Journal of Arid Environments (2003) **53**: 529–543
doi:10.1006/jare.2002.1066

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Does land use matter in an arid Environment? A case study from the Hoanib River catchment, north-western Namibia

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(Received 9 July 2001, accepted 11 June 2002)

The effect of intensive grazing and browsing of domestic stock and wildlife on the number of species and abundance of vegetation was investigated in the Hoanib River catchment, north-western Namibia. The seasonal abundance of ground cover, bare earth, canopy cover, annual grass, perennial grass and annual forbs were measured in each of the focus-study areas. In three of the focus areas where the ranges of both domestic stock and wildlife were restricted either by fencing or water availability, impact on the vegetation was greatest. The final focus area was a more 'open range' system that allowed for the free movement of wildlife. Under these conditions the species abundance and availability of browsing and grazing was greater than the other focus areas during both the wet and dry seasons. However, very little difference in abundance and availability of vegetation was observed between focus areas in both seasons regardless of landuse. There is generally a low abundance of perennial grasses and browse species affording the ecosystem little resistance and resilience to disturbance caused by grazing and drought.

Keywords: vegetation impact; arid environment; intensive grazing

Introduction

Several authors (Bourliere & Hadley, 1970; Walker & Noy-Meir; 1982; du Toit & Cumming, 1999) have reported that rainfall, fire and herbivory, and in some areas, frost are the prime driving variables in African savannahs. However, there has long been debate about the detrimental environmental effects caused by domestic stock farming in comparison with wildlife (du Toit & Cumming, 1999). Further, it has been reported that the impact of livestock management on savannah rangelands varied and depended on stocking rates and the interaction of rainfall, soil properties, topography and the occurrence of drought (Walker, 1993; Fynn & O'Connor, 2000). Kruger & Rethmann (1999) reported that in the Camel Thorn Savannah (*Acacia erioloba* Savannah) of eastern Namibia, variation in rainfall appeared to have a greater impact on the productivity of both Kalahari sand veld and livestock than stocking rate alone.

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Other authors (e.g. Ellison, 1960; Jameson, 1963; Dodd, 1994) suggested that heavy grazing pressure in an arid and semi-arid environment affects rangeland plant communities and individual plants' abundance. The most dramatic changes in species composition and productivity have been reported to occur near water points and human habitation, where trampling and intensive grazing forms distinct vegetation zones or piospheres (Lange, 1969; Andrew, 1988; Pickup, 1994). Other authors have referred to the degraded area around the water source as a 'sacrifice zone' (Sandford, 1983; Perkins & Thomas, 1993). High densities of domestic stock have been reported to induce changes in infiltration rates (Tarkar *et al.*, 1990), soil nutrient levels (Dean & Macdonald, 1994) and the resistance and resilience of ecosystems (Whitford *et al.*, 1999). However, the effect on bulk rangeland (more than a kilometre away from either water point or human habitation) was reported to be rare (Ellison, 1960; Jameson, 1963; Dodd, 1994; Ringrose *et al.*, 1996, 1997).

Wildlife and in particular elephants have been regarded as significant agents in changing vegetation in arid and semi-arid systems (van Wyk & Fairall 1969; Laws *et al.,* 1975; Barnes 1983; Trollope *et al.,* 1989; Ben-Shahar, 1993, 1996; Du Plessis *et al.*, 1998*a*, *b*). The larger migratory ranges of wildlife, however, have been considered to be less damaging on vegetation than domestic stock that are generally kept at higher stocking densities (Krueter & Workman, 1992).

The four focus areas of this study were all located in the same rainfall zone with the Hoanib River catchment in north-west Namibia, the most significant difference between the sites was the type of land use. The study reported in this paper was undertaken to examine the seasonal impact of wildlife and domestic stock on the distribution, abundance and availability of vegetation in restricted and unrestricted range conditions and make an assessment of the resistance and resilience of the ecosystem. It also formed part of a larger study of the Hoanib River Catchment Study (HRCS) that focused on appropriate basic socio-economic, biophysical and policy research on environmental issues important for sustainable use and development of natural resources.

The study site

The Hoanib River catchment is one of the 12 major ephemeral river catchments that occupy the arid areas of north-western Namibia. All 12 rivers flow into the Atlantic Ocean or end in the Namib Sand Sea. Many originate in commercial farmlands, flow through communal farming areas and, near their mouths, traverse a protected conservation area. The Hoanib River catchment in particular occupies an area of 17,200 km, 3% of which lies in private farm lands, 91% in communal farm lands, and 6% is protected in Etosha National Park and Skeleton Coast Park (Jacobson *et al.*, 1995) (Fig. 1).

Several studies on the effects of domestic stock on the vegetation in the communal lands of north-western Namibia have been reported in the literature (e.g. Van Warmelo, 1962; Loxton Hunting & Associates, 1974; Nærua *et al.*, 1993, Sullivan & Konstant, 1997; Sullivan 1996, 1998, 1999; Becker & Jurgens, 2000). Similarly, a number of studies on the effects of wildlife on vegetation of Etosha National Park have also been reported (Du Plessis *et al.*, 1998*a*, *b*). No comparative studies, however, have been reported on land use.

