holes and rockiness (Table 3.1). Canonical correspondence analysis (CCA) was used to clarify the possible influence of environmental variables. For further explanation of the ordination analysis refer to Ter Braak (1986).

These surveys were repeated during September 2004, which was a reasonably dry year. The mountains or inselbergs were not included in any survey since they form a much more complex system which is not often utilized by the large herbivores and therefore not within the scope of this study. For a description and list of species that may occur in the mountains consult Mannheimer, Strohbach, Greyling & Wulff (2005).

Table 3.1: Description of "rockiness" classes.

Class	Symbol	Size of rocks
Very small	Vsmall	1 to 10 mm
Small	Small	11 to 30 mm
Medium	Med	31 to 70 mm
Large	Large	71 to 150 mm
Very large	Vlarge	>150 mm
Solid rock	Solid	n/a

The September 2002 data were used to identify and classify plant communities. The TURBOVEG software package for processing phytosociological data (Hennekens 1996a) and the TWINSPAN classification algorithm (Hill 1979) were used for the input, processing, and presentation of phytosociological data, and subsequently Braun-Blanquet procedures (Mueller-Dombois & Ellenberg 1974; Kent & Coker 1994) were applied to arrange relevés and species into a meaningful phytosociological table, assisted by the MEGATAB visual editor software programme (Hennekens 1996b).

The species composition data was also ordinated with multivariate analyses to aid in the grouping of relevés. Detrended correspondence analysis (DCA) was used to ordinate the species data and compare groupings with the TWINSPAN results. The stepwise ordination approach developed by Mucina & van Tongeren (1989), and successfully used by Morgenthal, Cilliers, Kellner, van Hamburg & Michael (2001) was adopted to cope with the heterogeneity of the dataset. No formal syntaxonomical nomenclature rules were followed in naming the communities. Each community was given a two species name, the first species indicating a differential species and the second species being the dominant species in that community. Differential species occur together in a series of relevés and can thus be used to characterize plant communities (Kent & Coker 1996). Additionally the species richness, structure and rare species of each community were discussed. The vegetation structure was categorized according to Edwards (1983). No Red data species are recorded for the study area, however, a few species are rare and endemic, some also locally endemic to the Aus area (Loots 2005). Only the rare and locally endemic species are mentioned in the community descriptions. The plant communities were mapped on 1:50 000 topocadastral maps and the size of each community calculated. Only a few of the communities show a sharp transition, most communities have a broader transitional area and boundaries were drawn intuitively approximately in the centre of transitional areas between communities. A lack of available aerial photographs or satellite images with a large enough scale to identify small shrubs and grasses complicated detailed mapping.

3.2 Standing biomass of grasses and production curves

Standing biomass of grasses was determined during September 2002 following exceptionally good rain. All grass species were separately cut at a height of approximately 20 to 50 mm above ground level depending on the species, in such a way to simulate grazing. This collection covered 5 x 1 m² = 5 m² in each of 27 sites across the different plant communities (2 to 3 sites per sub-community). The grass was weighed before and after it was dried in an oven at 60ºC for 24 hours, most of the grass was already partly wind dried. The dry mass of the grass was transformed to the mean kg/ha for each sub-community. A similar collection of standing biomass was repeated during September 2004 but care was taken not to collect in exactly the same quadrates as previously. Results from a similar survey conducted in March and June 1994 (Greyling 1994) were also incorporated in the analyses.

Production curves for different plant communities were drawn with standing biomass values from 1994, 2002 and 2004 against effective rainfall. Different rainfall scenarios included: (1) total rainfall during the preceding summer or winter season (5 to 7 months); (2) total rainfall during the preceding 12 months (one year); (3) mean running rainfall of the preceding two years; and (4) mean running rainfall of the preceding three years. Vegetation productivity, measured as standing biomass, correlated strongly to rainfall. This correlation was measured by Seely (1978) in the Central Namib, and her results were consulted here for an indication of the shape as well as upper and lower limits of a production curve typical for the Namib Desert. This template was also used to extrapolate additional values for standing biomass at rainfall increments of 5 mm for the Garub data.

3.3 Grazing capacity

Grazing capacity correlated to rainfall and standing biomass were added to the above (3.2) production curves on the second y-axis. The 1994 grazing capacity figures were obtained from Greyling (1994) and transformed to kg/ha. The 2002 and 2004 grazing capacity figures were calculated in a similar way to the 1994 figures. This method is generally used in Agriculture (Bester 2003) where the available grass biomass (allowing some percentage for insects, desiccation, etc.) is divided by the nutritional needs of the herbivores. In this case a mature horse of approximately 350 kg requiring a mean of 7 kg of dry grass per day. The resultant graphs were accepted or modified according to their applicability, judged according to knowledge obtained through experience in the area. Various aspects that influence grazing capacity in the study area were also considered:

1) The study area is not entirely enclosed with consistent numbers of animals contained within it, the large herbivores (oryx, springbok and ostriches) vary regularly in numbers from zero to a few hundred.
2) The horses utilize annual herbs in addition to grass, but these herbs are only available unpredictably for short periods of the year depending on rainfall and cannot realistically be quantified, it is therefore not included into the standing biomass.
3) *Stipagrostis obtusa* and small tufts of *S. ciliata* die and weather away in the absence of regular rain, there are thus no long term build-up of a food reserve and the fluctuation in available biomass from year to year is extensive (supported by Nel 1983).
4) To quantify the amount of vegetation removed by abiotic factors such as desiccation and wind is almost impossible.
5) The use of conventional Ecological Index methods (e.g. Eckhardt, van Rooyen & Bredenkamp 1993) is not entirely feasible in the desert since the effect of grazing is mostly overshadowed by the effect of continual desiccation.
6) Termites have the potential of removing all the available standing biomass in specific patches (pers. obs.)

Given the above factors the following assumptions were made: (1) almost no large herbivores other than the horses will utilize the study area at low rainfall when the veld condition is poor, the number of game only increases after reasonable rain; (2) the available browse, annual herbs and vegetation in the mountains are not included in the measured standing biomass and will be regarded as a surplus to provide for possible inadequacies in the calculated grazing capacity; (3) in the absence of regular (every four months) significant rain (>10 mm), the established *Stipagrostis* tufts die, desiccate and weather away within 12 months; (4) normally termites remove only a percentage of the available phytomass, and only when an abundance of dry grass is available, their activity increase; (5) standing biomass, although already exposed to desiccation, wind and utilization by all herbivores, is assumed to be a good representation of the productivity of the grass component for the creation of production curves.

RESULTS & DISCUSSION

3.4 Identification of plant communities (September 2002)

The floral composition in the study area has not been investigated by other authors for the purposes of describing plant communities or vegetation structure. No comprehensive collection of plant specimens has occurred within the study area before this survey. Opportunistic previous collection was mostly concentrated along the B4 road and the mountain Dik Willem. The Sperrgebiet or Diamond area 1 was surveyed and divided into plant communities on a larger scale by Burke (2003). The southern part (south of the B4 road) of the study area was included in this description and mapped under "*Euphorbia gummifera* - *Stipagrostis ciliata* grassland" or "Northern gravel and sand plains". Another investigation recently described vegetation associations for the Aus Townlands, which borders the study area to the east (Mannheimer *et al.* 2005). Their division included a vegetation unit called "western desert plains" overlapping and similar to that in the study area but they did not describe this latter unit since no data was collected for it. During 1994 the study area was divided into five "veld types", named A to E, according to plant species composition (through wheel-point surveys), topography and geology (Greyling 1994). These five communities compare reasonably well with the present division of communities in that the areas are similar. The differences lie in more refined associations within the larger "veld types" and dividing the dune streets, slopes and crests into separate communities. The absence of annual herbs during the 1994 surveys contributed to the larger division of communities since some of the differential species that characterize the present sub-communities are annual herbs. It is important to realize that annual species are only present after good rainfall and the abundance of species (mostly *Stipagrostis obtusa*) will vary according to the amount and timing (month of the year) of rainfall.

During September 2002 a total of 92 plant species were recorded in 61 relevés (Appendix B). Analysis according to TWINSPAN showed four levels of division into 10 groups (Fig. 3.1). On level one, the dune crests (relevés 4, 40 and 42) were separated from all other relevés. On level two, three areas were separated from the remaining relevés (NW and SW facing gravel slopes - relevés 12 to 17, 18 to 20, 23,28; and NE facing sand ramp - relevé 41). The remaining relevés were separated on level four into four groups, which differentiated the eastern gravel slopes and dunes (relevés 22, 24 to 27, 30, 35,36, 43 to 56) into two groups. It further separated one riverbed (relevé 29) and grouped the western calcrete and stony plains together (relevés 1 to 11, 21, 31 to 37, 57 to 61). Further analysis following a stepwise ordination approach supported some, but not all, TWINSPAN divisions. Eight groups were identified with the DCA ordination by systematically removing outlying groups or individual relevés (Fig. 3.2), these groups were supported by the phytosociological table (Appendix B).

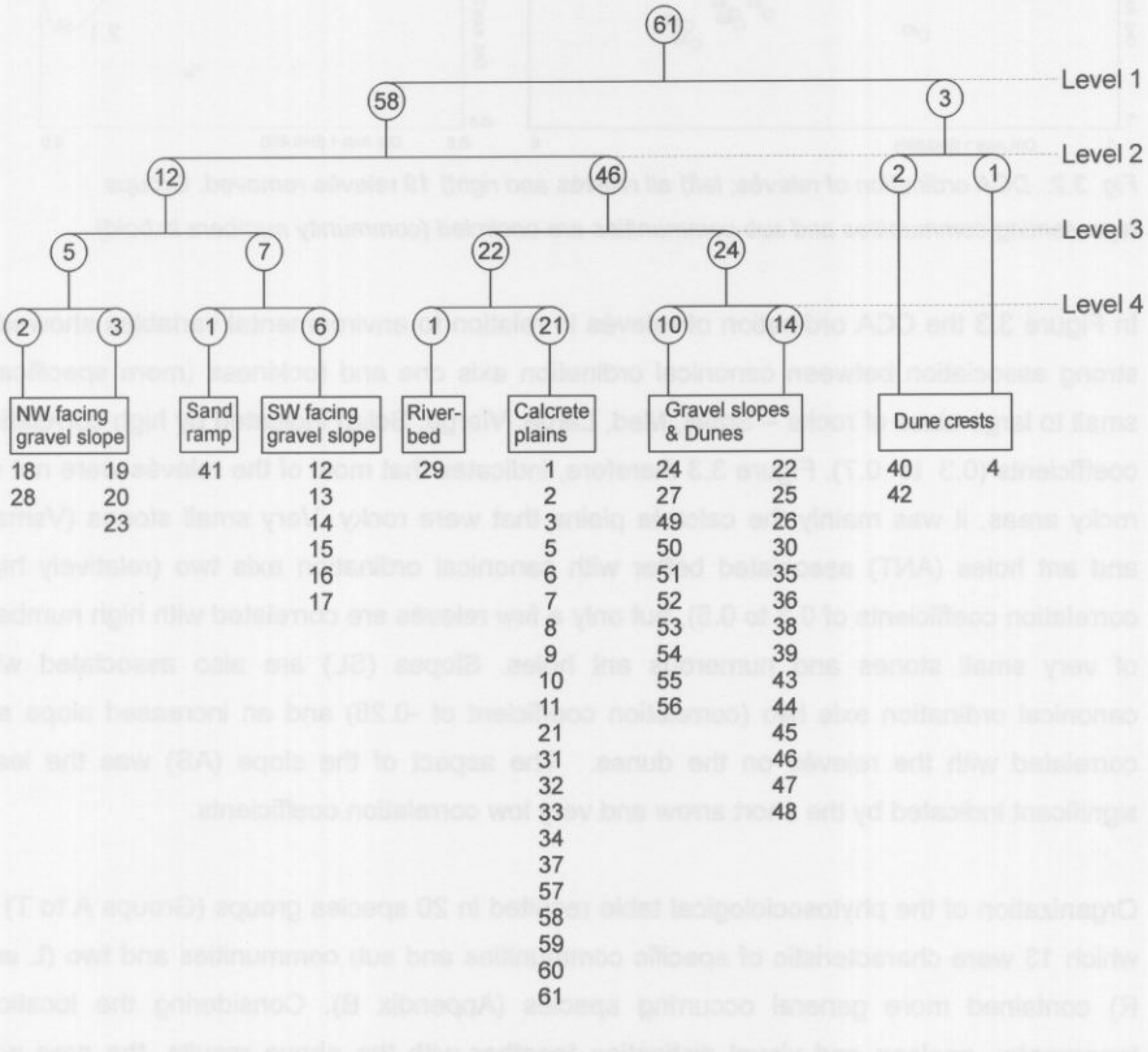


Fig. 3.1: Dendrogram showing relevé divisions according to TWINSPAN; encircled values represent the number of relevés in groups.

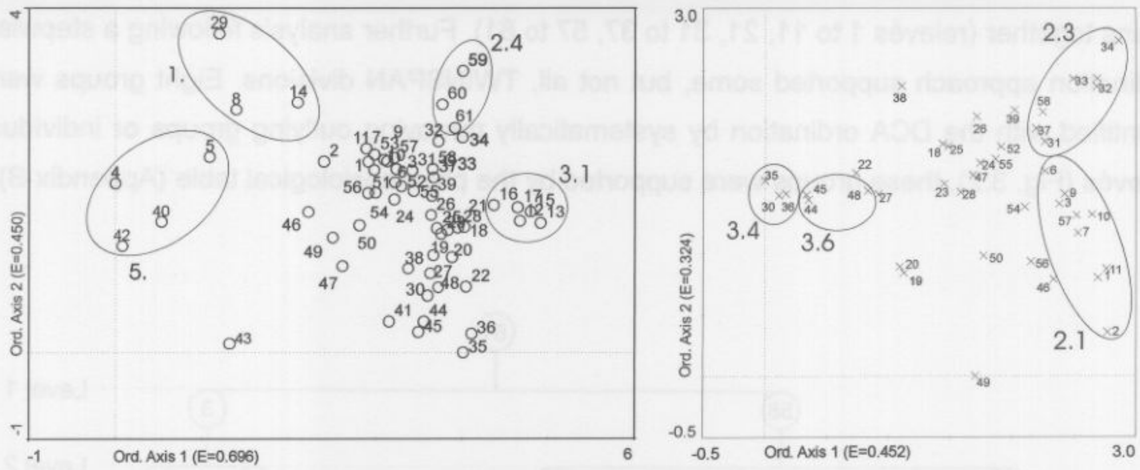
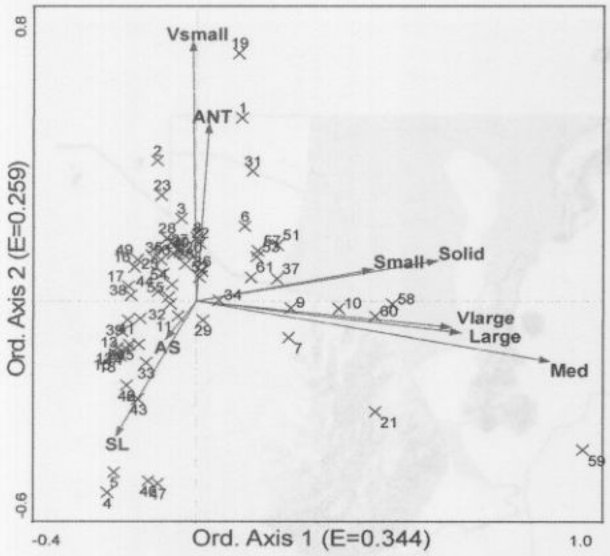


Fig. 3.2: DCA ordination of relevés; *left) all* relevés *and right) 19* relevés *removed. Groups representing communities and sub communities are encircled (community numbers in bold).*

In Figure 3.3 the CCA ordination of relevés in relation to environmental variables showed a strong association between canonical ordination axis one and rockiness (more specifically small to large sizes of rocks – Small, Med, Large, Vlarge, Solid) indicated by high correlation coefficients (0.3 to 0.7). Figure 3.3 therefore, indicates that most of the relevés were not on rocky areas, it was mainly the calcrete plains that were rocky. Very small stones (Vsmall) and ant holes (ANT) associated better with canonical ordination axis two (relatively high correlation coefficients of 0.3 to 0.5), but only a few relevés are correlated with high numbers of very small stones and numerous ant holes. Slopes (SL) are also associated with canonical ordination axis two (correlation coefficient of -0.28) and an increased slope are correlated with the relevés on the dunes. The aspect of the slope (AS) was the least significant indicated by the short arrow and very low correlation coefficients.

Organization of the phytosociological table resulted in 20 species groups (Groups A to T) of which 13 were characteristic of specific communities and sub communities and two (L and R) contained more general occurring species (Appendix B). Considering the location, topography, geology and visual distinction together with the above results, the area was finally divided into five main communities and 11 sub-communities (Table 3.2). A few of the species used in the community names are annual herbs that only occur after significant rain, *Stipagrostis obtusa* also increase and decrease significantly in abundance over time and therefore the most abundant or dominant species in a community may change over time. The description of the communities is based on the vegetation being in excellent condition following good winter rainfall.



Correlation coefficients

Factor	Ord. axis 1	Ord. axis 2
ANT	0.0268	0.3706
AS	-0.0639	-0.0797
SL	-0.1692	-0.2811
Vsmall	-0.008	0.5419
Small	0.3712	0.0658
Med	0.7473	-0.1266
Large	0.5588	-0.0672
Vlarge	0.5381	-0.0555
Solid	0.5084	0.0834

Fig. 3.3: CCA ordinations of relevés correlated to environmental variables (ANT-ant nests, AS-aspect, SL-slope, Rockiness: Vsmall-1 to 10mm; Small-11 to 30mm; Med-31 to 70mm; Large-71 to 150mm; Vlarge->150mm stones; Solid – solid rock).

Table 3.2: Plant communities and sub-communities of the Garub area.

Community Sub-community	Topography & geology	Dominant surface or soil type	September 2002 Mean species/relevé
1. *Forsskaolea candida - Stipagrostis ciliata* riverbeds	Riverbeds	River sand/alluvium	12
2. *Zygophyllum simplex - Stipagrostis obtusa* plains	Calcrete plains	Calcrete & pavement	11.8
2.1 *Helichrysum herniarioides - Stipagrostis obtusa*	Calcrete plains	Calcrete & pavement	8.6
2.2 *Zygophyllum decumbens - Stipagrostis obtusa*	Calcrete drainage area	Calcrete & river sand	8
2.3 *Salsola - Stipagrostis obtusa*	Calcrete plains	Calcrete & Aeolian sand	8.4
2.4 *Brownanthus ciliatus - Stipagrostis obtusa*	Calcrete plains	Calcrete	12
2.5 *Nemesia viscosa - Stipagrostis obtusa*	Calcrete ridges & sand depressions	Calcrete & river sand	22
3. *Eragrostis nindensis - Stipagrostis obtusa* slopes	Gravel slopes	Alluvium	10.6
3.1 *Brownanthus arenosus - Prenia tetragona*	SW facing slope	Alluvium	12
3.2 *Avonia albissima - Stipagrostis obtusa*	NW facing slope	Alluvium	13
3.3 *Leysera tenella - Stipagrostis obtusa*	W facing slope	Alluvium	16
3.4 *Kyllinga alba - Eragrostis nindensis*	NW facing slope	Aeolian sand	6.7
3.5 *Portulaca kermesina - Stipagrostis obtusa*	NE facing sand ramp	Dune sand (aeolian)	6.7
3.6 *Oncosiphon grandiflorum - Eragrostis nindensis* dune streets	Streets between dunes	Alluvium & Aeolian sand	9.3
4. *Oncosiphon grandiflorum - Stipagrostis obtusa* dune slopes	N facing dune slopes	Dune sand	15
5. *Centropodia glauca - Stipagrostis lutescens* dune crests	Dune crests & S facing slopes	Dune sand	7

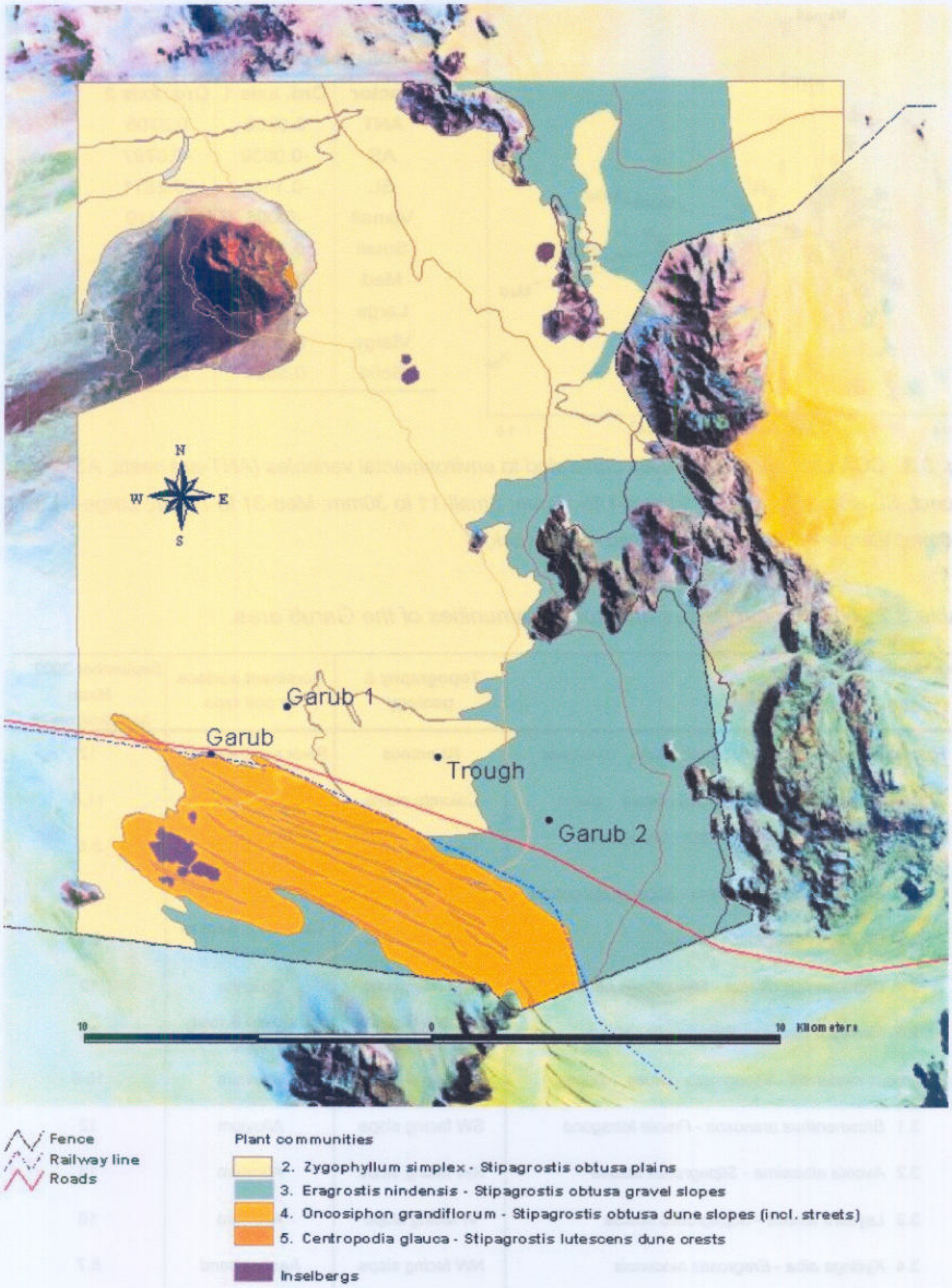


Fig 3.4: Plant communities of the Garub area. Note that the dune streets and dune slopes are not separated on the map.

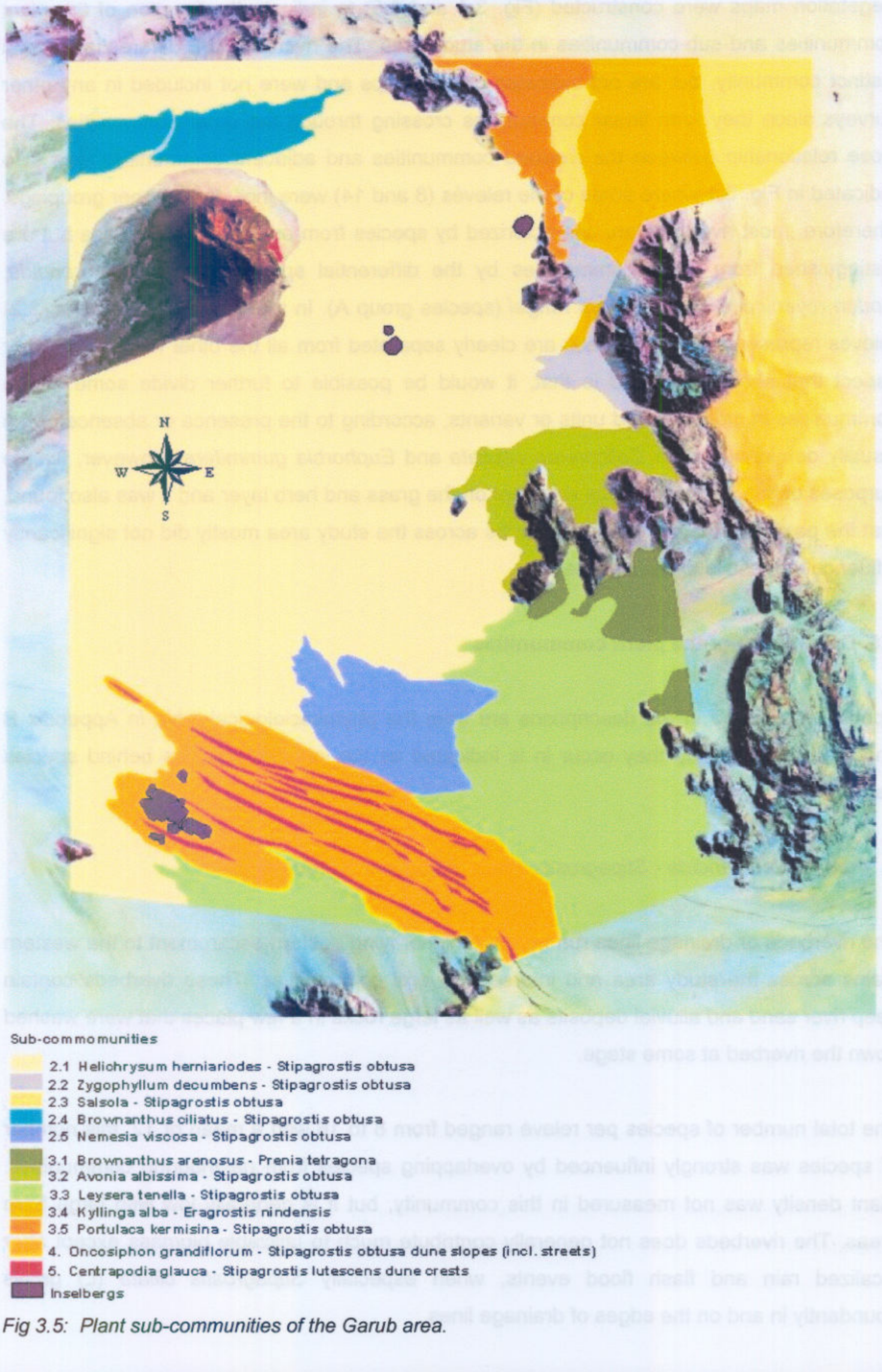


Fig 3.5: Plant sub-communities of the Garub area.

Vegetation maps were constructed (Fig. 3.4 and 3.5) to indicate the location of the plant communities and sub-communities in the study area. The riverbeds are differentiated as a distinct community, but are not indicated on the maps and were not included in any other surveys since they form linear communities crossing through the other communities. The close relationship between the riverbed communities and adjacent communities was also indicated in Fig. 3.1 where some of the relevés (8 and 14) were included in other groupings. Therefore, most riverbeds are characterized by species from adjacent communities but are distinguished from these communities by the differential species *Forsskaolea candida, Codon royenii* and *Merxmuellera rangei* (species group A). In the DCA-ordination (Fig. 3.2) relevés representing the riverbeds are clearly separated from all the other relevés. Another aspect that should be noted is that, it would be possible to further divide some of the communities in more detailed units or variants, according to the presence or absence of the visually dominant shrubs *Calicorema capitata* and *Euphorbia gummifera.* However, for the purposes of this study, the focus was kept on the grass and herb layer and it was also found, that the patchy distribution of these shrubs across the study area mostly did not significantly influence the results of the analyses.

3.5 Description of the plant communities

Species mentioned in the descriptions are from the phytosociological table in Appendix B and the species group they occur in is indicated as the letter in brackets behind species names.

1. *Forsskaolea candida - Stipagrostis ciliata riverbeds* **community**

The riverbeds or drainage lines run from the higher lying eastern escarpment to the western plains across the study area and intersect several communities. These riverbeds contain deep river sand and alluvial deposits as well as large rocks in a few places that were washed down the riverbed at some stage.

The total number of species per relevé ranged from 8 to 18 with a mean of 12, this number of species was strongly influenced by overlapping species from neighboring communities. Plant density was not measured in this community, but it is generally low with large bare areas. The riverbeds does not generally contribute much to utilizable biomass except after localized rain and flash flood events, when especially *Stipagrostis ciliata* (L) grows abundantly in and on the edges of drainage lines.

The differential species are indicated in species group A and include the herbs *Codon royenii, Forsskaolea candida, Indigofera auricoma, Kissenia capensis*, and the grass *Merxmuellera rangei.* The grass *Stipagrostis ciliata* (L) and the forbs *Forsskaolea candida* (A) were the most abundant species, followed by the herb *Indigofera auricoma* (A) and the grasses *Enneapogon desvauxii* (L), *S. lutescens* (S) and *S. obtusa* (R). Other species that were not recorded but typically occurred in the riverbeds especially in the east of the study area was the Camel Thorn tree, *Acacia erioloba* and the grass *Stipagrostis namaquensis.* Other species, which were characteristic of the adjacent communities sometimes also occurred in the riverbeds but were not characteristic of the riverbed community.

2. Zygophyllum simplex - Stipagrostis obtusa *plains* ***community***

This community covers the largest part of the study area, almost the entire western side from north to south. These plains are predominantly bare but sometimes with grassy patches, and stretch southwest, west, northwest and north of the water troughs. The elevation in this community range from 750 to 1000 m.a.s.l. It predominantly consists of exposed calcrete crusts, which were eroded away in some areas and is to a certain extent covered with soil in other areas. Aeolian sand that collected on the uneven surface and in the hollow pockets of the calcrete crusts created a substrate for vegetation to establish. These uneven distributions of aeolian sand therefore play a large role in the density of the vegetation that occurs in this area. Parts which do not have surface calcrete, have hard calcareous soil with a layer of small stones on the surface, most finer material between these stones are removed by strong winds. The surfaces of this community are generally hard, rocky and abrasive, especially on the calcrete areas.

The differential species for this community were the annual herbs *Zygophyllum simplex* (G) and *Gazania jurineifolia* (G) and the dwarf shrub *Peliostomum viscosum* (G). The most abundant species were the grasses *Stipagrostis obtusa (R), S. ciliata (L)* and *Enneapogon desvauxii (L).*

2.1 Helichrysum herniarioides - Stipagrostis obtusa ***sub-community***

The *Helichrysum herniarioides-Stipagrostis obtusa* sub-community covers the largest part of the *Zygophyllum simplex - Stipagrostis obtusa* plains community. The physical characteristics of this sub-community are similar to the above description for the community.

Several relevés from this community correlated with increased rockiness in Fig.3.3 due to the extensive stony and calcrete surfaces in this area.

The total number of species per relevé ranged between 5 to 12 with a mean of 8.6. The vegetation structure can be classified as low desert grassland, and was dominated by grasses (12% cover) at a mean height of 250 mm. In some areas the large (0.5 to 1.5 m high) succulent shrub *Euphorbia gummifera* (R) (1% cover) was conspicuous while prostrate herbs were generally hidden from view.

The differential species were the herbs *Helichrysum herniarioides* (B), *Lotononis strigillosa* (B), *Fagonia isotricha* (B), *Tribulus zeyheri* (B) and *Pent zia spinescens* (B). The most abundant species were the grasses *Stipagrostis obtusa (R)* and *S. ciliata (L)* followed by the herbs *Zygophyllum simplex* (G), *Dimorphoteca polyptera* (R), *Heliophila deserticola* (R), *Helichrysum herniarioides* (B), the grass *Enneapogon desvauxii (L)* and the succulent shrub *Euphorbia gummifera* (R). The latter shrub is the most prominent visual feature of this community although it occurs in patches and is absent from large areas. Due to very low rainfall (mean of 20 to 30 mm annually) in this area, almost no perennial species other than *E. gummifera* occur and this area often becomes fairly barren.

2.2 Zygophyllum decumbens - Stipagrostis obtusa ***sub-community***

This relatively small sub-community is located along the eastern boundary of the study area. It is a complex drainage area below the mountains of the escarpment. It also forms part of the division between the Garub plain with its slight slope facing west and the Koichab plains slightly facing northeast. The area is situated 11 to 14 km north-northeast from the water troughs with an elevation of 1000 to 1100 m.a.s.l. Landforms predominantly consist of calcrete crusts interspersed with drainage lines, the calcrete surfaces are coarse with little soil covering and the drainage lines have alluvial deposits, which are littered with rocks.

Only one relevé with nine species were recorded on this community in September 2002, it is a varied and complex system which is difficult to measure and interpret. The vegetation structure, low desert grassland, consisted of predominantly grasses (20% cover) at a height of 200 mm, but the shrub layer of leaf succulents (7% cover) at a height of 250 mm were more conspicuous, herbs/forbs (3% cover) especially *Blepharis furcata* (C) were also noticeable.

There were two differential species recorded in the relevé, the dwarf shrub *Zygophyllum decumbens* (C) and the forbs *Blepharis furcata* (C). However, the succulent shrub *Zygophyllum lignosa* was also characteristic of this community although not recorded in the relevé,. The most abundant species were *Zygophyllum decumbens* (C) and the grasses *Stipagrostis obtusa (R)* followed by *S. ciliata (L)* , *Eragrostis nindensis* (O), *Enneapogon desvauxii (L),* and the herbs/forbs *Blepharis furcata* (C), *Ifloga molluginoides* (O) and *Lachenalia giessii* (R). Another species which were not recorded but occur in this sub-community is the succulent shrub *Euphorbia mauritanica* which is a local endemic to the Aus area.

2.3 Salsola - Stipagrostis obtusa ***sub-community***

The *Salsola - Stipagrostis obtusa* sub-community is located in the northeast corner of the study area on the Koichab plains and is the furthest point where horses have been observed, albeit occasionally. It is 17 to 25 km from the water troughs with an elevation of 1000 m.a.s.l. The surfaces consist of calcrete crusts which are reasonably well covered with aeolian sand and it is also an area that gets on average more summer than winter rain.

The total number of species per relevé ranged between 6 to 11 with a mean of 8.4. The vegetation structure, low desert grassland, was dominated by grasses (20% cover) at a height of 150 mm but the *Salsola* dwarf shrubs (2.5% cover) at a height of 200 to 250 mm were visually more dominant and the herb layer (2.5% cover) was also noticeable.

The differential species were the dwarf shrubs *Salsola sp.* (D), *Peliostomum leucorrhizum* (D) and the herb *Monechma desertorum* (D). The most abundant species was the grass *Stipagrostis obtusa (R)* followed by *Zygophyllum simplex* (G), *Salsola sp.* (D), *Stipagrostis ciliata (L), Enneapogon desvauxii (L)* and *Monechma desertorum* (D).

2.4 Brownanthus ciliatus - Stipagrostis obtusa ***sub-community***

This sub-community forms a small island in the northwestern part of the study area within the larger *Helichrysum herniarioides - Stipagrostis obtusa* sub-community. It is situated 17 km north-northwest of the water troughs with an elevation of 1000 m.a.s.l. and consists of a fairly well vegetated calcrete crust. It is a very conspicuous area on both aerial photographs and satellite images.

The total number of species per relevé ranged between 11 to 14 with a mean of 12. The vegetation structure, short desert shrubland, was dominated by the herb (22% cover) and shrub (3% cover) components at a height of 250 to 800 mm, the grasses (15% cover) were less obvious at a height of 200 mm.

The differential species were the leaf succulents *Brownanthus ciliatus* (E), *Mesembryanthemum guerichianum* (E), and the dwarf shrubs *Aptosimum spinescens* (E) and *Galenia pruinosa* (E) . The most abundant species were *B. ciliatus* (E), the grass *Stipagrostis obtusa (R)* and the herb *Zygophyllum simplex* (G) followed by grasses, *Stipagrostis ciliata (L), Enneapogon desvauxii (L),* the herbs *Heliophila deserticola* (R), *Foveolina dichotoma (R)* and succulent shrub *Euphorbia gummifera* (R). Noticeably, in a patch next to and to a small extend overlapping with this community, numerous individuals of the succulent dwarf shrub *Augea capensis* occur.

2.5 Nemesia viscosa - Stipagrostis obtusa ***sub-community***

This sub-community is located around and to the west of the water troughs with an elevation of 800 to 850 m.a.s.l., and consists of a complex of calcrete ridges and riverbeds or sandy depressions. The calcrete surfaces are fairly exposed but have many sand hummocks behind shrubs. The hummocks and depressions contain aeolian sand ranging from a fine grain to coarser gravel that was deposited by strong Berg winds.

The total number of species per relevé ranged between 13 to 31 with a mean of 22, which is the highest diversity in any of the communities. None of the components really dominated the vegetation structure, short desert shrubland. The most conspicuous component was the large (500 to 800 mm) *Calicorema capitata* (L) shrubs (5.3% cover) with associated sand hummocks followed by the grasses (11% cover) at a height of 230 mm and herbs (7% cover).

The differential species were the dwarf shrubs *Nemesia viscosa* (F), *Hermannia spinosa* (F), *Lessertia falciformis* (F), *Galenia fruticosa* (F), *Aptosimum eriocephalum* (F) and *Lycium sp.* (F), the grass *Eragrostis annulata* (F) and the geophytes *Albuca sp.* (F). The most abundant species were the grass *Stipagrostis obtusa (R)* and herb *Zygophyllum simplex* (G) followed by *Stipagrostis ciliata (L), Calicorema capitata* (L), *Foveolina dichotoma (R), Heliophila deserticola* (R), *Dimorphoteca polyptera* (R), *Helichrysum cf. gariepinum* (Q), *Gazania jurineifolia* (G), *Nemesia viscosa* (F), *Hermannia spinosa* (F), *Eragrostis annulata* (F), *Lessertia falciformis* (F), *Hirpicium echinus* (Q), *Eragrostis nindensis* (O), *Hermannia paucifolia (L)* and *Enneapogon desvauxii (L)*. A few *Acacia erioloba* trees also occur in the main drainage course through this area.

3. Eragrostis nindensis - Stipagrostis obtusa *gravel slopes* ***community***

The *Eragrostis nindensis - Stipagrostis obtusa* gravel slopes include most of the eastern side of the study area and is further divided into six sub-communities. The gravel slopes comprise of west and northwest facing slopes with an elevation of 900 to 1100 m.a.s.l. Two areas on the Koichab plains are included with relatively high densities of *Eragrostis nindensis*, as well as the dune streets in the dune area south of the B4 road. The gravel slopes consist of alluvial and elluvial sand and rock fragments, deflation residue and talus deposits (referred to in this study as alluvium). On the Koichab plains and dune streets a layer of aeolian sand was deposited which have a finer texture than the typical gravel slopes.

The species diversity for this community ranged from 6.7 mean species per relevé on the Koichab plains to a mean of 16 on the gravel slopes, a slightly higher species diversity could be expected to occur on the Koichab plains after more significant rainfall in that area. The differential species for this community were the grass *Eragrostis nindensis* (O) and the herb *Ifloga molluginoides* (O). The most abundant species were the grasses *Stipagrostis obtusa (R)* and *Eragrostis nindensis* (O).

3.1 Brownanthus arenosus - Prenia tetragona ***sub-community***

This sub-community is situated on the eastern boundary of the study area, 7 to 8 km northeast of the water troughs. Its elevation is 1050 to 1100 m.a.s.l. It is a relatively small southwest facing gravel slope area just south of an east-west orientated mountain range. This area has a red-brown sandy soil classified as alluvium with a thin layer of gravel (1 to 5 mm diameter quartz and other stones), the wind action responsible for deeper gravel layers is not as severe in this area possibly due to the higher perennial vegetation cover or protection from the mountain range.

Total number of species per relevé in this sub-community ranged from 9 to 15 with a mean of 12. The vegetation structure, low desert herbland, was dominated by two species, *Brownanthus arenosus* (H) and *Prenia tetragona* (H). These species are leaf succulents of

300 to 500 mm high and have a cover value of about 25%. The mean grass cover was 13% with a height of 150 mm and the mean density was 15.7 tufts of grass per square meter.

The differential species were the leaf succulents *Brownanthus arenosus* (H), *Prenia tetragona* (H), and forbs and herbs including *Suessenguthiella scleranthoides* (H), *Limeum argute-carinatum* (H) and *Lessertia acanthorhachis* (H). The most abundant species were *Prenia tetragona* (H), *Brownanthus arenosus* (H) and the grass *Stipagrostis obtusa (R)* followed by *S. ciliata (L), Foveolina dichotoma (R), Eragrostis nindensis* (O) and *Ifloga molluginoides* (O).

3.2 Avonia albissima - Stipagrostis obtusa ***sub-community***

This sub-community is located north of the previous sub-community (*Brownanthus arenosus - Prenia tetragona*) separated by the mountain range mentioned above. It is a northwest facing gravel slope, which forms the immediate drainage area of the mountains along the eastern boundary; it is 7 to 10 km northeast of the water troughs with an elevation of 950 to 1200 m.a.s.l. The soil in this area vary from a fine sandy-loamy soil to a predominantly quartzite type river sand and alluvial deposits which reach at least 500 to 700 mm deep. The area is also reasonably littered with rocks of various sizes originating from the mountains.

The total number of species per relevé ranged between six (relevés on edge of community) to 17 with a mean of 13. The vegetation structure, low desert grassland, was dominated by grasses of about 250 mm high (20% cover), the herb layer consisting of a few leaf succulents was fairly obvious at a height of 150 to 250 mm (6.9% cover).

The differential species were *Avonia albissima* (I), *Indigofera* sp. (I), *Polygala leptophylla* (I), *Chascanum garipense* (I) and *Oxalis luederitzii* (I). The most abundant species were the grasses *Eragrostis nindensis* (O), *Stipagrostis obtusa (R)* and the multi-seasonal *Hypertelis salsoloides* (J) followed by *S. ciliata (L)*, *Hermannia paucifolia (L)*, *Dicoma capensis* (J), *Dimorphoteca polyptera* (R), *Ifloga molluginoides* (O) and *Avonia albissima* (I). Species group J as well as *Prenia tetragona* (H) indicate an affinity between the *Avonia albissima - Stipagrostis obtusa* and *Brownanthus arenosus - Prenia tetragona* sub-communities, which is most likely due to the close proximity of both communities with the difference being the aspect of their slopes on either side of the dividing mountain. The *Avonia albissima - Stipagrostis obtusa* community also has the most *Acacia erioloba* trees second to the dune area, these trees grow on the higher lying area close the mountains. *Dicoma capensis* (J) is listed as a possible red data species under the category Data Deficient and *Oxalis luederitzii* (I) is thought to be a local endemic to the Aus area.

3.3 Leysera tenella - Stipagrostis obtusa ***sub-community***

The *Leysera tenella - Stipagrostis obtusa* sub-community usually carries the highest density of large herbivores and receives on average the most rain in the study area. It is a west facing gravel slope located 2 to 10 km east of the water troughs with an elevation of 875 to 1100 m.a.s.l. and constitute the southeastern corner of the study area. The area consists of alluvium and the surface typically has a 10 to 20 mm layer of gravel which consists of 2 to 10 mm diameter stones. This community is exposed to severe wind action during strong Berg winds and the soil surface developed mega-ripples in places as well as large sand hummocks collected behind shrubs.

The total number of species per relevé ranged between 11 to 30 with a mean of 17, which is the second highest diversity in the study area. The vegetation structure, low desert grassland, was dominated by grasses (27% cover) at a height of 250 mm. C*alicorema capitata* (L) shrubs (3% cover) form an important feature of this community with the herb layer (6.8% cover) also noticeable. Patches of the succulent shrub *Euphorbia gummifera* (R) are also prominent.

The main differential species were the herbs *Leysera tenella* (K), *Lotononis falcata* (K), *Grielum humifusum* (K), *Arctotis fastuosa* (K), *Monsonia deserticola* (K) and *Asparagus exuvialis* (K). The most abundant species were the grasses *Stipagrostis obtusa (R)* and *S. ciliata (L)* followed by *Eragrostis nindensis* (O), *Ifloga molluginoides* (O), *Heliophila deserticola* (R), *Dimorphoteca polyptera* (R), *Foveolina dichotoma (R)* and *Leysera tenella* (K).

3.4 Kyllinga alba - Eragrostis nindensis ***sub-community***

This community is located on the Koichab plains along the eastern boundary; it is a north facing sandy slope 15 to 19 km north-northeast of the water troughs with an elevation of 1000 to 1100 m.a.s.l. The soil in this area is classified as aeolian sand and also have some gravel particles but does not have a gravel layer to the extend of the *Leysera tenella - Stipagrostis obtusa* sub-community.

The total species per relevé ranged between 5 to 8 with a mean of 6.7, which together with the *Portulaca kermesina - Stipagrostis obtusa* sub-community and *Centropodia glauca - Stipagrostis lutescens* dune crests community have the lowest diversity. The vegetation structure, low desert grassland, was dominated by grasses (14% cover) at a height of 70 mm, the herb layer (1% cover) was almost not apparent at the time. This is a very exposed area, which usually have a relatively low vegetation cover (14%) but it can improve significantly in the event of good summer rain.

Although the differential species was the herb *Kyllinga alba* (M) this sub-community was better characterized by the absence of species groups H to L and the relative low cover of the grass, *S. obtusa (R)* in comparison with the other sub-communities in this community. The most abundant species was the grass *Eragrostis nindensis* (O) followed by *Stipagrostis obtusa (R), Foveolina dichotoma (R)* and *Manulea gariepina* (Q).

3.5 Portulaca kermesina - Stipagrostis obtusa ***sub-community***

This community characterize an extensive northeast facing "sand ramp" (refer to Bertram 2003, for a description of sand ramps in the area), which is located on the eastern side of part of the mountain range that separates the Garub and Koichab plains. It is 17 to 20 km north of the water troughs with an elevation of 1000 to 1100 m.a.s.l. It consists of aeolian sand, which is continually exposed to wind action and have a typical *Centropodia glauca - Stipagrostis lutescens* dune crests community at the top of the ramp next to the mountain.

The total number of species per relevé ranged between 5 to 10 with a mean of 6.7. The vegetation structure, low desert grassland, was dominated by grasses (12% cover) at a height of 80 mm although visually the herb layer (6% cover) was more apparent due to the yellow flowers of *Foveolina dichotoma (R)*. This sand ramp, similar to the previous community, is usually sparsely vegetated (18% cover) but could produce significant vegetation after good summer rains.

Although the differential species were the succulent herb *Portulaca kermesina* (N) and the geophytes *Ammocharis coranica* (N), this sub-community is better characterized by the absence of species H to L and Q. The most abundant species were the grass *Stipagrostis obtusa (R)* and the herb *Foveolina dichotoma (R)* followed by *Eragrostis nindensis* (O), *Portulaca kermesina* (N), *Zygophyllum simplex* (G), *Ifloga molluginoides* (O), *Dimorphoteca polyptera* (R) and *Heliophila deserticola* (R). Noticeably, *Eragrostis nindensis* (O) is not uniformly distributed across this community but occur in typical circular patches localized to some parts of the sand ramp, these patches further create concentrations of some of the other species. A possible explanation for the absence of *S. ciliata (L)* could be the mean lower rainfall and continuous exposure to strong winds on the Koichab plains which inhibit the establishment of perennial *S. ciliata* tufts.

3.6 Oncosiphon grandiflorum – Eragrostis nindensis *dune streets* ***sub-community***

This sub-community is located in the sand dune area 3 to 7 km south of the water troughs at an elevation of 800 to1000 m.a.s.l. It comprises of the dune streets, 50 to 200 m wide, between the longitudinal dunes which are orientated in a southeast-northwest direction. The dunes are characterized by two other and separate plant communities which are discussed below. The most important differences between the streets and slopes were: the presence of *Eragrostis nindensis* (O) in the streets and the absence thereof on the slopes; the higher diversity of species on the slopes compared to the streets; and a relatively thin layer of dune sand in the streets compared to deep dune sand on the slopes.

The total number of species per relevé ranged between 9 to 10 with a mean of 9.3. The vegetation structure consisted of numerous very large (0.5 to 1.2 m high) *Euphorbia gummifera* (R) shrubs (5% cover) and predominantly grass (12% cover) with some herbs (4% cover).

The differential species for this sub-community were the herbs *Oncosiphon grandiflorum* (P) and *Lotononis sparsiflora* (P). *Oncosiphon grandiflorum* (P) is also a differential species for the dune slopes community and indicate the affinity between these two communities. The most abundant species were the grasses *Eragrostis nindensis* (O) and *Stipagrostis obtusa (R)* followed by *Oncosiphon grandiflorum* (P), *Foveolina dichotoma (R)*, *Heliophila* *deserticola* (R) and *Euphorbia gummifera* (R). The dune streets were further differentiated from the dune slopes by the absence of amongst others the grasses *Stipagrostis ciliata (L)* and *Brachiaria glomerata* (T). Numerous *Acacia erioloba* trees also occur in the dune streets and on the dune slopes in the northeastern part of the dune area.

4. Oncosiphon grandiflorum – Stipagrostis obtusa *dune slopes* ***community***

The *Oncosiphon grandiflorum – Stipagrostis obtusa* dune slopes community characterizes the north facing slopes of the longitudinal sand dunes in the south of the study area. These longitudinal dunes (approximately 7 to 8 km long) are orientated in a southeast-northwest direction with a gradual northern slope and a steep southern slope. The dune crests and steep southern slopes are characterized by the *Centropodia glauca - Stipagrostis lutescens* dune crests community.

The total number of species per relevé on the slopes ranged between 12 to 19 with a mean of 15. The vegetation structure, similar to that in the dune streets, consisted of numerous very large (0.5 to 1.2 m high) *Euphorbia gummifera* (R) shrubs (5% cover) and a combined grass (15% cover) and herb (17% cover) layer at a height of 150 to 250 mm.

Four species are indicated as differential species for this community since they are more abundant on the slopes than in the streets or on the crests, these were the herbs *Oncosiphon grandiflorum* (P), *Helichrysum leontonyx* (T), *Ursinia speciosa* (T) and the grass *Brachiaria glomerata* (T). The other species (in species group U) are not indicated as differential species due to their more equal distribution between the dune streets, slopes and crests. The most abundant species on the dune slopes were *Oncosiphon grandiflorum* (P) and *Stipagrostis obtusa (R)* followed by *Stipagrostis ciliata (L)*, *Euphorbia gummifera* (R), *Heliophila deserticola* (R), *Brachiaria glomerata* (T) and *Helichrysum leontonyx* (T).

5. Centropodia glauca - Stipagrostis lutescens *dune crests* ***community***

This community characterizes the dune crests in the study area that for the most part occur in the dune area in the south of the study area as described above. Two other patches of this community are located on the sand ramp against the eastern slope of the mountain Dik Willem and the sand ramp described under the *Portulaca kermesina - Stipagrostis obtusa* sub-community. The surface dune sand in this community is continually shifted due to wind action.

The total number of species per relevé ranged between 4 to 10 with a mean of 7. The vegetation structure was dominated by the relatively tall grass *Stipagrostis lutescens* (S) (9% cover) at a height of 0.5 to 1 m, *Centropodia glauca* (S) (2% cover) was sparser with a height of 300 mm and only few herbs (<1%) were present.

The differential species were the grasses *Centropodia glauca* (S), *Stipagrostis lutescens* (S), and the herbs *Cotyledon* sp. (S) and *Melolobium macrocalyx* (S). The most abundant species were *Stipagrostis lutescens* (S) and *Centropodia glauca* (S) with only few individuals of *Brachiaria glomerata* (T), *Stipagrostis ciliata (L), Cotyledon sp.* (S), *Foveolina dichotoma (R), Helichrysum leontonyx* (T), *Ursinia speciosa* (T) and *Limeum sp.* (T).

3.6 Standing biomass and grazing capacity

The mean standing biomass of grasses on the different plant communities during different years is listed in Table 3.3. together with the grazing capacities in kg/ha live animal biomass. The *Forsskaolea candida - Stipagrostis ciliata* riverbeds are not treated separately but are included within the other communities. The *Zygophyllum decumbens - Stipagrostis obtusa* sub-community were not surveyed separately for standing biomass but compare well with the *Brownanthus ciliatus - Stipagrostis obtusa* sub-community. The dune streets were included with the dune slopes for practical reasons.

Considering the different rainfall scenarios as presented in Table 3.4, it is obvious that the preceding season's (winter or summer) rainfall cannot be used when no effective rain occurred during those few months, which is not unusual for the study area. The three year running mean rainfall could potentially be inappropriate when exceptionally high rainfall years were part of the three years, since it increases the mean rainfall figure while the vegetation from that exceptional year already decreased significantly within one year (compare the 70 mm three year mean rain for 2004 with the low biomass remaining - Table 3.4). The two remaining scenarios were tested by constructing production curves of rainfall against grass biomass. It seemed as if the "total rainfall of the preceding year" best portrayed a realistic picture (Fig. 3.6.a) since the angle of this curve were similar to the angle obtained in the study of Seely (1978). The two-year running mean rainfall created curves that turned earlier with a steeper angle, therefore resulting in higher grazing capacities at lower rainfall (Fig. 3.6.b), which is unlikely. Only the *Leysera tenella - Stipagrostis obtusa* sub-community graphs are presented here since it shows similar results to the other communities.

Table 3.3: Standing biomass of grasses and grazing capacity on different plant communities at Garub.

	Plant community/sub-community	Area size (ha)	Mean Standing Biomass (kg/ha)			Grazing capacity (kg/ha)		
			1994	2002	2004	1994	2002	2004
2.1	*Helichrysum herniarioides - Stipagrostis obtusa*	21473	4	221.90	7.71	0.55	29.31	1.02
2.3	*Salsola - Stipagrostis obtusa*	1398	n/a	150.88	20.54	n/a	19.93	2.71
2.4	*Brownanthus ciliatus - Stipagrostis obtusa*	1041	n/a	23.03	8.88	n/a	3.04	1.17
2.5	*Nemesia viscosa - Stipagrostis obtusa*	1561	11.5	67.75	2.61	1.49	8.95	0.35
3.1	*Brownanthus arenosus - Prenia tetragona*	672	10.8	150.39	12.53	1.47	19.87	1.66
3.2	*Avonia albissima - Stipagrostis obtusa*	1131	17.1	181.87	18.88	2.29	24.02	2.49
3.3	*Leysera tenella - Stipagrostis obtusa*	6056	11.3	162.88	17.62	1.51	21.52	2.3
3.4	*Kyllinga alba - Eragrostis nindensis*	1807	n/a	140.07	25.05	n/a	18.5	3.31
3.5	*Portulaca kermesina - Stipagrostis obtusa*	764	n/a	26.46	13.12	n/a	3.5	1.73
4	*Oncosiphon grandiflorum - Stipagrostis obtusa*	4360	13.2	260.60	n/a	1.87	34.4	n/a
5	*Centropodia glauca - Stipagrostis lutescens*	225	2.7	230.80	n/a	0.53	30.5	n/a

Table 3.4: Rainfall figures (measured at Garub 2) for different rainfall scenarios compared to the resultant standing biomass of grasses on the Leysera tenella - Stipagrostis obtusa *sub-community around Garub 2.*

Year	Mean grass biomass (kg/ha)	Preceding effective rainfall (mm)			
		Season total	1 Year total	2 Year Mean	3 Year Mean
1994	11	0	27	25	27
2002	163	64	115	100	66
2004	<u>18</u>	35	49	45	<u>70</u>

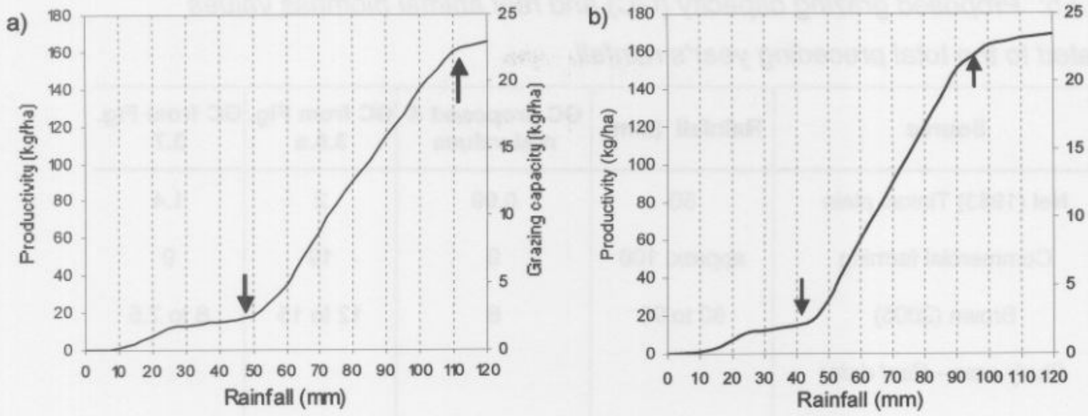


Fig 3.6: Production curves correlating standing biomass, rainfall and grazing capacity (from Table 3.3) of the Leysera tenella - Stipagrostis obtusa sub-community using a) total rainfall of the preceding year; and b) the preceding 2 years running mean rainfall.

The accuracy or applicability of the grazing capacity scale in Fig. 3.6a was evaluated against past real rainfall and live animal biomass figures from the study area as well as figures obtained by Nel (1983) for the Central Namib and known commercial farming values which were also used by Brown (2005) (Table 3.5). In general the grazing capacity values proposed by Nel (1983) were very low ranging from 0.12 to 3.78 kg/ha, even for an area that had 94 mm of rain. The only plant sub-community with higher values were the "*Stipagrostis ciliata* – Vegetative dunes" which had values between 7.19 to 10.08 kg/ha after about 20 and 80 mm rain respectively. Apart from this dune sub-community, the only other sub-community that could be reasonably compared with the *Leysera tenella - Stipagrostis obtusa* sub-community of the study area was the maximum value for the "*Stipagrostis obtusa* – Tinkas plain". It was found though that values for grazing capacity obtained from Fig. 3.6a were in general higher than existing proposed values. The grazing capacity scale was therefore adapted to proportionately reduce the grazing capacity correlated to rainfall (Fig. 3.7). It is important to note that the upper limit of grazing capacity was significantly reduced mainly so as to reduce too much fluctuation in the grazing capacity values even though the actual vegetation production after high rainfall events could sustain high grazing capacity values for limited periods.

Table 3.5: Proposed grazing capacity (GC) and real animal biomass values correlated to the total preceding year's rainfall.

Source	Rainfall (mm)	GC proposed & real values	GC from Fig. 3.6.a	GC from Fig. 3.7
Nel (1983) Tinkas plain	50	0.99	2	1.4
Commercial farming	approx. 100	9	19	9
Brown (2005)	80 to 90	6	12 to 15	6 to 7.5
Study area - Real data:				
December 1994	58	1.8	3	2
December 2003	42	1.4	1.5	1.2
June 2005	90	7.3	15	7.5

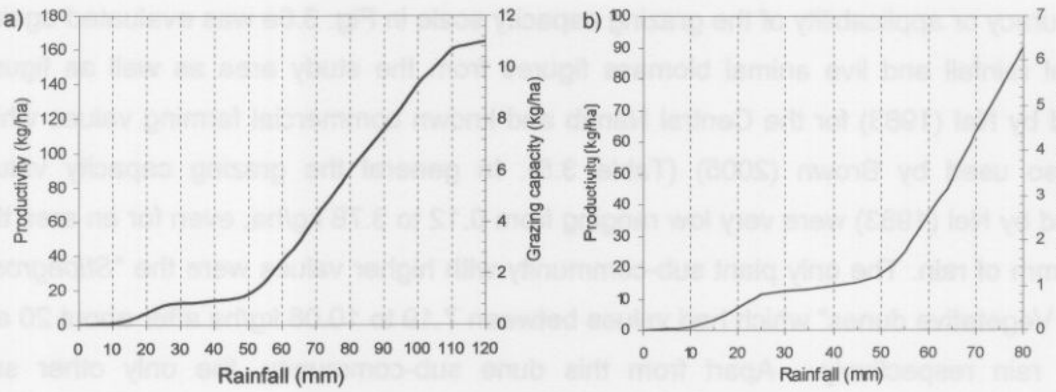


Fig 3.7: Final production curve correlating standing biomass, rainfall and grazing capacity for the Eragrostis nindensis - Stipagrostis obtusa *sand & gravel slopes community. a) 0 to 120 mm rainfall range; b) enlarged 0 to 80 mm rainfall range.*

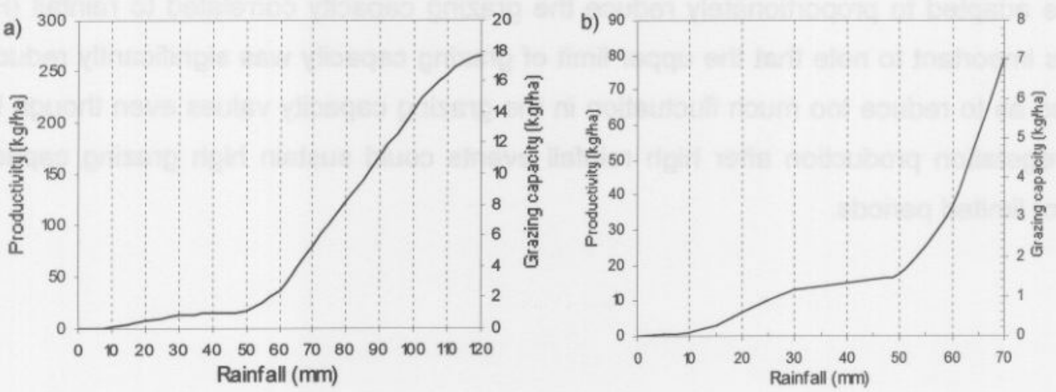


Fig 3.8: Final production curve correlating standing biomass, rainfall and grazing capacity for the Oncosiphon grandiflorum - Stipagrostis obtusa *dune slopes community. a) 0 to 120 mm rainfall range; b) enlarged 0 to 70 mm rainfall range.*

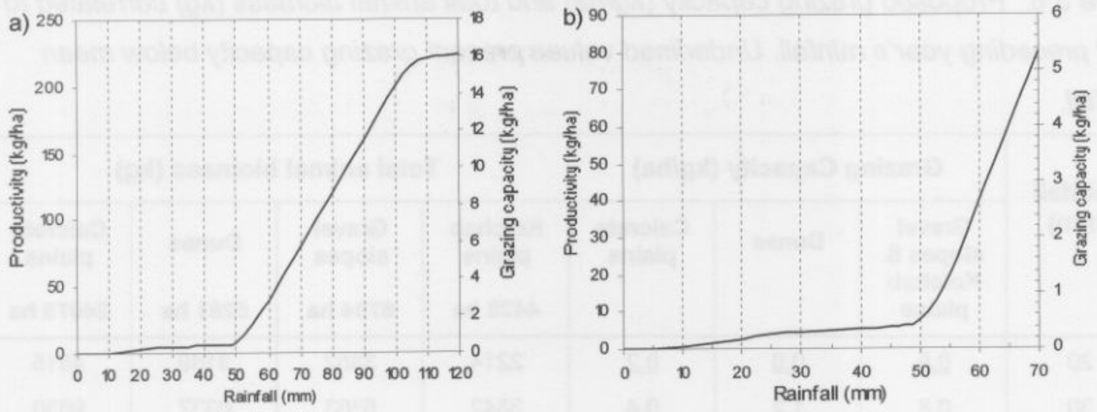


Fig 3.9: Final production curve correlating standing biomass, rainfall and grazing capacity for the Zygophyllum simplex - Stipagrostis obtusa *plains community (calcrete plains). a) 0 to 120 mm rainfall range; b) enlarged 0 to 70 mm rainfall range.*

Figures 3.7 to 3.9 were used to determine grazing capacity values of the different plant communities at 10 mm rainfall increments. The study area was divided into four regions (Table 3.10 and Fig. 3.10) to accommodate the different plant communities and patchy rainfall that often occur. Total animal biomass for these regions (Table 3.6) was calculated from the grazing capacity values. The total animal biomass (kg) were divided percentage wise to accommodate the horses and other large herbivores (referred to as game) according to the assumption that almost no game utilize the area at low rainfall (pers. obs.), where after the ratio increase to around 50%. The first results obtained in Table 3.7 presented fairly low numbers of animals below 60 mm rainfall, which was not a good representation of the actual numbers of animals sustained reasonably well in the study area during the past 10 years. Although the grazing capacity values obtained here compare well with Nel (1983) who suggested 0.6 kg/ha animal biomass for the Central Namib, and most likely could be true for the calcrete plains in the study area and barren plains further west, it is not typical of the gravel slopes or Pro-Namib. It seems as if the grazing capacity of the gravel slopes does not decrease as rapidly as presented in Fig. 3.7 and 3.8 at rainfall less than the mean of 55 mm. During the past 10 years (1994 to 2004) rainfall of seven years were below 50 mm and although the condition of the horses during this time indicated some stressed periods (end 1995, 1998 severely and beginning 2004), it was not typical all the time. Therefore the grazing capacity below 60 mm rainfall was adapted again towards the values obtained in 1994 for grazing capacity at mean rainfall.

Table 3.6: Proposed grazing capacity (kg/ha) and total animal biomass (kg) correlated to the total preceding year's rainfall. Underlined values present grazing capacity below mean rainfall.

Rainfall (mm)	Grazing Capacity (kg/ha)			Total animal biomass (kg)			
	Gravel slopes & Koichab plains	Dunes	Calcrete plains	Koichab plains 4428 ha	Gravel slopes 6704 ha	Dunes 5281 ha	Calcrete plains 24075 ha
20	0.5	0.6	0.2	2214	3352	3169	4815
30	0.8	1.2	0.4	3542	5363	6337	9630
40	1.0	1.3	0.4	4428	6704	6865	9630
50	1.2	1.6	0.5	5314	8045	8450	12038
55	1.8	2.2	1.2	7970	12067	11618	28890
60	2.8	3.4	2.6	12398	18771	17955	62595
70	4.6	7.0	5.3	20369	30838	36967	127598
80	6.2	8.0	8.8	27454	41565	42248	211860
90	7.8	11.0	11.5	34538	52291	58091	276863
100	9.5	14.0	14.0	42066	63688	73934	337050

Table 3.7: Proposed number of individuals (horses and game) that could utilize different regions in the study area correlated to the total preceding year's rainfall.

Rainfall (mm)	Proposed number of horses				Total horses	Proposed number of game				Total game*
	Koichab plains	Gravel slopes	Dunes	Calcrete plains		Koichab plains	Gravel slopes	Dunes	Calcrete plains	
20	7	10	10	15	35	0	0	0	0	0
30	11	17	19	30	66	0	0	0	0	0
40	11	17	17	24	57	4	6	6	9	21
50	13	20	21	30	70	5	7	8	11	26
55	15	22	21	53	97	14	22	21	53	96
60	19	29	28	96	153	28	43	41	142	226
70	31	47	57	196	301	46	70	84	290	444
80	42	64	65	326	455	62	94	96	482	672
90	53	80	89	426	596	78	119	132	629	880
100	65	98	114	519	730	96	145	168	766	1079

* Game = one gemsbok; to allow for springbok and ostriches, convert 1 gemsbok to 5 springbok or 2 ostriches.

Thereafter new grazing capacity values for below mean rainfall was calculated, by following the approach of Brown (2005), to reduce the values percentage wise below the mean rainfall (e.g. 55 mm = 100% = 1.8 kg/ha; 50 mm = 90% = 1.6 kg/ha) (compare the underlined values in Table 3.6 with Table 3.8). The resulting numbers of horses obtained in Table 3.9 more closely represent the actual numbers during the past 10 years.

Table 3.8: Adjusted grazing capacity (kg/ha) and total animal biomass (kg) correlated to the total preceding year's rainfall. Underlined values are below mean rainfall.

Rainfall (mm)	Grazing Capacity (kg/ha)			Total animal biomass			
	Gravel slopes & Koichab plains	Dunes	Calcrete plains	Koichab plains 4428 ha	Gravel slopes 6704 ha	Dunes 5281 ha	Calcrete plains 24075 ha
20	0.6	0.8	0.4	2657	4022	4225	9630
30	1.0	1.2	0.7	4428	6704	6337	16853
40	1.3	1.6	0.9	5756	8715	8450	21668
50	1.6	2.0	1.1	7085	10726	10562	26483
55	1.8	2.2	1.2	7970	12067	11618	28890
60	2.8	3.4	2.6	12398	18771	17955	62595
70	4.6	7.0	5.3	20369	30838	36967	127598
80	6.2	8.0	8.8	27454	41565	42248	211860
90	7.8	11.0	11.5	34538	52291	58091	276863
100	9.5	14.0	14.0	42066	63688	73934	337050

Table 3.9: Final proposed number of individuals (horses and game) that could utilize different regions in the study area correlated to the total preceding year's rainfall. Values in bold indicate numbers at mean rainfall for the specific regions. Refer to text for use of underlined values.

Rainfall (mm)	Proposed number of horses				Total horses	Proposed number of game*				Total game
	Koichab plains	Gravel slopes	Dunes	Calcrete plains		Koichab plains	Gravel slopes	Dunes	Calcrete plains	
20	8	12	13	30	55	0	0	0	0	0
30	14	21	19	**52**	92	0	0	0	**0**	0
40	**14**	21	21	53	96	**5**	8	8	20	35
50	17	26	26	65	118	6	10	10	24	43
55	20	**30**	**29**	71	129	7	**11**	**11**	26	48
60	19	29	28	96	153	28	43	41	142	226
70	31	47	57	196	301	46	70	84	290	444
80	42	64	65	326	455	62	94	96	482	672
90	53	80	89	426	596	78	119	132	629	880
100	65	98	114	519	730	96	145	168	766	1079

* Game = one gemsbok; to allow for springbok and ostriches, convert 1 gemsbok to 5 springbok or 2 ostriches.

No grazing capacity values are given for rainfall scenarios below 20 mm since that would be regarded as a severe drought and management steps will have to be taken regarding any population size during such period.

Table 3.9 can be used at any specific point in time to predict the current grazing capacity for the study area if the rainfall of the preceding 12 months is known. For each region a number of horses and game is proposed at different quantities of rainfall, and since the rainfall is normally patchy, numbers at different quantities of rainfall for the different regions could be extracted. For example, if the rainfall on the Koichab plains was 30 mm, on the Gravel slopes 50 mm, on the Dunes 40 mm and on the Calcrete plains 20 mm, then the study area could sustain 14+26+21+30=91 horses and 0+10+8+0=18 gemsbok (see underlined values in Table 3.9).

Table 3.10: Division of plant communities and sub-communities into four regions of the study area.

	Plant community/sub-community	Region
2.1	*Helichrysum herniarioides - Stipagrostis obtusa*	Calcrete plains
2.2	*Zygophyllum decumbens - Stipagrostis obtusa*	
2.4	*Brownanthus ciliatus - Stipagrostis obtusa*	
2.5	*Nemesia viscosa - Stipagrostis obtusa*	
3.1	*Brownanthus arenosus - Prenia tetragona*	Gravel slopes
3.2	*Avonia albissima - Stipagrostis obtusa*	
3.3	*Leysera tenella - Stipagrostis obtusa*	
3.4	*Kyllinga alba - Eragrostis nindensis*	Koichab plains
3.5	*Portulaca kermesina - Stipagrostis obtusa*	
2.3	*Salsola - Stipagrostis obtusa*	
3.6	*Oncosiphon grandiflorum - Eragrostis nindensis* dune streets	Dunes
4	*Oncosiphon grandiflorum - Stipagrostis obtusa*	
5	*Centropodia glauca - Stipagrostis lutescens*	

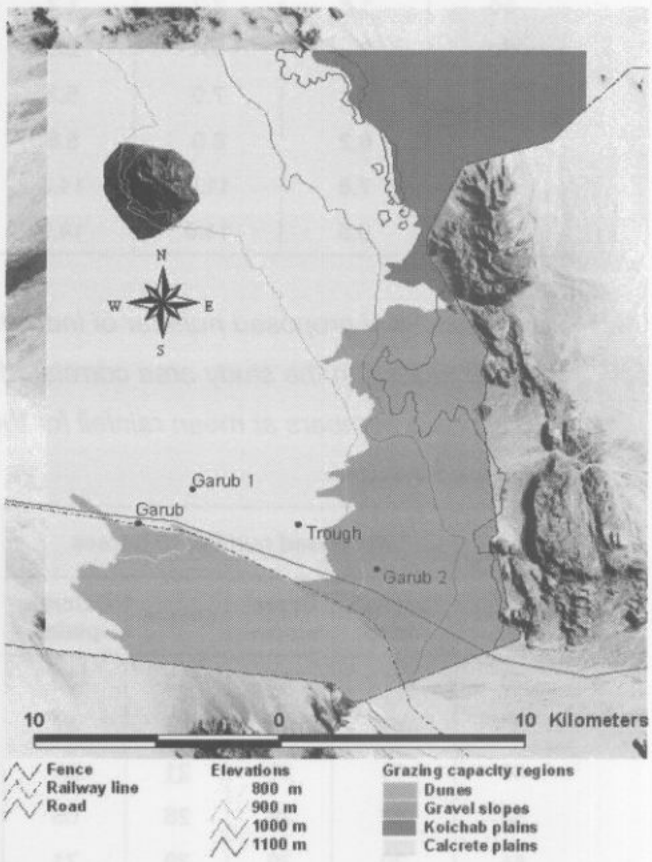


Fig. 3.10: Location and size of four regions used for determining animal numbers in study area.

If, as another example, half of the Calcrete plains receive 50 mm and the other half 30 mm of rain, the number of horses (65) for 50 mm could be divided by two (32) and the number (52) for 30 mm could be divided by two (26) to give a total of 58 horses for the Calcrete plains. Similarly the study area could sustain 14+30+29+52=125 horses and 5+11+11+0=27 gemsbok at mean rainfall over the different areas (see values in bold from Table 3.9).

CONCLUSIONS

Five main plant communities and 11 sub-communities, classified according to species composition, were identified within the study area. These communities and sub-communities also correlated with topography and geology (see Table 3.2 for a summary of these communities and Appendix B for the phytosociological table of species and relevés). The main communities represent a division of the study area according to the presence or absence of perennial species with a focus on the grass component. The sub-communities show variations within the larger communities mostly concerning annual species, but also with a few perennial leaf succulents and dwarf shrubs. These plant communities formed a basis for the collection of standing biomass and resultant calculation of grazing capacity for each community. The division of communities also indicated relatively homogeneous areas which were used for invertebrate surveys regarding the impact of the horses on their habitat.

The mean standing vegetation biomass for the study area, for the different rainfall periods, ranged between 2.61 to 260 kg/ha with the maximum for localized sites being 305 kg/ha. These quantities are much lower than values obtained by Seely (1978) and Nel (1983) in the Central Namib where 0 to 500 kg/ha and 3.3 to 2 524 kg/ha respectively were measured. This difference could most likely be attributed to the method of collection used. During this study, sampling attempted to simulate grazing, thus only cutting off the leaves and stalks of the grasses, leaving the base of the tuft intact. This contrasted with the other surveys which collected all the above-ground plant material for biomass calculations. However, these lower figures might also, at least partly, be due to the fact that these surveys were conducted in different areas/habitats. In general the grazing capacity of the western part of the study area could be compared with the gravel plains of the Central Namib, but it appears as if the higher probability of winter rain in the study area creates more consistent productivity on the *Eragrostis nindensis - Stipagrostis obtusa* gravel slopes and therefore higher grazing capacity than in the Pro-Namib areas of the Central Namib.

Determining and interpreting grazing capacity were approached from a perspective that vegetation productivity and therefore grazing capacity is directly linked to rainfall and varies significantly over short time intervals. Grazing capacity values were calculated with conventional methods and then compared and adjusted using real animal numbers and field experience in the study area. This resulted in a proposed range of numbers of game and horses that could be sustained in the study area related to rainfall (calculated on the total rainfall of the preceding 12 months). These proposed numbers are within the range that the population of horses has fluctuated during the past 10 years. Through this approach, the limitations of a fixed grazing capacity value are greatly reduced. The main problem remains of how to practically implement these numbers, in other words, the question of whether these numbers require artificial population control methods like capture, is not easy or straightforward to answer. It is, therefore, proposed that the number of herbivores obtained from Table 3.9 at any specific time serve as a forecasting/warning of possible emergency situations arising, rather than as a sign to initiate population control actions. The decision for population control measures should rather be based on an upper limit of the population size, since short term fluctuation in the grazing capacity is too large and numerous to continuously implement population control measures in keeping with this fluctuation in grazing capacity. Continuous artificial population control could also adversely affect the long term viability of the population, since our understanding of "natural selection" is still fairly limited for selection of individuals and the random removal of horses is potentially detrimental to the long term survival of the Namib horses (Gross 2000).

CHAPTER FOUR: GRAZER DYNAMICS

Chinese hand painted character.

INTRODUCTION

The horses could be a major grazing competitor for native species in the Namib Naukluft Park. Consequently, it is important to determine aspects of grazer dynamics, such as the distribution, density or activity, and interaction of grazers that utilize the area as an indication of possible competition between species. Knowledge regarding the way in which herbivores utilize the area could also contribute in assessing their impact on the vegetation. Any area is composed of a mosaic of different habitats, each with resources and conditions suitable and unsuitable for populations or individuals of different species. Although this mosaic of habitats determines the distribution of animals in any given area, it is not static and may change over time. A habitable patch may, for example, cease to be habitable when its resources are depleted by consumers or changing conditions, or when it is invaded by another species (Begon *et al*. 1996). The distribution of species is therefore continually changing, depending largely on the characteristics of the area, the resources available and the extent to which these changes occur.

Past observation (Greyling 1994) identified the following major grazers in the study area: large herbivores including horses, gemsbok, springbok and ostriches; smaller herbivores such as steenbok (*Raphicerus campestris*), klipspringer (*Oreotragus oreotragus*), hares and various smaller rodents; and herbivorous insects, the most important groups of which are the termites, ants, locusts and grasshoppers. The numbers and distribution of the large herbivores can be determined by game counting methods, which depend on the size and topography of the area, type of animals, available manpower, cost and purpose of the census (Bothma 1995). Complete census techniques were not within the scope of this project; therefore, a method that could be reliably repeated with the aim of establishing average numbers and distributions of these species was used for this study. Small mammal herbivore densities are low (see Chapter 6, 6.11 small mammals as bio-indicators) and are therefore not given further attention here.

Termites are probably the most economically important insect group with regards to grazing competition (Coaton & Sheasby 1975). These authors state that *Hodotermes mossambicus* could remove annually up to 3 000 kg of grass per hectare. However, this high figure was obtained from studies conducted in South African grasslands, where high grass standing biomass is found. Such a figure could not be used for the estimation of grass removed in the study area due to a much lower grass production in arid areas. Grass removal by harvester termites in this study was determined based on the findings of Grube (2000), which showed the extent to which *Hodotermes mossambicus* readily remove grass from bait-boxes.

Harvester ants (*Messor denticornis*) and other seed collectors, such as seed carrier ants (*Tetramorium* sp.) could potentially also remove a large amount of seeds from the above ground vegetation, but this would most likely not exceed the biomass removed by termites. Locusts and grasshoppers are also competitors for grazing and can consume large amounts of grass (Picker, Griffiths & Weaving 2002) mostly during swarming, which occurs sporadically in the study area. It is difficult to determine numbers and distribution of grasshoppers in the study area since they appear only seasonally and during very specific conditions.

The objectives of the this chapter were to determine: (1) the density and distribution of large herbivores in the study area; and, (2) the impact of *Hodotermes* termites on grazing, measured in terms of the quantity of vegetation biomass removed by them.

MATERIAL & METHODS

4.1 Large herbivore densities and distribution

The study area was divided into more or less equal sized zones, which correlated as far as possible with plant community structure, distance from the trough and topographical features. With the exception of a few weeks, a specific route was driven by vehicle every second week from July 2003 to December 2004 in order to monitor the number of horses and other game in the study area. Every sighting of horses or game was recorded with date, time, species, number, zone, status of vegetation and activity of animals entered on a field form. From this information the total number of each species for each survey were calculated as well as the mean number of animals per square kilometer and mean total biomass per hectare for each zone. The zones that fall within similar distance intervals from the trough as well as similar plant communities were combined and the average percentage of the horse population that occurred at these distance intervals and plant communities was calculated.

In order to get an indication of the accuracy of the ground surveys, the regular ground survey conducted on the 23rd of July was followed on the 28th of that month by an aerial survey of the study area. Figures from the aerial survey were compared with that of the ground survey as well as with the known number of horses at the time. For the aerial survey, a fixed-wing aircraft was used, the crew consisted of the author and a pilot highly experienced in game counting. The flight path consisted of 15 east-west transect lines 2 km apart, from the southern boundary of the study area to the northern end. A constant height of 50 to 100 m above ground level were maintained depending on wind conditions.

In addition to the ground and aerial surveys, water utilization surveys were done every third month to collect information on the numbers of animals that drink water at the troughs, the drinking frequency of these animals and the number of tourists visiting the public viewpoint. During each survey six to seven continuous days were spent at the viewpoint from sunrise to around midnight in the week preceding full moon. All animals were counted and recorded. Whereas horses could already be individually identified, an attempt was made to identify individual gemsbok in order to establish their drinking frequency and obtain accurate numbers. During the first half of the night, observations were made with a night vision monocular to determine the number of animals coming to drink. Additional to this, all tracks in a 1.5 m radius around the trough was raked every evening and the area investigated for tracks in the morning to establish the number of horses, gemsbok, jackal and hyena drinking at night.

4.2 Termite grass utilization

Following Grube (2000) and communication by E. Marais, plastic containers with chopped grass were used to determine the quantity of grass utilized by termites. Nine plots, representing the main plant communities and soil types of the study area, were chosen. The plastic containers were 120 mm in diameter with holes (5 x 15 to 20 mm) on four sides at ground level. Each container was filled with 10 g chopped grass (*Eragrostis tef*). Shihepo (2003) found no preference for any specific grass species utilized by *Hodotermes*. At each of the nine plots 25 containers were placed in a 5 x 5 grid at 2 m spacing, thus covering a 100 m² plot. During observations of active termites, it was noted that they forage within a 2 m radius from their nest entrance, an observation confirmed by Shihepo (2003). It is therefore assumed that containers at 2 m spacing have a high probability of being found by foraging termites within the plot. The containers were checked every two weeks and when a container was found empty, all the containers in that plot were replaced with full containers. In plots where containers remained with enough grass, it was left for a maximum of three months where after they were collected and replaced with new containers. The containers were first placed on 3 March 2004 and removed in February 2005. Although data from entire periods (mainly June and July 2004) were lost due to unforeseen circumstances, data was available for a total duration of 230 days, sufficiently covering most seasons. In order to compensate for the loss of the June and July 2004 data, containers were placed out during the same period in 2005, but no termite activity was found. Apart from the loss of the

June/July containers, every plot lost a few containers over time due to disturbance by larger animals and strong winds. Data for one entire plot was excluded from the analysis due to loss of too many containers. The data was transformed to the total amount (weight) of grass removed per square meter and per hectare.

Fig 4.1: left) Plastic containers on a plot and right) termites collecting grass from a container.

RESULTS & DISCUSSION

4.3 Large herbivore densities and distribution

The average density of large herbivores in the study area as calculated from the 2003/04 ground surveys was 150 hectares per individual (0.66 individuals/km²) or, expressed as herbivore biomass per area size, 1.74 kg/ha (174 kg/km²). The mean densities of all species as well as for individual species across the study area are presented in Fig. 3.2. and 3.3. The density of the Namib horses over the past 10 years has varied between 0.25 to 0.43 individuals/km² (T. Greyling unpubl. data). A study by Nel (1983) in the Central Namib indicated that the most important influence on distribution of game in the desert is the availability and status of water and grazing. He also showed clearly how game numbers fluctuated in response to grazing availability. In the study area, as in the Central Namib, the highest densities of game occur along the eastern boundary in correlation with the west to east increase in grazing across the desert. There are sporadic exceptions to this when patches of rain occur further west in the desert. In the study area the density of large herbivores fluctuated monthly due to the gemsbok, springbok and ostriches not being restricted to the study area but trekking to the north, west and southwest when rain occurs in those areas. This relative freedom of movement of the game contributes to the preservation of the desert ecosystem. However, unfortunately the eastern boundary fence of the NNP remains an obstacle to the migration of game causing high grazing pressure on a narrow strip along the boundary fence during times when rain has not occurred in the NNP or Sperrgebiet but on neighboring farms to the east (pers. obs.). Figure 4.2 and 4.3 shows the densities of large herbivores superimposed on the rainfall distribution map (Fig. 2.12). These figures clearly show that the eastern part of the study area where higher mean rainfall occurs also carries higher mean densities of herbivores.

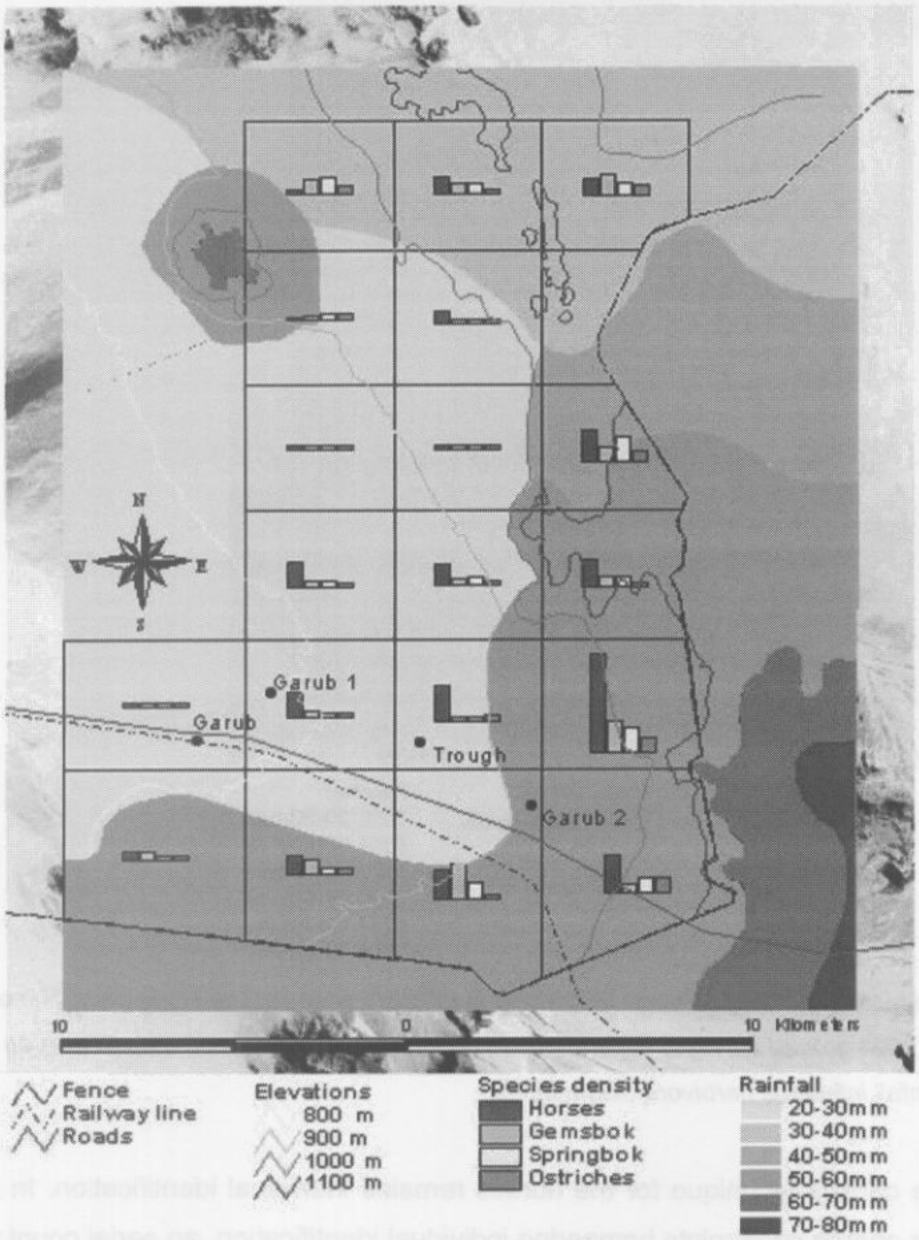


Fig. 4.2: The mean densities (individuals/km²) of large herbivore species in different zones of the study area (June 2003 to December 2004 ground surveys) superimposed on the rainfall distribution map to give an indication of how rainfall influence herbivore distributions.

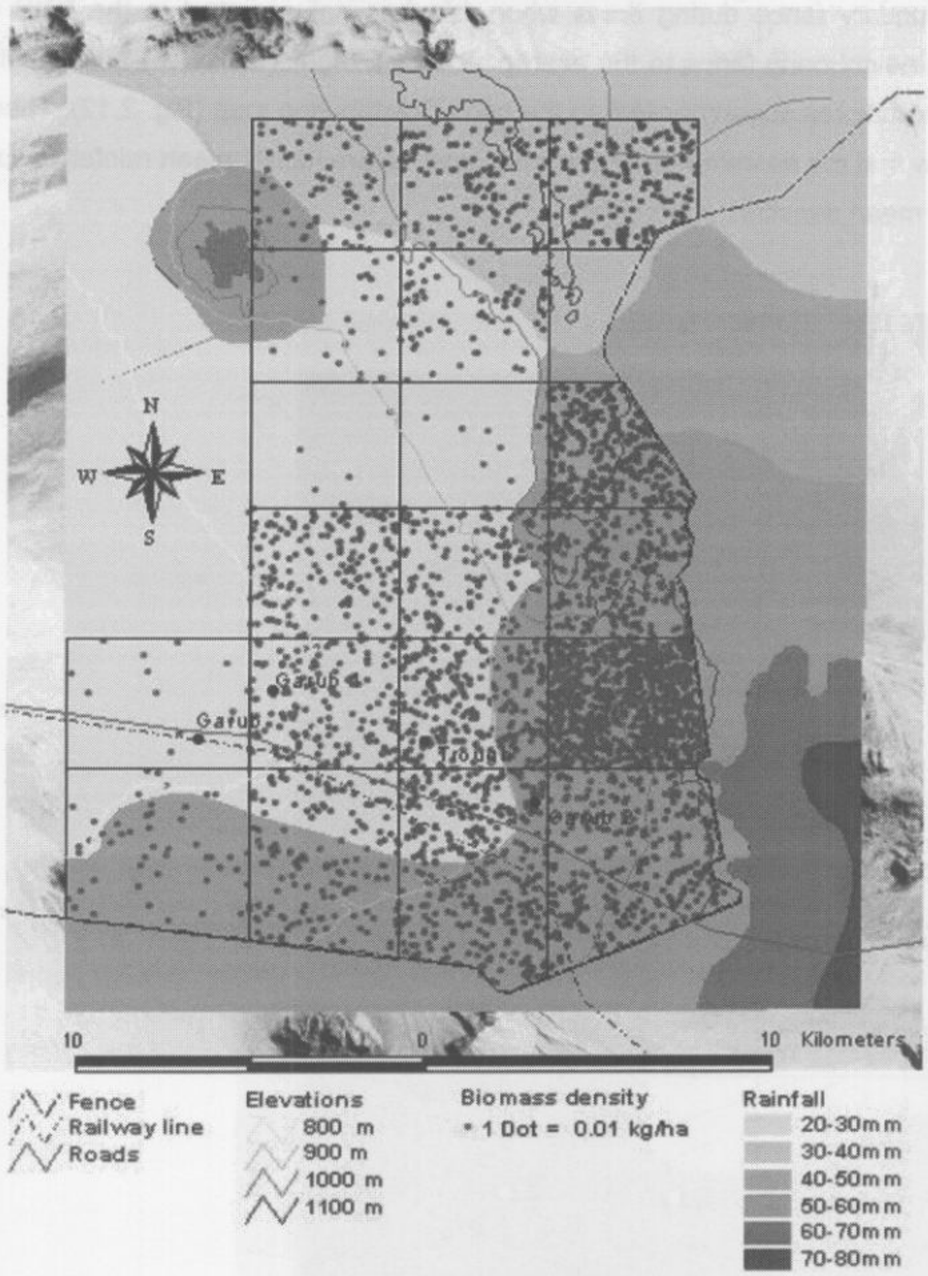


Fig. 4.3: The mean density (kg/ha) of all large herbivores in different zones of the study area (June 2003 to December 2004 ground surveys) superimposed on the rainfall distribution map to give an indication of how rainfall influence herbivore distributions.

The most accurate census technique for the horses remains individual identification. In the event of manpower or time constraints hampering individual identification, an aerial count will deliver better results than ground counts or water point counts. The horses are large, mostly darkly coloured animals and easily recognizable from the air. The aerial survey on 28 July 2003 counted 81% of the actual number of horses (102 of 126) in comparison with an average of 70% counted in the 2003/04 ground surveys using a vehicle. Foals and horses lying against bushes are not easily recognized from the air nor from a vehicle. It was found that only counting horses at the water point without individual identification, does not give a true reflection of the population size (pers. obs.).

The aerial count probably also provides better results for ostriches since they are dark coloured and conspicuously shaped when standing, whereas the gemsbok and springbok are reasonably well camouflaged against the sand and gravel and not easily seen from the air. This is especially true for the springbok due to their small size. The gemsbok and springbok are probably equally well counted from a vehicle if the distance for observation is not too far and without too much undulation or mountains. For more accurate aerial counts of specifically springbok, a relatively low altitude has to be maintained. The mean numbers per species for the 2003/04 surveys compare well with the mean numbers of game counted in 1994 (six days per month, January to July 1994: Greyling 1994) (Table 4.1).

Table 4.1: Numbers of large herbivores in the study area as per the 2003 to 2004 ground surveys (n=29, mean, min, max, SD), the ground survey conducted on 23 July 2003, the aerial survey conducted on 28 July 2003, and the figures obtained in the 1994 study (Greyling 1994).

Species	Mean	Minimum	Maximum	SD	Aerial survey (28 Jul 2003)	Ground survey (23 Jul 2003)	Greyling (1994)
Horses (known values)	133	126	140	-	126	126	117
Horses (survey values)	88	34	137	24	102	96	-
Gemsbok	46	0	215	53	82	95	50
Springbok	34	0	124	36	24	21	20
Ostriches	18	0	90	25	9	3	35

Through the surveys and observation done at the trough, it became evident that the number of game observed at the water trough is not a good representation of the number of game utilizing the study area at any specific time (Table 4.2). In general, ostriches and springbok do not drink at the trough regularly. Gemsbok, on the other hand, drink water regularly in numbers that depend on the status of available vegetation and the prevailing temperatures. More individuals come to drink water, and individuals drink with greater frequency, during the hot and dry summer months, while less individuals came to drink water during the cooler winters or when green vegetation is available. The large groups of gemsbok that came to drink water at the troughs entered the study area temporarily from the southwestern or northwestern neighbouring areas. It is unfortunately not known from exactly how far they come and the surveys were too short to determine accurately at what intervals they drank, but it is estimated from personal observations that they drink every 7 to 14 days.

Table 4.2: The number of gemsbok drinking at the troughs during 7-day surveys and the number of gemsbok counted in the study area during a ground count just before or after the water utilization survey.

Survey date	**Sep-03**	**Dec-03**	**Mar-04**	**May-04**	**Oct-04**
Gemsbok visiting trough	18	165	182	14	36
Gemsbok counted in study area	17	10	27	121	21

The horses visited the trough between twice a day to once every third day depending on vegetation status and prevailing temperatures. They follow footpaths from their present range to the trough and back and do not generally graze in close proximity of the trough. Typically they only spent 5 to 20 minutes at the trough. Sporadically while grass is green and abundant and the horses are in excellent condition, they congregate around the trough (100 m radius) for several hours a day for rest and relaxation.

The movement of the horses and game over time is directly correlated to food availability and therefore to rainfall. Fig. 4.3 is a good example of how the distribution of the horses changes over time (in this case 2003 to 2004). It should be noted that all the horses do not necessarily move to the same area, and if they do, they do not necessarily move there simultaneously; some groups choose to utilize a different area, or, if going to the same area, take longer to get there.

During the 2003/04 surveys the horses mostly utilized the *Leysera tenella* – *Stipagrostis obtusa* plant sub-community (see Chapter 3 for location and description of plant communities) while the other communities were utilized less but more equally (Fig. 4.5a). Reasons for this includes the higher rainfall on the eastern slope, higher plant diversity including the perennial grass *Eragrostis nindensis* and it being at the optimal walking distance from the trough. This community covers the second largest section in the study area. The *Helichrysum herniarioides* - *Stipagrostis obtusa* sub-community covers the largest surface area but was mostly sparsely vegetated and also have large abrasive areas with calcrete. The *Oncosiphon grandiflorum* - *Stipagrostis obtusa* dune slopes community or dune area is smaller than *Leysera tenella* – *Stipagrostis obtusa* sub-community and was occasionally utilized by high numbers of horses, the *Avonia albissima* - *Stipagrostis obtusa* and *Kyllinga alba - Eragrostis nindensis* sub-communities are smaller and further away from the troughs and therefore carries a lower percentage of horses. The lowest percentage of horses utilize the *Nemesia viscosa - Stipagrostis obtusa* and *Brownanthus arenosus - Prenia tetragona* sub-communities mainly due to it being fairly small areas with low grass density, an exception occurred in 2005 with high grass density on the *Nemesia viscosa - Stipagrostis obtusa* sub-community after a localized summer rainfall event of around 30 mm. Fig. 4.5b supports the results concerning the plant communities in that regions which is 4 to 10 km from the troughs (in any direction and community) are predominantly preferred by the horses. The numbers in Fig. 4.5 are based on the 2003/04 ground surveys and only about 70% of the population is represented on average. This is due to the fact that a complete count of the population was never possible because some horses were always on their way to the trough or at the trough when the surveys were conducted.

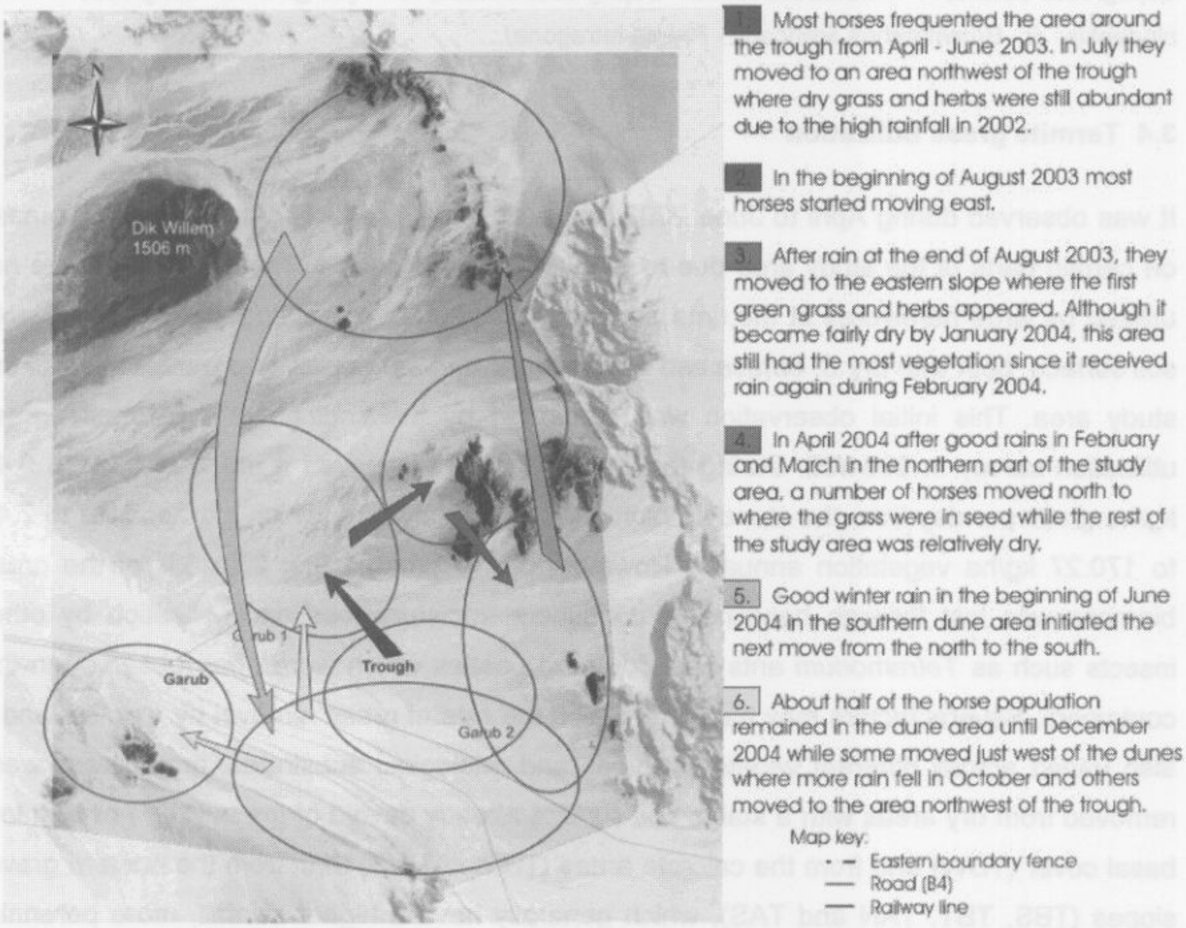


Fig. 4.4: The utilization of the study area by the horses from July 2003 until December 2004 as indicated by shaded arrows. The circles represent the approximate area the horses used for a specific time interval. An arrow indicates the majority of the population changing their current area of utilization over a relatively short period of time.

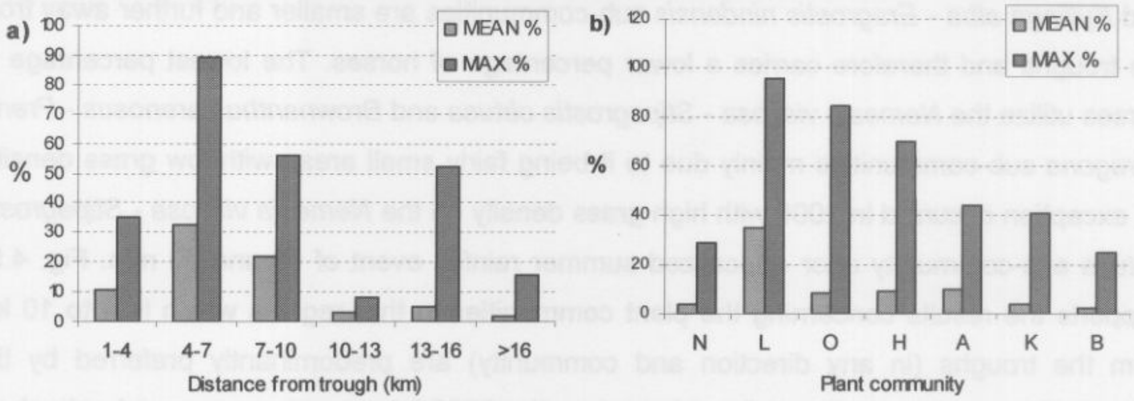


Fig. 4.5: The mean and maximum percentage of the horse population a) at different distance intervals from the trough and b) utilizing the different plant communities (June 2003 to December 2004 ground surveys), (N - Nemesia viscosa - Stipagrostis obtusa*; L* – Leysera tenella - Stipagrostis obtusa*; O* - Oncosiphon grandiflorum – Stipagrostis obtusa *dune slopes; H* - Helichrysum herniarioides - Stipagrostis obtusa*; A* – Avonia albissima – Stipagrostis obtusa*; K* - Kyllinga alba - Eragrostis nindensis*; B* - Brownanthus arenosus - Prenia tetragona*).*

3.4 Termite grass utilization

It was observed during April to June 2003 that a significant reduction in the grass biomass on certain parts of the study area due to termite activity occurred. These patches were not utilized by large herbivores at the time and were on calcrete areas and areas with a stable soil surface, both with dry *S. obtusa* and *S. ciliata* grass in the central and western part of the study area. This initial observation was supported by the findings of the termite grass utilization survey in 2004/05. During this survey termites removed a mean of 0.02 to 0.46 kg/ha grass per day from the standing biomass in the study area which extrapolates to 7.46 to 170.27 kg/ha vegetation annually. However, it is estimated that 2 to 3% of the grass biomass was lost through handling of containers, moisture loss and utilization by other insects such as *Tetramorium* ants and *Zophosis* beetles which were often observed in the containers. Several factors may have influenced the rate of grass removal by termites and it also varied across different vegetation types and geological substrates: more grass were removed from dry areas with a stable soil surface already devoid of grass (TG1) or with low basal cover (TDW) and from the calcrete areas (TR and TWS) than from the eastern gravel slopes (TBS, TBT, TAN and TAS), which generally have a higher rainfall, more perennial vegetation and a loose layer of sand and gravel on the surface (Table 4.3).

Table 4.3: The mean biomass of grass removed from plastic containers in various plots in the study area. TBS, TBT, TAN and TAS sites on eastern gravel slopes, TDW, TR, TWS and TG1 sites on calcrete and stony plains (western side of study area).

SITE	TBS	TBT	TAN	TAS	TDW	TR	TWS	TG1
g/m² per day	0.002	0.005	0.004	0.004	0.005	0.009	0.013	0.046
kg/ha per year	7.46	17.93	13.81	14.92	19.68	31.76	47.13	170.27

The most grass was removed from TG1 (stable soils and low basal cover) which is close to Garub 1 (the original borehole). This area had plenty of grass after the exceptional 2002 rains, but the grass was already consumed by the termites during 2003 (pers. obs.), well before the 2004/05 termite grass utilization survey started. This explains why it has a very low standing grass biomass during the time the bait-boxes were placed in the area. However, both the fact that the grass of TG1 was consumed by the termites in such a relatively short period of time, and the fact that this area had the highest biomass per unit of grass removed from the bait-boxes, indicate high termite activity, and thus potentially high termite densities, in this area. It could be argued that the higher removal of grass on the already sparsely vegetated areas may be due to the termites preferring to collect the standing vegetation rather than the grass from the bait-boxes in plots with more standing biomass, but this did not seem to be supported by observation of the sites; these ideas need further research to come to any conclusive theories. It thus seems as if the soil type and structure could be the most important characteristics that influence the distribution of Hodotermitidae in the study area. Calcrete and stable soil may be beneficial to the structure of nests and foraging ability of termites while loose soil which is unleveled by trampling and which thus requires more foraging effort, may restrict the termites to some extent. The gravel slopes with higher rainfall also support more species of termite predators.

Termite activity has been observed in all parts of the study area throughout the year but more often in the temperate months of April to June, and a frenzy of activity was observed just before rainfall events, even if it didn't really rain. These activity peaks were especially noticeable due to the increased activity of termite predators such as birds of various species and bat eared foxes (*Otocyon megalotis*). These activity patterns of the termites are confirmed by the results of the termite grass utilization survey conducted in 2004 to 2005: Table 4.4 indicates that the termites were not equally active during all times of the year, their peak activity seem to be in the months with mild temperatures from April to June. This corresponds to Grube (2000) who also found the highest level of termite activity in April and the lowest activity in July. Hewitt, van der Westhuizen, van der Linde & Mitchell (1990) in contrast found the highest activity in winter (May to October). Unfortunately, the quantity of grass removed cannot be compared with the studies by Grube (2000) or Hewitt *et al.* (1990) since the methods and expression of units differ. The unpredictable spatial activity reported by Wilson & Clark (1977) was also observed during this study and the provision of "bait-boxes" did not change this behaviour of the termites. This method seems to be a fair indication of the amount of biomass that needs to be allocated to termites on the different plant communities when determining grazing capacity. It may also provide a cost efficient method to investigate various other aspects of harvester termite behavioural ecology.

Table 4.4: The mean biomass of grass (g/m²) removed from containers at the TG1 location during a 15-day interval for different months of the year.

Time interval	3-23 Mar 04	22Apr-7May 04	7-22May 04	22May-6Jun 04	Oct-Dec 04	Jan-Feb 05
mean g/m² (15 days)	0.56	2.29	1.06	2.35	0.16	0.53

CONCLUSION

Horses, like other Equidae including zebra, are mobile animals able to cover large distances. Unlike most domestic livestock, they are not as restricted to a small radius around water points. It has been clearly shown here how the horses utilize various regions in the study area for different lengths of time. Long-term data showed higher densities of all animals in the higher rainfall areas; these areas, to the east of the troughs, also contain the highest plant diversity and are within the optimal walking distance for the horses (4 to 10 km). The horses showed rotational grazing strategies within the study area similar to what the game does on the larger scale of the NNP and Sperrgebiet. However, boundary fences artificially limit the natural movements of animals and therefore necessitate certain management strategies for both horses and game. These strategies include, for example, the provision of supplementary food during severe droughts for both horses and game.

From the termite data, it was clear that the quantity of grass utilized by the termites varies considerably and that the ecology of termites is still not well understood. It is therefore difficult to come to definite conclusions. Nevertheless, there was no correlation evident between the activity or quantity of grass removed by termites and the areas grazed or not grazed by the horses. Rather, it appeared as if other factors, such as the stability and type of soil may be more important to the activity or distribution of termites.

In general, there is no evidence that the horses are an unnatural grazing competitor in the study area. Since the horse density is generally low, they do not utilize excessive large percentages of available grazing in the study area and are unlikely to be in significant competition with termites. Furthermore, the horses' utilization area is situated at the edge of the Park, and covers a mere 0.7% of the total area size of the Namib Naukluft Park, or 0.46% including the Sperrgebiet (Diamond Area 1). Therefore, it is unlikely that the horses can compete with the other large herbivores in the Park.

INTRODUCTION

Information regarding the population dynamics and biology of the feral horses in the Namib Naukluft Park is essential as a technical basis to develop future management strategies. The horses' survival since the early 1900's was primarily influenced by the availability of water at a man-made borehole. This borehole was initially maintained for steam locomotives on the way to Lüderitz. From 1977, after steam locomotives were replaced by diesels, water was provided principally for the benefit of the horses. The population size of the horses during the first 75 years most likely fluctuated due to environmental stochasticity. Some human influence also occurred in relation to the water supply, or lack thereof, and competition for grazing with livestock in some years. Since 1987, two removals of horses, two severe droughts, as well as the moving of the water troughs and fencing of the eastern and southern boundary could have affected population dynamics significantly.

The overall research objectives for this chapter were to: (1) estimate the ideal population size and composition which would ensure a viable and sustainable future population; and, (2) assess the quality of life for the horses in their present habitat. These overall objectives were achieved by gathering information on the social structure, population dynamics, genetic contribution of individuals and health of the horses.

The social structure of most feral horse populations around the world is essentially similar. They form breeding groups (also known as harems, family groups or bands) and stallions, not associated with mares, are known as bachelor stallions or bachelor groups (Feist & McCullough 1976; Berger 1986; Goodloe, Warren, Osborn & Hall 2000; Linklater, Cameron, Stafford & Veltman 2000). However, from a review of the literature and communication with R. Hall, it is clear that there are many differences in specific relationships, dynamics and compositions of various feral horse populations. This may be due to one or a combination of environmental differences, breed characteristics or population history and tradition. There are also subjective differences amongst various scientists who may interpret and report observations of behaviour in different ways.

For this study, groups consisting of stallions, mares and juveniles were identified as breeding groups. Some breeding groups had two adult stallions within the group, which were neither dominant, nor subordinate to each other and they are referred to as co-operating stallions. When co-operating stallions exist within a breeding group, in some cases, each stallion associates more closely with his specific mare(s). Stallions accepted on the periphery of a breeding group are called "outsiders". These outsiders may interact with juveniles in the harem, but not with adult mares. They contribute to the defense and cohesiveness of the group, and more than one outsider occasionally associate with the same breeding group. Although not common, it was observed that five outsiders associated with a specific group for more than a year. In most studies, groups with more than one adult stallion are called "multi-male bands", but not all descriptions make a clear distinction between co-operating stallions and peripheral stallions (outsiders). With regard to dispersal, it was found that most fillies voluntarily leave their natal group between one and two years of age and most colts dispersed voluntarily between the ages of three to four years. Fillies growing up in a stable group during average to good environmental conditions come into estrous for the first time between one and two years of age and this initiates their dispersal. These fillies actively choose a new stallion or group to which they disperse. Exceptions to predominant dispersal patterns were found during drought or captures.

Data on population dynamics, social structure and behaviour can assist managers in estimating effective and thus minimum viable population sizes (Princée 1995). Factors such as sex ratio influence group sizes as well as number of groups, which in turn influence the number of individuals getting the opportunity to contribute to the gene pool. Saltz & Rubenstein (1995) have also shown that knowledge of population dynamics is essential for the correct assessment of population viability. The population dynamics of different feral horse populations vary considerably and may be due to different environmental and/or management practices (Cameron, Linklater, Minot & Stafford 2001).

Conservation managers today focus extensively on the maintenance of sufficient genetic variation to ensure long-term survival of small populations (Lacy, Ballou, Princée, Starfield & Thompson 1995). The estimation of minimum viable population sizes has also become a priority for the Bureau of Land Management (USA) and other managers of feral horses in the United States of America. Most of their existing populations range between 50 to 200 horses (Singer, Zeigenfuss, Caotes-Markle & Schwieger 2000). The possible negative consequences of loss of genetic variability include inbreeding depression, which is demonstrated through effects such as decreased fecundity, reduced juvenile survival and increased asymmetry of bilateral features or overall loss of vigor. However, moderate inbreeding is considered not to be necessarily detrimental, but could contribute to the population's adaptation to local environments (Singer *et al.* 2000).

To estimate the minimum viable population size, it is essential to calculate the genetic effective population size (N_e), i.e. that portion of the total population (N) which actually contributes genetically to the next generation (Singer *et al.*, 2000). The rate of genetic loss decreases with an increase in effective population size (Princée 1995). The effective size is equal to the population size in ideal populations (populations that follow the Hardy-Weinberg model), but most real populations are far from ideal. This is especially true for social structures with harem groups and unequal individual reproductive success which reduces the population's effective size. N_e is a complicated value to calculate and several formulas have been developed for which different demographic variables are required. Both the lack of detailed demographic data as well as the choice of a formula which best fits the type of social structure of the specific population appear to be constraints in calculating N_e. It is also important to note that there is no single estimate for the minimum viable population size that accurately represents any one population all the time (Foose, de Boer, Seal & Lande 1995).

In society today, the importance of considering the highly subjective "humane treatment" of the horses cannot be overlooked. Since the horses were introduced by the activities of man into an area regarded as inhospitable, the question has been asked if it is not cruel to keep horses in this harsh environment (van Aarde 2000). Unfortunately, there is not an easy answer to this question, since the exact line between natural or unnatural and cruel or humane is subjected to individual opinion. Therefore, the best option is to assess the quality of the horses' life within the confines of acceptable limits of the general public opinion. The horses' quality of life was measured by their physical condition over time, conformation, soundness, parasite burden and the fulfillment of their physical and psychological needs within the environment.

MATERIAL & METHODS

5.1 Population dynamics

During December 1993 all the horses were individually identified by their conformation, colour, permanent scars, facial and leg markings. These characteristics were cataloged, and any additional scars acquired or changes in color with aging were added thereafter. This was continued for each new born foal. From January to November 1994 the horses were intensively observed as part of a study on their behavioural ecology. From 1995 to 2002 the horses were visited at approximately 3 to 5 month intervals for 1 to 4 weeks at a time during which all records of horses could be updated. Since February 2003, when this project formally started, the horses have been observed on a daily to weekly frequency.

Observations were made with binoculars (8x40 and 10x20) either on foot or from a vehicle. The fact that the horses became habituated to vehicles and people made it easy to approach them. Most observations were made from a tourist viewpoint overlooking the water troughs, which increased observation frequency since all the horses have to come to this water point at least once in 2 to 4 days. Observations were mostly made from 100 to 200 m away in order not to influence the behaviour of the horses; it was only necessary to approach more closely when a specific aspect such as foal sex or injuries were investigated. The following modalities were regularly recorded: group composition and social category, reproductive status of mares, physical condition and injuries or other conditions of interest.

Data from group composition and social category were used to determine group stability and most likely paternity of foals. Group stability or rather instability was defined as the number of adult mares (thus excluding natal dispersal) that changed from one stallion to another and remained with that stallion for at least one month. The new stallion could be from a breeding group or it could be a bachelor stallion. If a mare changed between several stallions in the course of 1 to 2 weeks, this was recorded as one change only if she eventually remained with a new stallion. Due to practical limitations, accurate paternity could not be determined through analysis of blood proteins or DNA fingerprinting, as used by amongst others Cothran & Singer (2000). Paternity was therefore assigned to the harem stallion with whom a mare had been associated approximately 340 days prior to foaling. Kaseda & Khalil (1996) found 85% of foals sired by harem stallions and 15% by other stallions. This high reproductive success of harem stallions was also supported by Asa (1999).

The reproductive status of mares was judged on the presence of a foal and the physical appearance and behaviour of the mare. Due to practical difficulties accurate determination of pregnancy and abortions was not possible during this study. It was assumed that a mare was pregnant when she showed swollen mammary glands or an asymmetrical large abdomen, which is distinguishable from a "grass belly" by experienced observers; a mare in such condition was regarded to be in the later stages of pregnancy (last three months). A mare that was pregnant at one observation and not pregnant nor with a new foal at the following observation, was assumed to have foaled and the foal lost.

Ages of the horses were initially (1994) estimated according to their physical size and characteristics. Thereafter, the accuracy of these initial estimates were verified or adapted according to tooth patterns when horses died or were immobilized, or them showing signs of aging especially during dry periods. Known ages for all foals born since November 1993 was recorded and was used to compare with theoretical tooth wear patterns. The tooth wear of these horses was found to correspond well with theoretical tooth wear patterns, Singer *et al.* (2000) also found the tooth wear of Pryor Mountain feral horses similar to theoretical patterns. A horse was assumed to be dead if it was not seen during two consecutive observations. In cases where the carcass was found or conditions (such as an injury) shortly before death were known, a possible cause of mortality was investigated and assumed.

Following Garrott (1991) and Singer *et al.* (2000) the rate of population increase was estimated using the model for geometric population growth:

$$N_t = N_0 \lambda^t$$

where N_0 is the initial number of animals in the population, N_t is the number at time t, and λ is the finite population multiplier. In a stationary population $\lambda = 1$ whereas $\lambda = 1.20$ indicates population growth of 20%.

5.2 Genetic viability

Due to various limitations a comprehensive assessment of the genetic viability of the Namib feral horse population is not within the scope of this study. An attempt was made during this study to accumulate data and hair samples for later DNA analyses of genetic variation. Several formulas for the calculation of a genetic effective population size have been used for feral horses (e.g. Singer *et al.* 2000), these formulas require various aspects of population data and their reliability range widely. It was therefore decided not to include the use of these formulas at present, but instead use pedigree analysis for a preliminary indication of genetic effective population size (N_e) for the Namib population. The analysis included a pedigree diagram (tree) of all the horses contributing to the genetic pool during the 10 year period of 1994 to 2004 and counting the number of breeding mares and stallions alive in 1994 that contributed to live offspring in 2004 (one generation). This method may have shortcomings, but was found to give a reasonably good indication of the relative contribution of different individuals to the gene pool, which could preliminarily be used for an estimation of N_e.

5.3 Quality of life

Physical condition was estimated according to a scale used by Eyre (quoted by Meyer, 1988) but adapted here to accommodate the frequent dehydration of the horses which influence their physical appearance. In a state of dehydration of approximately 48 hours or more, all the horse's ribs are visible regardless of the body fat of the horse; therefore this is not an indication of condition but rather of dehydration (Fig. 5.1).

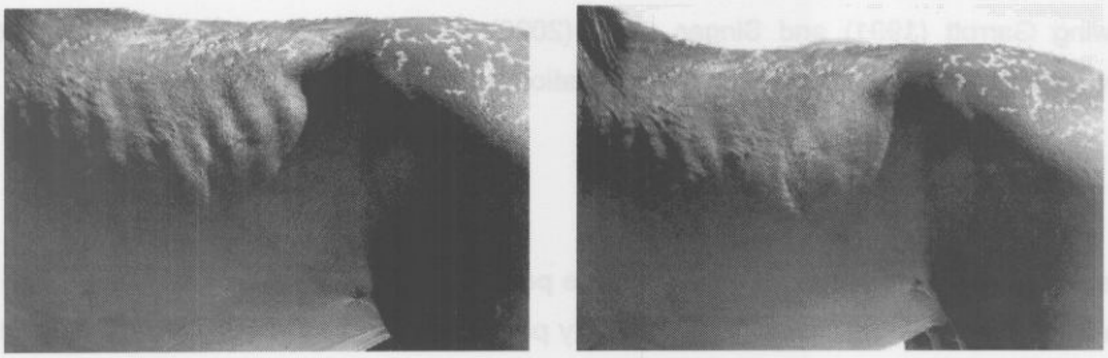
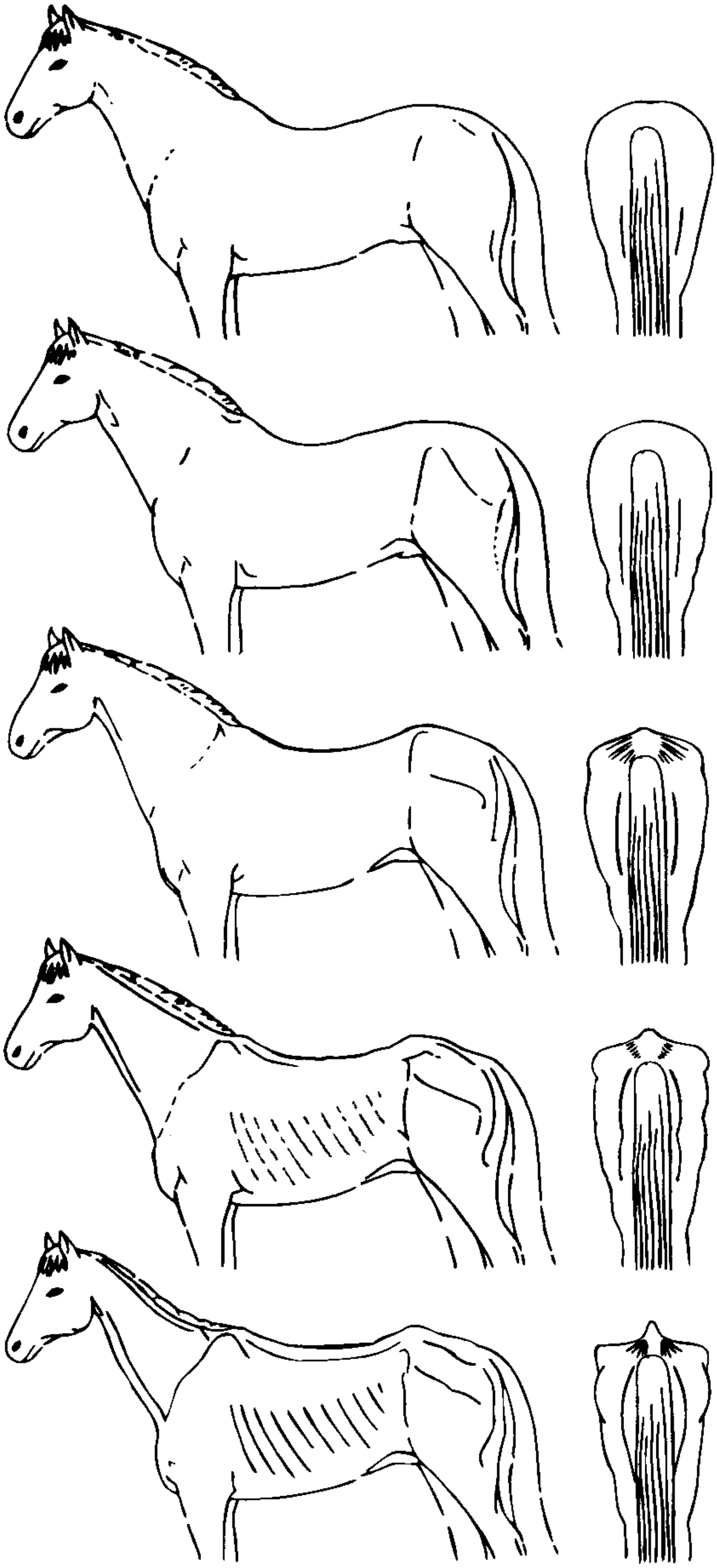


Fig. 5.1: The effect of dehydration and rehydration on a Namib horse, left) exposed ribs after 47 hours since drinking water, right) the same individual approximately 5 minutes after he started drinking water.

Figure 5.2 presents a description of the condition categories used during this study. In cases where the decision between two categories was difficult, a plus (e.g. when a horse in very poor condition was still strong and not in danger of dying soon) or minus (when a horse in very poor condition was about to die) were added to the number.

Whenever reasonably undamaged carcasses (not too much consumed by carnivores) were found, or when a horse was put down, they were examined for external and internal parasites. Further investigation of the occurrence of internal parasites was conducted by coprological examinations every second month.



Condition 1: VERY GOOD

A fat horse with no bony points (hip, spine, tail head) visible; neck muscular and shoulders well covered, hindquarters well rounded.

Condition 2: GOOD

A well muscled horse with bony points covered and not obviously visible; neck and shoulders muscled; hindquarters rounded with some muscle definition showing.

Condition 3: MODERATE

A reasonable looking horse with bony points discernible but not obviously protruding, the neck and shoulders not well muscled (i.e. no crest), the last lumbar vertebra and spine noticeable but the muscle on the hindquarters still rounded or convex.

Condition 4: POOR

A thin horse with bony points well definable, the neck top-line looks concave, the muscle on the hindquarters appears flat and the ribs are visible at all times.

Condition 5: VERY POOR

An emaciated horse with the points of shoulder, entire spine, hip bones and all the ribs clearly visible, the muscle on the hindquarters is very flat and gives a concave impression looking from behind.

Fig. 5.2: Description of the different condition categories of the horses.

RESULTS & DISCUSSION

5.4 Population dynamics

Population size

Table 5.1: The population size of the horses from 1993 to 2005 at 6 monthly intervals.

YEAR	Population size
1993	117
1994	125
	132
1995	131
	135
1996	133
	140
1997	147
	149
1998	148
	128
1999	91
	89
2000	92
	94
2001	96
	108
2002	112
	121
2003	126
	131
2004	135
	140
2005	147

Population size estimates during 1964 to 1984 ranged between 50 and 200 horses, with an average around 140 to 160 horses (J.H. Coetzer, pers. comm.). The rainfall data for Aus show a 10 year cycle with low rainfall from 1964 to 1974, and 1964 is remembered to have significantly reduced the population size (W.P.J. Swiegers, pers. comm.) to a low number (estimated ≤70 horses). However, the rainfall at Aus is not always the same as the rainfall in the horses' habitat and in 1971/72 the horses were in good condition therefore indicating higher rainfall in the horses' area compared to Aus (J.H. Coetzer, pers. comm.). The first reasonably accurate count of the population was an aerial count in September 1984 when 168 horses were counted (G. Noli, pers. comm.). In 1988, 24-hour full moon observation at the water troughs by Meyer (1988) estimated a population size of 150 to 200 horses. The observers noticed that the frequency at which the horses drank water changed with changing weather conditions which made this method unreliable if horses could not be individually identified. During a two-month observation period and attempt to identify the horses at the water trough, Ripart & Lambert (1991) counted 276 horses in September and October 1991.

Since December 1993 all horses were individually identified and the population size accurately counted (Table 5.1). The mean population size during these 12 years was 122 ± 19.86 (mean ± SD) horses.

A number of horses have been captured and removed on three occasions; the first in 1971/72 when 13 horses were captured by the Oranjemund Riding Club, the second in 1987 when 18 horses were removed, and the third in 1992 when a total of 104 horses were removed. In 1987, 12 horses were taken to the Veterinary Institute, Onderstepoort, in South Africa for research purposes and 6 horses were taken to Etosha National Park to be used as riding horses by the Ministry of Environment and Tourism in the north of Namibia. All of the 104 horses captured in 1992 were sold to interested buyers. In 1997, 35 horses were captured, transported to and kept in enclosures for six weeks at Hardap dam, 350 km north-east of Garub, to be sold on auction. The auction was cancelled and all 35 horses released back to Garub due to political reasons. This last capture caused no direct reduction in the population size, but had secondary effects on group dynamics and stability, which is obvious from data below. It can be assumed and was evident that the previous removals had similar effects on the population.

5.4.2 Population growth rate

The annual growth rates for 1993 to 2004 are given in Table 5.2 and Fig. 5.3. The mean annual growth rate of the population was 1.02 ± 0.133 (mean± SD). This growth rate of 2% is significantly lower than growth rates found by Garrott (1991) for feral horse populations in the USA, where most populations increased at or near their biological maximum or 20% annually. The mean annual growth rate for the Namib population was influenced by high mortality rates during the 1998/99 drought and therefore mean growth rates was calculated for three periods to separate different rainfall scenarios (Table 5.2). It is clear from Table 5.3 and Fig. 5.2 that the Namib population's growth rate is strongly influenced by rainfall combined with compensatory production after catastrophes (drought or removals) as well as the foaling frequency of mares in consecutive years.

Annual growth rates for the population before 1994 is not available, but could be calculated from the population size of 168 horses in 1984 and 276 horses in 1991. During this time 18 horses were removed in 1987 and the average annual rainfall was around 55 mm except for 1987, which had exceptionally high rainfall (above 100 mm). The mean annual growth rates during these seven years could have been 7%. Extrapolating these parameters, a possible mean population size from 1920 to the present could have been 130 horses.

Table 5.2: The annual growth rates of horses and mean λ for three periods of mean, very low and above average rainfall.

YEAR	Population size	Growth rate N_t/N_o	Mean Growth rate (λ)	Mean rainfall (mm)
1993	117			
1994	132	1.12		
1995	135	1.02	1.055 (5.5%)	55
1996	140	1.03		
1997	148	1.05		
1998	128	0.86	0.775	20
1999	89	0.69		
2000	94	1.05		
2001	108	1.14		
2002	121	1.12	1.092 (9.2%)	63
2003	131	1.08		
2004	140	1.07		

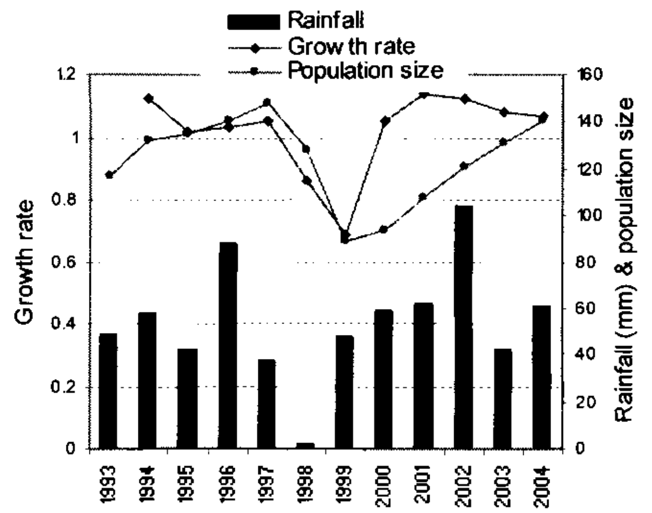


Fig. 5.3: Population size and growth rate of horses compared to rainfall during 1993 to 2004.

5.4.3 Life table and Survival rates

Table 5.3 presents the first half of a cohort life table for all foals born in 1994; the study was too short to follow the entire life span of these horses. Table 5.4 presents a static life table for the 2003 Namib population which shows several negative values due to age group gaps created by droughts and removal of horses. These gaps are clearly illustrated by Fig 5.4 which presents the k-values against age groups, it is therefore clear from this graph that the population is extensively influenced by climatic stochasticity and probably management practices.

Table 5.3: A cohort life table for Namib horses which were foals in 1994. k-values as well as mean mortality rates from Table 5.5 & 5.6 are included for comparison.

Age (years) x	Proportion of original cohort surviving to beginning of age-class x l_x	Proportion of original cohort dying during age-class x d_x	Mortality rate q_x	k-value ($\log_{10}(N_x)-\log_{10}(N_{x+1})$)	Mean Mortality rate from survival matrix
1	0.500	0.067	0.134	0.062	0.25
2	0.433	0.033	0.076	0.034	0.19
3	0.400	0.100	0.250	0.125	0.09
4	0.300	0	0	0	0.12
5	0.300	0	0	0	0.05
6	0.300	0	0	0	0.04
7	0.300	0	0	0	0.03
8	0.300	0.033	0.110	0.052	0.09
9	0.266	0	0	0	0.05
10	0.266	0	0		0.06

Table 5.4: A static life table for the 2003 Namib horse population.

Age (years)	Number of individuals of age x	Proportion of a_x = 16 surviving to beginning of age-class x	Proportion of a_x = 16 dying during age-class x	Mortality rate	Smoothed			k-value ($\log_{10}(a_x)-\log_{10}(a_{x+1})$)
x	a_x	l_x	d_x	q_x	l_x	d_x	q_x	
1	16	1.000	0.125	0.125	1.000	0.125	0.125	0.058
2	14	0.875	0.563	0.643	0.875	0.175	0.200	0.447
3	5	0.313	0.188	0.600	0.700	0.070	0.100	0.398
4	2	0.125	0.063	0.500	0.630	0.063	0.100	0.301
5	1	0.063	-0.500	-8.000	0.567	0.057	0.100	-0.954
6	9	0.563	0.125	0.222	0.510	0.051	0.100	0.109
7	7	0.438	0.000	0.000	0.459	0.046	0.100	0.000
8	7	0.438	-0.063	-0.143	0.413	0.041	0.100	-0.058
9	8	0.500	0.375	0.750	0.372	0.037	0.100	0.602
10	2	0.125	0.063	0.500	0.335	0.033	0.100	0.301
11	1	0.063	-0.125	-2.000	0.301	0.030	0.100	-0.477
12	3	0.188	-0.063	-0.333	0.271	0.027	0.100	-0.125
13	4	0.250	-0.063	-0.250	0.244	0.024	0.100	-0.097
14	5	0.313	-0.063	-0.200	0.220	0.022	0.100	-0.079
15	6	0.375	0.063	0.167	0.198	0.020	0.100	0.079
16	5	0.313	0.125	0.400	0.178	0.018	0.100	0.222
17	3	0.188	-0.063	-0.333	0.160	0.016	0.100	-0.125
18	4	0.250	0.000	0.000	0.144	0.014	0.100	0.000
19	4	0.250	0.125	0.500	0.130	0.013	0.100	0.301
20	2	0.125	0.000	0.000	0.117	0.012	0.100	0.000
21	2	0.125	0.000	0.000	0.105	0.011	0.100	0.000
22	2	0.125	-0.063	-0.500	0.095	0.009	0.100	-0.176
23	3	0.188	0.188	1.000	0.085	0.009	0.100	
24	0	0.000	-0.063	-	0.077	0.008	0.100	
25	1	0.063	0.063	1.000	0.069	0.069	1.000	

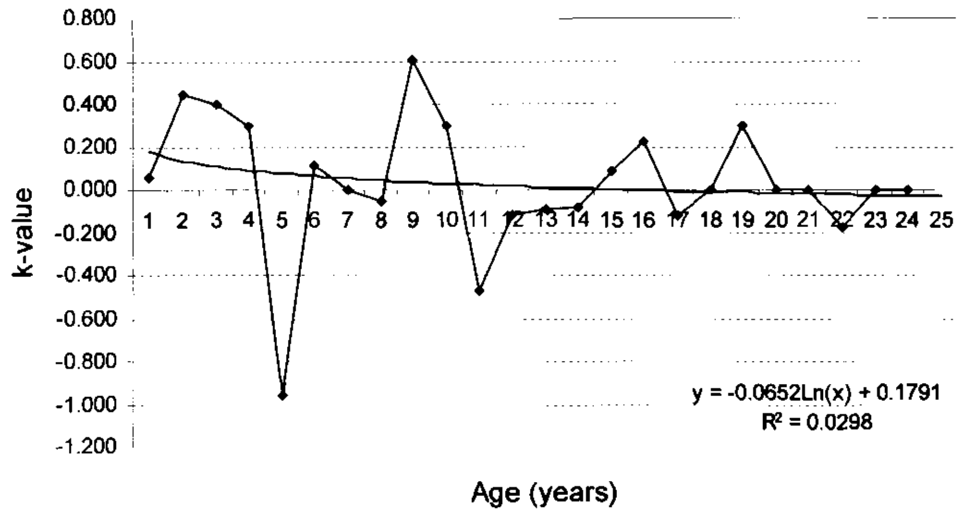


Fig. 5.4: k-values against age groups for the 2003 Namib horse population (Logarithmic trend line indicated).

An alternative method was also used to calculate survival or mortality rates through the creation of a survival matrix where the number of horses in each age class (males and females separately) for every year was tabulated. The number of horses in age class x in 1995 was then divided by the number of horses in age class (x-1) in 1994 and so on for all age classes and years 1993 to 2003 (Table 5.5 and 5.6). The mean mortality rates from these matrixes compare favourably with the first 10 years of the cohort life table for the 1994 cohort (Table 5.3 and Fig. 5.5). Variation between these survivorship curves is found in the first 3 years where the matrix curve is more smooth due to it presenting mean values, while the 1994 cohort curve presents real mortality which vary significantly annually according to environmental conditions.

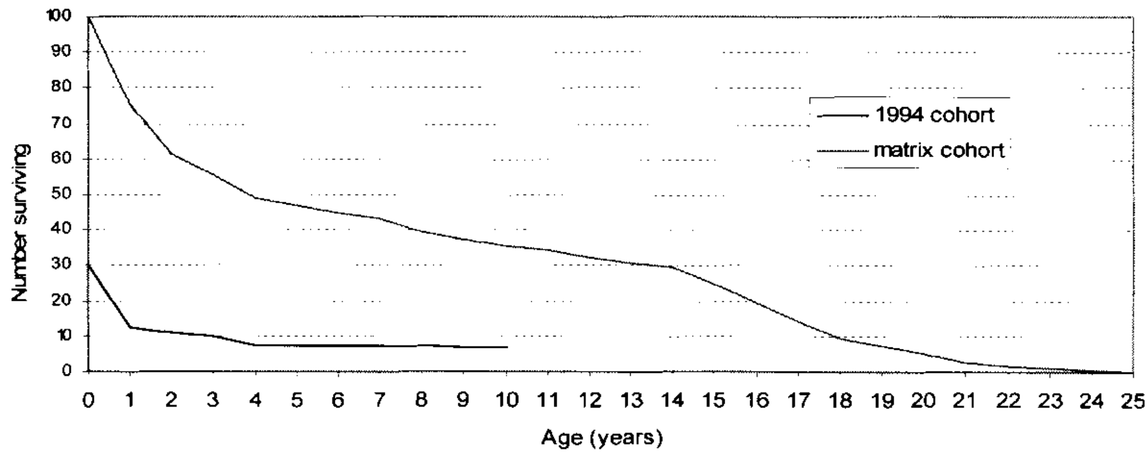


Fig. 5.5: Two survivorship curves, one for the 1994 cohort of Namib foals and the other an imaginary cohort (matrix cohort) of 100 foals surviving according to the mean survival rates determined in Table 5.5 & 5.6.

Table 5.5: A survival matrix for Namib mares from 1994 to 2003.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Mean survival rate
1	1.00	0.58	1.00	1.00	0.59	**0.25**	-	0.50	0.88	1.00	0.76
2	1.00	1.00	0.86	0.75	0.46	**0.40**	1.00	-	1.00	1.00	0.72
3	1.00	1.00	1.00	0.67	1.00	**0.67**	1.00	1.00	-	1.00	0.93
4	1.00	1.00	1.00	1.00	1.00	**0.67**	1.00	0.75	0.00	-	0.82
5	1.00	1.00	1.00	0.50	1.00	**1.00**	1.00	1.00	1.00	-	0.94
6	1.00	1.00	1.00	0.67	1.00	**1.00**	1.00	1.00	1.00	1.00	0.97
7	1.00	1.00	0.80	0.50	1.00	**1.00**	1.00	1.00	1.00	1.00	0.93
8	1.00	1.00	1.00	0.50	1.00	**1.00**	1.00	1.00	1.00	1.00	0.95
9	1.00	1.00	1.00	0.50	1.00	**0.50**	1.00	1.00	1.00	1.00	0.90
10	1.00	0.67	0.80	1.00	1.00	**0.50**	1.00	1.00	1.00	1.00	0.90
11	1.00	1.00	1.00	1.00	1.00	**0.67**	1.00	1.00	1.00	1.00	0.97
12	1.00	1.00	1.00	1.00	0.50	**0.75**	1.00	1.00	1.00	0.50	0.88
13	1.00	1.00	1.00	1.00	1.00	**0.50**	1.00	1.00	1.00	1.00	0.95
14	1.00	1.00	1.00	1.00	1.00	**0.50**	1.00	1.00	1.00	1.00	0.95
15	1.00	1.00	1.00	1.00	0.80	**0.67**	-	1.00	1.00	1.00	0.83
16	1.00	1.00	1.00	0.67	1.00	**0.50**	-	-	1.00	1.00	0.77
17	1.00	1.00	1.00	0.00	1.00	**0.25**	1.00	-	-	1.00	0.66
18	0.00	1.00	1.00	0.00	-	**0.00**	1.00	1.00	-	-	0.57
19	-	-	1.00	1.00	-	-	-	1.00	1.00	-	0.57
20	-	-	-	0.00	1.00	-	-	-	1.00	1.00	0.43
21	-	-	-	-	-	**0.00**	-	-	-	1.00	0.14

Table 5.6: A survival matrix for Namib stallions from 1994 to 2003.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Mean survival rate
1	0.50	0.62	0.83	1.00	0.50	**0.50**	1.00	0.80	0.89	0.88	0.75
2	0.00	1.00	0.75	0.70	1.00	**0.86**	1.00	1.00	1.00	0.88	0.91
3	1.00	0.00	1.00	0.83	0.86	**0.60**	1.00	1.00	1.00	0.75	0.89
4	1.00	0.60	0.00	1.00	1.00	**0.83**	1.00	1.00	1.00	1.00	0.94
5	1.00	0.60	1.00	0.00	1.00	**1.00**	1.00	1.00	1.00	1.00	0.96
6	1.00	1.00	1.00	0.67	0.00	**1.00**	1.00	1.00	1.00	1.00	0.96
7	1.00	1.00	1.00	1.00	1.00	**0.00**	1.00	1.00	1.00	1.00	1.00
8	0.83	0.50	0.88	0.86	1.00	**1.00**	0.00	1.00	0.80	1.00	0.87
9	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	0.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	**0.83**	1.00	1.00	0.00	1.00	0.98
11	1.00	1.00	1.00	1.00	1.00	**0.71**	1.00	1.00	1.00	0.00	0.97
12	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	0.80	**1.00**	1.00	1.00	1.00	1.00	0.98
14	-	1.00	1.00	1.00	0.83	**1.00**	1.00	1.00	1.00	1.00	0.98
15	1.00	-	1.00	0.75	1.00	**0.80**	1.00	1.00	1.00	1.00	0.84
16	1.00	1.00	-	1.00	0.67	**0.67**	0.75	1.00	1.00	1.00	0.79
17	1.00	1.00	1.00	-	1.00	**0.50**	1.00	1.00	0.75	1.00	0.81
18	1.00	1.00	1.00	1.00	-	**0.00**	1.00	1.00	1.00	1.00	0.78
19	1.00	1.00	1.00	1.00	1.00	-	-	1.00	0.50	1.00	0.94
20	1.00	1.00	1.00	1.00	1.00	**1.00**	-	-	1.00	1.00	1.00
21	-	1.00	1.00	1.00	1.00	**0.50**	-	-	-	1.00	0.92
22	-	-	1.00	1.00	1.00	**0.00**	1.00	-	-	-	0.67
23	-	-	-	1.00	1.00	**0.00**	-	1.00	-	-	0.50
24	-	-	-	-	1.00	**0.00**	-	-	1.00	-	0.33
25	-	-	-	-	-	**0.00**	-	-	-	1.00	0.17

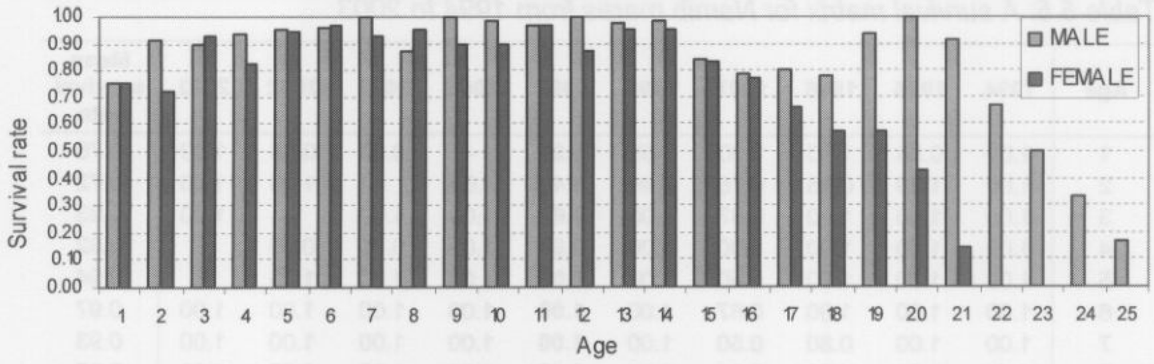


Fig. 5.6: The mean annual age specific survival rates for male and female horses from 1993 to 2003 as per survival matrix values.

Table 5.5 & 5.6 as well as Fig. 5.6 show that foal survival (birth to 1 year) did not differ between male and female and is on average 0.75 annually; it does vary significantly between years from 0.25 to 0.89. The survival of 1 to 2 year old fillies (0.72) is lower than that of colts (0.91) and is most likely due to fillies reaching puberty at this stage initiating their dispersal, which increase their chances of injury and harassment by stallions. Colts only disperse at 3 to 4 years old and their dispersal does not seem to create a significant reduction in their survival rate. The survival of fillies decrease again from 0.93 to 0.82 between 3 to 4 years old, which indicates another vulnerable phase where most fillies have their first foals. From five to 13 years old the survival of mares vary between 0.88 to 0.97 where after it decreases steadily to 21 years or older. The oldest estimated age according to tooth wear for a mare was 23 years, this may not represent the oldest age that mares reach since not all carcasses were found to verify their age. The survival of stallions is generally higher than that of mares between seven to 14 years old ranging from 0.97 to 1. The only exception being in the eight year old class (0.87), which corresponds to the age at which stallions become more active in the competition for mares and their chances to be injured during stallion fights therefore increase. Injuries can also be obtained from exploratory activities of stallions at this age and both injuries from fights or exploration could result in impaired mobility and consequently death. From 15 to 18 years old the survival of stallions decreases to 0.78 where after it improves to 0.88 to 0.94 at the ages of 19 to 21 years. An explanation for this pattern is not apparent, but it could be possible that some horses are better adapted to survive extreme conditions during droughts and therefore have a longer life expectancy. This latter group seems to reach senescence around 21 years old, where after their survival decreases steadily. Mares seem to reach senescence earlier around 15 years of age most likely due to the higher energy demands of producing and caring for foals for most of the mares' life.

Fig. 5.7: The age specific survival rates for male and female horses during the 1998/99 drought.

Fig. 5.7 shows the age specific survival rates during the 1998/99 drought. Survival of foals was low (0.25 to 0.5), and juvenile survival improved steadily up to four years of age in both sexes. The survival of mares between five and eight years was very good, where after their survival decreased and varied between 9 to 15 years of age (0.5 to 0.75). Survival of mares older than fifteen decreased rapidly and most likely no mares older than 18 years survived the drought. The survival of stallions between five and 14 years was very good, except for the 10 to 11-year-old group. This exception could not be explained from the results and may be due to chance or lack of sufficient numbers of individuals. Survival of stallions older than 15 also decreased rapidly. The apparent high survival in the 20 and 21-year-old classes is due to the low numbers of horses in these classes, however, it shows that a few old stallions are able to survive extreme conditions.

5.4.4 Mortality

Age and sex specific mortality numbers of Namib horses are presented in Table 5.7 and Fig. 5.8. It is clear from these figures that the main mortality factor in the Namib population is adverse environmental conditions causing exhaustion, dehydration and/or lameness of young foals or malnutrition in old horses during severe drought periods. Foals and juveniles (up to 18 months old) are also vulnerable to predatory since the main predator in the area is the spotted hyena (*Crocuta crocuta*); they generally do not attack healthy adult horses, but can easily kill juveniles and injured or weak adults. The rate of predation seemed to change from time to time due to predator movements, which is probably influenced by the availability of other prey species. The hyenas seem to increase their focus on the horses when other game becomes more scarce either due to drought or movement of game to areas further south and beyond the range of the hyenas. The hyenas were often observed near the horses during the end of 2000 to beginning of 2001, which increased foal mortality during that time (Fig. 5.9a). Another possible predator of healthy young foals in close proximity of mountains is leopard (*Panthera pardus*), although the incidence of predation by leopards is fairly low. Foals, weakened by dehydration, have been attacked by black-backed jackals (*Canis mesomelas)* leaving wounds that eventually caused the death of the foal.

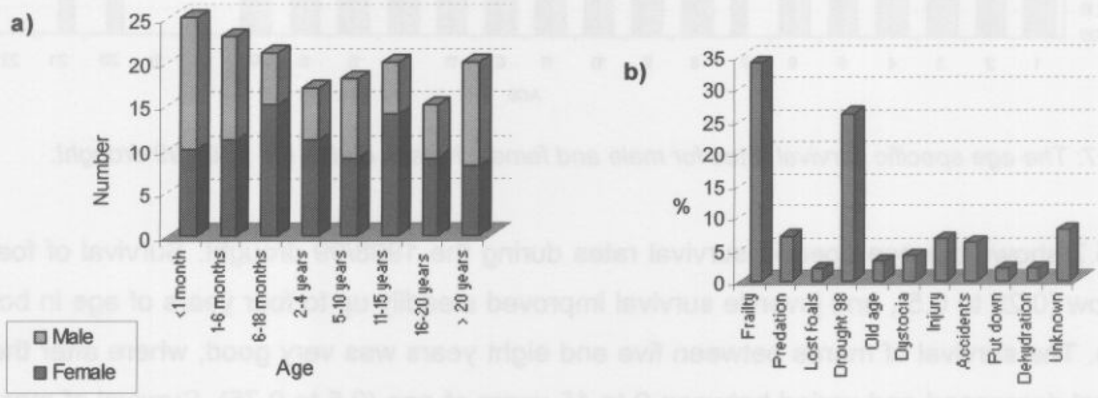


Fig. 5.8: a) Age and sex specific number of horses that died during Dec 1993 to Dec 2004, and b) the percentage of horses during this period that died due to various mortality factors.

Four juveniles died due to dehydration in1997 (Table 5.7) when the outlet tap from the water reservoir was closed (due to unknown reason and by an unknown person) and the horses were without water for approximately 7 days. The 16 horses of “unknown” mortality in Table 5.7, were horses that disappeared and were thus assumed dead, although the cause of death was not apparent. Eight of these were mature stallions who may have died due to injuries (which could impair mobility and secondarily cause death due to dehydration) acquired either in stallion fights or exploratory activities.

Foal mortality seems to be influenced by a few factors, but mainly by climatic stochasticity which in turn affects the physical condition of mares, and to a lesser extent group instability and predation rates (Fig. 5.9). During dry periods, mares are in a poor condition, and the horses usually need to cover longer distances between food and water. This in turn reduces the survival potential of foals as indicated by the correlation between mare condition and percentage foal mortality (Fig. 5.9b). A weak correlation also exists between group instability and percentage foal mortality (Fig. 5.9c). When groups are unstable and mares change between groups, confusion often results in injury of foals or separation from their mothers. A significant influence of group instability on foal mortality (see circled point in Fig. 5.9c) happened in October 1997 just after a number of horses were temporarily removed; this resulted in an unusually high number of mare changes (eight) during one month. The effect of the removal was probably enhanced by stress induced by dehydration due to lack of water.

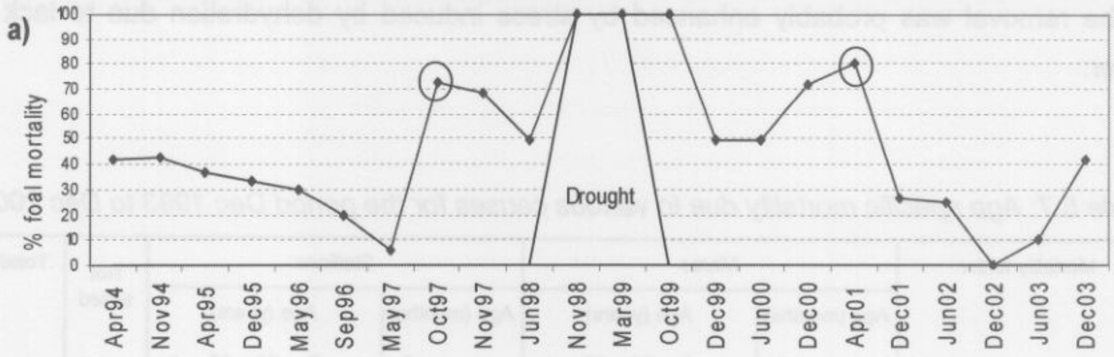
Table 5.7: Age specific mortality due to various causes for the period Dec 1993 to Dec 2004.

Mortality factor	Mares								Stallions								Not sexed	Total
	Age (months)			Age (years)					Age (months)			Age (years)						
	< 1	1-6	6-18	2-4	5-10	11-15	16-20	> 20	< 1	1-6	6-18	2-4	5-10	11-15	16-20	> 20	**	
Frailty and/or predation*	7	3							10	3	1	1					44	69
Predation of healthy foals	1	4	2						3	4								14
Foals seperated (lost) from dams	1	1							1	1								4
Malnutrition during drought of 1998/99			6	6	4	10	8	1			1	2	1	3	5	6		53
Malnutrition due to old age (other than during 1998/99)								4								2		6
Complications of birth giving (i.e. dystocia)				3	4	1												8
Injuries inhibiting mobility or lead to secondary causes of death		1	1			2		1	1	3			1			3		13
Motor vehicle accidents	1	1	1	1		1	1			1	2	1		1	1			12
Put down***								2					1			1		4
Dehydration (1997)		1	2								1							4
Unknown			3	1	1						1	2	6	2				16
Total	10	11	15	11	9	14	9	8	15	12	6	6	9	6	6	12		203

* This group includes possible abortion (final stages of pregnancy), young foals either born with low anti-body counts (weak) and/or weakend by severe climatic conditions and long distances travelled as well as older juveniles in poor condition (due to teeth or other deformities) which cause them to be easy prey to predators.

** Of these 44 foals, 10 were seen but dissapeared before their sex could be determined and 34 were assumed to be born.

*** Three of these horses were put down by the MET for the purposes of post mortem examinations since they were in very poor condition and one eight year old stallion were shot presumably for recreational purposes by an unknown person.



Note: The time intervals on the x-axis are not exactly equal but all parameters were standardized per time periods (e.g. per month) for each time interval on the x-axis (for all graphs presenting parameters over time).

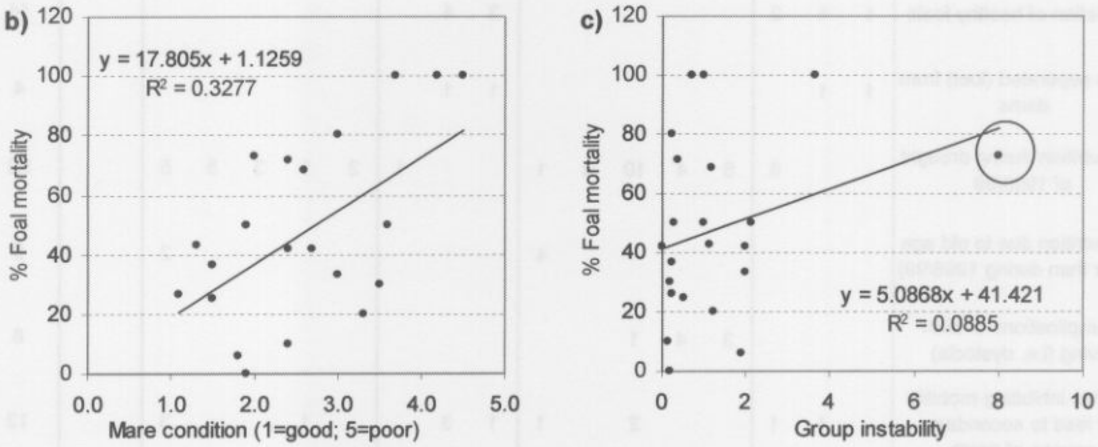


Fig. 5.9: a) Foal mortality (%) over time, b) the relationship between foal mortality (%) and the condition of mares (related to rainfall), and c) the relationship between foal mortality (%) and group instability (measured as the number of mare changes per month).

5.4.5 Foaling rates

Table 5.8 presents the monthly number of foals born from November 1993 to December 2004. A total of 232 foals were born; the sex of 187 of these foals was determined as 90 colts and 97 fillies (0.93:1). The mean number of foals per year was 20 (range 5 to 38; SD ± 8.635). Of 121 foals born from 1994 to 1999 only 34 (28%) reached adulthood (5 years of age).

Figure 5.10a indicates that the study area receives winter as well as summer rain and therefore no restrictive foaling season occurs. The number of foals born in different months of the year fluctuated according to the rainfall of the previous year. The highest mean number of foals was born in September. This corresponds with the higher average rainfall from May to August which increases the incidence of green vegetation and flowers during August to September, and thus high conception rates in October. The reason why July has the lowest foaling rate is probably due to the vegetation as well as mare hormonal cycles responding poorly during the coldest winter months (July and August). In general the summer rainfall is more unpredictable and patchy and therefore foaling rate is lower during late summer (January to March) than early summer. Early summer still benefits from residual vegetation response to winter rain.

Table 5.8: The number of foals born monthly during November 1993 to December 2004.

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Assumed born
1993											2	1	3	0
1994	1	7	1	3	3	3	0	1	1	3	6	1	30	1
1995	1	1	2	1	0	2	2	0	1	1	1	5	17	2
1996	0	2	3	0	0	0	0	2	7	1	2	2	19	1
1997	1	1	2	2	1	0	0	9	6	11	4	1	38	7
1998	1	2	3	1	0	0	0	0	1	0	2	4	14	7
1999	0	0	1	0	0	0	0	0	0	0	0	4	5	3
2000	3	1	1	1	1	1	0	0	3	2	1	1	15	6
2001	1	1	1	2	0	1	1	0	7	2	5	3	24	6
2002	2	1	2	1	1	1	0	3	7	1	1	2	22	0
2003	3	1	2	0	1	3	0	3	5	4	0	0	22	1
2004	2	2	0	2	1	1	0	0	11	0	2	2	23	3
Total	**15**	**19**	**18**	**13**	**8**	**12**	**3**	**18**	**49**	**25**	**26**	**26**	**232**	**37**

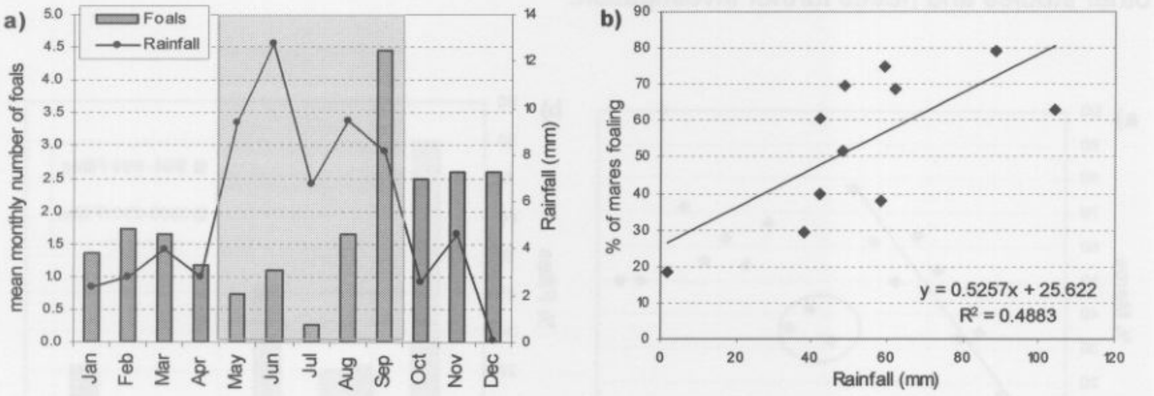


Fig. 5.10: a) The mean monthly number of foals born (1993 to 2004) with the mean rainfall (mm) over the same period (the shaded area indicates winter months), and b) the correlation between annual foaling rate (measured as the percentage of breeding mares that foaled) and the rainfall of the preceding year.

From Fig. 5.10b it is obvious that the annual foaling rate corresponds to the rainfall of the previous year (F-value = 7.897, p = 0.02). The foaling rate is secondarily influenced by a compensatory response after droughts and the capacity of mares to foal continuously in consecutive years. Few mares foaled during 1993 following the 1992 drought, while 70% of mares foaled during 1994. Fewer mares (38 and 40%) foaled during 1995 and 1996 due to the high percentage foaling in 1994 and the below average rainfall in 1995. In 1997 an exceptional 79% of mares foaled in response to the high rainfall in the late winter and low foaling rates of 1996. Following the high percentage of mares foaling during the last months of 1997 and the below average rainfall of 1997, only 29% of mares foaled in 1998, which decreased further to 19% in 1999 possibly due to no rain in 1998. The rainfall in 1999 and 2000 was average, and since most mares were barren as a result of the drought, the foaling rate increased to 75% in 2001. Although 2002 showed exceptionally high rainfall, the foaling rate slowly decreased (69% in 2002 and 63% in 2003) due to some mares not being able to foal continuously in consecutive years. The rainfall in 2003 was below average resulting in a further decreased foaling rate of 61% in 2004.

Figure 5.11a indicates the relationship between mare age and the percentage of mares that produce foals. A linear increase occurs between the ages of one to seven years, after which the percentage of mares varies between 30% and 77% up to the age of 21. One exception is the 100% foaling rate in the 19-year-old class, which is probably an outlier due to the low number of mares in the older age classes. The 11 to 13 year old group shows low foaling percentages (32, 42 and 36%) with no apparent reason, but this may indicate a "rest" phase after the mares' earlier active reproductive life. Such rest phase has not been reported in other studies and needs further investigation.

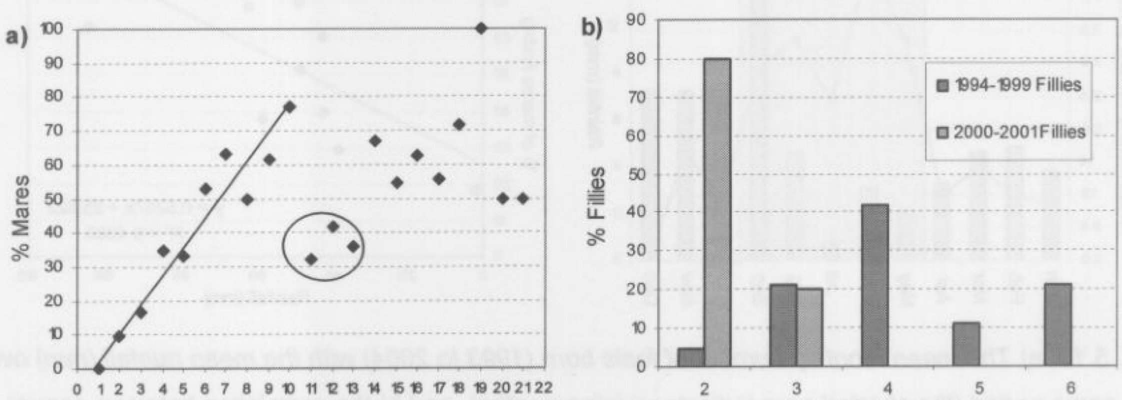


Fig. 5.11: a) The mean percentage of mares in each age group producing foals and b) the percentage of fillies in different age groups producing their first foals.

Figure 5.11b shows the possible influence of environmental conditions on the first reproductive age of fillies. Most fillies which grew up in dry years (such as 1994 to 1999) only produced their first foals at 4 to 6 years of age. Fillies born in 1996 (above average rainfall) produced their first foals at two and three years of age (represented by the 2 and 3 year old bars for the 1994 to 1999 group in Fig. 5.11b). In contrast, most fillies (80%) born in 2000 to 2001, who during their first two years experienced favourable conditions, produced their first foals at two years of age. This response of fillies to favourable environmental conditions has also been reported by Berger (1986).

The mean number of fillies reaching reproductive age annually was 3.6 (2.7 and 5.7 for the 1994 to 1999 and 2000 to 2002 groups respectively; range 0 to 8). Reproductive age was reached at three years old in the 1994 to 1999 group and at two years old in the 2000 to 2002 group.

5.4.6 Reproductive success

Not all mares and stallions were equally successful in their contribution to the genetic pool. Some mares foaled almost every year, while others only foaled once in a number of consecutive years. Some mares died before or with their first foal; in the case of a few other mares none of their foals survived to adulthood. Out of a total of 71 stallions of seven years and older only 36 sired foals, while 35 possibly did not sire any foals. Although stallions start their active reproduction activities around seven years of age, this does not mean that they do not get the opportunity to service mares and possibly sire foals prior to that. It has been observed that group stallions allow colts to service mares in their group. These figures do not represent the actual contribution of different stallions to the genetic pool, as not all foals survive. Stallions and mares which produce more fillies will make a larger contribution to the population's genetic effective pool (see 5.5.1 for further explanation).

Stallions generally disperse from their natal bands between 3 to 4 years of age and become bachelor stallions, mostly joining other older bachelor stallions for the first year or two. They usually only start showing increased activity to become part of a breeding group as an outsider or acquiring their own mares around 7 to 8 years old. Exceptions to this occurred during the drought of 1998, when colts were separated early from their dams (mothers) due to several mares dying and groups dispersing. One or two 3- and 4-year-old colts managed to "retain" a mare for a short time during this period.

Stallions generally become more successful with age and Fig. 5.12 indicates that most groups stay with stallions of 11 to 15 years old. Lower numbers in older age classes result from the fact that there are fewer stallions in these classes.

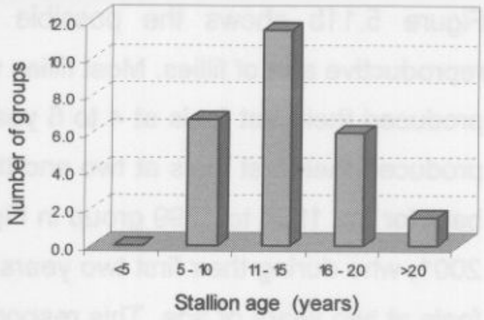


Fig. 5.12: The number of groups with stallions in different age classes.

5.4.7 Age structure and sex ratio

Table 5.9 and Fig. 5.13 present available data on age structure and sex ratio of the Namib feral horse population. The variability of the data presented in Table 5.10 is an artifact of the different methods or interpretations used by different authors. Observers not familiar or experienced with feral horse social structures may assume that each breeding group has only one stallion and often count the co-operating stallion as a female. Other differences can be found in the estimation of age, as a three or four year old may easily be counted as an adult if the correct age is not known. The higher male biased sex ratio from 1993 onwards could possibly be attributed to the female biased removal of horses with the 1992 capture (45% males and 55% females) and the higher mortality of females during droughts. It could also have been skewed further due to the abovementioned different interpretations by different authors.

Table 5.9 and Fig. 5.13 also show the influence of the 1992 and 1998 droughts on the sex ratio of the Namib population. In both droughts the sex ratio changes from near equal before to fairly and significantly male biased just after the drought. However, although still apparent, the influence of the 1992 capture and 1992 drought is not as obvious as the influence of the 1998 drought on the sex ratio. The reason for this could be that the 1992 drought started and ended with a relatively large number of horses (276 before and 113 surviving) compared to the 1998 drought which started and ended with a much lower number of horses (149 before and 89 surviving).The 1998 drought was probably exacerbated by the already male biased adult sex ratio carried over from 1992, when the 1998 drought started. From 1999 to 2004 the population's sex ratio steadily decreased towards equal ratios (1 male : 1 female) which were similar, but less obvious, to the 1993 to 1997 period (1.21 decreasing to 1.01 before the 1997 capture).

*Table 5.9: Age structure and sex ratio of the Namib population. Sources: Eyre (quoted by Meyer, 1988), Meyer (1988), Ripart & Lambert (1991) and unpublished data from the author. *Author's figures represent the population in December of each year.*

Source	Year	Adult sex ratio	% Adults	% Juveniles
Eyre	1985	0.75	74.2	25.8
Meyer	1988	1.02	76.6	23.4
Ripart	1991	1.09	59	41
author*	1993	1.18	71	29
*	1994	1.21	70	30
*	1995	1.17	77	23
*	1996	1.20	72	28
*	1997	1.23	65	35
*	1998	1.48	64	36
*	1999	1.90	69	32
*	2000	1.91	73	27
*	2001	1.74	69	31
*	2002	1.72	65	35
*	2003	1.72	60	40

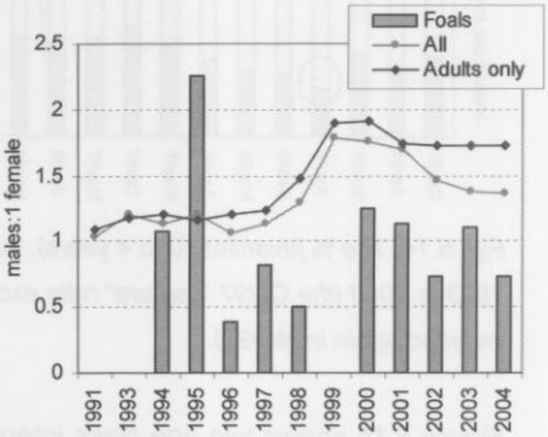


Fig. 5.13: The sex ratios (males : 1 female) during 1993 to 2004 for the total population, the adults only (>5 years), and the annual foal crop.

Figure 5.14 shows variation in age structure ratio through two cycles, the first following the 1992 drought and the second following the 1998 drought. In the years directly after the droughts (1993 and 1999 respectively) the percentage of old horses was lowest, as the majority of old horses does not survive droughts. A reduction in the percentage of juveniles also occurred as a delayed response to the drought. This is due to the low to zero survival of foals during, as well as low foaling rates directly after these droughts, both factors which only became apparent three years after the respective droughts. The juvenile percentages for these periods were 18% in Apr95 and 23% in Apr01. Following a few years with median to above average rainfall, the juvenile : adult : old ratio shifted to higher percentages of juvenile and old horses (see Fig. 5.14, Nov97 and Dec03, note that Oct 97 was caused by artificial removal). The ratios of these "restored" populations approach 40% juvenile : 40% adult : 20% old horses compared to 20% juvenile : 65% adult : 15% old horses after droughts. The juvenile : adult ratio found by Ripart & Lambert (1991) in 1991, following a number of favourable years, is similar to that of the 1997 and 2003 populations.

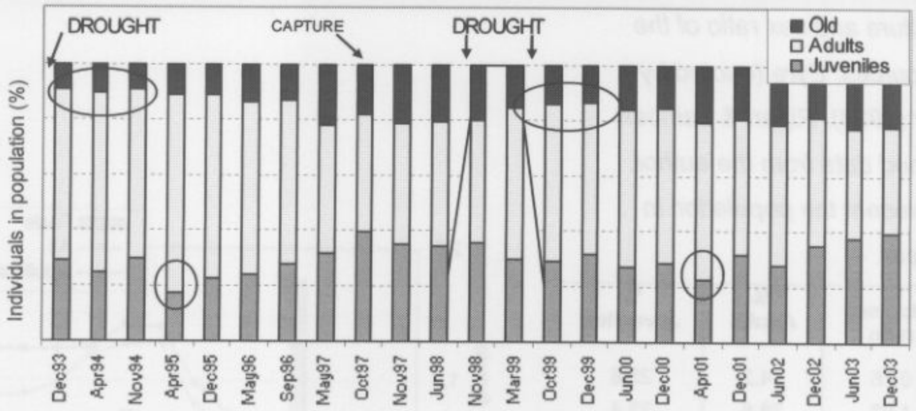


Fig. 5.14: The % juveniles (0 to 4 years), adults (5 to 15 years) and old horses (>15 years) during 1993 to 2003 (the Oct97 "capture" ratio excludes 35 horses temporarily removed; these horses are included again in Nov97).

Figure 5.15 shows two age class intervals with low numbers of individuals (3 to 5 and 10 to 12 year old groups) in the 2003 population. This corresponds to the 1992 and 1998 droughts. With the exception of these, the number of horses per age class decreases gradually with increase in age. The 15-year-old age class stands out with a relatively high number of horses. This corresponds to the exceptionally high rainfall in 1987 which most likely resulted in a high foal crop for 1988. The 2002 group is also higher since foal survival was high during 2002 due to favourable conditions (high rainfall).

The birth sex ratio of the Namib horses is 1:1 (T. Greyling unpubl. data), which is apparent in the 0 to 3 year old group. However, the sex ratio is significantly male biased (1.3 males : 1 female) in the 6 to 10 year old group and 12 to 25 year old group (2.1 males : 1 female). This supports that the survival of adult stallions, especially in the older age classes, is much higher than that of adult mares (see also Fig. 5.6). A birth sex ratio of 1:1 and male biased sex ratio of old horses were also found by Garrot (1991) for mustang populations in the USA. He, however, found that the sex ratio favored females in the immature to adult (1 to 10 years) age classes.

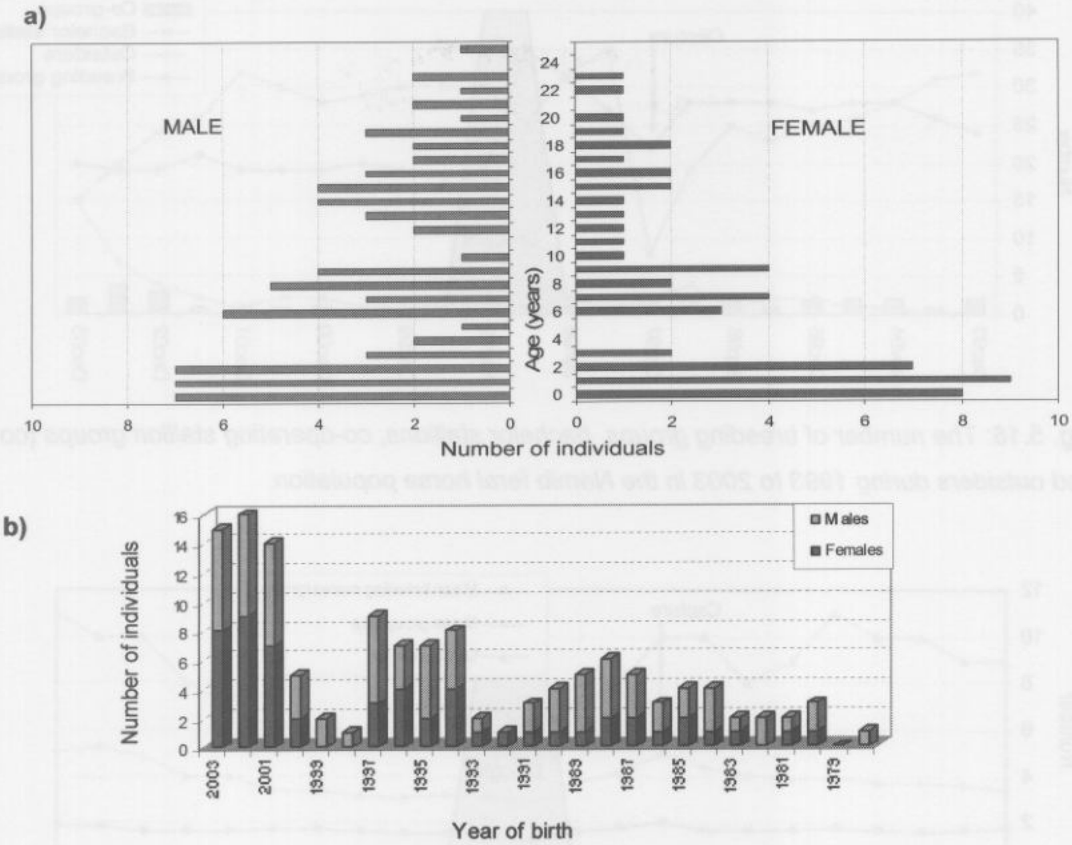


Fig. 5.15: Number of horses in each age class for the 2003 Namib population (ages observed for 0 to 12 years and estimated for horses older than 12 years), a) indicating age in years and b) indicating year of birth.

5.4.8 Group dynamics and stability

The group dynamics of the Namib population is portrayed in Fig. 5.16 & 5.17, which show the variation in dynamics during the past 11 years in phases corresponding to natural (climatic) and artificial (capture) disruptions. The significant confusion and reorganization of groups as a result of the 1997 capture followed by the 1998 drought is clearly illustrated in Fig. 5.18. The small number of breeding mares left after the 1998 drought limited the number of breeding groups, and consequently the percentage of stallions associated with breeding groups. However, after this major disruption there was a gradual integration of bachelor stallions into breeding groups, so that in 2003 the percentage of bachelor stallions compared to stallions associated with breeding groups again approached 50%. These stallions integrated with the breeding groups either as co-operating stallions or as outsiders. It therefore seems that, regardless of the sex ratio, around 50% of adult stallions in the population will in some way associate with breeding groups.

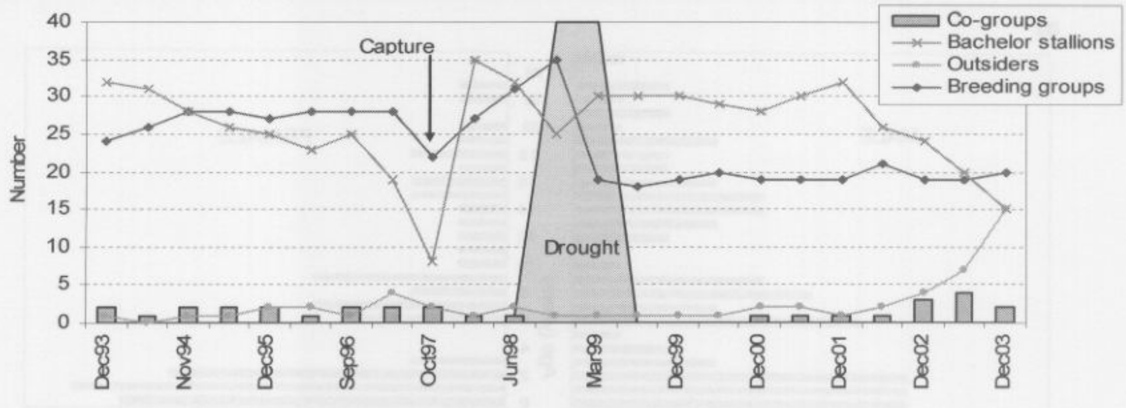


Fig. 5.16: The number of breeding groups, bachelor stallions, co-operating stallion groups (co-groups) and outsiders during 1993 to 2003 in the Namib feral horse population.

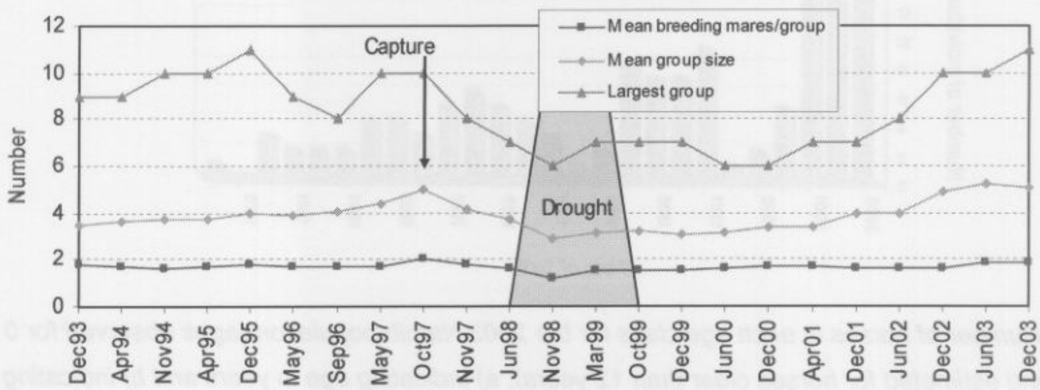


Fig. 5.17: The mean number of breeding mares per group, mean group size and number of horses in the largest group.

Fig. 5.17 illustrates a reduction of mean group size as well as the number of individuals in the largest group after the 1997 capture and 1998 drought. The mean group size generally followed the increase and decrease in population size, as did the mean number of breeding mares per group, although the latter varied little and remained below two breeding mares per group for the duration of 1993 to 2003.

Group stability/instability is portrayed in Fig. 5.18 and seems to have been predominantly affected by climatic stochasticity and management practices. During 1993/94, one and a half years after the removal and drought of 1992, a mean of two mare changes per month occurred. At the end of 1994 grazing was abundant and the groups were relatively stable. Rainfall during 1995 was low and groups became more unstable towards the end of 1995. The relatively low rate of changes continued until October 1997, when 35 horses were temporarily removed from the population. The removal together with high levels of stress due to dehydration for a period of approximately seven days during this time resulted in several group changes during that month. These changes occurred in the four weeks after the 35 horses were removed. The next unstable phase (with 3.6 changes per month) came about with the drought during December 1998 to March 1999 following the death of several adult horses. The horses which died included older group stallions which resulted in their groups dispersing to other stallions. From March 1999 to 2003, favourable conditions prevailed and less than one mare change per month occurred.

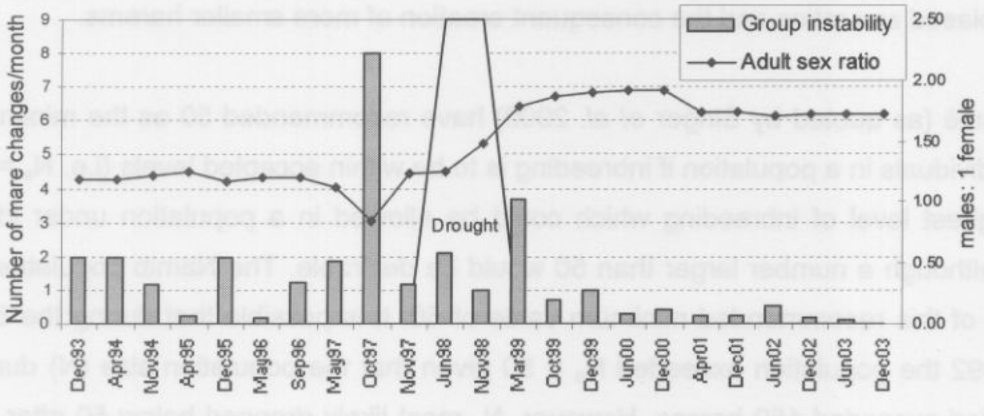


Fig. 5.18: Group instability plotted with adult sex ratio (males :1 female).

Concerning the temporary removal of horses during 1997 a considerable attempt was made to minimize disturbance to the social structure of the population by means of immobilizing individual horses to minimize disruption of breeding groups. The selected 35 horses were chosen on the basis of sex ratio, age structure, genetic relatedness and group composition. In retrospect data show that this attempt failed and that any significant shift in population size will cause a disruption of the social structure of the remaining population (Fig. 5.9, 5.16 & 5.18). Sex ratio could also possibly influence group stability, but as it can not be separated from the population reductions or environmental conditions in the data the extent thereof is not clear.

5.5 Genetic viability

5.5.1 Genetic effective population size

Appendix C presents a pedigree tree of all the mares and stallions (alive from 1994 to 2004) which produced offspring still alive in 2004 as well as only the offspring alive in 2004. Appendix C is thus a simplified representation (it does not include all horses or foals born) due to the limitation in space and to make interpretation easier. Out of 51 mares and 60 stallions, 31 mares (60%) and 24 stallions (40%) respectively contributed to the 2004 population, through own foals and/or second generation foals. Therefore 55 individuals or

48% of the total population (N=115; including foals) in the beginning of 1994 probably contributed to the gene pool of the next generation. The age structure of the 1994 population was 29% juveniles and 71% adults and the adult sex ratio was 1.18:1. The sex ratio during these 10 years remained male biased and the group structure consisted of smaller groups rather than few big groups, with the mean number of breeding females per group never exceeding two. Singer & Zeigenfuss (2000) calculated a N_e of only 27% of the Pryor Mountain Wild Horse population before 1994 which increased to 36% after 1994 due to higher male biased sex ratios and the consequent creation of more smaller harems.

Frankel & Soulé (as quoted by Singer *et al.* 2000) have recommended 50 as the minimum number of individuals in a population if inbreeding is to be within accepted levels (i.e. N_e = 50 being the highest level of inbreeding which could be allowed in a population under ideal conditions), although a number larger than 50 would be desirable. The Namib population is on the verge of this recommended minimum value of 50. It is possible that during the 80's and up to 1992 the population exceeded N_e = 50 given that the population size (N) during that time-period exceeded 150 horses. However, N_e most likely dropped below 50 after the 1998 drought and also possibly so in the droughts of 1927, 1949 and 1964. A point of importance concerning the 1997 capture is the possible outcome, if the planned removal had been carried through. Most likely it would have resulted in an even smaller population (71 horses) remaining after the 1998 drought, with only 28 females left. This would probably have reduced the genetic effective population size to approximately 34 horses instead of 46.

These possible bottlenecks could be responsible for the low genetic variation found in the Namib horses, as determined with blood samples taken from 30 horses captured in 1987 and 1992 (Cothran 1994). It is, however, important that N_e = 50 should not be seen as an absolute, but rather as a guiding figure. The desirable N_e depends on various factors such as type of organism, selection pressures, etc. Furthermore, the relationship between heterozygosity and population vulnerability to extinction is not clear (Hedrick, Lacy, Allendorf & Soulé 1996). What is important is to realize that environmental stochasticity can lead to extinction of small populations and therefore management strategies, such as culling, should be carefully considered. The minimum population size to be allowed in the Namib horses, their actual level of inbreeding as well as the effect of high homozygosity on their survival abilities demands further research.

5.6 Health of horses

5.6.1 Conformation

In March 1984 F.J. van der Merwe (Chief Director for Animal Production, Department of Agriculture, South Africa) visited the Namib horses and wrote a short report, wherein he described the horses as "hot blooded type" with desirable conformation. Other comments on the conformation of the horses (as seen on photographs) by a few show judges stated that the horses are a "good type".

The only obvious deformity which occurred in the Namib population is the formation of distal interphalangeal joint flexural deformity (club/boxy hooves). Foals are not born with this condition; it develops between four weeks and six months old, mostly secondarily as a response to a painful condition in the foot such as an abscess or worn feet or a sudden increase in nutritional quality and quantity (Dyson & Turner 1991). In some Namib foals this condition caused a permanently deformed or boxy hoof, while other foals started to walk normally and the hoof regained a normal shape and angle. The present population has no horses with this condition. Nevertheless this condition will most likely continue to occur sporadically due to the long distances traveled which frequently wear the hooves of foals short. This then renders the hooves prone to injuries of the sole and consequently abscesses or other painful conditions. Another condition was observed in one foal who was born with lax flexor tendons (Dyson & Turner 1991), which caused her hooves to wear unequally, thus forming long toes. She improved with age and her hooves were normally shaped by the age of three months. In general the Namib horses have good conformation with a small percentage of skeletal deformities.

5.6.2 Physical condition

From Table 5.10 and Fig. 5.19 it is clear that the mean condition of the Namib horses was most of the time above average (very good to moderate condition), only 16% of the time they were in poor condition. The entire population was at no time in a very poor condition; several stallions remained in moderate condition even during the 1998 drought. Stallions are generally in much better condition than mares, although old stallions frequently tend to be in a condition similar to that of lactating mares. Usually mares older than 15 years, often with foals at foot, are in the worst condition. Juveniles are mostly in a similar or better condition than adult stallions, except for foals of 2 to 3 year old primaparous mares. In general these foals are in moderate condition, and they are also relatively smaller in body size than foals from adult mares.

Table 5.10: The mean condition of the total population and various groups of Namib horses during 1993 to 2004 for periods before, during and after the 1998 drought (1-excellent to 5-very poor).

	Mean condition		
	Jan 94-Apr98	Jun 98-Mar 99	Apr99-Dec03
Total population	2.1	3.7	1.9
Fillies	1.9	3.5	1.7
Adult mares	2.4	4.1	2.3
Old mares	2.8	4.3	3.1
Colts	1.7	3.2	1.5
Adult stallions	1.8	3.3	1.5
Old stallions	2	3.8	1.8

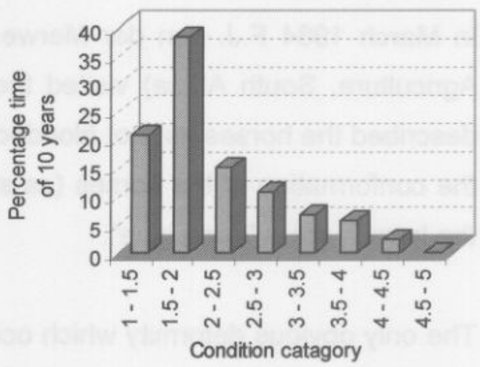


Fig. 5.19: The percentage time (over 120 months from Jan 1993 – Dec 2003) that the Namib horses were recorded in different condition categories (each month was placed in a category according to the mean condition of horses during that month).

Figure 5.20 illustrates the relationship between rainfall and condition of horses. Rainfall is directly correlated to grass quality and production (see Chapter 3) which in turn correlates to the condition of the horses, as indicated by the regression line. Other factors also contribute to the condition of the horses such as the temperatures prevailing and distance of grazing from the water troughs; both influence the frequency and severity of dehydration in the horses. Condition also depends on the energy needs of any horse at a specific time, for example lactating mares have a much higher energy requirement than bachelor stallions who are not actively involved in social competition. Therefore, the condition of the horses varies over time between very good to very poor. The condition of the horses was poor to moderate in the 60's and very good in the late 70's (J.H. Coetzer pers. comm.; see also rainfall in Fig. 2.9, Chapter 2). Van der Merwe (1984) described the horses to be in a poor condition during his visit in March 1984, Eyre (as quoted by Meyer 1988) found the horses in moderate to poor condition in 1985, Marinier (1987) and Meyer (1988) both found the horses in good to excellent condition during 1987/88. Sneddon, Krecek & Louw (1993) found the horses in April 1991 in moderate to good condition and the horses were in moderate to very poor condition in June 1992 (pers. obs.).

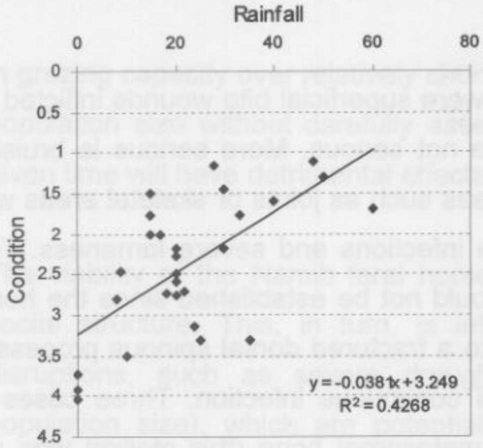


Fig. 5.20: The relationship between rainfall and condition of horses.

Injuries, increased activity (i.e. stallions defending breeding groups actively), high botfly infestations, dehydration, teeth problems and other physiological conditions also cause horses to loose condition. Loss of condition due to these factors usually occurs over a short period of time.

5.6.3 Parasites and disease

No symptoms or evidence of diseases such as biliary, dourine, African horse sickness or equine influenza was observed in the Namib horses. Parasites were generally not a cause of discomfort or health impairment to the horses. Exceptionally few external parasites (ticks) were found on carcasses or seen on any horses. Sneddon *et al.* (1993) found four families of internal nematode parasites (strongyles, small and large pinworms and stomach worms) and stomach botfly larvae during an investigation of carcasses in April 1991. During this study botfly larvae (*Gastrophilus pecorum*) were found regularly in carcasses both during summer and winter. The larvae of *Gastrophilus* attach to the cardiac portion of the stomach and could cause ulceration of the stomach wall. Opinions differ though on the importance of bots as a significant parasite in horses and there is little critical evidence to bots having a debilitating effect in horses (Soulsby 1968). In carcasses of horses in good condition generally less than 100 *Gastrophilus* larvae were found in the stomach, while in three horse carcasses in poor to very poor condition, more than 600 larvae were found. The degree of infestation by *Gastrophilus* seemed to be more severe during drought periods, when horses lost condition due to poor quality and quantity of grazing, or in old emaciated horses.

No helminthes eggs were found in the coprological examinations, which were probably not due to the absence of helminthes parasites, but rather to the very low numbers surviving. The life cycle of most strongyles involves an external phase as eggs or free living larvae which are quickly affected by desiccation (Soulsby 1968); the dry conditions of the desert therefore may prevent the survival of large numbers of internal parasites.

5.6.4 Injuries and other painful conditions

The most common injuries sustained by the horses were superficial bite wounds inflicted by other horses; these rarely broke the skin and were not serious. More serious is bruising caused by kick impacts (especially on vulnerable areas such as joints or skeletal areas with little muscle covering), which in some cases cause infections and severe lameness. Two cases of ataxia were observed: the cause of one could not be established since the horse disappeared and the other may have been related to a fractured dorsal spinous process in the cranial thoracic region (wither) which caused continuous infection. Three cases of fractures have been observed: one was the third metacarpal bone (this stallion was put down), and two were fractures of the carpus (knee), which stabilized over a six month period. Other injuries were wounds caused by predators, sharp points on man-made structures as well as one case of a puncture wound which eventually caused septicemia - this could have been a stab wound from the horn of a gemsbok (*Oryx gazelle*). The injuries caused by motor vehicle accidents were mostly fatal on impact or a few hours later. One colt was severely lame but without obvious fractures and disappeared shortly after, most likely caught by a predator. Also observed were mild colic symptoms, which occurred when dehydrated horses drank large quantities of water, especially cold water in the mornings. This also occurred during the 1998 drought, when the horses were given supplementary lucerne (alfalfa hay). The colic symptoms exhibited included tail swishing and kicking towards the stomach and, less often, biting or fly chasing towards the stomach. Most horses executed these actions while drinking, and it was observed more often in winter than in summer.

CONCLUSION

Practical and resource limitations inhibited certain procedures and data collection methods, therefore, potential sources of error exist in the data represented above. Areas which may include possible inaccuracies are: aging of horses; judging reproductive status of mares; and, nominating true paternity of foals. However, the data showed that these sources of error seem to be negligible and would probably not significantly influence the results.

Climatic stochasticity and management practices, rather than population density, have principally influenced population size, growth rates, reproductive success and mortality rates of the Namib feral horses. The desert ecosystem is different to most other habitats where populations are traditionally managed - it is highly unpredictable with considerable variation in grazing capacity over relatively short time intervals. This study proves that simply reducing population size without carefully assessing and considering all related parameters at any given time will have detrimental effects on the population's long-term survival.

The viability of the Namib feral horse population depends mainly on population size and social structure. This, in turn, is influenced by natural or artificial disruptions. Natural disruptions, such as severe drought, could create population bottlenecks (very low population size), which are potentially detrimental to the genetic pool. However, these natural disruptions seem to create a degree of social restructuring preventing stagnant groups, yet not adversely affecting group stability. Artificial reductions in population size, as well as interference, cause a high level of stress and create excessive social disorder, which is more detrimental than beneficial to the social structure.

It is unrealistic to calculate a single specific value for the minimum viable population size, therefore, some broad guidelines are presented. An ideal, genetically risk-free population would most likely be a relatively large number of horses or at least more than 200 horses on a long-term. The present area available to the horses is not large enough to sustain such a population at mean rainfall (see Chapter 3, 3.6, grazing capacity). The minimum total population size which could still exceed the minimum genetic effective population of the recommended number of 50, is most likely 100 horses in the Namib population. Other managers regard a minimum total population of 150 horses as more desirable (Singer & Zeigenfuss 2000). It is further important that the population should have a slightly male biased sex ratio (around 1.2:1). To ensure a minimum population of 100 horses, the actual population size should be rather higher to allow for deaths of older horses during dry periods, since no effort of supplementary feeding will "save" all horses. An alternative method used in small populations to preserve genetic variation is the creation of metapopulations (Foose *et al.* 1995). Individuals from these metapopulations can then be moved between populations at a rate of 1 to 3 individuals every generation (10 years).

In general the Namib horses are very healthy with a good quality of life as long as management practices are implemented with care and consideration. Horses in general have adapted to a large variety of ecosystem types around the world, as long as the habitat provided in their basic needs. These are food (mainly grasses but also herbs and shrubs), water and space. The importance of providing not only for the horses' physical needs but also for their psychological needs is becoming increasingly apparent today in the world of the domestic horse. The suffering of animals is widely exhibited through stereotypic and depressive behaviour (Fraser 1988). These etho-anomalities do not occur in feral Namib horses and it may be assumed that the space and social contact these horses have fulfill their psychological needs.

CHAPTER SIX: IMPACT ON BIODIVERSITY

Bayeaux Tapestry depicting the NORMAN invasion of ENGLAND (1066 AD).

INTRODUCTION

Biodiversity is defined in many ways. In its simplest form it is defined as species richness. It can also be viewed on smaller or larger scales, but generally it is assumed to concern everything that contributes to the variety in the living world (Begon *et al.* 1996). In this study, biodiversity refers to all the plant and animal species that occur in the study area and their functional and genetic variability. Owing to the growing concern around the world regarding the conservation of biodiversity, many threats to species have been identified, amongst which is the introduction of alien species. Introduced species seem to have had their worst effect on islands and freshwater communities since these habitats are isolated and often include endemic communities (Savidge 1987 and Kaufman 1992 as quoted by Begon *et al.* 1996). Horses being a domesticated species, eradicated from the wild by human action, are now regarded as an alien or exotic species wherever they become wild (feral). The population in the NNP is no exception (Barnard 1998). It has been shown that feral horses and other ungulates in island ecosystems influence vegetation community dynamics (Wood, Mengak & Murphy 1987). Concerns from some quarters claim that the feral horses in the NNP overgraze their habitat, remove the grass, including roots, compete with termites for food and therefore, have a negative impact on species such as endemic reptiles and birds, which are higher up in the food chain (Van Aarde 2000). However, no prior investigations have been conducted on the impact of the horses on the environment at Garub. Such a study is clearly a priority given that the population's continued existence in the desert is uncertain. Exotic species are generally undesirable in Namibia's National Parks, but the cultural and historic values of the horses constitute a strong link with Namibia's history. The horses draw large numbers of tourists and they present a natural case study of horse adaptation to extreme conditions. It is, therefore, not a simple matter and the horses cannot be removed without sufficient reason and a thorough impact study.

The objectives of this chapter were to: (1) measure the level of ecological disturbance created by the horses in the Garub area; and, (2) determine if any red data species occur in the Garub area and whether they have any relation to the horses.

Environmental impact assessments have become the buzz word in government legislation and among environmentalists during the past decade. The methodology for these assessments ranges from desktop reviews to hands-on biodiversity surveys. An attempt was made in this study to acquire first-hand information about the potential influence of the horses on biodiversity and identify and quantify any ecosystem-change in the Garub area. Various taxa were considered as bio-indicators of environmental change. These groups included small mammals, reptiles, invertebrates and vegetation. Bio-indicators are apportioned into three categories namely; environmental indicators, ecological indicators and biodiversity indicators. Ecological indicators are sensitive to identified environmental stress factors (McGeoch 1998) and could be used to identify possible ecological disturbances caused by the horses in their habitat. For the selection of bio-indicators the following prerequisites should be considered: accessibility; sensitivity; relevance; measurability; reliability; and, functionality. In addition particular biological characteristics need to be considered such as speciose (when dealing with higher taxa), high ecological fidelity (stenotopic), high abundance, damped population fluctuations, well known taxonomy, known biology and quick, predictable and linear response to disturbance (McGeoch 1998). In many habitats, small mammals generally conform to most of the above prerequisites and characteristics. They are reported as having responded to overgrazing in the Nama Karoo of southern Namibia (Hoffmann & Zeller 2004) and in other habitats in Africa (Salvatori, Egunyu, Skidmore, de Leeuw & van Gils 2001; Avenant & Kuyler 2002). Small mammals could thus be tested as a possible indicator group for overgrazing or structural change of vegetation in the study area. Such surveys could also contribute to biodiversity information, which is in short supply for the study area at present. Reptiles, on the other hand, mostly do not comply with all the above criteria especially concerning measurability and abundance. However, in desert ecosystems, reptiles, specifically lizards, do fulfill most of these criteria. Nevertheless, after some trial surveys it was decided that time and practical limitations prevented the inclusion of lizards in this study. Terrestrial arthropods have been proposed as indicators for various types of ecological disturbances (Kremen, Colwell, Erwin, Murphy, Noss & Sanjayan 1993) and in recent years ants (Formicidae) have been proven to comply with most criteria for successful indicators (Andersen & Majer 2004). Ants are diverse and abundant, functionally important at all trophic levels, easily randomly sampled, highly sensitive to environmental variables and ants respond rapidly to environmental change (Andersen 1990). Beetles have also been used in some studies such as Van Hamburg, Bronner, Morgenthal, Vermaak, De la Rey, Meyer, van Heerden & Kotzé (2003).

The following assumptions were necessary to assess ecological impact of the horses without any quantitative baseline information available prior to the introduction of horses: (1) a piosphere existed around the water point causing any disturbance to have a great impact close to the water trough and less impact away from the trough, (2) an area chosen as control would closely resemble the horses' habitat without their grazing effect. This area (henceforth Control area) would be outside the area utilized by the horses (henceforth Horse area) but still within a protected area (Sperrgebiet) and geographically close enough to be similar in climate, geology and vegetation structure.

Artificial water provision is generally thought to have a negative impact on the environment and several studies have measured the radial change in vegetation structure around artificial water points. Thrash, Theron & Bothma (1993) found that water troughs in the Kruger National Park have a significant impact on the herbaceous composition surrounding them, with the main disturbance occurring within 300 m from the troughs. Nangula (2003) did not find vegetation degradation at radial distances from water points in northern Namibia. He, however, noted that these water points had been established only recently. Arzani, Poor & Moghaddam (2003) states that range condition improved with increasing distance from watering points in Iran. Meyer (1988) determined herbaceous species composition and standing biomass in 1 to 7 km transects outwardly around the water point at Garub 1, and stated that overgrazing occurred in the 0 to 1 km area and possibly in the 4 to 5 km area where the horses spent most of their time. However, radial species composition surveys from the water troughs at Garub will intersect different plant communities. These communities vary in species composition and density most likely not due to the assumed radial grazing disturbance by the horses but rather due to variations in soil type, geology and rainfall. Furthermore, rainfall in the study area is often patchy and unpredictable, further affecting density. In March 2005 for example, the area immediately around the troughs had a high production and diversity of vegetation while 10 km away, where lower rainfall was measured, the vegetation was dry and scarce.

In addition to the use of bio-indicators for measuring environmental change, it was considered necessary to identify any red data species that could be negatively affected by the horses, since such species are important for conservation in their own right. The Southern Desert and Succulent Karoo biomes have high endemism of various taxa (Barnard 1998), but with little information available (Pallett 1995). The occurrence of endangered, vulnerable, rare or insufficiently known species in the study area is quite possible and the relationship of these species to the horses is an important field of investigation.

Most studies measuring or monitoring the impact of large herbivores on vegetation use fenced plots that exclude large herbivores or use areas where large herbivores have been removed for a number of years (Burke 1997; Beever, Tausch & Brussard 2003; Ricketts 2004). This study applied several methods to measure/monitor the impact of large herbivores on vegetation. These included comparison with historical photographs, exclusion camps, species diversity surveys in different plant communities, as well as the comparison of species composition and density at various utilization intensities by the horses between the Horse and Control areas. Exclusion camps had been erected in 2003 but despite several modifications the fences had to be removed six months later because the camps endangered the lives of horses and game and had become points of attraction for them which caused more environmental damage than preservation.

MATERIAL & METHODS

6.1 Impact on vegetation structure

a) *Photo comparisons:* A search was conducted for historical photographs from the study area. Photographs with landmarks which would enable the creation of comparative photographs in present time were chosen. These photographs gave an indication of the possible change in vegetation structure over time.

b) *Gradient determination within Horse area:* Grass density and standing biomass were compared for plots at various distances from the trough. Two to five plots on each of four distance intervals (3 to 4, 7 to 8, 10 to 12 and 16 to 18 km from the trough) on each of a Northwest and Northeast transect were surveyed. At every plot, the density and standing biomass was determined in five quadrates (one square meter each) from which the mean for that plot was calculated. These surveys were conducted in September 2002 and September 2004.

c) *Comparison of grass densities between Horse and Control areas*: Grass density (the mean of six quadrates) was determined at each of four plots on the Eastern slopes in the Horse area and in the Control area. These locations corresponded with the ant surveys on the Eastern slope and at four locations in the Control area. Student's t-test was used to compare the mean density in the Horse area to that in the Control area. This survey was done in August 2004.

d) *Vegetation species composition (within Horse area and between Horse and Control areas)*: Vegetation species composition was determined at each of 14 locations (corresponding with the invertebrate survey plots) with the wheel-point method. At each location, 200 points (two meters apart) were recorded and at each point the closest perennial and annual plant was recorded. If there were no plants within a 450 mm radius, it was recorded as a bare patch. The Eastern slope and Control plots were the same as those described in (c) above. The vegetation species composition was determined in order to compare the Horse and Control area and to determination whether a gradient effect exists from the trough.

6.2 Ants as ecological indicators

Sampling plots

Due to an east-west rainfall gradient, diversity in plant communities and short available distance to the south, it was concluded that the only representative and practical radius from the trough would be in a northeast and/or northwest direction. Observations of the horses' grazing behaviour (Greyling 1994) showed that the horses mostly use areas 3 to 9 km from the trough with decreasing numbers up to 18 or more kilometers. It was therefore decided to use locations at 2, 4, 7, 11 and 16 km from the trough which were situated in areas of comparable plant communities. The Control area was chosen due to its relative similarity in plant community structure to the northeast transect, its relative proximity to the study area (within 25 km from the trough), yet without the historical effect of horse grazing due to the Park boundary creating a barrier. The first survey, conducted in the Horse area during 25 July to 1 August 2003 included sampling in two plots (500 m apart) at 2, 4, 7, 11 and 16 km respectively along the Northeast (10 plots referred to as East) and Northwest (10 plots referred to as West) transects; a total of 20 sampling plots with 15 pit traps each, totaling 300 traps. The second survey during 12 to 19 August 2004 included a replicate of the Northeast transect in the Horse area (10 plots), two new plots at the trough and four locations with two plots each (500 m apart) in the Control area (again 20 plots with a total of 300 pit traps) (Fig. 6.1).

This experimental design, not unlike most others, has limitations. Firstly, in using distance from water as a surrogate for grazing intensity and therefore disturbance gradient. The difficulty being in finding homogeneous locations at the different distance intervals and assuming these locations represent a grazing gradient. The sites were therefore carefully chosen, specifically open grassland with no shrubs, not too close to drainage lines, patches of shrubs or rocky outcrops, and as far as possible with similar soil type. The same criteria were aimed for in the Control area, however, this was not entirely possible and the Control area sites were in general closer to the mountains with a slightly higher density of the perennial grass *Eragrostis nindensis* (the density of *E. nindensis* generally decrease at further distances from the base of mountains). The Horse and Control areas could also have unknown intrinsic variation independent of the effect of horses, or native grazers could effect these two areas differently since the effect of native grazers is not known. An alternative Control area could have been exclusion areas within the Horse area, but as demonstrated above, such exclusion areas were detrimental to ecosystem in general.

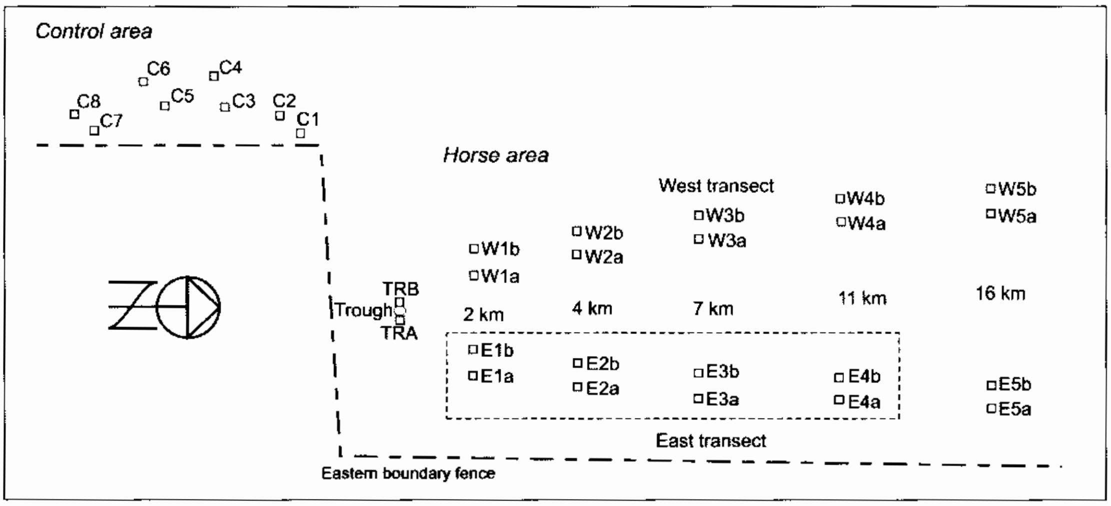


Fig. 6.1: Diagram of the layout of invertebrate pitfall sampling plots in the study area (E – east; W – west; C – Control area; plots within dotted block were compared with Control area).

Additional sampling was conducted quarterly (Oct 2003, Jan, Apr and Aug 2004) at five additional plots (15 pit traps each) for a period of five days, to determine the seasonal variation of invertebrate abundance. These plots were along the eastern boundary of the Horse area: two plots on the horses' side of the fence, two plots on neighbouring farmland and one plot in the road servitude along the B4 road. Due to variation in vegetation structure between plots, these plots were not included in the analysis to determine the impact of horses. They were only used to determine seasonal variation in species richness and abundance.

Sampling

Each plot was sampled with a 5 x 3 grid (10 m spacing) of pitfall traps. The traps were 50 mm diameter plastic honey jars (150 mm deep) partly filled with 40% propylene glycol as preservative. All the jars were planted with their lids level with the soil surface. Only once all jars were planted (over 2 to 3 days), they were opened on the same day. They were all collected seven days later on one day. Initially, all invertebrates collected in the pittraps were sorted to order level. Thereafter the ants and beetles were sorted to species level after which the number of individuals per species was counted for each trap. Each species was given a code number and was later identified as far as possible to species level by relevant specialists. Unidentified species were given codes, which apply to this study only. A collection of voucher specimens is held at the School of Environmental Sciences and Development, Northwest University, in Potchefstroom, South Africa. The rest of the material collected was deposited at the National Museum of Namibia in Windhoek, Namibia.

Analysis

The abundance of ant species in each trap were scored according to a 5-point scale (1 = 1 ant; 2 = 2 to 5 ants; 3 = 6 to 10 ants; 4 = 11 to 20 ants; 5 = >20 ants) to avoid data distortions caused by some traps being close to a nest or foraging trail (A.N. Andersen, pers. comm.). The resultant abundance per plot is the summed value of these scores for the 15 traps. **Firstly** the number of species and total ant abundance per plot was plotted against the distance from the trough. Students' t-tests or Mann-Whitney U-tests were used to determine the significance of difference of the mean species richness and abundance per plot between the Horse and the Control area.

Secondly the software package PRIMER v 5 (Clark & Gorley 2001) was used for most of the multivariate analysis that follows. The plots were classified according to species composition with group-averaging clustering using Bray-Curtis similarity matrices based on either standardized abundances or presence/absence. These similarity matrices were further used for multidimensional scaling (MDS) to ordinate plots according to ant composition. Range-standardized abundance and species presence/absence transformations were found to be most significant or applicable to discriminate land condition by Andersen, Fisher, Hoffmann, Read & Richards (2004). The data from the different transects were first analyzed separately, thereafter it was pooled. Thereafter, the East transect surveys were analyzed, comparing the two sampling years as well as the Horse versus the Control area. The 2004 data, consisting of data from the Horse area versus the Control area, were subjected to the analysis of similarity (ANOSIM) test to distinguish significant differences (Clarke & Warwick 2001).

Thirdly, an attempt was made to assign species to functional groups according to Andersen & Majer (2004) to help interpret distributional patterns. **Fourthly**, rank-abundance patterns were compared so as to give an indication of environmental change as suggested in Begon *et al.* (1996). **Lastly**, multivariate analysis using the software package CANOCO Version 4.5A February 2003 (Ter Braak 1988) was used to identify correlations of ant species composition and abundance to environmental variables. The variance of ant abundance during different seasons is also presented.

Species of which only one individual had been recorded, were excluded from the analyses. The two plots at the trough (TRA and TRB) were also excluded since trampling, hyenas and jackals disturbed too many traps in these plots.

6.3 Beetles as ecological indicators

The Tenebrionidae is a particularly diverse group in the Namib Desert and worth investigating as a possible bio-indicator in this region. The data on Tenebrionidae collected in the above ant surveys was used in the same way as for the ants except that the 5-point scale for abundance was not used. Rather, the actual number of individuals was used and these abundances were transformed as indicated in the results.

6.4 Small mammals as ecological indicators

Capture-recapture surveys of small mammals were conducted on one-hectare plots with 45 Sherman box traps per plot, initially placed at 15 m spacing, set for four consecutive nights. For the first survey in May 2004, eight plots were chosen, four each in the Horse and Control areas. These plots included habitat types on an open plain with no shrubs, a plain with large *Euphorbia gummifera* shrubs (6 to 10 shrubs/hectare), a riverbed with rocks and small shrubs and an area near the foot of a mountain with granite boulders. Cotton wool was placed in the back of the traps and bait (mixture of rolled oats, peanut butter, syrup and sunflower oil) on the trip plate. The traps were checked three times during the day and at first light in the morning. Fresh bait was put in the traps every evening. The survey was repeated in August 2004 on the same *E. gummifera* shrub plots used in May plus on two additional but similar plots. In November 2004 the same four *E. gummifera* plots were used but these were increased to cover two hectares, still placing 45 traps. The two riverbed and two rocky outcrop plots used in May were again included. The open plain plots were excluded from both the latter two surveys given that no small mammals were found in these plots during the first survey.

Each small mammal that was captured was put in a plastic bag for weighing and then into a glass tube (various diameters were used for the different sized individuals) where they could be measured, sexed and marked with minimum stress from handling so as to reduce trap shyness. The individuals were marked with small tattoo spots of non-toxic ink (four different colours) at four positions on the underside of the tail close to the base. The following was recorded for each individual: species, weight, total length, tail length, length of back foot, sex, lactating, pregnant and any scars present.

Only two plots could be operated simultaneously due to limitations of the number of traps available (90) and manpower (one person only). Therefore climatic variations could have had an effect on the rate of capture between plots that were not operated simultaneously. This, together with the low density of small mammals on the plains, terminated further surveys. The results of the conducted surveys were not analyzed.

6.5 Ecologically sensitive species

Whenever vertebrate species were encountered throughout the study, an attempt was made to identify the species or to take photographs that could be identified by a specialist. Several plant species were collected during the Braun-Blanquet surveys and identified by the National Herbarium in Windhoek. The vertebrate and plant checklists or distribution data for the Quarter degree square 2616CA were obtained from the National Herbarium and Scientific Services departments of the Ministry of Environment and Tourism to verify which species may occur in the study area. The Conservation status of species was obtained from Griffin (2003) and Loots (2005). Various specialists were consulted to identify possible ecologically sensitive species that occur in the study area and their potential relationship to the horses. The pitfall surveys collected a large number of insects and arachnids which were deposited at the National Museum of Namibia. These will be identified over time. Given the fact that invertebrates are not well known, and that it would be mostly impossible to identify specific vulnerable species among the collected specimens within the scope and time frame of this study, these groups are not further discussed here.

6.6 Competition, secondary and subsequent effects

Possible interaction between the horses and other vertebrates and invertebrates were continually investigated through observations, literature, as well as consultations with various specialists. Any secondary or subsequent effects on species which do not have a direct relation to the horses, but which could result from the competition between the horses and another species, were considered.

6.7 Impact of the water point

Apart from vegetation surveys already dealt with in Chapter 3 and above, the number of animals other than horses that utilized the troughs were determined quarterly from September 2003 to December 2004 as described in Chapter 4.

RESULTS & DISCUSSION

6.8 Impact on vegetation structure

a) *Photo comparisons:* Fig. 6.2 portrays the vegetation structure at different localities in the study area over different time periods. These photos show that no significant change in the vegetation structure seems to have occurred over the past 90 years during which the horses utilized the area. However, Fig. 6.3 clearly shows how considerably the standing biomass or veld condition can vary in response to rainfall; shown between 1994 and 2005.

b) *Gradient determination within Horse area:* Great variation in grass species density and standing biomass were recorded both between years and amongst plots. However, no consistent trend or gradient from the trough up to 18 km could be detected that could indicate a grazing gradient or lower density and biomass in areas that the horses frequent (Table 6.1 and Fig. 6.4). The density and biomass in any area at any time was mainly related to the quantity of rainfall and time since the last rainfall (pers. obs.).

c) *Comparison of grass densities between Horse and Control areas:* The densities of *Stipagrostis obtusa* and *Eragrostis nindensis* on the Eastern slopes in the Horse area and on the Control area is presented in Table 6.2. Students t-test show no significant difference between the Horse and Control areas for density of either *S. obtusa* (p=0.848) or *E. nindensis* (p=0.293) (Fig. 6.5). The Control area sites have a slightly higher density of E. nindensis due to their closer proximity to the mountains, as indicated in 6.2 above.

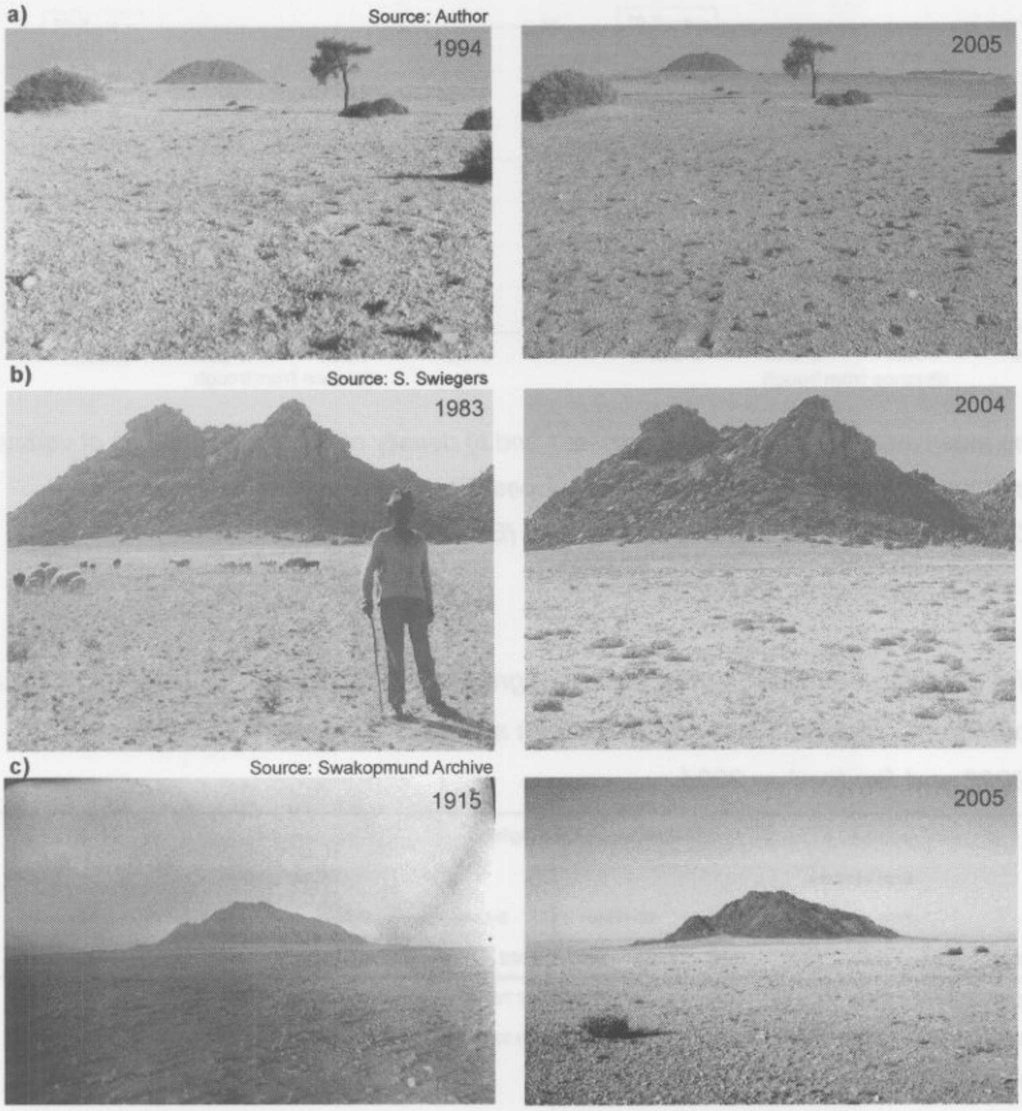


Fig. 6.2: Comparison of vegetation structure over different years at three places in the study area: a) Acacia erioloba *tree and* Euphorbia gummifera *bushes 1 km south-east of the trough over 10 years, b)* Stipagrostis *grassland at Letterkuppe over 20 years and right) relatively bare calcrete plains northeast of the mountain Dik Willem over 90 years.*

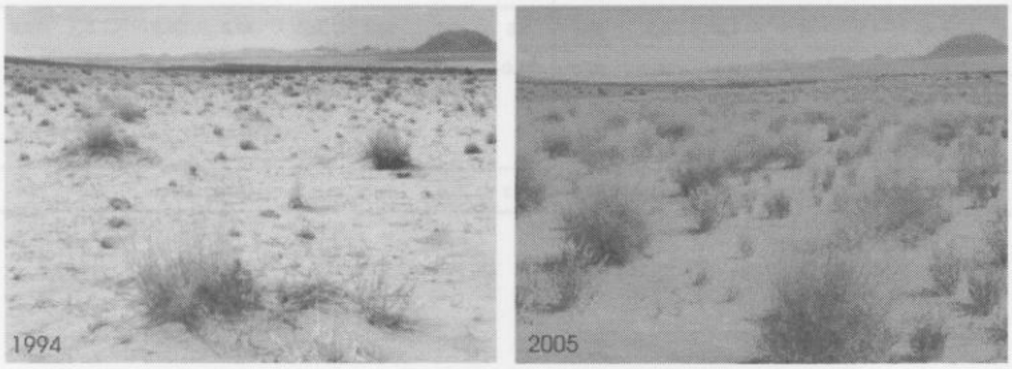


Fig. 6.3: The veld condition as seen on the dune crests in the south of the study area during left) February 1994 and right) March 2005.

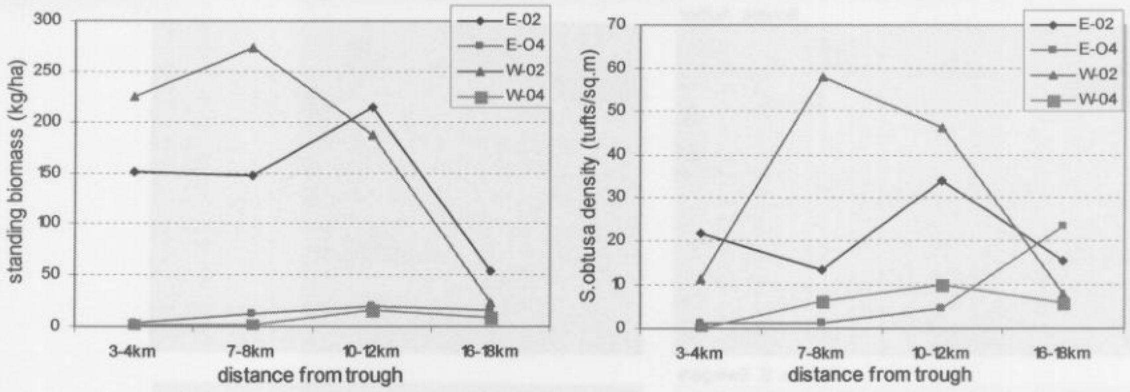


Fig. 6.4: a) The mean standing biomass of all grasses and b) density of Stipagrostis obtusa *at various distances from the trough measured on the eastern slopes (E) and western plains (W) during September 2002 (E-02 and W-02) and September 2004 (E-04 and W-04).*

Table 6.1: The standing biomass (kg/ha) and Stipagrostis obtusa density (tufts/m²) at various distances from the trough measured on the eastern slopes and western plains during September 2002 and September 2004.

Standing biomass (kg/ha)																
	East transect								West transect							
Site	3-4km		7-8km		10-12km		16-18km		3-4km		7-8km		10-12km		16-18km	
	2002	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**
1	111.44	**2.94**	194.36	**25.42**	169.38	**12.34**	104.00	**37.06**	147.78	**0.00**	241.48	**0.00**	115.74	**19.78**	14.12	**7.52**
2	188.34	**3.76**	94.40	**0.72**	258.66	**27.40**	57.56	**10.70**	300.32	**2.06**	305.26	**3.14**	249.02	**5.30**	31.94	**10.24**
3	151.60	**1.72**	129.96	**4.30**			39.08	**10.98**					194.30	**23.66**		
4			170.82	**17.86**			13.84	**8.96**								
Mean	150.46	**2.81**	147.39	**12.08**	214.02	**19.87**	53.62	**16.93**	224.05	**1.03**	273.37	**1.57**	186.35	**16.25**	23.03	**8.88**

Stipagrostis obtusa density (tufts/square meter)																
	East transect								West transect							
Site	3-4km		7-8km		10-12km		16-18km		3-4km		7-8km		10-12km		16-18km	
	2002	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**	**2002**	**2004**
1	5.4	**1.0**	24.0	**1.8**	29.6	**1.0**	0.2	**25.0**	9.6	**0.0**	69.4	**0.0**	38.2	**30.0**	2.8	**10.6**
2	54.6	**2.0**	1.0	**0.0**	38.4	**8.0**	16.0	**20.0**	13.0	**0.0**	46.6	**12.6**	50.6	**0.0**	12.8	**1.2**
3	7.0	**0.5**	18.4	**2.0**			34.6	**37.0**					49.6	**0.0**		
4			10.6	**1.8**			11.0	**12.0**								
Mean	22.3	**1.2**	13.5	**1.4**	34.0	**4.5**	15.5	**23.5**	11.3	**0.0**	58.0	**6.3**	46.1	**10.0**	7.8	**5.9**

Table 6.2: The density (tufts/m²) of Stipagrostis obtusa and Eragrostis nindensis at different plots in the Horse (H) and Control (C) areas.

	Density (tufts/m²)										
Site	H1	H2	H3	H4	Mean	SD	C1	C2	C3	C4	Mean	SD
S.obtusa	13.3	27.3	4.7	22.0	16.8	9.9	38.0	1.4	0.0	19.7	14.8	17.9
E. nindensis	2.3	0.3	7.0	6.0	3.9	3.1	0.3	14.2	12.2	5.3	8.0	6.4

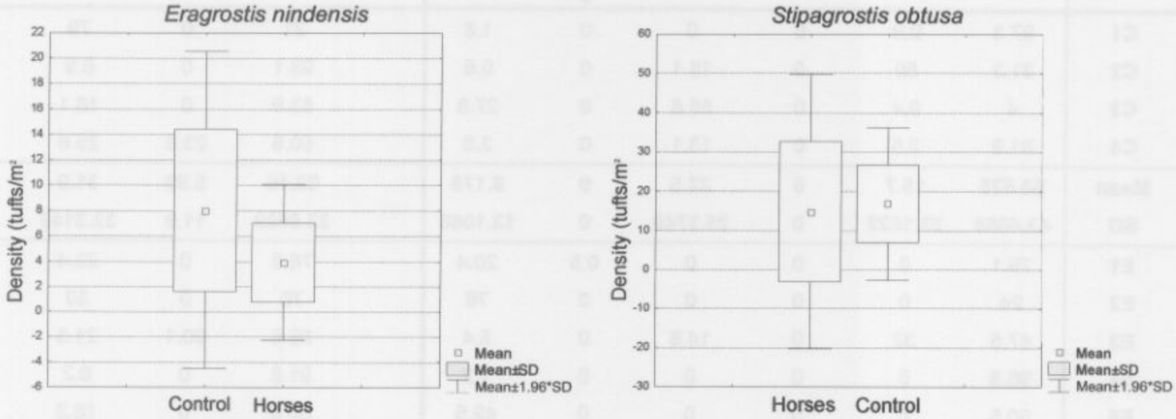


Fig. 6.5: Variation in density (tufts/m²) of Stipagrostis obtusa *and* Eragrostis nindensis *in the Horse and Control areas.*

d) *Vegetation species composition (within Horse area and between Horse and Control areas)*: The herbaceous species composition on the Western plains and Eastern slopes in the horse area as well as four plots in the Control area is presented in Table 6.3. According to this table no apparent difference exists between the Horse and Control areas. No statistical analyses were thus done on the data. Also, no consistent trend could be found at increasing distances from the trough. A few dry annual herbs were still recognizable in the Control area at the time of surveying since this area had more rain during the preceding season while the northern part of the Horse area did not receive significant rain during that season.

Table 6.3: Herbaceous species composition (%) as measured on 10 plots (200 points each) at various distances from the trough in the Horse area and four plots in the Control area, note that the surveys for annuals and perennials were done separately (C-Control; E-East transect; W-West transect; at 1=2km; 2=4km; 3=7km; 4=11km; 5=16km; S. ob – Stipagrostis obtusa*; S. cil –* S. ciliata*; Z. sim –* Zygophyllum simplex*; E. nin –* Eragrostis nindensis*; and BP – Bare patches).*

	% Composition of annuals						% Composition of perennials		
Site	*S. ob*	*S. cil*	*Z.sim*	Herbs	Legumes	BP	*E. nin*	*S. cil*	BP
C1	97.3	0.9	0	0	0	1.8	21	0	79
C2	31.3	50	0	18.1	0	0.6	93.1	0	6.9
C3	4	9.4	0	58.8	0	27.8	83.9	0	16.1
C4	81.9	2.5	0	13.1	0	2.5	50.6	23.8	25.6
Mean	**53.625**	**15.7**	**0**	**22.5**	**0**	**8.175**	**62.15**	**5.95**	**31.9**
SD	**43.4666**	**23.1622**	**0**	**25.3749**	**0**	**13.1068**	**32.9529**	**11.9**	**32.3148**
E1	79.1	0	0	0	0.5	20.4	76.6	0	23.4
E2	24	0	0	0	0	76	70	0	30
E3	47.6	32	0	14.8	0	5.4	58.6	20.1	21.3
E4	98.8	0	0	0	0	1.2	91.8	0	8.2
E5	50.5	0	0	0	0	49.5	83.8	0	16.2
Mean	**60**	**6.4**	**0**	**2.96**	**0.1**	**30.5**	**76.16**	**4.02**	**19.82**
SD	**29.1987**	**14.3108**	**0**	**6.61876**	**0.22361**	**31.7087**	**12.7424**	**8.98899**	**8.16652**
W1	85	0	0	0	0	15	20	0	80
W2	70.4	21.3	0	0	0	8.3	0	0	100
W3	99	0	0	0	0	1	36	0	64
W4	86	1	0	0	0	13	1	0	99
W5	89	0	4	0	1	6	0	0	100
Mean	**85.88**	**4.46**	**0.8**	**0**	**0.2**	**8.66**	**11.4**	**0**	**88.6**
SD	**10.2748**	**9.4238**	**1.78885**	**0**	**0.44721**	**5.5882**	**16.1802**	**0**	**16.1802**

6.9 Ants as ecological indicators

6.9.1 Species richness

Twenty species from nine genera were recorded from pitfall traps during the study (Appendix D), though not all within the study area. The plots in the main surveys were on fairly bare open plains with no shrubs within a 50 m radius in contrast with the sites along the eastern boundary which included more dense vegetation and shrubs. The highest diversity in any plot was recorded in the road servitude with 18 species from eight genera; two of these genera (*Pheidole* and *Lepisiota*) were not recorded in the East and West transects or in the Control area. In the July 2003 East and West transect survey 13 species from six genera were recorded. In the August 2004 Horse vs. Control survey eight species from four genera in the Horse area and 10 species from six genera were recorded in the Control area, of the latter one individual ant contributed one of the species and genera. In these main surveys the genera *Monomorium* (four species) and *Tetramorium* (three species) were the most abundant with few individuals from *Camponotus* (two species), *Anoplolepis* (two species), *Messor* and *Ocymermex*.

Table 6.4 and Fig. 6.6 present the species richness and abundance across plots at distance intervals from the trough as well as the Horse vs. Control areas. No consistent pattern was found in richness or abundance at increasing distance from the trough (Fig. 6.6a&b). Three species (*Anoplolepis* sp. nr. *steingroeveri*, *Messor denticornis* and *Cataulacus* sp. A) were recorded in the Control area in 2004 which were not recorded in the Horse area in 2004, but two of these species was recorded in the Horse area in 2003. This was most likely because the Control area received more rain in 2004 than the Horse area as well as the closer proximity of sites to the mountains. One species (*Tetramorium grandinode*) was recorded in the Horse area but not in the Control area. The mean ant species richness and abundance per plot did not differ significantly between the Horse and Control areas (the eight plots at 2 to 11 km from the trough was used to compare with the eight Control plots) according to t-tests for independent variables ($p=0.770$ for number of species and $p=0.205$ for abundance) (Fig. 6.6c&d).

Table 6.4: Ant species richness and abundance (summed score values of 15 traps) at each plot on the East and West transect (Horse area) as well as the Control area during the 2003 and 2004 surveys.

	West 2003		East 2003		East 2004		Control 2004		
Distance from trough	Number of species	Total abundance	Number of species	Total abundance	Number of species	Total abundance	Plot	Number of species	Total abundance
2km	7	77	6	62	5	55	C1	4	74
2km	5	103	5	54	4	37*	C2	4	51
4km	6	46*	6	50*	6	94	C3	6	34
4km	6	68	5	60	4	58	C4	5	45
7km	4	84	6	68	3	55	C5	4	47
7km	4	75	8	78	5	60	C6	4	34
11km	8	98	8	113	4	45	C7	4	41
11km	8	100	8	73	4	46	C8	5	44
16km	8	104	7	35	4	96			
16km	9	123	6	80	4	45			

* Four to five traps were removed by hyenas and jackals

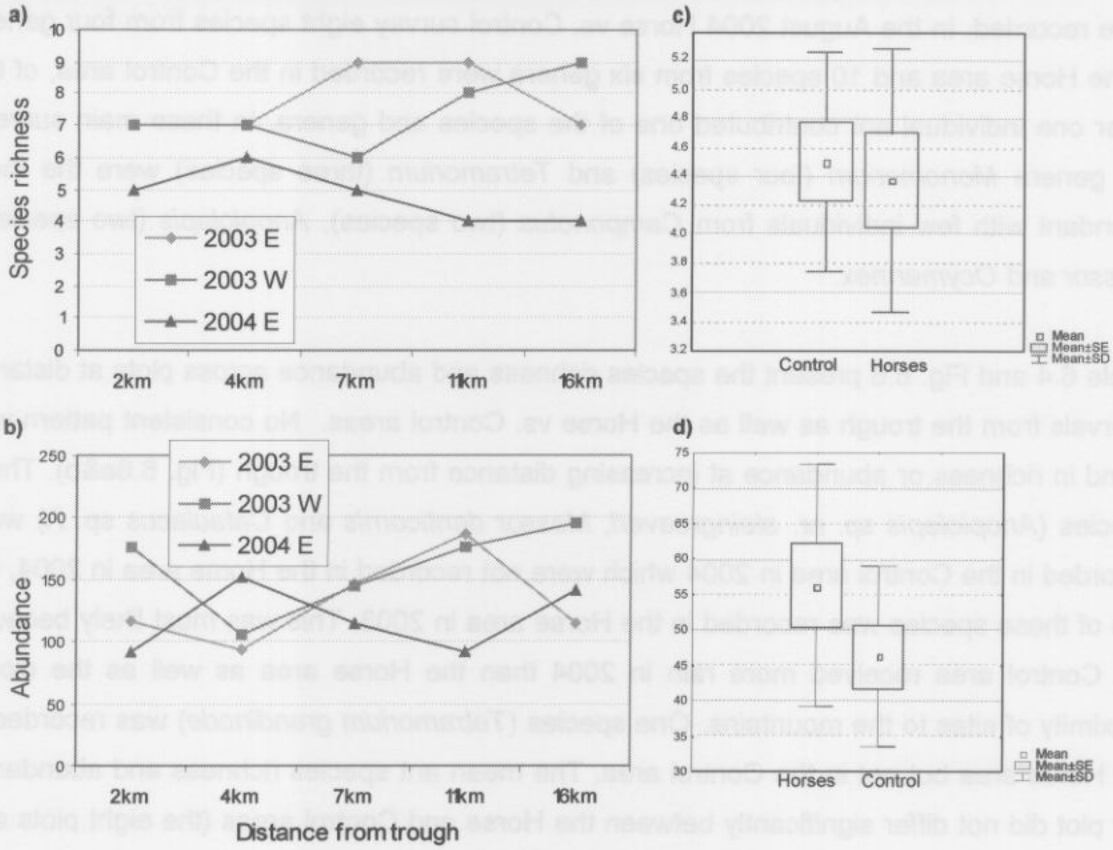


Fig. 6.6: a) The total ant species richness and b) abundance at increasing distance from the trough; and c) the mean species richness and d) mean abundance per plot compared between the Horse and Control areas.

6.9.2 Effect of distance from the trough

Classification of plots with group-averaging clustering did not separate plots according to distance from the trough, grouping were rather random. Ordination with multi-dimensional scaling (MDS) based on standardized abundances in the East 2003 transect separated one 16 km plot (E5A) from the rest on the first axis. The other plots were in an undifferentiated cluster. Ordination according to presence/absence on this transect showed a gradient along the first axis of some plots which correlated with distance from the trough but four of the plots did not fit into this gradient. One plot (E2a) was expected to give low diversity results since five of the 15 traps were removed by hyenas (Fig. 6.7a). The West 2003 transect showed an opposite response, ordination according to standardized abundance as well as square root transformations created a distribution of plots in a more or less horse shoe shape, while ordination according to presence/absence provided a fairly undifferentiated cluster with one 4 km plot (W2a) as an outlier (Fig. 6.7b). No clear gradient correlating with distance from the trough was shown in this transect.

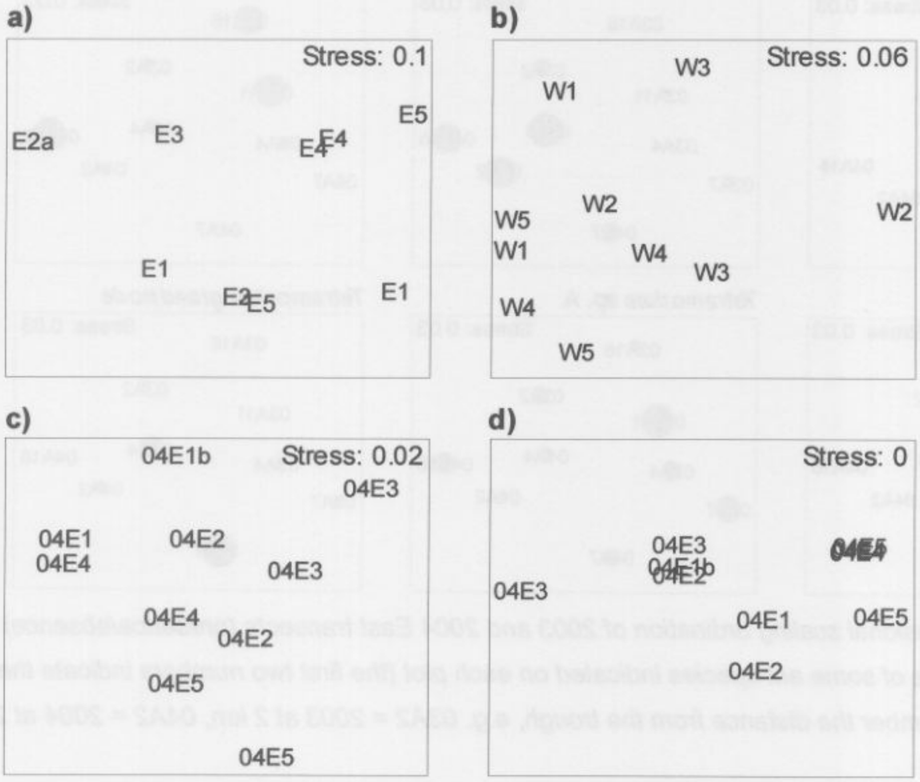


Fig. 6.7: Multidimensional scaling ordination: a) East 2003 transect (presence/absence); b) West 2003 transect (presence/absence); c) East 2004 transect (standardized abundance); and d) East 2004 transect (presence/absence). The distance intervals are 1=2 km, 2=4 km, 3=7 km, 4=11 km and 5=16 km.

The East 2004 transect were different again with the ordination according to standardized abundance (or square root transformations) creating more or less equal distances between plots along the first and second axis and no clear gradient correlated with distance from the trough (Fig. 6.7c). The ordination according to presence/absence of this transect provided a gradient with four groups spaced along the first axis but distance from the trough do not correlate well with this gradient either (Fig. 6.7d).

The significant difference between 2003 and 2004 on the same plots (East transect) was shown both by group-averaging clustering and ordination. The difference in abundances of specific species between years was evident and is superimposed on the presence/absence ordination (Fig. 6.8). *Monomorium kitectum* and *Tetramorium grandinode* was more abundant in 2004 than 2003. *Ocymermex dekerus*, *Camponotus bellinger* and *Tetramorium* sp. A was more abundant in 2003 than 2004 and *Monomorium* sp. B was almost equally abundant in both years, but varied across plots.

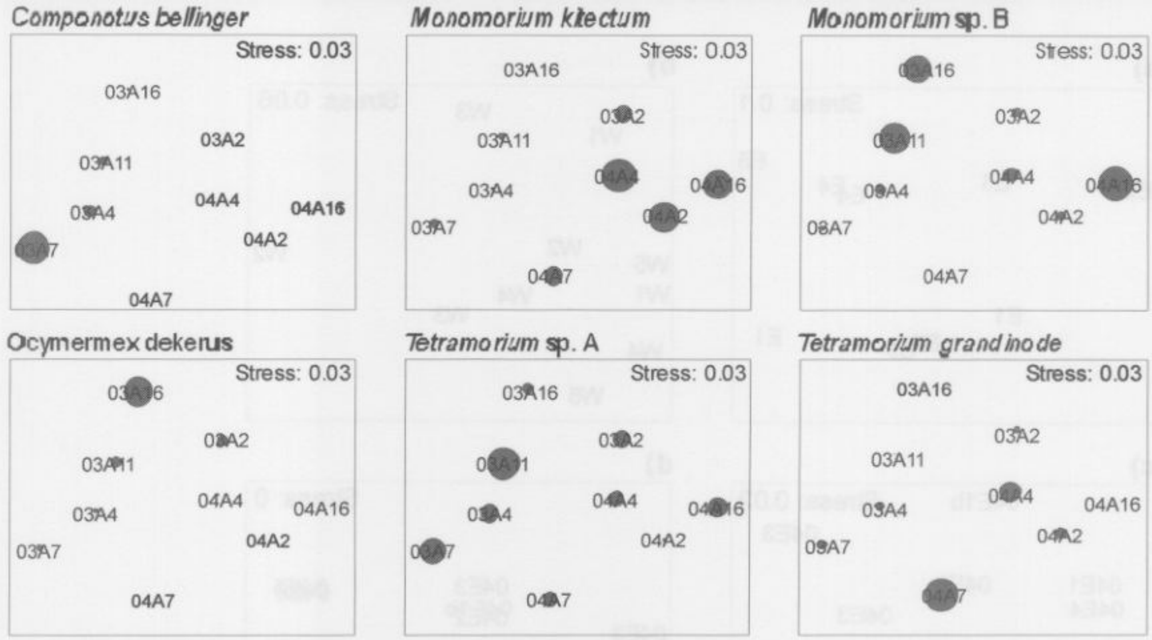


Fig. 6.8: Multidimensional scaling ordination of 2003 and 2004 East transects (presence/absence) with the abundances of some ant species indicated on each plot (the first two numbers indicate the year and the last number the distance from the trough, e.g. 03A2 = 2003 at 2 km, 04A2 = 2004 at 2 km).

6.9.3 Horse vs. Control plots

All ant species recorded in the Control area except one (*Cataulacus* sp. A, which was excluded from the multivariate analysis) was recorded in the Horse area (considering both years). Not all the species recorded in the Horse area in 2003 were recorded either in the Horse or Control areas in 2004. The general species composition and abundance between the Horse and Control plots were similar except for a higher abundance of *Tetramorium* sp. A and *T. grandinode* in the Horse area. Classification of the plots with group-averaging clustering (standardized abundance) revealed a grouping of most horse plots together, except two horse plots that grouped with the control plots. The percentage similarity within horse plots was generally less than that within control plots. The separate clustering of the Horse and Control area is confirmed by the MDS ordination (standardized abundance) along the first axis (Fig. 6.9). However, classification according to presence/absence with group-averaging clustering does not divide the Horse and Control areas into distinct groups but the ordination with MDS (presence/absence) still shows the Control and Horse plots spaced more separately along the first axis (Fig. 6.9).

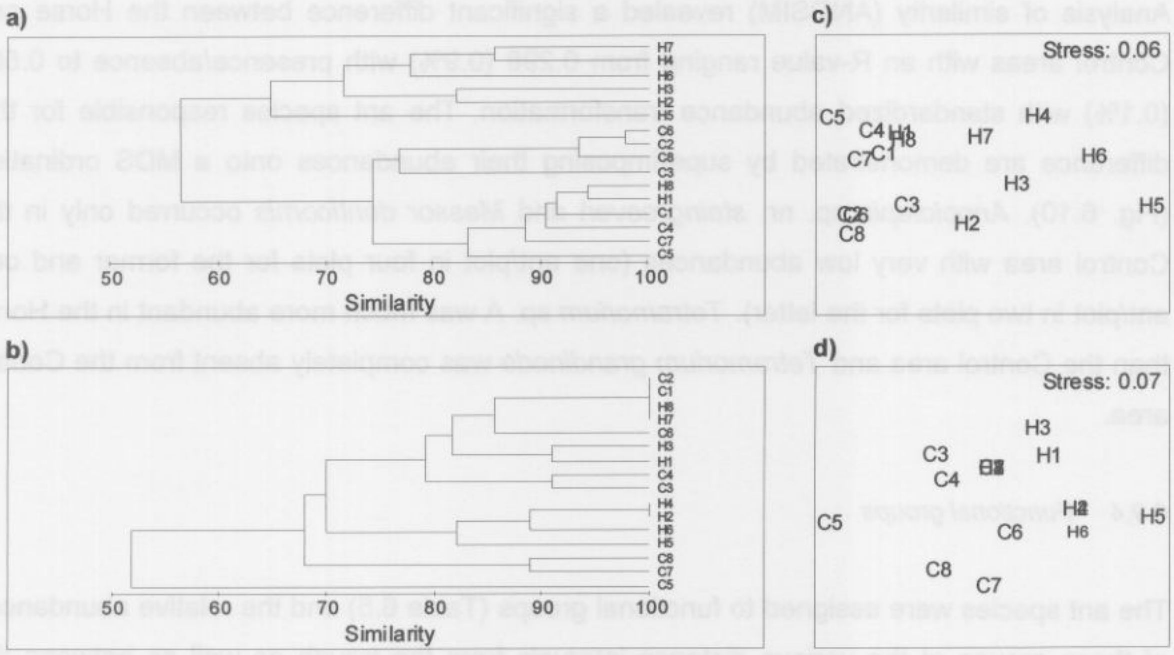


Fig. 6.9: a & b) Classification (through group-averaging clustering) and c & d) multidimensional scaling ordination of the Horse (H1 to H8) and Control (C1 to C8) areas based on species composition (standardized abundance (a & c) and presence/absence (b & d)).

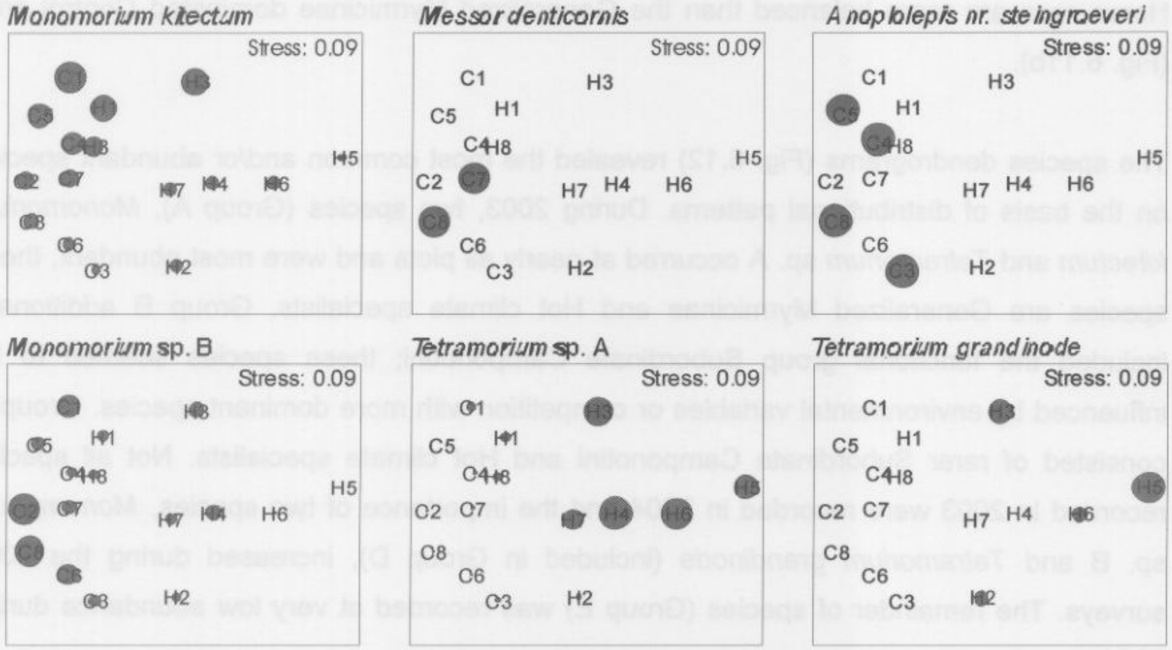


Fig. 6.10: Ant species presence and abundance between horse (H) and control (C) plots as superimposed on a MDS ordination according to species composition (no transformation).

Analysis of similarity (ANOSIM) revealed a significant difference between the Horse and Control areas with an R-value ranging from 0.298 (0.9%) with presence/absence to 0.501 (0.1%) with standardized abundance transformation. The ant species responsible for this difference are demonstrated by superimposing their abundances onto a MDS ordination (Fig. 6.10). *Anoplolepis* sp. nr. *steingroeveri* and *Messor denticornis* occurred only in the Control area with very low abundances (one ant/plot in four plots for the former and one ant/plot in two plots for the latter). *Tetramorium* sp. A was much more abundant in the Horse than the Control area and *Tetramorium grandinode* was completely absent from the Control area.

6.9.4 Functional groups

The ant species were assigned to functional groups (Table 6.5) and the relative abundances of these groups at the various distance intervals from the trough as well as between the Horse and Control areas are presented in Fig. 6.11. Only during 2003 all functional groups were recorded in the surveys, it is therefore possible that the reduction in grass biomass and generally increasing dry conditions from 2003 to 2004 reduced the percentage of specialist species (Fig. 6.11a – E2003 : E2004). The influence of the horses appear to be not as significant as climatic conditions and interestingly the distribution of functional groups in the Horse area are more balanced than the Generalized Myrmicinae dominated Control area (Fig. 6.11b).

The species dendrograms (Fig. 6.12) revealed the most common and/or abundant species on the basis of distributional patterns. During 2003, two species (Group A), *Monomorium kitectum* and *Tetramorium* sp. A occurred at nearly all plots and were most abundant, these species are Generalized Myrmicinae and Hot climate specialists. Group B additionally included the functional group Subordinate Camponotini; these species seemed to be influenced by environmental variables or competition with more dominant species. Group C consisted of rarer Subordinate Camponotini and Hot climate specialists. Not all species recorded in 2003 were recorded in 2004 and the importance of two species, *Monomorium* sp. B and *Tetramorium grandinode* (included in Group D), increased during the 2004 surveys. The remainder of species (Group E) was recorded at very low abundance during 2004.

Table 6.5: Ant species assigned to different Functional groups (GM-Generalized Myrmicinae; Opp-Opportunists; SC-Subordinate Camponotini; HCS-Hot Climate Specialists).

Species	Functional group			
	GM	Opp	SC	HCS
Anoplolepis sp. A				#
Anoplolepis sp.nr. *steingroeveri*				#
Camponotus fulvopilosus			#	
Camponotus bellinger			#	
Camponotus sp. B			#	
Camponotus sp. C			#	
Lepisiota sp. A		#		
Messor denticornis				#
Monomorium drapenum	#			
Monomorium kitectum	#			
Monomorium sp. B (setuliferum gr.)				#
Monomorium sp. C	#			
Ocymyrmex dekerus				#
Pheidole sp. A	#			
Tetramorium grandinode				#
Tetramorium peringueyi				#
Tetramorium sp nr. *sereiceventre*		#		
Tetramorium sp. A (solidum gr.)				#
Tetramorium sp. C				#

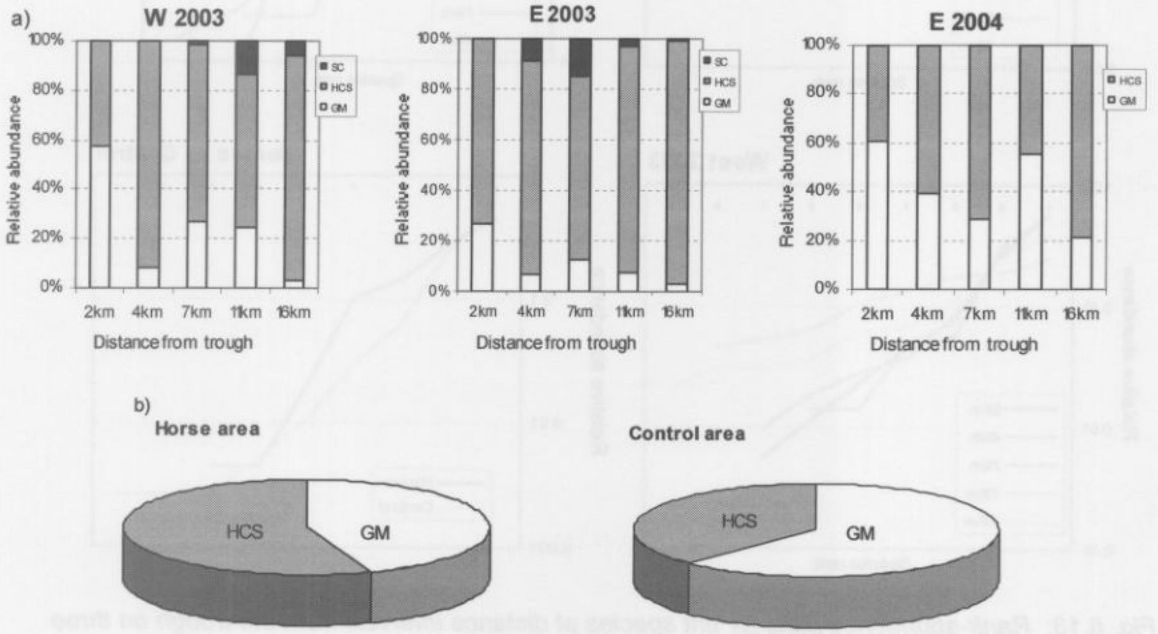


Fig. 6.11: Relative abundance of different ant Functional groups a) at various distances from the trough for the East and West transects as well as b) the Horse and Control area (GM-Generalized Myrmicinae; SC-Subordinate Camponotini; HCS- Hot Climate Specialists).

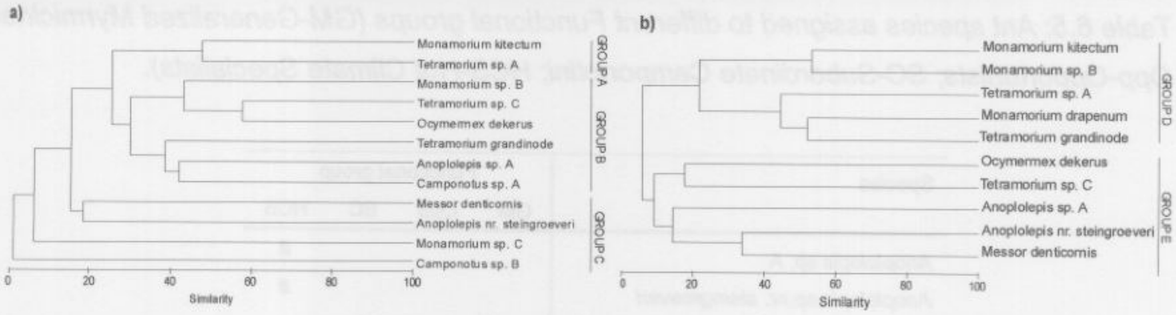


Fig. 6.12: Classification (through group averaging clustering) of ant species on a) 2003 East and West transects and b) the Horse and Control area.

6.9.5 Rank-abundance patterns

Fig. 6.13 indicates a measure of ant diversity across localities with rank-abundance plots.

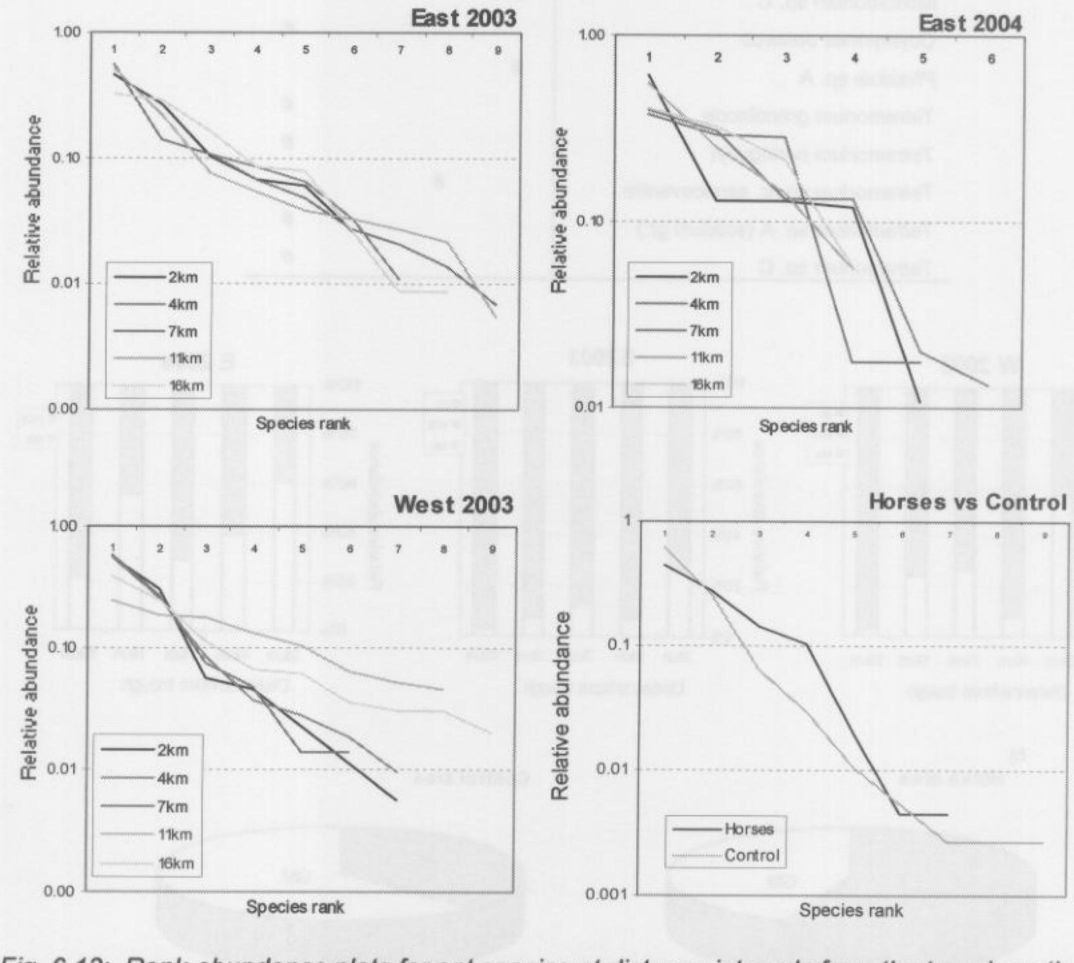


Fig. 6.13: Rank-abundance plots for ant species at distance intervals from the trough on three transects (total ant abundance in two plots at each distance interval) and the Horse vs. Control area (mean ant abundance/plot).

The curves for the distance intervals from the trough on the 2003 East transect do not show much differentiation among the distance intervals, neither does it show a steep or strong broken stick pattern which therefore indicate a low level of dominance. The curves on the 2004 East transect are rather broken due to lower species diversity but again show no clear distinction between the different distance intervals. On the 2003 West transect there is a change in ant diversity along the distance from the trough gradient, with the 11 and 16 km distances being less steep and showing higher diversity than the 2, 4 and 7 km curves. This could indicate either a grazing gradient or variation in environmental conditions such as higher rainfall at the 16 km sites (see also 6.10.4). Considering that the other transects did not indicate a gradient effect, this result is more likely due to higher rainfall than grazing disturbance. The Horse area curve almost represents a broken stick model while the Control area curve tends towards a log series which indicate a slightly higher diversity per site in the Control area but higher dominance.

6.9.6 Ants relation to environmental variables

The above analyses have in some cases found patterns of differences between areas or plots while in others no clear difference could be detected. It is however not apparent if the horses as such or other environmental variables were responsible for the observed differences. Fig. 6.14 presents an ordination by means of Canonical Correspondence Analysis (CCA) of the ant species relation to environmental variables on the East and West transect during 2003 as well as the 2004 Horse vs. Control survey. Four of the species, *Tetramorium grandinode*, *Anoplolepis* sp. A, *Camponotus bellinger* and *Camponotus* sp. B seem to be positively correlated to grass height which indirectly would indicate the presence/abundance of *Stipagrostis ciliata*. This likely correlation is verified by the presence or increased abundance of these species on plots with an abundance of *Stipagrostis ciliata* (Appendix D). Fig. 6.14 shows standing biomass correlated with rainfall but not with grass height. A likely explanation for this is that the grass height (indirectly grass species composition) was influenced by rainfall of 2002, while the rainfall of 2003 (which is represented in Fig. 6.14) was not sufficient to influence grass height. *Messor denticornis, Tetramorium* sp. C, *Monomorium* sp. B and *Anoplolepis* sp. nr. *steingroeveri* are to some extent correlated with the areas that received the most rain during 2003 and 2004, yet only areas where the grass was not too long. The weakest correlations were with horse spoor/manure, gemsbok spoor/dung and Veld condition score, only *Monomorium kitectum* to some extent correlated with these variables. The number of termite heaps is strongly correlated to the percentage utilized vegetation. *Tetramorium* sp. A does not seem to be significantly influenced by any of the measured environmental variables and *Ocymermex dekerus* and *Monomorium* sp. C are outliers for which no clear or consistent correlation is apparent.

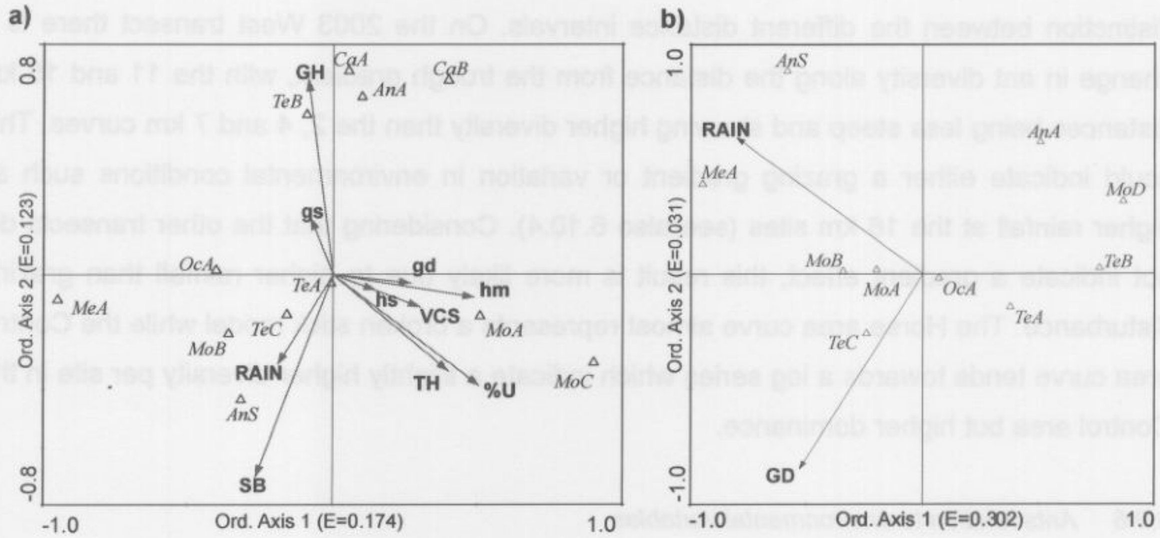


Fig. 6.14: Ordination with Canonical Correspondance Analyses (CCA) of ant species and environmental variables on a) 2003 East and West transects and b) 2004 Horse and Control areas. (AnA – Anoplolepis *sp. A, AnS –* Anoplolepis *sp. nr.* steingroeveri, *CaA –* Camponotus bellinger, *CaB –* Camponotus *sp. B, MeA –* Messor denticornis, *MoA –* Monomorium kitectum, *MoB –* Monomorium *sp. B, MoC –* Monomorium *sp. C, MoD –* Monomorium drapenum, *OcA –* Ocymermex dekerus, *TeA –* Tetramorium *sp. A, TeB –* Tetramorium grandinode *and TeC –* Tetramorium *sp. C; GH – grass height, gs – gemsbok spoor, gd – gemsbok dung, hs – horse spoor, hm – horse manure, VCS – veld condition score, TH – termite soilheaps, %U - % utilized vegetation, RAIN – rainfall, SB – standing biomass and GD – grass density).*

Further observations concerning the ants can be found in Appendix D, including possible competition or dominance between some species. *Tetramorium* sp. A seems to have a competitive advantage over *T. grandinode* in areas where, or times when, grass is abundant. Likewise, *Monomorium kitectum* and *Monomorium* sp. B appear to have an inverse relationship with *Monomorium* sp. B being more abundant in plots with shorter and sparse vegetation cover or maybe more stable soil surface. *Monomorium kitectum* was the only ant species collected in pitfall traps around the troughs (within a 100 m radius) and either is very resilient to disturbance or benefits in some way from horse manure.

Monomorium sp. C is a minute inconspicuous species with most likely a specialist function and therefore not represented well with pitfall trapping or in the plots chosen. *Ocymermex* *dekerus* occurred mostly at plots with perennial vegetation and the highest rate of trapping was recorded in January (hot months). They were not well represented in the main surveys during July and August (coldest months) and may be inhibited by cold temperatures. *Messor denticornis* showed depressed activity during food scarcity (Marsh 1985) and therefore will be trapped rather unsuccessfully during such times. *Messor denticornis* as well as *Ocymermex dekerus* are not effectively sampled by pitfall traps (Marsh 1984) which, together with the above mentioned reasons, would explain why so few individuals of these species were trapped. Therefore, results obtained regarding these two species should be carefully checked and conclusions should not be based on records where only a few individuals were recorded.

6.9.7 Seasonal fluctuation

Figure 6.15 shows a constant decrease in ant abundance from October 2003 to August 2004 and the number of species varied with the highest species richness recorded in October 2003 coinciding with the highest abundance. The consistent decrease in ant abundance could be due to seasonal changes with October to April being warmer months and August the coldest month. However, it is likely that the steady decrease in vegetation cover and overall invertebrate abundance that was observed from 2002 to 2004 (due to good rains received in 2002, followed by lower rainfall in the following two years – see Fig. 6.4), also played a major role. This is supported by the surveys on the northeast transect that were repeated on the same plots at the same time of year in 2003 and 2004 (total ant abundance: 2003 - 656 and 2004 - 591; number of species 2003 - 12 and 2004 - 7).

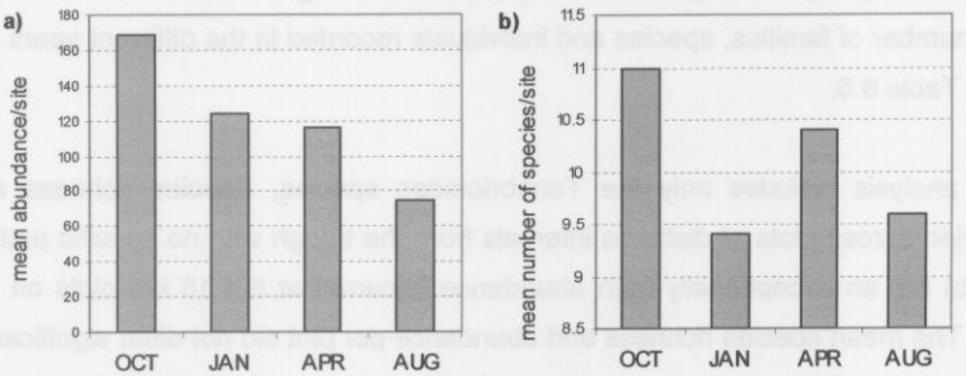


Fig. 6.15: a) The mean abundance and b) mean number of species per plot (5 plots) along the NNP eastern boundary measured on 4 occasions; Oct 2003, Jan 2004, Apr 2004 and Aug 2004.

In the Central Namib an increased forager abundance in response to rainfall was also found by Marsh (1988) as well as high activity levels during warm months and the lowest abundance during August (Marsh 1985). The lowest species richness was recorded in January and August 2004 which are the hottest (Jan) and coldest (Aug) times of the year. Marsh (1985) found that some species, especially nocturnal species, become almost inactive during August and this may account for the low species diversity in August during this study. On the other extreme it could be likely that some species become less active during the hottest months of January and February especially if food is scarce during this time. However, looking at the actual species that were absent and present in the relevant months, the above does not seem to explain the results in Fig 6.15b.

6.10 Beetles as ecological indicators

6.10.1 Species richness

Approximately 80 species (± 6 due to uncertainty of identifications) of Coleoptera from 16 families were recorded from pitfall traps during the study (Appendix E). The highest number of species in any one plot (15 traps) was recorded at E5b (2003) with 19 species (16 of which were Tenebrionidae), while the highest abundance was recorded at W5a (2003) with 1073 individuals (1059 of which were Tenebrionidae). The most diverse families were Tenebrionidae (36 species), Curculionidae (±12 species), Scarabaeidae (9 species) and Carabidae (3 species). The most abundant species belonged to the Tenebrionidae and included *Pterosticula* cf. *arenicola* (2597 individuals), *Cauricara phalangium* (1096), *Zophosis* cf. *arcana* (1052), *Histrionotus lightfooti* (714), *Rhammatodes* sp. A (430), *Zophosis pedinoides* (352) and *Zophosis boei* (325, but this might include more than one species). The number of families, species and individuals recorded in the different years are summarized in Table 6.6.

The following analysis includes only the Tenebrionidae species. Species richness and abundance varied across plots at distance intervals from the trough with no specific pattern (Fig. 6.15a & b) but an exceptionally high abundance occurred at the 16 km plots on the West transect. The mean species richness and abundance per plot did not differ significantly between the Horse and Control areas according to Students t-tests (Fig. 6.16c & d).

Table 6.6: Number of species and individuals of Tenebrionidae and "other" (non-tenebrionid) Coleoptera families recorded in 2003 and 2004. The 2004 East transect repetition and the Road plot (seasonal surveys) is given separately to demonstrate the influence of rainfall or vegetation status – note that rain preceded (with three weeks) the April survey on the Road plot.

	Total 2003	Total 2004	East 2003	East 2004	EB sites*	Road site			
					total	Oct	Jan	Apr	Aug
Families	10	13	7	9	15	5	2	10	4
Species - other	11	26	7	19	26	5	1	10	4
Species - tenebrionidae	26	22	23	18	19	2	6	1	8
Total species	**37**	**48**	**30**	**37**	**45**	**7**	**7**	**11**	**12**
Other : Tenebrionidae ratio	30:70	54:46	23:77	51:49	58:42	71:29	14:86	91:9	33:67
Individuals - other	106	463	43	141	217	7	1	62	17
Individuals - tenebrionidae	6160	599	2068	365	323	3	14	1	17
Total individuals	**6266**	**1062**	**2111**	**506**	**540**	**10**	**15**	**63**	**34**
Other : Tenebrionidae ratio	2:98	44:56	2:98	28:72	40:60	70:30	7:93	98:2	50:50

* Five sites on the Eastern boundary of the study area surveyed seasonally.

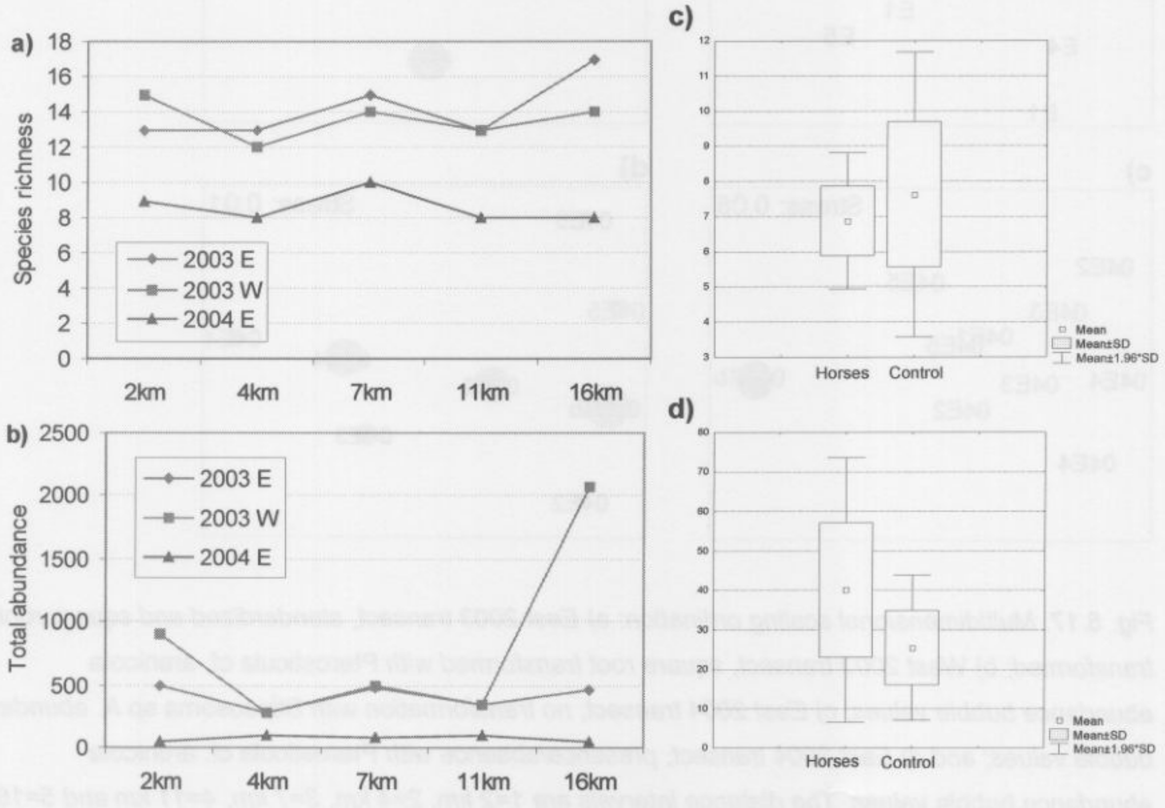


Fig. 6.16: a) Tenebrionidae species richness and b) abundance at increasing distances from the trough on three transects; and c) the mean species richness and d) abundance per plot compared between the Horse and Control areas.

6.10.2 Effect of distance from the trough

Classifying plots with group-averaging clustering as well as ordination with multidimensional scaling (MDS) based on various transformations resulted in different spatial distributions for different transformations and transects. For the 2003 East transect most transformations gave a similar arrangement of plots, with the only difference being in the distances between plots and clusters. One of these ordinations is presented in Fig. 6.16a. The two 16 km plots clustered together spaced well away from the other plots due to the exceptionally high abundance of *Cauricara phalangium*. The other outlier is E2a which was expected since five of the 15 traps were removed by hyena. The rest of the plots are clustered together with no gradient effect (Fig. 6.17a).

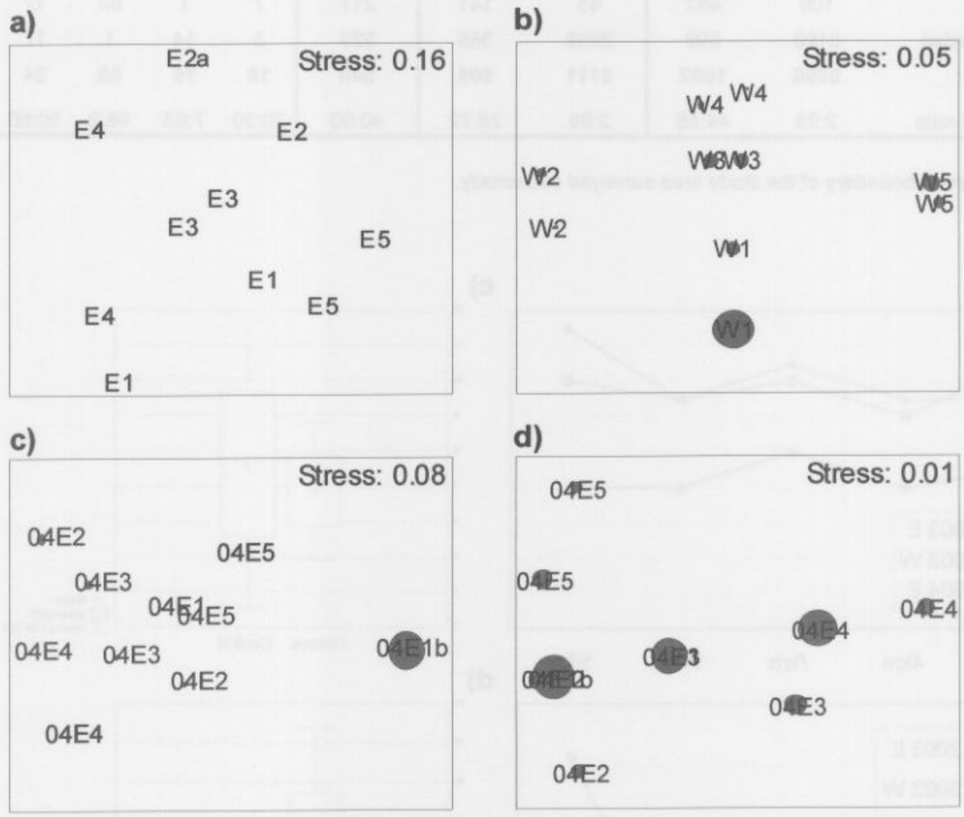


Fig. 6.17: Multidimensional scaling ordination: a) East 2003 transect, standardized and square root transformed; b) West 2003 transect, square root transformed with Pterosticula cf. arenicola *abundance bubble values; c) East 2004 transect, no transformation with* Stipsosoma sp A. *abundance bubble values; and d) East 2004 transect, presence/absence with* Pterosticula cf. arenicola *abundance bubble values. The distance intervals are 1=2 km, 2=4 km, 3=7 km, 4=11 km and 5=16 km.*

The 2003 West transect is the only transect that showed a gradient effect along both axes which correlated to the distance from the trough, it was best demonstrated by the square root transformation in Fig. 6.16b. This gradient did not indicate an increase in species richness further away from the trough but rather exceptionally high abundances of two specific species *Cauricara phalangium* and *Histrionotus lightfooti*, the presence and abundances of some less conspicuous species were again higher in plots closer to the trough and thus strengthened the strong gradient effect.

In the 2004 East transect ordination with no transformation (Fig. 6.17c), Eb1 is indicated as an outlier. Again, this was to be expected since five of the 15 traps in these plots were removed by hyenas. Nevertheless, when looking at the data, it became clear that the number of species and abundance for Eb1 were not exceptionally lower than in some of the other plots. The reason for it being an outlier is found due to the presence and high abundance of primarily three species namely *Somaticus aeneus, Stipsostoma* sp. A and *Eurychora* sp. A (Fig. 6.17c). Also on this transect a strong gradient was shown along both axes according to presence/absence transformation, but this gradient was not correlated to the distance from the trough. The superimposed abundance values of *Pterosticula* cf. *arenicola* is a good demonstration of the gradient on the ordination (Fig. 6.17d).

Classification of the East transect plots from 2003 and 2004 with group-averaging clustering and ordination with MDS divide the two years in distinct groups. This is due to the abundance of most species decreasing from 2003 to 2004 as demonstrated by the abundance (bubble) values of *Rhammatodes* sp. A, which is superimposed on the MDS (Fig. 6.18).

a)

b)

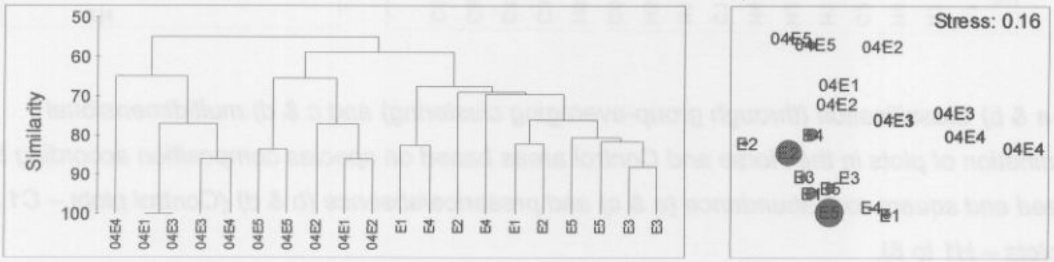


Fig. 6.18: a) Classification of plots with group-averaging clustering and b) multidimensional scaling ordination (presence/absence) of 2003 and 2004 East transect plots. The abundance of Rhammatodes *sp. A is indicated as bubble values on each plot in the ordination (2003 plots – E1 to 5; 2004 plots – 04E1 to 5).*

6.10.3 Horse vs. Control areas

Sixteen tenebrionid species were recorded in the Control area, 14 species were recorded in the eight plots in the Horse area used in the analyses. However five more species were recorded at the remaining four plots (E5a & b, TRA and TRB) in the Horse area. Four species were only recorded in the Control area and five species only in the Horse area, these species were represented by one or a few individuals only. Classification of the plots with group-averaging clustering (standardized and square root transformed) revealed a grouping of most horse plots together with the exception of one horse plot that grouped with the control plots, and two control plots that grouped with the horse plots. Classification according to presence/absence does not divide the Horse and Control areas into distinct groups. The ordinations with MDS according to above transformed similarity matrices confirm the separation according to the classifications (Fig. 6.19).

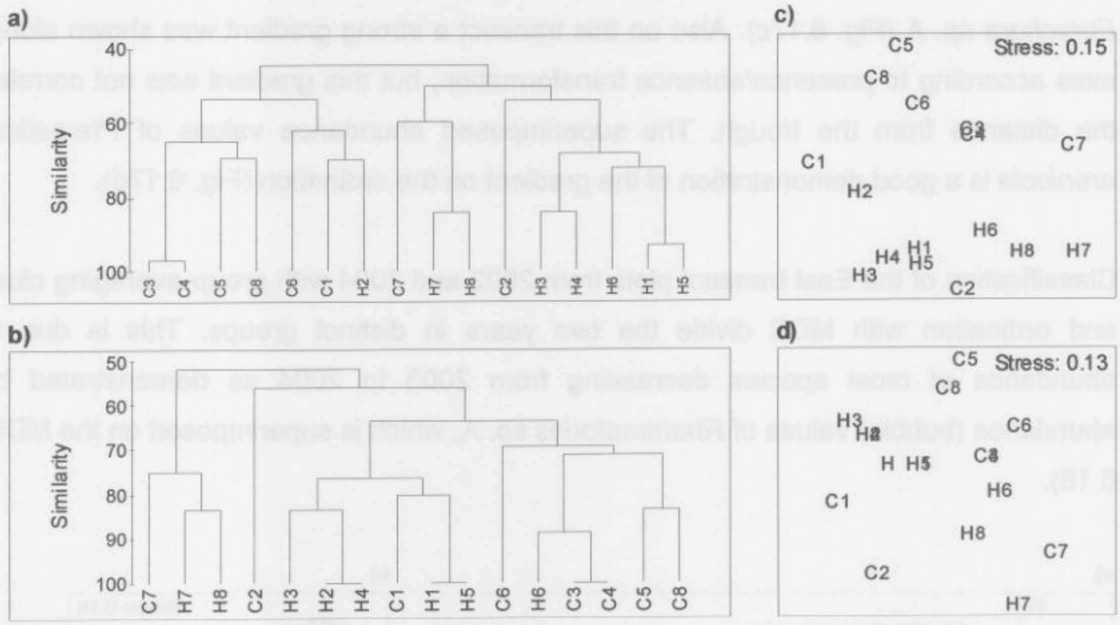


Fig. 6.19: a & b) Classification (through group-averaging clustering) and c & d) multidimensional scaling ordination of plots in the Horse and Control areas based on species composition according to standardized and square root abundance (a & c) and presence/absence (b & d) (Control plots – C1 to 8; Horse plots – H1 to 8).

Analysis of similarity (ANOSIM) revealed a significant difference between the Horse and Control areas with an R-value of 0.503 (0.1%) according to standardized and square root transformed abundance and species composition. The difference was not as significant based on presence/absence of species (R = 0.085 at 17,3%). Abundances of specific species varied between the Horse and Control area with some species more abundant in the Horse area (species that were at least twice as many included *Pterostichula* cf. *arenicola, Histrionotus lightfooti, Pachynotelus longipilis* and *Eurychora* sp. A) and other species more abundant in the Control area (*Stipsostoma* sp. A, *Rhammatodes* sp. A and *Pachynotelus dimorphus*).

6.10.4 Rank-abundance patterns

Figure 6.20 shows rank-abundance curves for each transect and the Horse vs. Control areas. On the 2003 East and West transect, no gradient of Tenebrionidae diversity is apparent at increasing distance from the trough.

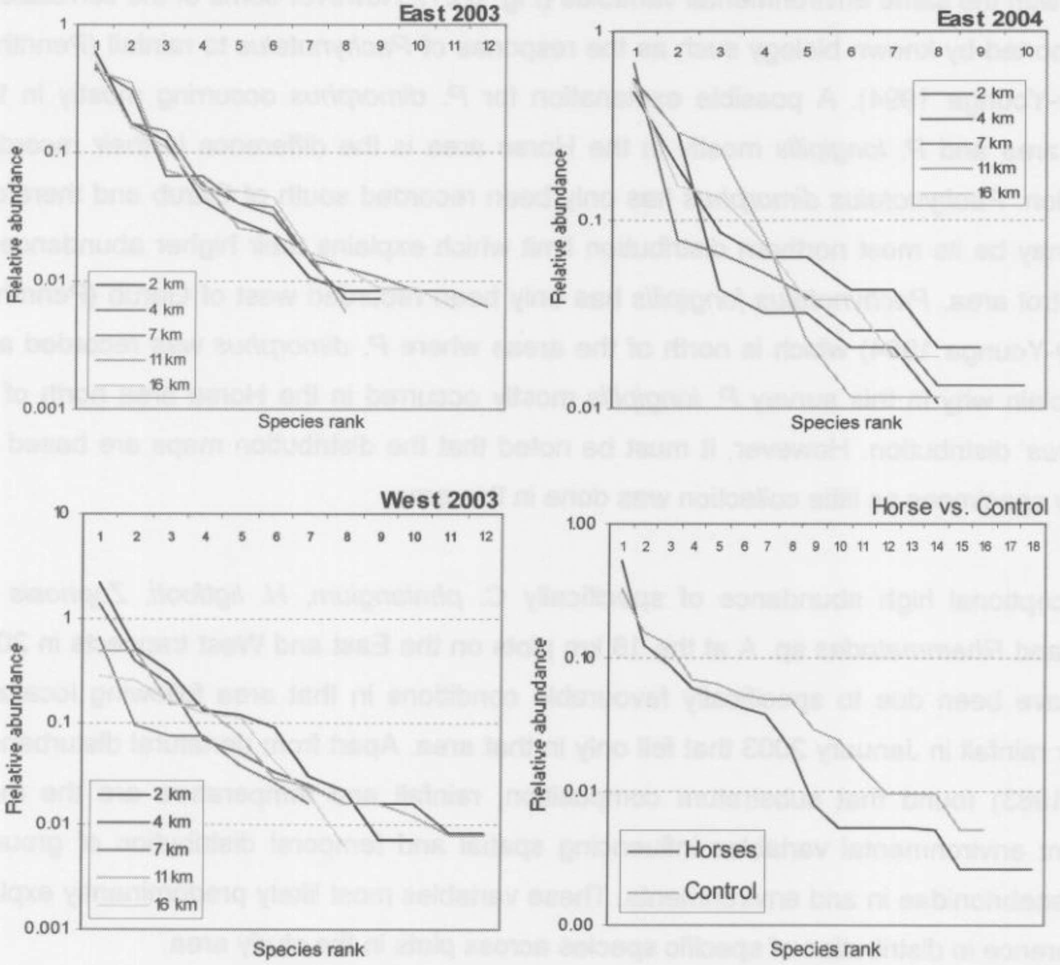


Fig. 6.20: Rank-abundance curves for Tenebrionidae species at distance intervals from the trough on three transects (total abundance in two plots at each distance interval) and the Horse vs. Control areas (mean abundance per plot).

On the 2004 East transect, the highest diversity is indicated closest to the trough at 2 km, while the 11 km plots show high dominance of certain species. The Control area curve is slightly less steep than the Horse area showing higher diversity per plot.

6.10.5 Influence of environmental variables

The Tenebrionidae species with the greatest influence on the spatial distribution of plots on the ordination axes were *Cauricara phalangium, His trionotus lightfooti, Pterostichula* cf. *arenicola, Pachynotelus longipilis, Eurychora* sp. A, *Somaticus aeneus, Stipsostoma* sp. A, *Rhammatodes* sp. A, *Pachynotelus dimorphus* and *Sulcipectus levis*. Multivariate analysis of species composition and environmental variables did not consistently correlate specific species with the same environmental variables (Fig. 6.21). However some of the correlations are supported by known biology such as the response of *Pachynotelus* to rainfall (Penrith & Endrödy-Younga 1994). A possible explanation for *P. dimorphus* occurring mostly in the Control area and *P. longipilis* mostly in the Horse area is the difference in their recorded distribution. *Pachynotelus dimorphus* has only been recorded south of Garub and therefore Garub may be its most northern distribution limit which explains their higher abundance in the Control area. *Pachynotelus longipilis* has only been recorded west of Garub (Penrith & Endrödy-Younga 1994) which is north of the areas where *P. dimorphus* was recorded and may explain why in this survey *P. longipilis* mostly occurred in the Horse area north of *P. dimorphus'* distribution. However, it must be noted that the distribution maps are based on very few specimens as little collection was done in this area.

The exceptional high abundance of specifically *C. phalangium, H. ligtfooti, Zophosis* cf. *arcana* and *Rhammatodes* sp. A at the 16 km plots on the East and West transects in 2003 could have been due to specifically favourable conditions in that area following localized summer rainfall in January 2003 that fell only in that area. Apart from unnatural disturbance, Louw (1983) found that substratum composition, rainfall and temperature are the most important environmental variables influencing spatial and temporal distribution of ground-living Tenebrionidae in arid environments. These variables most likely predominantly explain the difference in distribution of specific species across plots in the study area.

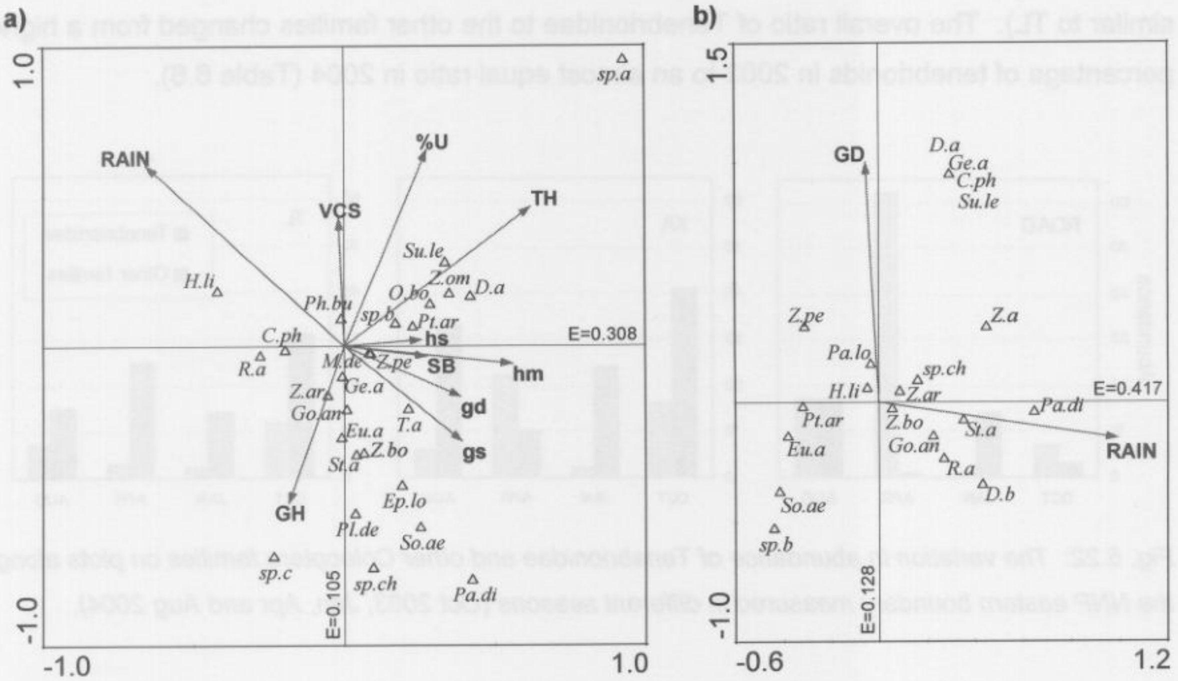


Fig. 6.21: CCA of Tenebrionidae species composition and environmental variables on a) the 2003 East and West transects and b) 2004 Horse and Control areas (GH – grass height, gs – gemsbok spoor, gd – gemsbok dung, hs – horse spoor, hm – horse manure, VCS – veld condition score, TH – termite soil heaps, %U - % utilized vegetation, RAIN – rainfall, SB – standing biomass and GD – grass density; C.ph - Cauricara phalangium, *H.li -* Histrionotus lightfooti, *Pt.ar -* Pterostichula cf. arenicola, *Pa.lo -* Pachynotelus longipilis, *Eu.a -* Eurychora *sp. A, So.ae -* Somaticus aeneus, *St.a -* Stipsostoma *sp. A, R.a -* Rhammatodes *sp. A, Pa.di -* Pachynotelus dimorphus *and Su.le -* Sulcipectus levis*).*

6.10.6 Seasonal fluctuation

A general decrease in Coleoptera abundance occurred from October 2003 to January 2004 (except at the Road plot). From January 2004 to August 2004 two responses occurred in different plots regarding the ratio of tenebrionids and other families. Three plots (Road, KA and HKA) received rain in March 2004 and two plots (HT and TL) did not. The tenebrionid abundance in the plots that received rain decreased while the abundance of other beetles (mainly Melyridae) increased. In the two dry plots (HT and TL) the tenebrionid abundance increased during April and the other families remained low. Wide-spread winter rain occurred in June, but the Melyridae did not re-occur in August and the abundance of other families in the Road, KA and HKA decreased while the tenebrionids increased. In contrast, Tenebrionidae in HT and TL decreased in August while the other families in these two plots increased (Fig. 6.22 presents three of the five plots, HKA were similar to KA and HT were similar to TL). The overall ratio of Tenebrionidae to the other families changed from a higher percentage of tenebrionids in 2003 to an almost equal ratio in 2004 (Table 6.6).

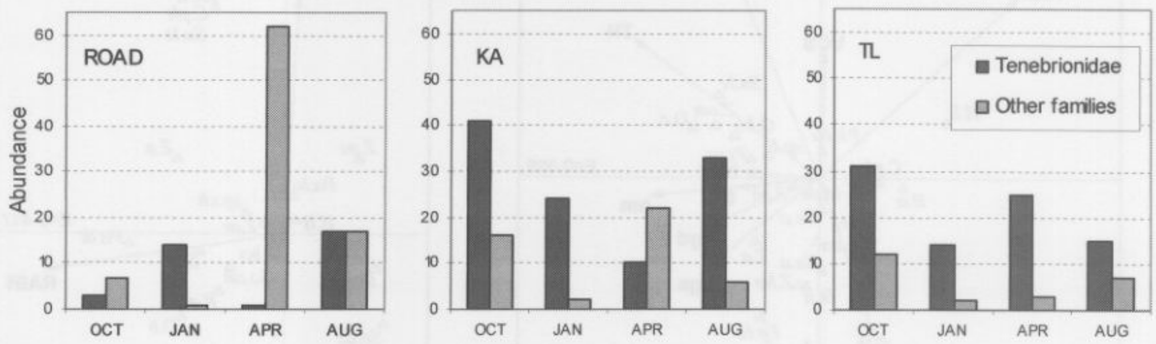


Fig. 6.22: The variation in abundance of Tenebrionidae and other Coleoptera families on plots along the NNP eastern boundary measured in different seasons (Oct 2003, Jan, Apr and Aug 2004).

Louw (1983) found the species diversity of Tenebrionidae consistently higher than the other Coleoptera at a Namib plot (farm Kanaan, ±100 km north of Garub) while on two occasions the ratio were equal at a plot in the Kalahari. However, it was not necessarily in response to rainfall. Louw (1983) did find species diversity to reach a peak in response to rainfall and the lowest diversity was recorded during summer (January).

6.11 Small mammals as ecological indicators

Eight species of small mammals were recorded during three surveys in 2004. From a total of 3600 trap-nights, 106 captures were made, which constituted 59 individuals (some individuals were re-captured). All eight species were recorded in the rocky habitat and associated riverbeds but only two of the species were captured on the plains habitat where *Euphorbia gummifera* shrubs occurred. No small mammals were captured in open plains or riverbed plots that did not have large shrubs. Also, in the *E. gummifera* plots, no captures were made with traps placed in the open areas between shrubs - a trap had to be at least within three meters, but most effective next to a shrub for any capture. Some individuals were re-captured regularly, sometimes four nights in a row in different traps across the plot (up to 100 m apart). It seemed as if open areas between shrubs were traversed at great speed without stopping along the way to forage, which is a probable adaptation to avoid predation. Boyer (1987) also found that small mammals prefer habitats with high cover in the Central Namib to avoid predation. During favourable periods when grass density and height is adequate to provide sufficient cover, dispersion and thus higher densities of small mammals could be expected to occur on the open gravel plains (M. Griffin, pers. comm.). A summary of the surveys is presented in Table 6.7.

The activity patterns of the different species were also noted during the study and it corresponded well with the findings of Withers (1979) in the Central Namib. It seemed as if gerbils and mice are mainly active during the early evening, while elephant shrews are active at dusk and dawn but mainly just before sunrise and on a few occasions during the mid to late morning. The dassie rats were active at various times during the day and responded to prevailing weather conditions, for example, they were not active during low pressure systems. In general, the density of small mammals was very low on the desert plains in comparison with other habitats and depended on enough shrubs or other means of shelter for the small mammals to survive. Even though not all species were captured in both the Horse and the Control areas, some of these species were observed in both areas, and it is believed that all these species do actually occur in both. An increased capture effort in rocky and mountainous habitats will most likely record more species.

Table 6.7: Species and numbers of small mammals recorded in the Horse and Control areas during surveys conducted in 2004. The first letter of the plot refers to H-horses or C-control, and the next two letters to the habitat type, RB-riverbed, GB-granite boulders/rocky, ES-euphorbia shrubs and OP-open plain.

	Sex	May 2004*					Aug - Sept 2004				Nov 2004**						
		HGB	CGB	HES1	CES1	CRB	HES1	HES2	CES1	CES2	HRB	CRB	HGB	CGB	HES2	CES1	CES2
Desmodillis auricularis	M	1															
	F					1											
Gerbillurus paeba	M						2	2	1							1	5
	F		1	2	2	2	2	1	1	1							1
Aethomys namaquensis	M	1					1						2	3			
	F	2											1	1	1		1
Petromyscus sp.	M											1	1	5			1
	F	1	1										1	1			
Rhabdomys pumilio	M										1						
Elephantulus intufi	M	1	1										1	1			
	F												1				
Elephantulus proboscideus	F																1
Petromus typicus#	F													1			
Number of species		4	3	1	1	2	2	1	1	1	1	1	3	4	1	1	4
Number of individuals		6	3	2	2	3	5	3	2	1	1	1	7	12	1	1	9
Total captures		**9**	**10**	**3**	**5**	**7**	**12**	**3**	**3**	**3**	**1**	**1**	**12**	**23**	**1**	**1**	**12**

* Sites HOP, COP, HRB had no captures.

** Site HES1 had no captures most likely due to unfavourable weather conditions.

The traps were not really big enough for Petromus and just 1 smaller female were captured.

6.12 Ecologically sensitive species

Three reptiles and seven mammals that have been recorded or are expected to occur in the study area, were identified as potentially sensitive due to their conservation status (Table 6.8). One plant species is Near Threatened and a few Rare, a number are listed as Least Concern of which several are endemic to Namibia and a few locally endemic to the Aus area. A few more plant species were listed in Golding (2002) with Vulnerable status but their status have been revised or are in revision presently. It seems as if no plant or animal species in the study area are "critically endangered" or "endangered" but four species are "vulnerable", most of which do not have a direct relation (as food item or competing for the same food resource) to the horses.

Table 6.8: Conservation status of possible sensitive species in the study area. Classification is according to Griffin (2003) for the reptiles and mammals and according to Loots (2005) for the plants.(EN – Endangered; VU – Vulnerable; R – Rare; IN – Indeterminate; IK – Insufficiently Known; SP – Status Provisional; END – Endemic; NT –Near Threatened; R – Rare; Aus End – Local endemic to Aus area).

Species	Conservation Status						
	EN	VU	R	IN	IK	SP	END
Reptiles:							
Homopus sp. nov.				#			#
Psammobates tentorius (Bell 1828)		#				#	
Dipsina multimaculata (A.Smith 1847)						#	#
Mammals:							
Laephotis namibensis (Setzer 1971)					#	#	#
Felis lybica (Foster 1780)		#					
Acinonyx jubatus (Schreber 1775)					#		
Parahyaena brunnea Thunberg 1820					#		
Proteles cristatus (Sparrman 1783)					#		
Vulpes chama (A.Smith 1833)		#					
Otocyon megalotis (Desmerest 1822)		#				#	

Plants:	EN	VU	NT	R	END	A-End
Bulbine namaensis Schinz				#		
Eragrostis kingesii De Winter					#	#
Euphorbia mauritanica L. var. foetens A.C.White, R.A.Dyer & B.Sloane					#	#
Lotononis mirabillis Dinter				#	#	#
Moraea graniticola Goldblatt				#	#	#
Oxalis luederitzii Schinz					#	#
Oxalis schaeferi R.Knuth				#	#	#
Stipagrostis lanipes (Mez) De Winter					#	#
Titanopsis schwantesii (Schwantes) Schwantes			#			

6.13 Impact of the water point

A 100 m radius around the water troughs at Garub is visibly sacrificed. Trampling of large herbivores inhibits the growth of vegetation and to some extent changes the species composition of mainly annuals (pers. obs.). The vegetation outside of this area does not show a degradation impact and the range condition does not improve with increasing distance from the trough (see 6.8 Impact on Vegetation structure). Several vertebrate species other than the horses drink water at the troughs and their approximate numbers are presented in Table 6.9.

Table 6.9: The number of animals drinking water at the troughs at Garub during 2003/04.

		Mar-03	May-03	Sep-03	Dec-03	Mar-04	May-04	Oct-04
Days observed		4	3	7	7	7	6	7
Nights observed		3	2	6	6	6	5	6
BIRDS:								
Namaqua sandgrouse	N/day	435	186	294	240	82	6	40
Rock pigeons	N/day	26	2	-		54	12	50
Black crows	N/day	6	3	4	5	5	5	3
Pied crows	total N			2				1
Owls	total N					1		
Ostriches	total N	30			6			
MAMMALS:								
Jackals	total N	4	1	9	8	7	3	11
Spotted hyenas*	N nights			3	2	2	2	5
Springbok	individuals				2			
Gemsbok	individuals	65	19	18	165	182	14	36
% Male gemsbok	%	43	68	72	44	47	56	42
% Female gemsbok	%	57	32	28	56	53	44	58
Juvenile gemsbok	N	3	-	2	14	29	-	-

* The frequency at which the hyenas (1 to 4 individuals) came to drink e.g. Sep 03: 3 out of 6 nights

CONCLUSION

The expected degradation gradient radiating out from the water troughs due to over-utilization by the horses was not found. Neither vegetation species composition, density, nor standing biomass measured at various distances from the troughs confirmed a degradation gradient. Instead, vegetation production and species composition was mainly influenced by rainfall. Nel (1983) also found a strong correlation between vegetation production, rainfall and temperature in the Central Namib, as well as the lack of any longer-term vegetation "reserve", since termites, wind and desiccation were removing all utilizable standing biomass even in the absence of large herbivores. The relatively low density of the horses and their rotational grazing strategy seem to explain why no significant change in floral species composition or structure were found despite this being expected due to trampling or selective grazing. Also, contrary to some perceptions, the Namib horses rarely pull tufts of grass out of the ground. Rather, the tufts are cropped, without uprooting, at a level depending on the grass height and status. Only occasionally are poorly rooted annual tufts of *Stipagrostis obtusa* removed from the ground. Furthermore, the climatic stochasticity and aridity of the study area generally inhibit "increaser" or "decreaser" responses to the grazing of plant species.

The ant surveys did not indicate a consistent degradation gradient from the troughs up to 16 km, according to multivariate analysis. Rank abundance curves on the 2003 and 2004 East Transects showed no clear distinction between plots at various distances from the trough. West transects indicated a higher diversity of species at the 16 km plots. It is unlikely that this result indicates a degradation gradient due to utilization by the horses, since no consistent gradient was found throughout the analysis. However, only the area around the 16 km plots received summer rain in January 2003, which most likely created favourable conditions in this area (as mentioned in paragraph 6.10.5). Regarding all transects, the species diversity did not show a consistent pattern/trend at increasing distances from the trough. Analysis of similarity, according to species composition and abundance, indicated a significant difference between the Horse and Control areas. However, the difference was mainly in species composition, as the species diversity did not differ significantly between these areas. Three species were recorded in the Control area (only one, two and four individuals respectively) which were not recorded in the Horse area (although two of these had been recorded in the Horse area in 2003). One species (summed score value of 65) was only recorded in the Horse area. Furthermore, comparison of functional group composition between the Horse and Control areas shows a more balanced division of functional groups in the Horse area and dominance of Generalized Myrmicinae in the Control area.

The interpretation of the above results poses an interesting challenge. In most other studies ants have shown consistent responses to disturbance, with species diversity and abundance generally low in highly disturbed plots, while natural or control plots have high species diversity but not necessarily high abundance (Andersen 1997; Andersen, Hoffmann & Somes 2003; van Hamburg et. al. 2004). Generalized Myrmicines usually predominate in plots with moderate levels of disturbance or stress and Opportunists predominate in plots with high levels of disturbance (Andersen & Majer 2004). The relative percentages of the different functional groups in undisturbed plots are usually more balanced (proportionately divided), while disturbed plots show high dominance of the afore-mentioned functional groups (Andersen 1997). These patterns were not found in the study area. This could be an indication that the horses do not create a high level of disturbance in their habitat. However, whether ants generally show the same kind of response to disturbance in more arid ecosystems as in the ecosystems researched in the above studies, has not yet been investigated.

The greatest species richness is expected to occur at intermediate levels of disturbance. Grazing by large herbivores, or the absence thereof, can create disturbance at low, intermediate or high levels depending on the grazing history, type and level of grazing (Hobbs & Huenneke 1992). Cases where large herbivore grazing induces high levels of disturbance are mostly found on islands where such grazers did not occur historically, but have been introduced through human activities. The native species in these island systems are usually adversely affected by such invasions (Coblentz 1978 and Hamann 1975 as quoted by Hobbs & Huenneke 1992). The Namib Desert was historically, albeit periodically, utilized by large herbivores including Equidae species and therefore, the horses in the Namib Naukluft Park do not necessarily present an unnatural/non-native type of grazer.

No literature was found on the use of Tenebrionidae in particular as a bio-indicator in arid environments. Results from the analyses of Tenebrionidae species composition and abundance portrayed a similar picture to that of the ants. This indicates that tenebrionids could possibly be used successfully as an indicator group in the Namib Desert, especially since they are particularly diverse and abundant. Similar to the ants, no pattern or consistent increase of species diversity occurred at increasing distances from the trough and no significant difference in species diversity existed between the Horse and Control areas. However, also similar to the ants, a significant difference existed between the Horse and Control areas concerning species composition, with some species being more abundant in the Horse area and others more abundant in the Control area. These differences lie most likely in the variation of environmental variables (primarily rainfall) and possibly in the distribution patterns of species, rather than in the influence of horses on the environment. The spatial and temporal distribution of Tenebrionidae in general is most likely fairly variable, depending on climatic stochasticity.

The density of small mammals was mainly determined by the vegetation structure which provided their food and shelter. Vegetation structure was not changed by the horses and it is unlikely that the horses have any direct or indirect effect on the small mammal diversity or abundance in the study area. Nevertheless, small mammals did not serve as a good indicator for disturbance by the horses due to their very low population density on the plains habitat, which is the habitat predominantly used by the horses. It is predicted though that, given the density and trap ability of small mammals in the koppies and mountains, good comparative data could be obtained in these habitats, by which the impact of livestock browsing or human disturbance can be determined in these habitats.

All the listed (Table 6.8) vulnerable species have been observed in the study area in numbers or densities expected to be normal for the particular type of habitat type. Some individual endemic plants to Namibia (*Euphorbia namibensis*, *E. juttue, Lithops* sp. and *Titanopsis schwantesii*) which were monitored throughout the study were never damaged by the horses. However, invertebrate utilization was found and desiccation occurred. Geophytes are mostly poisonous to horses and are usually consumed only accidentally. Some of the annual herbs are utilized by the horses, but not to the same extent as by the large native herbivores. The vulnerable mammals are mainly insectivores which also opportunistically catch small mammals, e.g. aardwolf, Cape fox and bat-eared fox. Since the results (6.9, 6.10 and 6.11) indicate that the horses do not have a negative impact on either the invertebrates or the small mammals, it is unlikely that they would negatively affect the mentioned vulnerable species. Cheetahs previously occurred in the study area and on neighbouring farms and were known to occasionally hunt foals, but they seem to have disappeared from the area due to hunting or poisoning by commercial farmers. In the study area, several mortalities of eco-sensitive and vulnerable vertebrate species were caused by motor vehicles on the B4 Lüderitz-Aus road (pers. obs.).

Indirect competition for grazing with large native herbivores is also unlikely, since these herbivores, unlike the horses, are not restricted to the study area and the horses therefore cannot adversely affect the growth or survival of these species. Surveys of termite grass utilization showed no correlation or direct competition of the horses with termites. On the contrary, the termites opportunistically utilized the horse manure. The suggestion of an indirect secondary impact of horses on species at higher trophic levels is unfounded since the horses do not have a negative or adverse impact on the ecosystem's primary levels. It rather seems as if the extreme environment creates a level of disturbance which is not exceeded by the horses.

The horses, similar to the native large herbivores, contribute to the energy cycle by converting primary energy into utilizable energy for other native species, serving as food source for predators and as carcasses for scavengers and carrion feeding invertebrates. The Namib Naukluft Park and the Sperrgebiet are no longer entirely natural systems that could sustain themselves within the boundaries that were erected by humans. Before the construction of fences, these systems could depend on neighbouring areas, providing access to grazing and water during specific periods of drought. This access has been blocked by the developments of the past ±16 years so that water that is provided for the horses, now also benefits a number of native species.

CHAPTER SEVEN: SOCIO-ECONOMIC IMPACT

Greek stone carved Horse head c.400BC.

INTRODUCTION

In evaluating the fate and management strategies of the Namib Horses, it is imperative to take into account their socio-economic value and impact. During most of their ±90 years of existence at Garub there was relatively little interaction between horses and people, be it people living on neighbouring farms or those only passing through the area. Nevertheless, with time, these horses were regarded as an integral part of the environment by most inhabitants of the Aus area. The broader public only became aware of their existence when the horses' traditional habitat became part of the Namib Naukluft Park. Increasing media coverage subsequently led to a situation where many people, Namibians and tourists alike, were captivated by the Namib Horses. The mere fact that these horses have survived in a seemingly hostile or unsuitable environment enthused the interest not only of the general public but also of scientists. Several articles in popular magazines as well as television documentaries appeared which contributed to the Namib horses' international fame and inspired the interest of people from around the world. The "mystery" surrounding the origin of this group of horses is often revisited by journalists.

This study attempted to estimate and quantify the socio-economic value and/or impact of the horses, an issue that was not dealt with in the previous studies conducted by Meyer (1988), Sneddon, van der Walt & Mitchell (1991) and Greyling (1994). Fact is that the Namib Horses are an exotic species within a National Park, which in itself could justify their removal. With time, however, it became clear that the horses had developed historic, scientific, aesthetic and economic value that cannot be ignored by future managers. When deciding about their fate, all these values have to be considered. Regarding the historical value, the horses were left behind by people in a period of dramatic shifts in the political history of Namibia and so they bear testimony to the turmoil and hardships during those times. Horses in general form an integral part of human history, as portrayed all around the world in the numerous statues and tributes to the horse. From a scientific point of view the Namib Horses' existence at Garub during the past 90 years resembles a "natural experiment in time" with extensive value for research concerning adaptation and behaviour. The horses continued to survive against all odds in a desert ecosystem thought to be uninhabitable by domestic horses. They opportunistically utilized natural ephemeral water sources or water spilling from boreholes and they adapted to the continuous fluctuation in food availability due to unpredictable rainfall. Over time and through selection pressures they have become a unique population of horses. They have developed distinct physiological and behavioural characteristics such as the ability to tolerate dehydration and they adapt their time allocation to grazing availability.

An indication of the aesthetic value of the horses is their popularity as a tourist attraction in the area, which can be measured by the proportion of visitors to the area that visits the horses as well as by an evaluation of people's perceptions of the horses. The direct economic value, gain or loss, is the easiest to measure and is calculated here in terms of gains generated from their selling (for domestic or tourist purposes) and costs involved in ensuring water provision, maintaining roads and other management implications/ implementations. To determine the socio-economic impact of the horses, this study placed its focus on the aesthetic and economic values.

The objectives of this chapter were to define and describe: (1) the importance of the horses as a tourist attraction; (2) the positive economic value of the horses; (3) the management costs of the horses; and (4) the public opinion about the socio-economic impact of the horses.

MATERIAL & METHODS

7.1 Importance as tourist attraction

The number of tourists visiting the public viewpoint at the horses' trough was determined as part of the water utilization surveys (see Chapter 4, grazer dynamics) done every third month by spending seven continuous days at the viewpoint from sunrise to around midnight. General observations on tourist behaviour were made simultaneously. Opinions on the preferences of tourists were obtained through questionnaires (Appendix F) placed at the viewpoint as well as at the reception of Klein-Aus Vista (the accommodation facility closest to Garub and belonging to the concession holder of the area. A questionnaire rather than a personal interview was chosen in order to minimize the influence of the interviewer on the respondent e.g. through 'leading' the respondent to certain answers. Some questions in the questionnaires were changed after an initial trial period when it was found that they were not clear to the respondents. This is one reason for the varying numbers of questionnaires, which were used for the different analyses. The other reason is the fact that only questions where the response showed clearly that the question was understood, were incorporated in the analyses. The number of participants in guided excursions to the horses was obtained from the records of the concession holder (Desert Horse Adventures – Klein-Aus Vista).

7.2 Actual Economic value

The actual economic value of the horses in terms of sale value for domestication or slaughter was determined by comparing it with known values for domestic horses and through consultation with several horse dealers and breeders.

7.3 Management costs

Maintenance costs such as supplementary feeding during drought were determined by consulting the records of the Ministry of Environment and Tourism (MET) and a logbook that since July 2003 records all the fuel used to pump water.

7.4 Public opinion

The opinion of the public in general was assessed through the questionnaire for visitors as mentioned above as well as through a questionnaire for local inhabitants (Appendix F) that was placed at the Aus municipal office and the grocery shop.

RESULTS & DISCUSSION

7.5 Tourist value

Namibia as a tourist destination is marketed as the country of wide-open spaces, where visitors can experience a unique sense of freedom and safety. Photographs used to advertise tour operations and accommodation establishments often show landscapes with magnificent sand dunes or desert plains with eye-catching island mountains. The results of this study support the statement that people choose Namibia as a holiday destination predominantly because of its desert landscapes. In addition to the desert experience, visitors to Namibia find an abundance of African wildlife within a relatively short travel distance from the desert. This is most likely a good reason why people choose the Namib desert instead of for example the Sahara desert. Other attractions such as the wild horses and various historical sites are an additional bonus for the visitor. Importance and relevance of these attractions obviously vary regionally. While wildlife numbers may be lower in the South of Namibia the importance of the wild horses as a tourist attraction cannot be overlooked. Judging from observations and communication with tourists it seems that almost everybody who had heard about the wild horses at Garub wanted to see them provided that it was easily accessible and affordable to enter.

From a total of 147 questionnaires analyzed, the "wild horses" were rated as the most important attraction by 7% of participants, as second preference by 20%, as third preference by 35% and as least important by 38%. Other choices were "desert landscapes", "African wildlife" and "historic sites" though the question did not specify a specific region (Fig. 7.1a). Analyzing 179 questionnaires, most people chose to visit Namibia for its "desert landscapes" and almost as many to see "African wildlife", which explains why Sossusvlei and the Etosha National Park are Namibia's main tourist attractions. After desert landscapes and African wildlife, the wild horses were rated as the third most important tourist attraction just above historic sites (Fig. 7.1b). However, visitor numbers to the horses are less than to Kolmanskop (or Kolmanskuppe - a ghost mining town near Lüderitz). This may be due to the fact that a number of people do not drive to the public viewpoint once they have stopped and seen the horses along the B4 road. It is also possible that they are not aware of the viewpoint and do not notice the turnoff sign. Conversely, a potential bias might have been introduced by the fact that questionnaires were only presented to people visiting the South of Namibia, and specifically Aus and the horses. Had the questionnaires been placed in Lüderitz to also reach people, who had not necessarily visited the horses, the comparison between historical sites and wild horses might have been different.

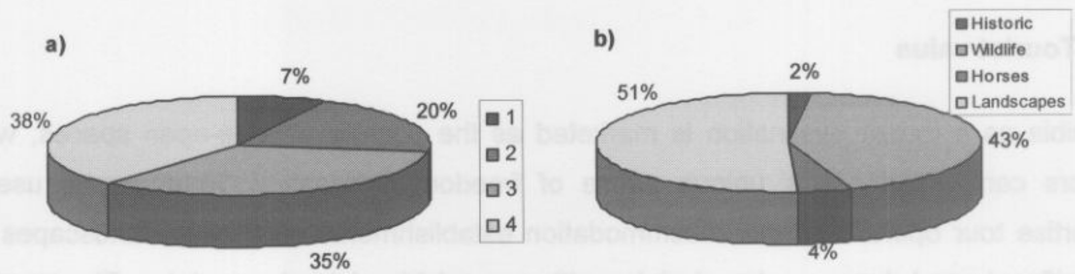


Fig. 7.1: a) The percentages of people who rated the wild horses as first, second, third or fourth preference and b) the percentages of people rating the different attractions as first preference.

Fifty three percent of 120 people completing the questionnaires indicated that they would like to go on a guided excursion to see and learn more about the horses. Out of those, 54.5% would have paid less than N$100; 43% were prepared to pay between N$100 and N$200 and 2.5% were prepared to pay more than N$200 for a 1 to 2 hour excursion. From January 2002 to June 2005, 982 guests of Klein-Aus Vista went on sunset drives specifically to see the horses (Fig. 7.2), 314 went on half-day and 267 on full-day drives, which include amongst other attractions also a visit to the horses. Out of a total of 11 263 guests staying at Klein-Aus Vista during 2003, 775 (7%) went on excursions to the horses (including sunset, half-day and full-day drives). This relatively low percentage was caused by several factors such as the time of about two years that was initially needed to properly market the excursions and ensure they were widely known. Also during this time suitable vehicles had to be obtained and knowledgeable, trustworthy guides had to be recruited. The fact that the horses could often be observed right next to the B4 main road might also have contributed to this low number as well as the easy and free of charge access to the public viewpoint. The extent to which both, the close proximity of the horses to the B4 main road and the easily accessible viewpoint have influenced the actual number of people participating in the excursions is clearly reflected in Fig. 7.2, which amounted to 20 to 30% of the total time excursions could have been conducted. Guided excursions to the horses are thus only viable at times when grazing is scarce, which results in the horses being far from the B4 road and not spending much time at the troughs.

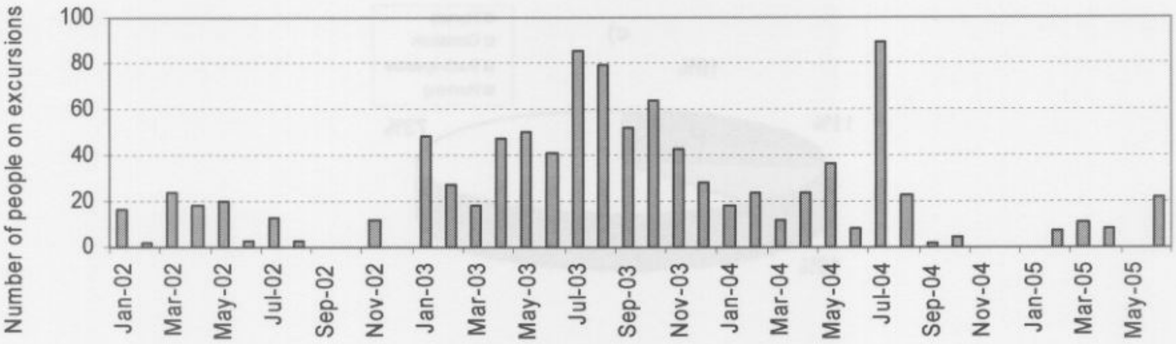


Fig. 7.2: The total monthly number of participants on sunset drives to the horses from January 2002 to June 2005 (source: records kept by concession holder – Desert Horse Adventures).

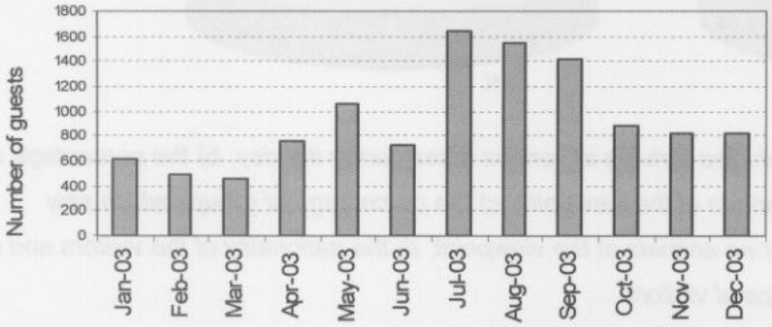


Fig. 7.3: The monthly number of guests at Klein-Aus Vista during 2003.

A total of 1916 people (452 vehicles) visited the public viewpoint at the horses' water trough during 47 days of observation. This is an average of 41 people per day. Depending on the season, the daily number of visitors ranged between 25 and 100. The total number of visitors to the viewpoint for the past three years could then be estimated at 15 000 to 20 000 visitors/year. This compares reasonably well with the nearby well-known tourist attraction Kolmanskop, which had 24 000 to 28 000 visitors per year for 2003/2004. An indication of the peak and low tourist seasons is given by the statistics of guests at Klein-Aus Vista in Fig. 7.3.

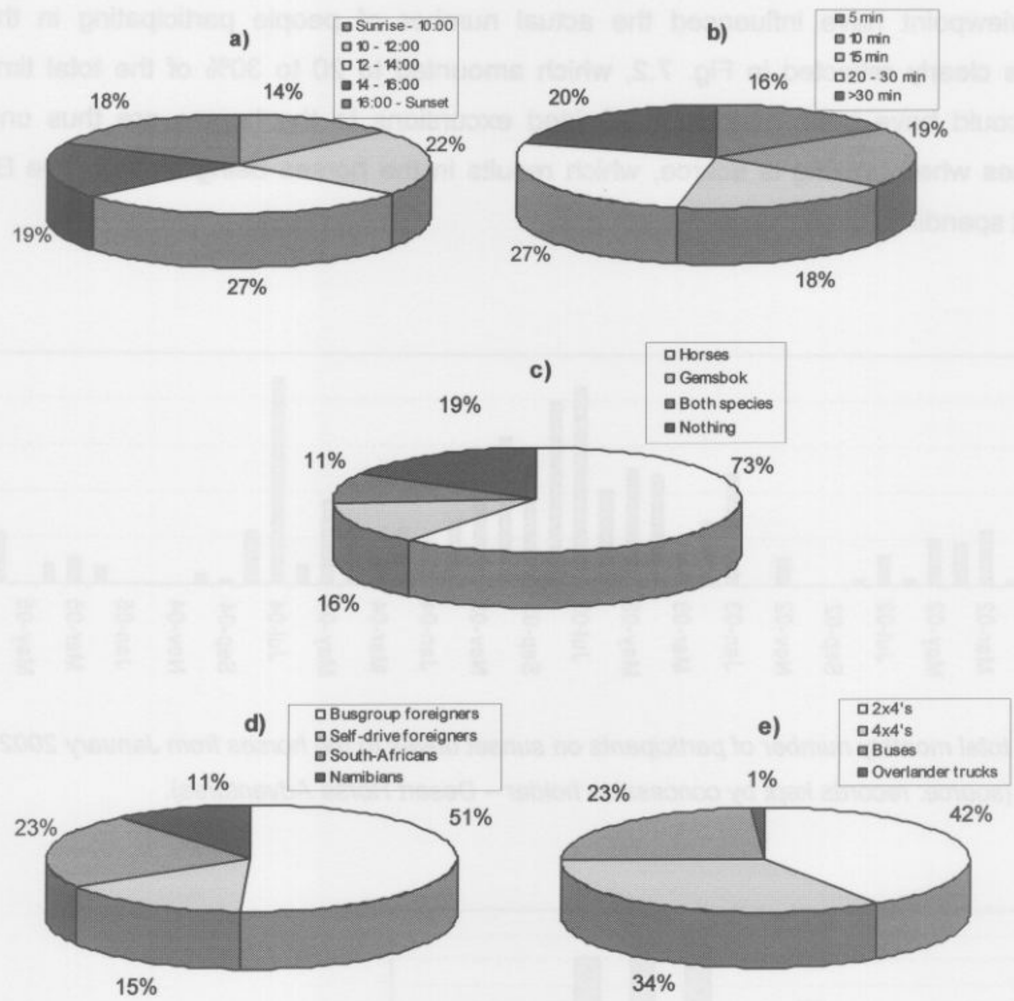


Fig. 7.4: a) The percentage of vehicles arriving at various times during the day, b) the percentage of groups spending different time periods at the viewpoint, c) the percentage of groups which saw horses, gemsbok, both species or no animals at the viewpoint, d) the nationality of the visitors and e) the mode of transport of the groups of visitors.

The profile and habits of the visitors to the Garub Wild Horses viewpoint are presented in Fig. 7.4 showing: a) the time of day when most visitors came; b) the time they spent at the viewpoint; c) which animals they saw in addition to the horses; d) what nationality they were; and e) their mode of transport. On average 9 to 11 vehicles visited the viewpoint daily.

Figure 7.4c shows that 19% of vehicles arrived at the viewpoint when no animals were present at the trough. Of these vehicles, 8% turned around without stopping longer than one minute, 7% came back for a second visit on the same or the following two days. The wooden shelter at the viewpoint was used by most visitors, with only 26% of all groups not entering the shelter but staying in their vehicles or standing outside. The shelter was used as a convenient place for lunch by 5% of the groups. People from 12% of all visiting groups walked to the troughs or tried to approach the horses more closely. A number of people tried to feed them lucerne, sugar, apples, biscuits and bread. This occurred particularly when the horses spent a lot of time around the troughs, the viewpoint and close to the road at times when grazing was abundant. Generally the horses accepted the food offered to them only sometimes but a few of the younger horses have in the meantime learned to readily accept food from people.

7.6 Marketing and indirect tourism value

An indirect tourism and social value of the horses are their marketing and job creation value. For example, a 20 to 40 minute film on the Namib Wild Horses is aired on international television on average once every year. Considering general airtime costs for marketing and advertising, an airtime bracket would cost approximately € 6 000 to € 9 000 per minute. A 20 to 40 minute transmission on Namibian "wild horses" could thus relate to a substantial value in advertising for Namibia. The horses also forms part of the "Tourism package" that is offered on the international market to attract tourists to Namibia. An estimated number of 300 000 tourists visit Namibia annually at present (2005). These tourists stay on average seven days and spend around N$10 000 during their stay (M. Goldbeck, pers. comm.).

It is estimated that every 12 tourists visiting Namibia create one job opportunity. If publicity for the horses, as indicated above, would continue consistently, the spin-off for the country's tourism sector in terms of job creation would be considerable. The horses also contribute directly to job creation in the form of tourist guides for the concession holder.

7.7 Actual economic value

The only sale of the Namib feral horses to the general public in June 1992, did not create any relevant income. They were sold at a price of N$120 per horse regardless of the horses' condition, age or sex. These horses generally did not adapt well to domestication and only a few of them or their progeny have subsequently been re-sold at prices ranging from N$500 to N$8 000. The latter price being the exception to the rule, paid for an outstanding filly on a public auction in South Africa. Most of the other horses did not sell for more than N$2 500. The price of horses in general depends strongly on their breed/pedigree, level of training and competitive performance. Only a few of the 104 captured Namib horses were successfully trained or excelled as working or competition horses. If Namib horses from Garub are captured and sold in future, an estimated value of N$1 500 to N$3 000 could be expected for "ideal" horses around four years old, untrained, with good conformation and in good condition. The value could increase if the horses received basic training in order to facilitate transport and handling by the new owners. If the horses are sold for slaughter, their value would range between N$300 to N$1000 for a horse of 300 to 400 kg live weight.

As a tourist attraction, the horses provided direct income to the Garub/Koichab concession holder for the past five years. The fees paid by the concession holder again yielded revenue for the State coffins. The concession fees (10% of the gross turn-over) ranged between N$5 000 and N$16 000 annually, depending on the number of people participating in the excursions. After four and a half years a total of N$52 000 had been paid over to the State. The concession holder also contributed in kind to assist the Ministry of Environment and Tourism with cleaning-up activities, road maintenance and general checking and pumping water supportive to the Ministry's staff.

7.8 Management costs

7.8.1 Maintenance costs

At present the most important maintenance cost concerning the horses is the provision of water, which is pumped with a Lister engine at more or less weekly intervals. From July 2003 to June 2005, a total of 604 liters of diesel fuel were used to pump water, ranging from an average of 20 liters per month during winter and 30 liters per month during summer (Fig. 7.5). Additional costs arise from time to time for servicing of the engine and maintenance of the reservoir, pipes, ball valves and troughs. This adds to a total estimate of N$10 000 to N$15 000 required annually for the provision of water, assuming fuel prices remain around N$4.00 to N$6.00/liter. A percentage of a MET ranger's salary should still be added to this amount. For the period 1993 to 1997 the overall costs for water provision were less because the water was pumped with a solar powered pump, sponsored through funds raised by the German magazine "*Das Tier*". Further maintenance costs include expenses for improvements and maintenance of the shelter and toilet at the public viewpoint and the grading of roads for which an amount of N$2 000 to N$3 000 annually can be allocated.

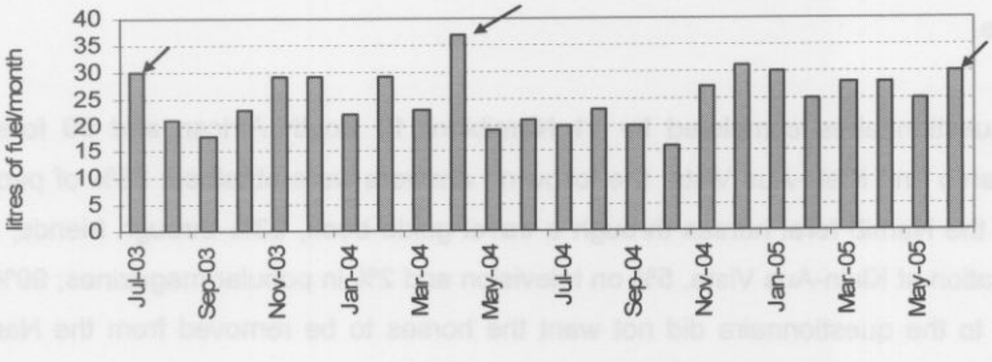


Fig. 7.5: The total monthly amount of fuel used to pump water at Garub from July 2003 to June 2005.

7.8.2 Drought induced costs

During 1992 and 1998 supplementary food in the form of baled lucerne or grass was provided to ensure that a reasonable number of horses survive the drought. Most of the costs for purchase and delivery of hay were covered by philanthropic funds while labour and transport to distribute the feed at Garub were provided by the MET. The total costs during 1992 were approximately N$10 000 to N$15 000, and during 1998/99 N$60 000 to N$70 000.

The projected costs for supplementary feeding at present are as follows: to supplement 120 horses with a minimum of 50% of their nutritional requirements, 20 bales of hay (±22 kg/bale) are required daily at a cost of N$40/bale, equaling N$24 000/month. Adding transport from Aus to Garub and labour for distribution, the amount is likely to increase to N$28 000 to N$30 000/month.

7.9 Public opinion

The use of questionnaires for tourists was effective to obtain an indication of public opinions. Questionnaires in both English and German were provided since a large percentage of visitors to Namibia are German speaking. The fact that relatively few questionnaires were completed is mainly due to them being "passively" distributed instead of actively given to visitors. Also, they were only available at two distribution points. Individuals from the local community completed only a small number of questionnaires. However, they could well be regarded as representative for the community's opinion when compared to the number of individuals attending community meetings, which ranged between 30 to 50 people. A larger number of local people could have been reached and the aspect of illiteracy amongst the older population could have been eliminated had an interview been used instead of a questionnaire.

From 120 questionnaires completed by 11 Namibian, 10 South African and 99 foreign visitors to Garub and Klein-Aus Vista, the following answers were obtained: 58% of people heard about the Namib feral horses through a travel guide book, 23% through friends, 8% found information at Klein-Aus Vista, 5% on television and 2% in popular magazines; 99% of respondents to the questionnaire did not want the horses to be removed from the Namib Naukluft Park (Garub), only 1% felt that they should be removed from the desert. The questions only offered a choice between "yes" and "no" and two respondents felt that they needed more information before being able to make a choice; 2% of the people wanted the horses to receive supplementary food on a regular basis, 18% did not want the horses to ever get supplementary food and 79% felt that they should only be fed in severe droughts. Nineteen percent of people thought the number of horses should be artificially controlled while 74% felt that this should merely happen by natural selection. Eighty one percent of people felt that old horses should be left to die naturally - from malnutrition or predators, 13% felt that old horses should be put down by the authorities and 6% wanted the old horses to be removed to domestication.

The 31 inhabitants of Aus, who had completed the questionnaire gave the following answers: everyone knew about the existence of the horses at Garub and everyone had seen the horses; 29% felt that the horses should be removed from Garub and 71% felt that they should remain there; 81% were of the opinion that the horses benefited Aus to a certain extent while 19% felt that they did not have any benefit for the community; 23% of the participants wrote additional comments on the questionnaire raising their concern about the horses being responsible for serious road accidents. The repeated occurrence of road accidents is one of the main reasons why people feel that the horses should be removed from Garub.

CONCLUSIONS

Although it is difficult to quantify historic and scientific value of the horses realistically, it must be acknowledged that these values are important enough to justify the protection of the Namib Wild Horse population as an entity. Should it be found that the horses need to be removed from Garub for ecological or other reasons, the relocation of the total population rather than the dispersal of individual horses should be considered as a viable and just alternative in order to acknowledge and respect their historic and scientific value. It is apparent that the horses have become an important tourist attraction in the south of Namibia, a fact that contributes positively to the economy of the region. The Namib Wild Horses are clearly an asset to Namibia, contributing considerably to the "package" that is offered to tourists and marketed internationally. It is clear that the revenue created by the sensible marketing of the horses can exceed their annual management costs. The revenue created by the wild horses through tourism has the potential to increase, if the present management strategies are adapted to add value to possible tourism opportunities.

On the other hand certain negative aspects or impacts concerning the horses also need to be considered: 1) Uncontrolled interaction between tourists and horses, which has resulted in the habituation of horses to vehicles and people. Some of the young horses have become used to people feeding and touching them and readily approach people to satisfy their inquisitiveness. As is the case with other wild animals, which receive food from people, this may lead to: i) the injury of visitors, ii) the confusion of the horses, iii) the separation of foals from their mothers or injury of foals, iv) damage to vehicles or personal belongings e.g. camera equipment and v) it subtracts from their status as "elusive wild horses" which will in the long run influence their economic value as a tourist attraction. 2) The increasing incidence of tourists driving off-road to approach the horses more closely when they are within sight of the main road is obviously detrimental to the track-sensitive area. 3) The horses' close proximity to the main road where they cause motor vehicle accidents is a serious concern, these accidents have already claimed the lives of two people in 1987 and 1997.

The results from the questionnaire show that the majority of people perceive the Namib Wild Horses as part of wildlife and feel that they should be granted a natural life with little if any human interference. It thus seems that most people would be willing to understand and accept, within limits, the reality of life and death created by the wet and dry cycles of an ecosystem. Providing relevant comprehensive information can curtail public outcry as well as uninformed criticism of the authorities. It is also clear that most tourists do not regard the horses as an exotic species that does not belong in the Namib Naukluft Park, rather to the contrary - most people feel that the horses have adapted to and therefore deserve the right to live a free life in the desert, just like other wild animals of the park.

CHAPTER EIGHT: CONCLUSIONS

South African rock wall painting dating back to 1870's .

CONCLUSIONS

The objectives of this study were to evaluate the justification of the continued existence of the Garub feral horses in the NNP as well as to provide baseline information and recommendations regarding management of these horses. The approach to achieve these objectives included investigating possible negative and positive impacts the horses may have on the natural ecosystem and socio-economic environment. It further included investigation of the botanical component and grazing capacity of the area together with the intrinsic values, demography and quality of life of the horses. The collected data was then used as a technical basis for the development of a draft herd management plan. Input from several people was garnered during a stakeholder workshop. Management objectives were discussed and various options for actions, linked with appropriate criteria, were proposed. Ideas discussed at the workshop, with their respective viability explored, can now be used as the basis for recommendations that guide the future management of the feral horses.

The *first* component of the study was to identify different plant communities in the study area. This formed a basis for determining grazing capacity and for choosing homogeneous locations in which to conduct the surveys to determine whether or not, and to what extend, the horses impact on biodiversity of the area. Five main plant communities were identified with 11 sub-communities. The plant communities correspond to geology and topography which influence rainfall patterns. The higher altitude areas generally receive higher mean rainfall leading to more perennial vegetation and higher grazing capacities. The number or density of all large herbivores and their pattern of utilization of the study area were recorded over a two year period. The mean long term distribution of large herbivores correlated well with the higher rainfall areas. Short term distribution of large herbivores varied significantly according to the amount and distribution of the patchy rainfall patterns.

A range of grazing capacity values related to the different plant communities and the total rainfall of the preceding 12 months, were proposed. Thus, based on rainfall, this grazing capacity table can be used to obtain the estimated number of horses and game which could be sustained in the study area at a given time. According to this table, a population of 125 to 130 horses can be sustained at mean rainfall which confirms the historical mean population size of around 130 horses. It further appears as if the study area can reliably support a range of 80 to 189 horses together with up to 185 gemsbok equivalents (divided proportionately to include springbok and ostriches) over a normal rainfall range of 20 to 70 mm. Due to the great variation in rainfall, and thus grazing capacity, from year to year, high death rates of horses can be expected in some years, particularly amongst very young and very old age cohorts. High death rates of game also occur occasionally in the larger Sperrgebiet area, and particularly along the eastern boundary fence of the NNP. However, the native game is not affected to the same extent as the horses within the study area, since they are more capable of roaming beyond the study area. Grazing capacity is not only influenced by the quantity of grass but also by the quality of grass available, both of which decrease markedly during prolonged intervals without rain.

The *second* study component concerns demographic data recorded by the author since 1994. This data clearly indicates that natural stochasticity, as well as artificial interference influences the dynamics, survival and viability of the population. It is important to note that, due to the restriction of the population to a specific area (due to boundary fences and extreme desert conditions) and limited natural surface water in the area, the continued survival of the horses is entirely dependant on continued artificial provisioning of water. Historically, the population size appears to have fluctuated within a range of 80 to 180 horses with occasional exceptions below or above this range, e.g. the large population of 276 horses in 1991 after several years of relatively high rainfall. This fluctuation can be attributed to the large variation of grazing potential from year to year, which in turn influences the annual growth rate of the population (mainly through differential survival of young horses), and ultimately, induces periodic swift population declines during specific low rainfall intervals. Due to the slow growth rate of Namib horse populations, coupled with occasional sharp declines in population size due to the limits on grazing range imposed by the distance to and from a single artificial water source, the population rarely reaches a size which exceeds the grazing capacity of the total area over which they can roam under normal conditions.

A possible reason for the historical survival of the population and predicted continued survival without artificial population control is the ability of the middle age group (5 to 10 years old) to survive droughts fairly well. This age group is able to successfully utilize low quality grazing at further distances from the water point than younger or older horses. Low quality grazing, together with the energy expended to travel long distances, appear to be the main limiting factors during droughts. The implications of this on management includes maintaining or at least not artificially reducing the population size to low numbers with few individuals in the middle age classes. This may appear contradictory to the point of view that the population should be reduced to below grazing capacity values to ensure enough grazing and thus survival for most horses. However, that point of view is valid only when the quantity of grazing is at issue. In the desert (study area), it is predominantly the poor quality, not the quantity of grazing that causes most deaths during prolonged droughts. Therefore, even if the population size during a drought is at a number below the drought's grazing capacity (quantity of grass), most old and young horses will still die, reducing the population size by proportions similar to those of a larger population. Additionally, the effect of a small starting population and thus, an even smaller remaining post-drought population would likely cause a genetic bottleneck.

The demographic data additionally showed that artificial removal of even a small percentage of the horses from the herd for relatively short periods of time (six weeks before re-introduction) have extensive affects on group stability, foal survival and social structure which also can influence genetic viability. Although the question of genetic viability of the Garub horses fell outside the scope of this study, low genetic variability for these horses have been reported by Cothran, van Dyk & van der Merwe (2001). DNA analysis together with further investigations of the genetic effective population size could be the objectives of further studies.

Opinions regarding the harshness of the environment for the horses, or rather their assumed cruel struggle for survival, will always differ and depend on the individual person's background and perception of life, rather than definitive evidence. All of nature experiences a struggle for survival, sometimes cruel, but always beautiful in its capacity for an unwavering drive towards the promulgation of the species. These horses are not suffering; they are living. Quality of life is measured by subjective opinions, this study showed that the basic needs of the horses are fulfilled by the Garub environment and that they are generally in good health.

The *third* component of the study entailed the investigation of the impact of the horses on the natural biodiversity of the study area. Through these surveys, a contribution was made to the existing list and databases of species recorded in the Garub area by the collection of numerous plant and invertebrate specimens. During plant community surveys, at least 92 species were recorded, a number of which were not previously listed for the particular quarter degree square in which the study area fall. During pitfall trap surveys to determine the impact on biodiversity, 20 ant species (Hymenoptera: Formicidae) from nine genera, 80 Coleoptera species from around 54 genera belonging to 16 families, numerous specimens of six other insect orders and five orders of arachnids were collected, as well as an additional eight species of small mammals recorded. The collected specimens were deposited at the

National Herbarium and National Museum of Namibia. The results obtained through these surveys indicated that the horses did not seem to have a significant impact on their habitat. This seemingly insignificant impact of the horses on the ecosystem could be due to the area being a suitable habitat for grazing large herbivores, including Equidae, the relatively low density of horses, as well as their rotational grazing activity. The horses' impact on biodiversity of the area is most likely minor compared to that of the continued and frequent desiccation in the desert. The added limitation to the range of the horses by having only one water point may also contribute to slow population growth, as well as limit the ability of the horses to overexploit the study area during favourable years. It may be considered, however, that additional water points and therefore an increased or relocated grazing area for the duration of low rainfall intervals could spread or move the pressure off the area around the traditional water point.

The *fourth* component, socio-economic investigation, revealed that the horses have cultural, historic, scientific, aesthetic and economic values that demonstrate significant interest in their conservation. Recently, some negative aspects have also started to arise, such as uncontrolled interaction of horses and tourists and motor vehicle accidents, which could become problematic from a public relations standpoint. Negative aspects of the horses' existence could influence the tourism and social value of the horses. The general public opinion seems to be that the horses should remain at Garub and be treated as wild animals with minimal artificial interference, except during extreme conditions. It also became apparent that the horses have the potential to become an economic self-sustaining entity, potentially generating enough revenue through tourism to cover their maintenance and management costs. The option of capturing and selling horses for income is less desirable, due to the cost of the capture efforts, in relation to their relatively low market value. Selling the horses to the public also lowers their "exclusivity" value in eco-tourism.

The direct management costs of the horses, including the provisioning of water, are relatively low (currently N$10 000 to N$15 000 annually for the whole population). Historically, these costs were paid for in kind by the South African Railways, Consolidated Diamond Mines and the Ministry of Environment and Tourism. If no change is made regarding additional water points or grazing areas, the provision of supplementary hay during extreme droughts will require high costs (amounting to approximately N$1 000 per day at 2005 outlay). During two previous droughts (1992 and 1998), these costs were covered by local and international philanthropic funds as well as labour and transport from the MET.

The *final* component of the study included a stakeholder workshop at which the study results were presented, discussed and used to formulate a draft management plan/objectives for the horse population (Appendix G). The goals of the workshop included the sharing of information and results obtained through the study and to provide some subjective validation to the work carried out in the thesis by a range of stakeholders. The reactions of workshop participants were generally positive and the results, which included contributions from the participants, formed a broad consensus of objectives, actions and outcomes. The information gathered during the study and presented at the workshop also proved to be valuable as a technical basis for the framework of a draft management plan that was prepared during the workshop.

Some important aspects were emphasized by the participants of the workshop. As expected, there was a difference of opinion regarding the appropriateness of the presence of the horses in a conservation area due to their exotic nature, but there was consensus concerning the horses' historical and scientific value. Additionally, participants expressed the opinion that the horses utilize such a small portion of the conservation area that it is not imperative to remove them. Some of the participants considered the horses to be an asset to the NNP and concluded the horses were best exploited through their preservation, rather than through increasing their numbers and selling them to the public. Most participants believed the mean population size and area utilized by the horses should remain close to the historic value or size, which is 130 horses ranging between 80 to 180 horses within the present study area, which historically also included property outside the NNP, such as parts of neighbouring farms and Aus Town land (a large stretch of municipal land available for grazing to community members).

An important conceptual difference between management when population size is within the stable range and when the population size approaches the lower or upper limits, became apparent. For the former, the *population* as such is managed, while in the latter situation, it is *individuals* that are managed. This means that broad demographic indicators, such as growth rate and grazing capacity, are considered important to management near the mean population size. When the population size reaches the extremes, the condition of individual animals or the contribution to the genetic pool from a particular horse becomes important. It seems unlikely the population would be allowed to fluctuate completely naturally, without any artificial interference, due to political opinions and public emotions. The general consensus for a management strategy at this time appears to provide for minimal interference around a mean and normal range of population size, but a more invasive management of individuals when the population approaches upper or lower limits.

The workshop participants felt strongly that the wild or untamed nature of the horses should be protected. The extent of "interference" caused by management could significantly alter the status (wild or domestic) of the population, as well as their continued existence and viability. The tourist value of the horses is influenced by their status as "wild horses". Excessive interaction between people and the horses removes their wild image and decreases their tourist value. Extensive management of the horses, such as regular captures and feeding, also decreases natural selection. Decreasing the population's natural selection could possibly lead to genetic loss, as well as a decrease in their "wild" status.

The workshop participants also felt that continued monitoring, both of the horse population and the wider environment (vegetation and faunal components), was extremely important. It was proposed that such monitoring should be coordinated by, for example, a trust, foundation or monitoring centre, which would help ensure the sustained collection and preservation of information regarding the horses and the environment. Such a body could also be responsible for education and public awareness concerning the horses and their habitat.

In consideration of the above issues and the four (4) goals for management identified through the workshop, there are several implications to the implementation of these goals. The goals were: i) maintenance of a stable population; ii) maintaining low management costs; iii) complementing the tourism value; and, iv) contributing to science and education. Regarding the first two goals, the implications to management of maintaining a stable population at low management costs, include feeding or providing additional water points during emergency periods. The provision of supplemental food can be costly. Therefore the alternative, installation of additional water points, could either enlarge the potential grazing area or provide access to an area with better quality and quantity of grazing until conditions improve. At present, the horses are limited in their utilization of the full grazing potential in their geographical range due to the distance to the water point, coupled with prevailing temperatures. Since drought conditions exacerbate the precarious balance between energy expended and energy gained, additional water points could contribute to shift this balance and reduce or eliminate the necessity of supplemental feeding. When these water points are located at a distance from the public road and viewpoint, it has the added advantage of reducing public outcry from viewing emaciated horses during extreme periods of drought.

This does not mean that the reality of the horses' struggle during droughts should be hidden from the public, rather that the public should be informed and educated regarding the natural cycle of life, but granting individuals the choice of being visually exposed to these realities.

In maintaining a stable population, it may become necessary to reduce the population size when it exceeds the upper limits. Culling was not advised or accepted by the workshop participants. Alternative options, such as selling a small number of young horses at a time to owners approved according to a strict set of criteria, (considering the fact that the feral horses have limited domestic uses) were discussed as a preferential method of management. Alternatively, another option involved the relocation of young horses to another area or farm, as a possible research or genetic metapopulation. Since the numbers and frequency for removal would most likely be low and infrequent, these options could also be substituted with the use of contraceptives. Contraceptives are successfully used to reduce rapid population increase in feral horse populations in the USA (Turner, Liu, Rutberg & Kirkpatrick 1997) and could be potentially suitable for the Namib horse population, if used in conjunction with other, financially viable options.

Tourism is generating an essential influx of foreign revenue to Namibia and the horses have proved to be an important part of the tourism package drawing people to Namibia, regardless of whether they actually visit the horses. Considerations in the management of the horses should, therefore, attempt to complement their tourism value, both in preserving their "wild" image/status and allowing for unique tourist experiences.

The fourth goal of management concerns science and education, which would include public awareness and education or research opportunities for students, as well as monitoring of the horses and the environment. Monitoring of the population dynamics of the horses may, for example, reveal important effects and trends for the future, allowing managers to make better preparations for emergencies that may arise. Several conditions which could affect the population in future are changes in the amount and distribution of rainfall possibly due to global warming, changes in the distribution of game leading to potential competition with the horses for food and water, changes or implementation of management strategies such as additional water points or enlarged grazing area and the effect of increased community involvement or tourism activities. One of these changes, the growth in tourist visits to the horses, has already started to influence the horse population during the past five years, in that the increased interaction of tourists with horses has resulted in habituation of horses to people. The horses are therefore increasingly being labelled as "tame" animals.

Monitoring of the horses would ideally include recognition of individual horses and continuous recording of births, deaths and injuries of the specific horses. In addition, at least quarterly monitoring of the horses' condition and group structure, such as recording which individual horses are associated within certain groups, would provide detailed data on population dynamics and genetic lineages. If continuous monitoring or recognition of individual horses cannot be accomplished or maintained, it is recommended that an annual aerial count be conducted as this would give a reliable estimate of the population size of the horses. Such an aerial count should also include game, and could be complemented with an annual count at the water troughs to estimate sex ratio and age structure.

The most important and the simplest environmental factor that should be monitored is the amount of rainfall at quarterly intervals. Monitoring of the biodiversity in the study area and surrounding desert areas should also continue to better evaluate the results obtained during this study. The most important factors influencing invertebrate density and distribution seemed to be rainfall and vegetation structure. It is therefore important for future comparative surveys to choose sites with homogeneous vegetation structure and to monitor rainfall continuously at these sites. In times of higher rainfall, invertebrate densities are higher. It is thus recommended that surveys are conducted in periods of high rainfall when larger numbers of invertebrates would be recorded, which are more desirable for statistical analyses. It is further recommended that the areas with higher long term horse density are compared to comparable areas with low or non-existent horse density. This study found no piosphere effect around the water point, except for a 100 m radius around the troughs. Comparing sites at ever-increasing distances around the troughs is not recommended since the horses do not utilize the area in a radial grazing pattern. Continuous biodiversity monitoring is preferable, at least for some components of biodiversity, but taking into account the availability of manpower and resources. However, to obtain useful data for scientifically evaluating changes or identifying patterns in the biodiversity of the area, comprehensive monitoring should at least be repeated once every 3 to 5 years, opportunistically exploiting high rainfall years. It is, however, difficult to predict rainfall and a constant awareness of the rainfall is necessary to seize arising opportunities. Some surveys during low rainfall intervals would be useful to compare or indicate the affect of rain. Ants and tenebrionid beetles proved to be practical, measurable and successful indicators during this study and should be considered in future. Other groups such as arachnids could also be considered if a specialist becomes involved to sort, identify and interpret the data. Data on order level could also be tested in the future.

The objectives set out at the beginning of this study were adequately achieved within certain limitations. These limitations, similar to most other research activities, included the availability of resources, increasing decline of basic research expertise such as taxonomists and the limitation of time. However, the study contributed new information crucial to the management of the Garub horses and the results and findings seem to justify the continued presence of the horses in the NNP. However, people's opinions will always vary, changing over time as new information surfaces or environmental and political circumstances change. For these reasons, continued monitoring would provide accurate information to be used in the event the status of the horses is re-evaluated.

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APPENDIX A: Properties and composition of water from Garub 2.

ANALYTICAL LABORATORY SERVICES cc

P.O. Box 2108, Windhoek, Namibia

Tel (061) 210132 Fax (061) 217102 e-mail analab@mweb.com.na

TEST REPORT

To: **Ms. T. Greyling**
P.O. Box 25
Aus

Date received: **25-Mar-04**
Date required:
Date completed: **19-Apr-04**

Attn: 0

Fax: **063 258021**

Your Reference: verbal
Lab Reference: I040232

Assay / Your sample I.D. / Lab. #	- I040232/1	Units	Recommended maximum limits – Human consumption Group A	Group B	Group C	Livestock watering
pH	7.0		6-9	5.5-9.5	4-11	
E[illegible]ctrical Conductivity	80.2	mS/m	150	300	400	
Turbidity	0.90	NTU	1	5	10	
Total Dissolved Solids (calc.)	537	mg/l				6000
P-Alkalinity as $CaCO_3$	0	mg/l				
Total Alkalinity as $CaCO_3$	226	mg/l				
Total Hardness as $CaCO_3$	233	mg/l	300	650	1300	
Ca-Hardness as $CaCO_3$	167	mg/l	375	500	1000	2500
Mg-Hardness as $CaCO_3$	66	mg/l	290	420	840	2057
Chloride as Cl^-	85	mg/l	250	600	1200	1500-3000
Fluoride as F^-	0.6	mg/l	1.5	2.0	3.0	2.0-6.0
Sulphate as SO_4^{2-}	24	mg/l	200	600	1200	1000
Nitrate as N	4.1	mg/l	10	20	40	100
Nitrite as N	<0.01	mg/l				10
Sodium as Na	72	mg/l	100	400	800	2000
Potassium as K	3.1	mg/l	200	400	800	
Magnesium as Mg	16	mg/l	70	100	200	500
Calcium as Ca	67	mg/l	150	200	400	1000
Stability pH, at 25°C	7.3					
L[illegible]gelier Index	-0.3	>0=scaling, <0=aggressive, 0=stable				
Ryznar Index	7.6	<6.5=scaling, >7.5=aggressive, ≥6.5 and ≤7.5=stable				
Corrosivity ratio	2.2	Applies to water in the pH range 7-8 which also contains dissolved oxygen; ratios <0.2 no corrosive properties; ratios >0.2 increasing corrosive tendency				

Remark: Overall classification of water, considering only constituents that have been tested for:
Group A, excellent quality water
Water has corrosive properties and can dissolve calcium carbonate

Interpretation based on guidelines for the evaluation of drinking water for human consumption. DWA, Namibia, July 1991

S Rugheimer
S. Rugheimer
Section head Water Quality

APPENDIX B: Phytosociological table of relevé data.

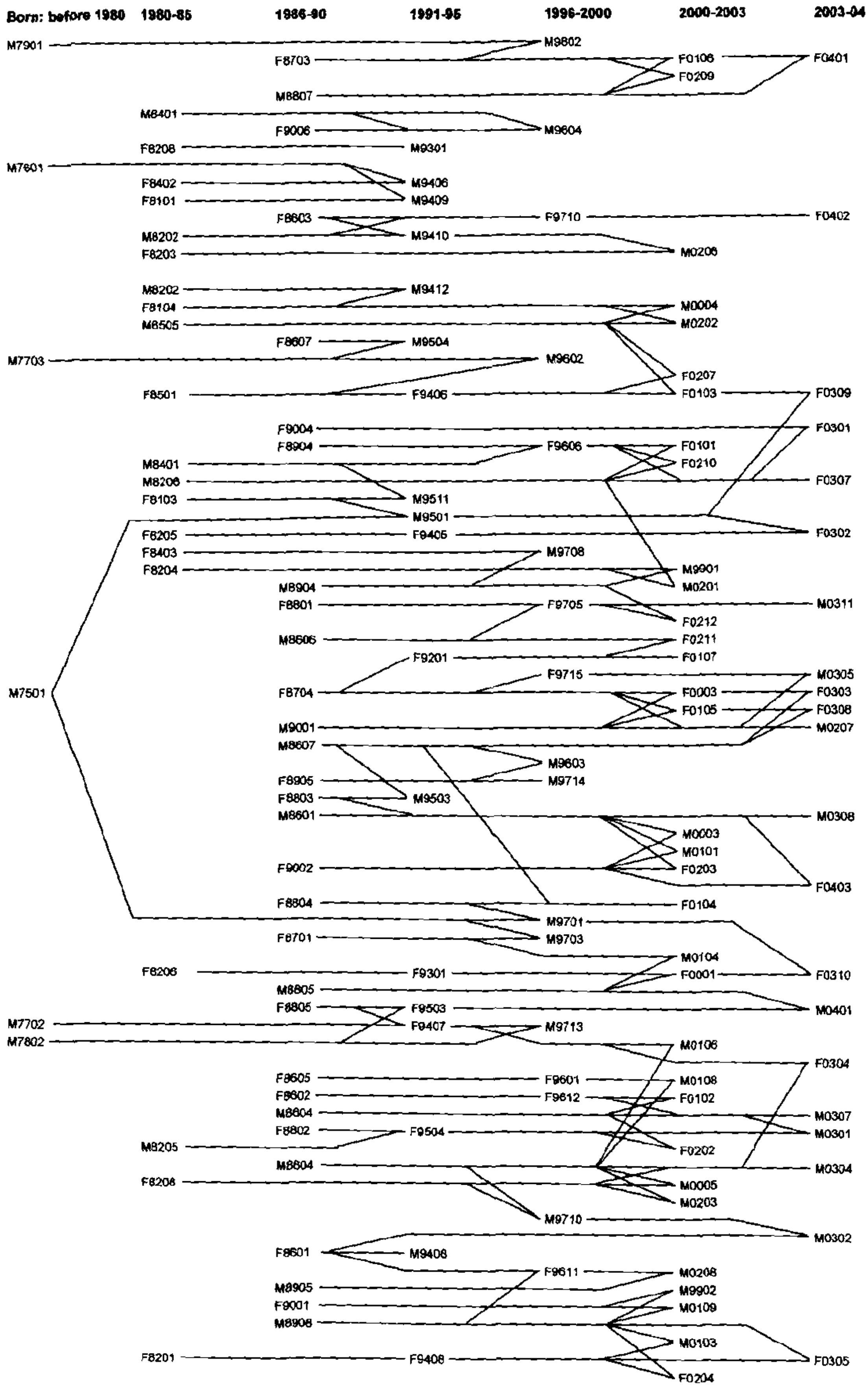
Communities	1			2																					3																														4			5		
Sub-communities				*2.1*									2	*2.3*					*2.4*			*2.5*			*3.1*					*3.2*							*3.3*									*3.4*			*3.5*			*3.6*								
Releves	29	8	14	58	1	2	3	6	7	9	10	11	21	31	32	33	34	37	59	60	61	51	53	52	16	17	12	13	15	18	28	19	20	22	23	57	24	27	49	50	54	55	56	25	26	30	35	36	38	39	41	44	45	48	43	46	47	40	42	4
Species Groups																																																												
A																																																												
Forsskaolea candida L.f.	+b		+																																	+																								
Indigofera auricoma E. Mey.	+r		b																			+																	++							+														
Codon royenii L.	+		+																																																									
Kissenia capensis Endl.	+																																																											
Merxmuellera rangei (Pilg.) Conert	+																																																											
B																																																												
Helichrysum herniarioides DC.		r				+			++						+																																													
Fagonia isotricha Murb. var. *spinescens* (Schwartz) Hadidi					r			r			+	+											+													+																								
Lotononis strigillosa (Merxm. & A. Schreib.) A. Schreib.					++																										++						+								+															+
Tribulus zeyheri Sond.									r	r		+r																																																
Unidentified geophyte					r	r	r																																																					
Lotononis strigillosa (Merxm. & A. Schreib.) A. Schreib.					r		r																																																						
Pentzia spinescens Less.												+																																																
C																																																												
Zygophyllum decumbens Delile var. *decumbens*													b																																															
Blepharis furcata (L.f.) Pers.													+																				+																											
D																																																												
Salsola sp.												+			++b			+															+																											
Monechma desertorum (Engl.) C.B. Clarke															+++																																													
Peliostomum leucorrhizum E.Mey. ex Benth.																+																																												
E																																																												
Brownanthus ciliatus (Aiton) Schwantes ssp. *schenkii* Ihlenf. & Bittrich																			b	b	b																																							
Mesembryanthemum guerichianum Pax																				+r																						r																		
Aptosimum spinescens (Thunb.) Weber																				+																																								
Galenia pruinosa Sond.																				+																																								
F																																																												
Nemesia viscosa E.Mey. ex Benth.																						++																																						
Hermannia spinosa E.Mey. ex Harv.																						++														+							+																	
Eragrostis annulata Rendle ex Scott-Elliot																						++																		+																				
Lessertia falciformis DC.																						++																																						
Albuca sp.																						r	r																				+																	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Galenia fruticosa (L.f.) Sond.					+	+						r		
Euphorbia prostrata Aiton						+								
Lycium sp.						+								
Aptosimum eriocephalum E.Mey. ex Benth.						r								
G														
Zygophyllum simplex L.		+++ ++++ +		+++++	b ++b	b +		+	+b +		+			
Gazania jurineifolia (DC.) subsp. *scabra* (DC.) Roessler		++				++								
Peliostomum viscosum E.Mey. ex Benth.	r	++		+	+			+						
H														
Brownanthus arenosus (Schinz) Ihlenf. & Bittrich							+b +b b							
Prenia tetragona (Thunb.) Gerbaulet					+ r		b b b b b	+ +						
Suessenguthiella scleranthoides (Sond.)Friedrich	+						++						+	
Limeum argute-carinatum Wawra & Peyr.	+						+							
Lessertia acanthorhachis (Dinter) Dinter							r r							
I														
Avonia albissima Marloth				+				+++ +						
Indigofera sp.								+ +						
Polygala leptophylla Burch.								+						
Chascanum garipense E. Mey.								r						
Oxalis luederitzii Schinz.								r	+					
J														
Hypertelis salsoloides (Burch.) Adamson				+	+		+++	b +b ++	+r			+		
Dicoma capensis Less.	+	+				+r	+ +	+ ++ ++						
Berkheya schinzii O.Hoffm.	+				+		+	r						
K														
Leysera tenella DC.						+			++++ ++					
Lotononis falcata (E.Mey.) Benth.	+								r + +++					
Grielum humifusum Thunb.						+			++ +				+r	
Arctotis fastuosa Jacq.	r								+ r r				r	
Monsonia deserticola Dinter ex R. Knuth														
									+ +					
Sarcocaulon patersonii (DC.) G.Don				+	r	+			+r					
Euphorbia namibensis Marloth						r			+ r					
Asparagus exuvialis Burch.									r r					
Tephrosia dregeana E. Mey. var. *dregeana*														
						+			+					
Galenia africana L.									+					
Jamesbrittenia glutinosa (Benth.) Hilliard									+					
L														
Stipagrostis ciliata (Desf.) De Winter	+b ++	+b ++++b b	++	++ +	++++b		++++++	+++ +b	++b b b + b +r				+b	r +
Enneapogon desvauxii P.Beauv.	+++++	+ r +	++	+++	++++	++	+ +	+++ ++	+ + ++				+	

Hermannia paucifolia Turcz.	.	r ++	.	+	.	++	.	+ b + +	+++ +	.	.	.	.	.
Calicorema capitata (Moq.) Hook.f.	.	.	.	+	.	b ++	.	++ +	+ +++ +	.	.	.	.	.
Hermannia gariepina Eckl. & Zeyh.	.	+ +	.	+ +	+	.	.	++ +	r +	.	.	.	.	.
M														
Kyllinga alba Nees	.	.	.	.	.	.	.	.	.	+	.	.	.	.
N														
Portulaca kermesina N.E. Br.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Ammocharis coranica (Ker Gawl.) Herb.	.	.	.	.	.	.	.	.	r	.	+	.	.	.
O														
Eragrostis nindensis Ficalho & Hiern	+	+	+	+	.	+ +	+r + ++b	+ b b b b	+ b +++ b +b +b	b b	+++	b b b	.	.
Ifloga molluginoides (DC.) Hilliard	+	.	+	.	r	+ +	+++ ++	++ +++	+b ++ ++ ++	.	+	++	+	.
P														
Oncosiphon grandiflorum (Thunb.) K„llersj"	.	.	.	.	.	.	.	.	+	.	.	+++	b +b	.
Lotononis sparsiflora (E. Mey.) B.E. van	.	.	.	.	.	.	.	.	.	.	.	++	.	.
Q														
Manulea gariepina Benth.	.	.	.	.	.	++	.	.	+ ++r + r	++	.	+	++	.
Manulea androsacea E.Mey. ex Benth	.	.	.	.	.	++	.	.	+ +++ +	+	.	.	++	r
Hirpicium echinus Less.	.	.	.	.	.	+ +	.	.	++ +	.	.	+	+	.
Schmidtia kalihariensis Stent	.	.	.	.	.	.	.	.	++ +	.	+	+	r +	.
Helichrysum cf. *gariepinum* DC.	+	.	.	+	+	+++	.	.	r ++ ++	+	+	.	.	.
Bulbine namaensis Schinz	.	.	.	r r	.	.	.	.	r	r	r	.	.	.
R														
Stipagrostis obtusa (Delile) Nees	++	b ++b b +b b b	b	b b b b b	+b b	b b b	b +b +b	b b ++b b b	b b b b b b b b	++ +b	b +	++b	+b b	r
Heliophila deserticola Schltr.	.	+++ +++	.	+	++ r	+++	+	+	+ + ++ + + +	r	+	+++	+++	.
Dimorphotheca polyptera DC.	r +	+++ + + +	.	.	.	+++	+ + +	++ +++	+ + + + +	.	+	+	++	.
Foveolina dichotoma (DC.) K„llersj"	+	+	.	.	+ +	++	+++ ++	++ +	+ + + + + +	+ r	b +b	+++	+	.
Euphorbia gummifera Boiss.	.	++ +	.	.	++	.	++	.	+ ++	.	.	+ +	+++	.
Lachenalia giessii W.F.Barker	.	.	++	r	.	r r	.	r r r	r + +	r r	.	.	r	.
S														
Stipagrostis lutescens (Nees) De Winter	++	.	.	.	.	.	.	.	.	.	.	.	+	b b b
Centropodia glauca (Nees) Cope	.	.	.	.	.	.	.	.	.	.	.	.	.	+ ++
Cotyledon sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Melolobium macrocalyx Dummer	.	.	.	.	.	.	.	.	.	.	.	.	.	r
T														
Brachiaria glomerata (Hack.) A.Camus	.	.	.	.	.	.	.	.	.	.	.	.	++++	+
Helichrysum leontonyx DC.	.	.	.	.	.	+	.	.	+	.	.	.	+++	+
Ursinia speciosa DC.	.	.	.	.	.	.	.	.	.	.	.	.	+++	.
Limeum sp.	.	.	.	.	.	.	.	.	.	.	.	.	++	+
Felicia namaquana (Harv.) Merxm.	.	.	.	.	.	.	.	.	+	.	.	.	+	.
Chenopodium sp.	.	.	.	.	.	.	.	.	.	.	.	r	+	.

4

APPENDIX C: Pedigree tree of Namib horses (1994-2004) who contributed to the genetic pool (only offspring alive in 2004 shown).



APPENDIX D: Distribution of ant species across study sites. (Abundances equels summed scores for 15 traps; score/trap: 1=1, 2=2-5, 3=6-10, 4=11-20 and 5=>

Ant species	East transect - July 2003										West transect - July 2003										
	E1A	E1B	E2A**	E2B	E3A	E3B	E4A	E4B	E5A	E5B	W1A	W1B	W2A**	W2B	W3A	W3B	W4A	W4B	W5A	W5B	Total
Tetramorium sp. A *(solidum gr.)*	27	27	15	37	39	43	62	36	1	33	22	32	17	43	46	38	17	15	40	36	626
Monomorium sp. A***	22	9	4	2	6	10	4	10	1	2	39	48	3	6	18	21	20	24	4	2	255
Monomorium sp. B *(setuliferum gr.)*	6	6	3	10	2	5	27	14	15	23	5	5	16	11		7	4	4	19	30	212
Ocymyrmex dekerus	3	4		3	3	1	3	4	12	7	2		3	1			5	6	11	11	79
Tetramorium grandinode		8	10			10		1							11		15	16		13	84
Camponotus bellinger				8	17	4	2	3	1								15	8	10	2	70
Tetramorium sp. C	3						3	3		10	4	4	1	2			4	5	1	6	46
Anoplolepis sp. A			1			3	4		1					1		2	7	11			30
Anoplolepis sp.nr. *steingroeveri*							8	2			1		2						2	2	17
Monomorium sp. C						2						2									4
Messor denticornis	1								4	5									1	5	16
Camponotus sp. B					1										2						3
Total abundance	**62**	**54**	**33**	**60**	**68**	**78**	**113**	**73**	**35**	**80**	**73**	**91**	**42**	**64**	**77**	**68**	**87**	**89**	**88**	**107**	
Number of species	**6**	**5**	**5**	**5**	**6**	**8**	**8**	**8**	**7**	**6**	**6**	**5**	**6**	**6**	**4**	**4**	**8**	**8**	**8**	**9**	

	East transect - August 2004										Trough		Control area - August 2004								
	E1A	E1B**	E2A	E2B	E3A	E3B	E4A	E4B	E5A	E5B	TRA**	TRB**	C1A	C1B	C2A	C2B	C3A	C3B	C4A	C4B	Total
Monomorium kitectum	38	18	40	18		2	20	30	8	6	5	2	48	28	16	33	37	18	28	20	415
Monomorium sp. B	7	5	10	10		2	7	6	34	12			14	20	8	6	8	13	9	18	189
Tetramorium sp. A	8	4	22	25	19	25	16	7	44	13			7	2	4	4		2	3	2	207
Tetramorium grandinode	1	10	17	3	23	11															65
Monomorium drapenum				2	13	18			6	10										2	51
Tetramorium sp. C	1		3				2	3	4	4			5	1	4	1					28
Ocymyrmex dekerus			2														1				3
Anoplolepis sp. A						2									1						3
Anoplolepis sp.nr. *steingroeveri*															1	1	1			1	4
Messor denticornis																			1	1	2
Cataulacus sp. A																		1			1
Total abundance	**0**	**0**	**2**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**2**	**1**	**1**	**2**	
Number of species	**5**	**4**	**6**	**4**	**3**	**5**	**4**	**4**	**4**	**4**	**1**	**1**	**4**	**4**	**6**	**5**	**4**	**4**	**4**	**5**	

APPENDIX D (continue)

	ROAD				KA				TL				HKA				HT				
	Oct	Jan	Apr*	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr	Aug	Total
Monomorium sp. A***	50	37	33	20	74	41	47	23	45	29	19	7	57	47	41	20	56	20	27	25	718
Monomorium sp. B	16	10	17	5	35	19	20	8	19	15	11	5	22	24	15	8	5	7	5	2	268
Tetramorium sp. A	10	4	14	10	13	13	18	22	22	22	8	25	12	19	29	12	20	9	4	2	288
Tetramorium grandinode	26	16	40	34	9	6	7	1	42	23	38	29	26	4	3	23	6	3	1		337
Monomorium sp. C		10	3	1	2	22	7	2	9	14	20	6		3		1	6	10	19	2	137
Ocymyrmex dekerus	11	13	8		16	24	2		17	9	7	3	12	23	2	3	14	12			176
Anoplolepis sp. A	17		2	1	10		5	2	13	4	3	3	29	20	19	1	2		2		133
Anoplolepis sp.nr. *steingroeveri*	7	1	6	1		3	1	2			4		4			4			2		35
Lepisiota sp. A	18	1	3	3	1	3	3				2								1	2	37
Pheidole sp. A	19	19	15	7		29	10					1									100
Camponotus fulvopilosus	8	1	2	12								2									25
Tetramorium sp nr. *sereiceventre*	6	10	16	11		1			2	7											53
Tetramorium sp. C	5	6	1	2	3				1												18
Tetramorium peringueyi	5	1	12	3				3													24
Camponotus sp. B	1	1	1			3															6
Camponotus sp. C			3	1																	4
Camponotus bellinger	5				2		2	1	1								1				12
Messor denticornis	9			5	5		2	7	4	3	1	1	1				14				52
Total abundance	**213**	**130**	**176**	**116**	**170**	**164**	**124**	**71**	**175**	**126**	**113**	**82**	**163**	**140**	**109**	**72**	**124**	**61**	**61**	**33**	
Number of species	**16**	**14**	**16**	**15**	**11**	**11**	**12**	**10**	**11**	**9**	**10**	**10**	**8**	**7**	**6**	**8**	**9**	**6**	**8**	**5**	

* Three of the 5 sites received rain 3 weeks before the survey and had green vegetation while TL and HT were still dry.

** Sites with 5 or more traps out of 15 removed by hyena and jackals.

*** *Monomorium* sp. A refers to *M. kitectum* and *M. drapenum* not differentiated at the time of counting, *M. drapenum* is more scarce and less abundant.

APPENDIX E: Distribution of Coleoptera across study sites. Total abundance/plot (15 pitfall traps).

		East transect - July 2003										West transect - July 2003									
Family	**Species**	**E1A**	**E1B**	**E2A****	**E2B**	**E3A**	**E3B**	**E4A**	**E4B**	**E5A**	**E5B**	**W1A**	**W1B**	**W2A**	**W2B**	**W3A**	**W3B**	**W4A**	**W4B**	**W5A**	**W5B**
Histeridae	*Exosternus* sp. A	4	2	1	2	5	1	2	5	4	3	1		1	1	3	3	2	4	2	5
Bruchidae	*Spermophagus* sp. B	1						1	1		1	10	5	1	1	1				2	5
Carabidae	*Graphipterus tuky* (Basilewsky 1937)																	1			
Carabidae	*Graphipterus velox agilis* (Péringuey 1892)													2							
Curculionidae	*Hyomora manca* (Marshall 1959)								1		1					1	1				
Cybocephalidae	Sp. L															1					
Dermestidae	*Attagenus* sp. A				1																
Dermestidae	Sp. M	1								1			1								
Phalacridae	*Stilbus* sp. A																				1
Scarabaeidae	*Scarabaeus bohemani* (Harold 1868)	1							2									1		1	
Staphylinidae	*Bledius* sp. A			1	1									1	1					1	3
Tenebrionidae	*Pterostichula* cf. *arenicola* (Koch 1952)	215	74	3	119	119	109	56	93	20	32	160	450	118	52	173	151	35	84	192	132
Tenebrionidae	*Rhammatodes* sp. A	4	7	4	15	1	5	2	7	6	17	10	14	1	2	9	4	15	3	45	190
Tenebrionidae	*Zophosis* cf. *arcana* (Koch 1958)	28	30	39	54	37	42	26	98	9	12	1		5	3	22	15	60	42	103	154
Tenebrionidae	*Cauricara phalangium* (Gebien 1920)	26	53	4		12	6	1		136	105	62	42	9	38	16	21	17	18	275	242
Tenebrionidae	*Zophosis pedinoides* (Gebien 1920)	14	6	12	10	9	17	9	17		4	28	55	2	4	20	26	27	10	31	53
Tenebrionidae	*Zophosis boei* (Solier 1834)		5	1	10	47	21		6	26	47	19	13	1	1	15	4	4	3	1	41
Tenebrionidae	*Histrionotus lightfooti* (Péringuey)	13	1		1	2	17	4	17	11	12	1				2		3	3	348	220
Tenebrionidae	*Eurychora* sp. A		2	1	1	2	3			2	2	2				1	1	3	1	1	5
Tenebrionidae	*Geophanus* sp. A				1	3	4	4	4	1	2	4	2			5	3	2	2	8	12
Tenebrionidae	*Stipsostoma* sp. A	1	1			1	2	1		3	3		1		2			2		1	
Tenebrionidae	*Sulcipectus levis* (Louw)		1		9		2			3	5	8	27	22	6		1	1	1	6	7
Tenebrionidae	*Physadesmia bullata* (Péringuey 1888)	1	3	2	1							1	1							3	
Tenebrionidae	*Gonopus angusticostis* (Gebien 1920)									1	1	1			2	1		2	1		2
Tenebrionidae	*Onymacris boschimana* (Péringuey 1888)		4								1	3	5		1						
Tenebrionidae	*Drosochrini* sp. A							1			2	1		3	1						
Tenebrionidae	*Planostibes dentipes* (Koch)			2			1			1						1		1			
Tenebrionidae	*Somaticus aeneus* (Solier)			1		3	1		2												
Tenebrionidae	*(Cryptochilini)* Sp. P					1					1										
Tenebrionidae	Sp. B	1																			
Tenebrionidae	*Pachynotelus dimorphus* (Koch 1952)					4															
Tenebrionidae	*Ephiphysa louwrensi* (Koch 1951)							1													
Tenebrionidae	*Trachynotidus* sp. A								1												
Tenebrionidae	Sp. D										2										
Tenebrionidae	Sp. A													1							
Tenebrionidae	*Metriopus depressus* (Haag-Rutenberg 1875)															2					1
Tenebrionidae	*Zophosis omnigena* (Penrith 1977)																1				
Total tenebrionidae abundance		**303**	**187**	**69**	**221**	**241**	**230**	**105**	**245**	**219**	**248**	**301**	**610**	**162**	**112**	**267**	**227**	**172**	**168**	**1014**	**1059**
Number of tenebrionidae species		**9**	**12**	**10**	**10**	**13**	**13**	**10**	**9**	**12**	**16**	**14**	**10**	**9**	**11**	**12**	**10**	**13**	**11**	**12**	**12**

APPENDIX E (continue - p2):

		East transect - August 2004										Trough		Control area - August 2004							
		E1A	E1B**	E2A	E2B	E3A	E3B	E4A	E4B	E5A	E6B	TRA	TRB	C1A	C1B	C2A	C2B	C3A	C3B	C4A	C4B
Anthicidae	*Formicomus* sp. A														1		3	4	10		1
Bruchidae	*Spermophagus* sp. A																		1		
Carabidae	Sp. E	1			1	2	2	5	2												
Chrysomelidae	Sp. F									1	4										
Chrysomelidae	Sp. G		1			2				2	1	2		93	6	11	44	1		1	
Chrysomelidae	Sp. H			11		17		1							1	4	4	25			9
Curculionidae	*Hyomora manca* (Marshall 1959)						1		2			3									
Curculionidae	*Ocladius* sp. A																		7		
Curculionidae	Sp. J	1					3			3	1				1					1	
Curculionidae	Sp. K							1													
Curculionidae	various species (± 5)									3	4										
Cybocephalidae	Sp. L																		1		
Dermestidae	*Attagenus* sp. A		1		1	2	4	1						3	4	2					
Dermestidae	Sp. M			2				1		3				6	2						
Histeridae	*Exosternus* sp. A	4	2	2	1	1		1	2	2	2			8	3	4	2	1	4		2
Histeridae	*Hister* cf. *coprophilus* (Reiche)								1												
Melyridae	*Dinometopus* sp. A								1							1	5	3	21	3	
Ptinidae	*Stethomezium notiale* (Péringuey 1899)			3												1			1		
Scarabaeidae	*Adoretus* sp. A																2				1
Scarabaeidae	*Chasme kochi* (Schein 1959)						1														
Scarabaeidae	Sp. O	6		1		3					1										
Scarabaeidae	*Pachysoma* cf. *valeaflorae (Ferreira)* - male								2								1				
Scarabaeidae	*Scarabaeus bohemani* (Harold)			1	1	1	3	2	3												
Scarabaeidae	*Scarabaeus proboscideus* (Guérin-Méneville 1884)															3					
Staphylinidae	*Bledius* sp. A	1	1	1	1	1			1	1		3	2	4	1	2				1	
Staphylinidae	*Zyras* sp. A											1									
Total abundance		**13**	**5**	**21**	**5**	**29**	**14**	**12**	**14**	**15**	**13**	**9**	**2**	**114**	**19**	**28**	**61**	**34**	**45**	**6**	**13**
Number of species		**5**	**4**	**7**	**5**	**8**	**6**	**7**	**8**	**7**	**6**	**4**	**1**	**5**	**8**	**8**	**7**	**5**	**7**	**4**	**4**

APPENDIX E (continue - p3):

		East transect - August 2004										Trough		Control area - August 2004							
		E1A	E1B**	E2A	E2B	E3A	E3B	E4A	E4B	E5A	E5B	TRA	TRB	C1A	C1B	C2A	C2B	C3A	C3B	C4A	C4B
Tenebrionidae	*Pterostichula* cf. *arenicola* (Koch 1952)	18	4	14	38	32	19	14	33	18	10			2	3	2	2				1
Tenebrionidae	*Zophosis* cf. *arcana* (Koch 1958)	1	2	9	18	1	4	2	5	3	1					4	4	1	7	4	12
Tenebrionidae	*Stipsostoma* sp. A	1	8	1	2	2	1		1			1		13	2	7	6	4	24	5	5
Tenebrionidae	*Zophosis boei* (Solier 1834)	2	1		4	2	2		1	6	1	4	2	2	1	1	1	1	2		3
Tenebrionidae	*Rhammatodes sp. A*	1	1	1	2	1				5	3			1		3	3	4	2		
Tenebrionidae	*Histrionotus lightfooti* (Péringuey)	2				2	4	11	14			6	2			2	3		2	7	
Tenebrionidae	*Pachynotelus longipilis* (Gebien 1920)						2	11	9						1	3	3			3	
Tenebrionidae	*(Chryptocheilini)* Sp. P							1	1										1	1	
Tenebrionidae	*Eurychora* sp. A		4	1	1					2											
Tenebrionidae	*Gonopus angusticostis* (Gebien 1920)			1			1									1	1			1	
Tenebrionidae	Sp. C	1					2														
Tenebrionidae	*Zophosis pedinoides* (Gebien 1920)				2																
Tenebrionidae	*Drosochrini* sp. B						1									1	1	1	1		1
Tenebrionidae	*Somaticus aeneus* (Solier)		1									4									
Tenebrionidae	*Cauricara phalangium* (Gebien 1920)											6	2		1						
Tenebrionidae	*Pachynotelus dimorphus* (Koch 1952)										1	2				4	3	4			15
Tenebrionidae	*Drosochrini* sp. A									1	1			4	2						
Tenebrionidae	*Sulcipectus levis* (Louw)										1			1	1						
Tenebrionidae	*Geophanus* sp. A														1						
Tenebrionidae	*Onymacris boschimana* (Péringuey 1888)											1									
Tenebrionidae	*Zophosis* sp. A														1		1				
Total tenebrionidae abundance		**26**	**21**	**27**	**67**	**40**	**36**	**39**	**64**	**35**	**18**	**24**	**6**	**23**	**13**	**28**	**28**	**15**	**39**	**21**	**37**
Number of tenebrionidae species		**7**	**7**	**6**	**7**	**6**	**9**	**5**	**7**	**6**	**7**	**7**	**3**	**6**	**9**	**10**	**11**	**6**	**7**	**6**	**6**

APPENDIX E (continue - p4):

		ROAD				KA				HKA				HT				TL			
		Oct	Jan	Apr*	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr	Aug	Oct	Jan	Apr	Aug
Anthicidae	*Formicomus* sp. A	1		2	11												1				
Buprestidae	*Agrilus* sp. A			6																	
Carabidae	*Graphipterus tuky* (Basilewsky 1937)					5			1	3			2	10				1			
Carabidae	Sp. E													1			1	1			
Chrysomelidae	Sp. F									1											
Chrysomelidae	Sp. G			3					10			2	2				1				2
Chrysomelidae	Sp. H												2				2				1
Curculionidae	*Brachycerus* sp. A			1																	
Curculionidae	*Spartecerus mendax*			1																	
Curculionidae	various species (about 5)								2				1								
Cybocephalidae	Sp. L	2																			
Dermestidae	*Attagenus* sp. A																8				3
Histeridae	*Exosternus* sp. A	2	1		1	9	2	3	1	6	1		1	11	1	1	1	7	1		1
Histeridae	*Hister* cf. *coprophilus* (Reiche)			1																	
Meloidiae	*Paractenodia freyi*			3																	
Melyridae	Sp. N			43				19				30									
Phalacridae	*Stilbus* sp. A									1											
Ptinidae	*Stethomezium notiale* (Péringuey 1899)			1																	
Scarabaeidae	*Adoretis* sp. A			1								1						1			
Scarabaeidae	*Chasme kochi* (Schein 1959)																	1			
Scarabaeidae	*Cheironitus* sp. A					1															
Scarabaeidae	*Pachysoma* cf. *valeaflorae (Ferreira)* - female												1								
Scarabaeidae	*Scarabaeus bohemani* (Harold)	1			4				1	1											
Scarabaeidae	*Scarabaeus fritchi*	1			1	1															
Staphylinidae	*Bledius* sp. A									1			1				1		1	2	
Staphylinidae	*Zyras* sp. A																	1		1	
Total abundance		**7**	**1**	**62**	**17**	**16**	**2**	**22**	**15**	**13**	**1**	**33**	**10**	**22**	**1**	**1**	**15**	**12**	**2**	**3**	**7**
Number of species		**5**	**1**	**10**	**4**	**4**	**1**	**2**	**5**	**6**	**1**	**3**	**7**	**3**	**1**	**1**	**7**	**6**	**2**	**2**	**4**

APPENDIX E (continue - p5):

		ROAD				KA				HKA				HT				TL			
		Oct	Jan	Apr*	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr*	Aug	Oct	Jan	Apr	Aug	Oct	Jan	Apr	Aug
Tenebrionidae	*Zophosis* cf. *arcana* (Koch 1958)		8			20	19	5	11	2	18	6	10	23	9	11	4	22	12	20	4
Tenebrionidae	*Zophosis boei* (Solier 1834)		1		1	3	1	1	3	2	1		3	2	2			2	1		1
Tenebrionidae	*Rhammatodes* sp. A	1			1	15	4		4	5	2			7		1		2	1		
Tenebrionidae	*Stipsostoma* sp. A		1		4	1			4	3		1	11					2			
Tenebrionidae	*Pachynotelus dimorphus* (Koch 1952)				4	1			6					20			1	1			7
Tenebrionidae	*Gonopus angusticostis* (Gebien 1920)		2			1		1				1			2	3		1		3	1
Tenebrionidae	*Eurychora* sp. A		1					1										1		2	1
Tenebrionidae	*Cauricara phalangium* (Gebien 1920)		1		1				1						1						
Tenebrionidae	*Histrionotus lightfooti* (Péringuey)				2				2												
Tenebrionidae	*Drosochrini* sp. A				3																
Tenebrionidae	*Onymacris boschimana* (Péringuey 1888)				1																
Tenebrionidae	*Drosochrini* sp. B			1																	
Tenebrionidae	*Planostibes dentipes* (Koch)	2																			
Tenebrionidae	*Blenosia semicostata*								1	2											
Tenebrionidae	*Pterostichula* cf. *arenicola* (Koch 1952)								1												
Tenebrionidae	*Epairopsis superbus*							1													
Tenebrionidae	*Somaticus aeneus* (Solier)							1								4					
Tenebrionidae	*Somaticus dimorphus* (- female															1					
Tenebrionidae	*Physadesmia bullata* (Péringuey 1888)																				1
Total tenebrionidae abundance		**3**	**14**	**1**	**17**	**41**	**24**	**10**	**33**	**14**	**21**	**8**	**24**	**52**	**14**	**20**	**5**	**31**	**14**	**25**	**15**
Number of tenebrionidae species		**2**	**6**	**1**	**8**	**6**	**3**	**6**	**9**	**5**	**3**	**3**	**3**	**4**	**4**	**5**	**2**	**7**	**3**	**3**	**6**
Number of species - all fence sites beetles		7	7	11	12	10	4	8	14	11	4	6	10	7	5	6	9	13	5	5	10

* Three of the 5 sites received rain 3 weeks before the survey and had green vegetation while TL and HT were still dry.

** Sites with 5 or more traps out of 15 removed by hyena and jackals.

APPENDIX F: Questionnaires used for socio-economic survey.

Liewe Aus inwoner

Ek sal dit baie waardeer as u 'n tydjie sal afstaan om 'n paar kort vrae te beantwoord deur 'n kruisie in die aangewese blokkie te maak, die vraelys is deel van 'n navorsingsprojek op die Garub perde.

VANDAG SE DATUM: 2003/ (maand) / (dag)

1. NAAM:

2. GESLAG:

MAN	VROU

3. OUDERDOM:

20 of jonger	21-35	36-50	51-65	Ouer as 65

4. Het u geweet dat daar "wilde" perde in die Namib Naukluft Park by Garub is?

JA	NEE

5. Waar het u die eerste keer van hulle gehoor?

Tydskrif	Koerant	Radio	Vriende	Self gesien	Ander manier:

6. Het u self al die perde gesien?

JA	NEE

7. Dink u die perde moet weggeneem word uit die Namib Naukluft Park?

JA	NEE

8. Dink u die perde kan tot voordeel wees vir Aus?

JA	NEE

Enige opmerkings wat u wil byvoeg:

....

....

....

Baie dankie vir u bydra!

Dear Visitor,

We, the Research team, would be very grateful if you would take the time to complete this questionnaire, by ticking the appropriate boxes. It forms part of a research project on the socio-ecology of this area. Your input will be much appreciated!

1. NATIONALITY:

Namibian	South African	Other

2. GENDER:

MALE	FEMALE

3. AGE GROUP:

20 and younger	21-35	36-50	51-65	Older than 65

4. Why did you choose to visit Namibia? Rate your preferences from **1(most** important) – **4(least** important):

Historical sites	African Wildlife	Wild horses	Desert landscapes

5. Where did you first hear of the wild horses of the Namib?

Magazine	Television	Travel guide	Friends	Klein-Aus Vista	Garub viewpoint	Other source:

6. What do you think of the general condition of the horses and gemsbok (if you have seen them)?

HORSES	Very Good	Rather Good	Neither Good nor Poor	Rather Poor	Very Poor
GEMSBOK	Very Good	Rather Good	Neither Good nor Poor	Rather Poor	Very Poor

7. Do you think the horses should be removed from the Namib Naukluft Park?

YES	NO

8. Do you think the horses and wildlife should be given supplementary food?

Regularly	Never	Only severe draughts

9. Do you think the number of horses should be artificially controlled?

YES	NO

10. What do you think should happen to old animals in the wild?

Left to die naturally from malnutrition/predators	Shot (put down) by authorities	Removed to domestication

11. Would you like to see the wild horses and scenery with a guided excursion?

YES	NO

12. How much would you be prepared to pay for such an excursion ***(1-2 hours)***?

Less than N$100	N$100 – N$200	More than N$200

With many thanks for your time and effort!

APPENDIX G: Proceedings of the stakeholder workshop concerning the feral horses.

Stakeholder Workshop: Strategies for management of the feral horses in the Namib Naukluft Park

DATE: 10-11 November 2005

VENUE: Cañon Village (Gondwana Cañon Park, southern Namibia)

Summary

This workshop was initiated and organized by the Northwest University study group of the feral horses in the Namib Naukluft Park. It was staged with support from Nature Investments (trading as Gondwana Desert Collection) as well as Klein-Aus Vista and Klein-Aus Dairy. The aim of the workshop was two-fold: i) to present the results of a study regarding the history, origin, demography, impact on biodiversity and socio-economic impact of the horses, and ii) to use this information as a technical basis and solicit input from local stakeholders for the proposal of a draft management plan for the horses.

The proceedings were facilitated by Prof John Mumford from the Centre for Environmental Policy, Imperial College London, United Kingdom. A total of nineteen participants from different sectors (science, tourism, Government (State veterinary services, Ministry of Environment and Tourism), private and the media) contributed to the discussions during the workshop.

Proceedings

On Thursday morning, 10 November 2005, all participants were welcomed to Gondwana Cañon Park by the Managing Director, Mr Mannfred Goldbeck. Thereafter a brief background to the project and broad aims of the workshop were communicated by the Project Supervisor, Prof Huib van Hamburg, who also introduced the workshop facilitator, Prof John Mumford.

Thursday morning and early afternoon was filled with five presentations which included questions and answers during and after each presentation:

1. Origin & history of the Namib feral horses	Mr Mannfred Goldbeck
2. Controversy regarding the horses	Ms Telané Greyling
3. The horses' impact on biodiversity	Prof Huib van Hamburg
4. Socio-economic value/impact of the horses	Mr Mannfred Goldbeck
5. Demography of the horses	Ms Telané Greyling

After a mid-afternoon tea break, the aim was to identify principal management objectives for the horses and the Garub area they inhabit.

On Friday, 11 November 2005, Prof John Mumford continued to facilitate more detailed discussions on each of the specific objectives that were identified during the previous afternoon. The sensitive nature of the ideals and intricacies surrounding management of the feral horses proved to be a rather complex issue and discussions continued but were well concluded and summarized by 5 pm on Friday afternoon thanks to the expertise of Prof John Mumford. At this point Prof Huib van Hamburg closed the workshop, emphasizing that the workshop marked the beginning of a structured way forward for the Garub Wild Horses. He also expressed the gratitude of the organizers to Prof John Mumford for facilitation of the workshop, to Nature Investments for hosting the workshop and to the participants who took the time to attend and contribute to an important first achievement regarding future management of the Garub Wild Horses.

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WORKSHOP OUTPUT:

A. Management objectives
B. Options/actions
C. Evaluation of options
D. Criteria for success

1. Goals (ideal)

1.1 "Stable" wild horse population

- Population fluctuates naturally within sustainable limits determined by grazing capacity
- Selection pressure maintained through wild conditions
- No impact at mean density
- Low impacts at peak density
- Low extinction risk
- No feeding (unless low rainfall depresses grazing capacity or population is near lower limit)
- No culling
- Good animal welfare; no public concern over deaths

1.2 Low management costs
- Routine water point
- Clear rules for other inputs
- No/few limits on other Park management issues or policy

1.3 Complement tourism value
- Accessible and reliable public viewing of horses
- Opportunity for concession operators
- Interpretation of ecology/history for visitors to add value
- Demonstrable value to nation and local community

1.4 Science and education
- Scientific basis for population management
- Improve public understanding of scientific basis of management
- Build on baseline of scientific monitoring

2. Problems

2.1 There is no current management plan to maintain stable population
2.2 There is little public understanding, but much public interest
2.3 National and Community value has not been fully demonstrated
2.4 There is no ongoing science and education activity

3. Management policy

a) Low input maintenance of the wild horse population within a stable range, with some selection pressure, in the original vicinity of Garub
b) Additional intervention only if the population approaches the low end of the stable range
c) Potential sustainable utilisation if population exceeds stable range
d) Enhance historical/cultural value
e) Realise value to national and local community

4. Implementation

4.1 Timescale

The Management Plan should have a 7 year planning horizon, with periodic review

4.2 Responsibility

A wild horse management/monitoring centre is needed for good management and to raise status

4.3 Operations

Clear management rules must be provided for operational management to meet objectives

5. Management issues

5.1. Managing population or individuals?
- Within the stable range the *population* is managed
- At the extremes *individuals* are managed

5.2. Technical basis?
- Public emotions are likely to affect intervention decisions at low and high end of stable population range along with the shift in emphasis to management of individual horses

5.3. Community participation?

- The balance of shared value, capacity and responsibility amongst participants in the community is a social issue that can affect the technical management of the horses

6. Management options

6.1 Water

- Routine provision of water at viewpoint
- Emergency water in another location

6.2 Emergency feeding

- To preserve at low population levels
- To reduce welfare concerns from the public during periods of population stress

6.3 Sales?

- *If sustainable utilisation criteria are met*

6.4 Relocate?

- *If conditions require an alternative genetic reservoir*

7. Management description

"Stable population"

- The population fluctuates within natural limits set by the grazing capacity
  - No long term change in grazing capacity after installation of fencing *prevented emergency farm grazing*
  - No change of geographical range for grazing
- Management interventions occur before extremes are reached
- Slow population growth rate dampens fluctuation
- The mean is low enough to ensure some selection pressure

8. Yearly rain to grazing capacity

Rainfall (mm)	Proposed number of horses				Total horses	Proposed number of game*				Total game
	Koichab plains	Gravel slopes	Dunes	Calcrete plains		Koichab plains	Gravel slopes	Dunes	Calcrete plains	
20	8	12	13	30	55	0	0	0	0	0
30	14	21	19	52	92	0	0	0	0	0
40	14	21	21	53	96	5	8	8	20	35
50	17	26	26	65	118	6	10	10	24	43
55	20	30	29	71	129	7	11	11	26	48
60	19	29	28	96	153	28	43	41	142	226
70	31	47	57	196	301	46	70	84	290	444
80	42	64	65	326	455	62	94	96	482	672
90	53	80	89	426	596	78	119	132	629	880
100	65	98	114	519	730	96	145	168	766	1079

*Game = one gemsbok; to allow for springbok and ostriches, convert 1 gemsbok to 5 springbok or 2 ostriches.

9. Management plan

1. Mean population range

    - Short term (5 yr) 80-180 (+/-50 from long term mean)
    - Long term (50 yr) mean so far is around 130

2. Routine actions/monitoring

    Aims:
    - Monitoring population to alert regarding possible emergency
    - Monitoring ecological impact

    Actions:
    - Aerial population count annually in winter (Sep)
    - Water troughs count (Mar/Apr) for age structure/sex ratio
    - Need to determine acceptable sampling error
    - Quarterly rainfall monitoring
    - Periodic (3-5 yr) ecological monitoring for impact

3. Emergency water hole

    Aims:
    - Population preservation

    Actions:
    - Open another water point in an alternative grazing area to give more access to grazing without long trek back to water

    Criteria:
    - Signal for falling capacity based on formula relating numbers in year N to conditions of rainfall and horse numbers in year N-1
    - Phase in emergency water hole if mean horse condition falls to "average-poor"; phase out again when significant rain increases capacity
    - Impact monitoring related to horse numbers?
    - Competition from game or termites decreases grazing capacity?

4. Emergency feeding

    Aims:
    - Population preservation; animal welfare
    - Feeding policy would reduce their "wild" status, but should not recondition the horses to domestic state
    - Fencing reduced available range and limits overall population
    - Feed if condition continues to fall after opening emergency water hole

    Actions:
    - Move horses from view during emergency by feeding and watering location away from viewpoint
    - Unlikely emergency grazing on neighbouring farms but could become available as future option

    Criteria:
    - Prediction of emergency based on rainfall in previous year
    - Start monitoring horse condition when rainfall has been low
    - Mean animal condition score is basis for feeding

5. *Sale of horses?*

   Aims:
   - Income (Sustainable utilization)
   - Animal welfare
   - Create good will
   - Genetic reservoir (sub-populations)?

   Actions:
   - Approve owners and new locations for suitability
   - Sale by auction to approved buyers
   - Maintain stud book of sold horses (unique "breed")

   Criteria:
   - Desert horses have limited potential use in private ownership and lose their status as wild horses, sale for "breeding purposes" only
   - Sales only at high population (>>mean?)
   - Remove young (2-4 yr old) horses (up to 10 in number, up to around 25% of age cohort, 50:50 sex ratio)
   - Relocate in early winter so vaccination is possible

6. *Relocate?*

   Aims:
   - genetic reservoir?;
   - reduce population pressure

   Actions:
   - Vaccinate relocated animals (other health issues)?

   Criteria:
   - Selection criteria for relocation (individuals, numbers, place)?
   - Criteria for return to original population group?
   - Lead time to gather information prior to considering?

7. Management of co-species

   Actions:
   - No active management of co-species (Natural competition for horses (low input), Gemsbok, termites and other grazers, Predators/scavengers)

8. Fencing

   Aims:
   - Prevent inward or outward movement of horses, game, livestock and people

   Actions:
   - For the moment none (No gaps opened in the fencing, no emergency grazing access, and no increase in permanent grazing area)

9. Management cost recovery

   Aims:
   - Support for sustainable management input

   Options/status:
   - Attributable costs (water, hide, management time, vet care)
   - Emergency feeding by philanthropic fund

- Should any cost recovery be set against general tourism value or specific value in Aus?
- Concession holder already makes partial contributions
- A specific Management/Monitoring Centre could require funding in the future?

10. How to keep/enhance value?

Aims:
- Identify, increase and share value of horses
- Keep the horses wild (no public feeding, interaction)

Actions:
- Maintain access at viewpoint, recognise that many visitors will see very little depending on activity of the horses
- Concession provides a different experience/value for tourists
- Develop business plan for Concession/MET management?
- Link operation (viewpoint) to Concession?
- Interpretation/Information on tours, and in Information Centre
- Foundation/Trust/etc helps to preserve information, publicise resource?

Criteria:
- Publicity, education, monitoring is important
- Joint management of resource by MET, Concession, Aus Community Conservation Trust, Foundation?
- Concession demonstrates community benefit?
- Feedback to MET, Concession, Aus Community Conservation Trust

11. Legal status

Aims:
- Legal status should be clarified formally

Actions:
- Name should be defined: *Garub wild horses*
- Regulations should be changed/added to protect Garub wild horse population from disturbance
- Regulations should cover the historic/cultural role of the Garub wild horses
- Unlikely to create precedents if there are regulations specific to the horses?

12. Science and education

Aims:
- Provide technical basis for management
- Improve public understanding

Actions:
- Continued study of horse population and the associated ecology

Criteria:
- Both emotion and science affect the public view
- Role of Monitoring Centre: advising management and Information Centre?
- Coordination, resources, training needed for Monitoring Centre (role for Foundation?)
- Practical role for Concession holder in monitoring
- Ecology education opportunity for University students

CRITERIA FOR SUCCESS:

1. Management Plan implemented and reviewed

2. No wild horse extinction

3. Stakeholder satisfaction
    a) Less "worry" about extinction, condition

4. Scientific basis for management
    a) Active dissemination

5. Business-like management
    a) Continued profitable Concession
    b) Three bottom line business plan

6. Leadership for Future needs
    a) Champion arises to develop management, science, business

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