The eastern section of the Hoanib River catchment received above average rainfall (Table 1) during the 2000 wet season, this represented the highest annual rainfall recorded since 1967 (Leggett *et al.*, 2001*a*). Vegetation transects from Otjokavare, Hobatere, Kaross and Palmfontein were compared. All have similar rainfalls, geographic, geological conditions and large animal biomass (Table 2). The main

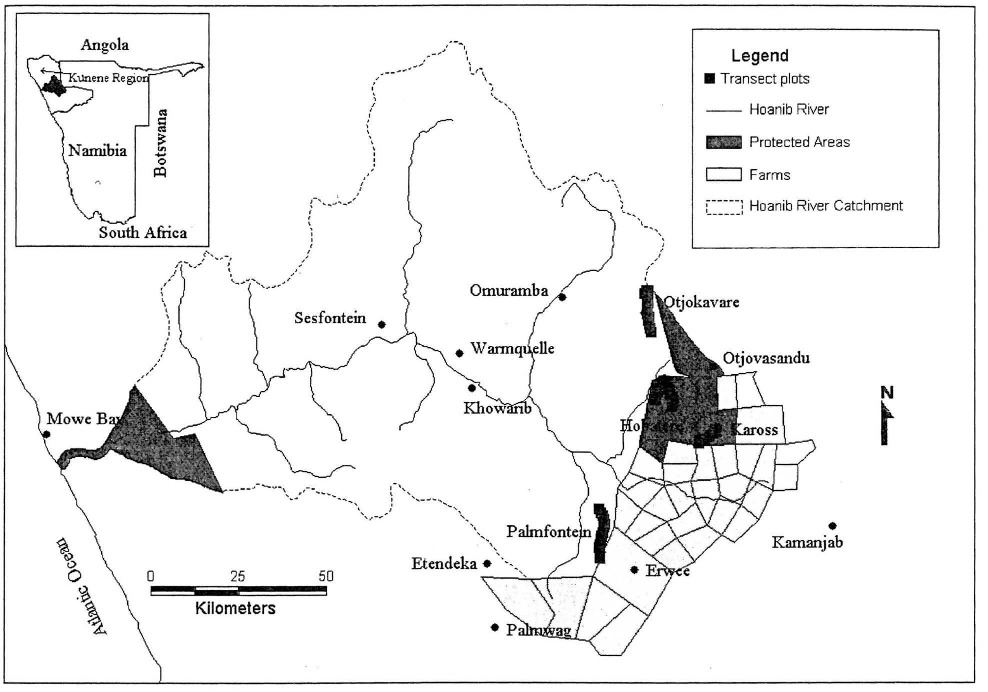


Figure 1. Map of Hoanib River catchment area showing the location of transects in the eastern section of the catchment, north-west Namibia.

Table 1. *1999–2000 rainfall data from the Hoanib River catchment, north-western Namibia*

Location	Distance from the coast (km)	Rainfall 1998–1999 (mm)	Rainfall 1999–2000 (mm)	Long-term mean (mm)
Möwe Bay*	0	20·9	2·9	13·45
Sesfontein	100	N/a	106·5	107·9
Khowarib	120	115·5	310·5	N/a
Warmquelle	125	N/a	232·5	N/a
Erwee† (Atlanta Post)	150	159	N/a	N/a
Omuramba†	155	N/a	N/a	N/a
Etendeka Mountain Camp*	150	92·5	288	N/a
Hobatere Game Park	180	182·5	432	251·38
Otjokavare	185	211·0	431·5	N/a
Otjovasandu	190	N/a	N/a	299·8
Kamanjab*	210	85	345	305

*Located outside the Hoanib River catchment.
†Insufficient data collected.
N/a — not available.

difference between the areas is the type of land-use the vegetation is subjected to. Palmfontein and Otjokavare are communal lands under heavy livestock grazing pressure with very little management input from local communities. Hobatere was

Table 2. *Large animal units (LAU) and biomass (per ha) of animals in each of the focus areas in the Hoanib River catchment, north-western Namibia.*

Focus area	Approx. grazing areas* (ha)	LAU†	Large animal biomass (LAU ha^{-1})
Otjokavare	110,000	3992·27	0·036
Hobatere	32,000	1325·67 (wet season)	0·041 (wet season)
		191·53 (dry season)	0·006 (dry season)
Kaross	14,000	708·87	0·051
Palmfontein	80,000	1040·87	0·013

*Areas calculated using a Graphical Information System (MAPINFO).
†All domestic stock and wildlife numbers have been converted to large animal units (LAU) $(m/450)^{0·75}$ × no. of animals.
The average weight of individuals within a population was taken from Bothma (1996).

subjected to heavy livestock grazing pressure up until the early 1980s when it became a hunting and game concession. Since this time it has been subjected to limited management by rangeland ecologists with the Ministry of Environment and Tourism (MET). Kaross has long been part of Etosha National Park. Since the late 1970s it has functioned as a protected species game reserve and is moderately to heavily stocked with endangered species, namely black rhino (*Diceros bicornis*), sable (*Hippotragus niger*), roan (*Hippotragus equinus*) with additional numbers of Hartmann's mountain zebra (*Equus zebra hartmannae*), blue wildebeest (*Connochaetes taurinus*), giraffe (*Giraffa camelopardalis*) and gemsbok (*Oryx gazella*) (Special Support Services, 1999). Kaross has been the subject of intensive management by the MET over many years.

For the purposes of this study, annual grasses and forbs were defined as species that grow and seed seasonally, but tend not to survive through the dry season. In contrast, perennial grasses generally form tufts and both perennial grasses and forbs retain their leaf throughout the year. Growth, flowering and seeding in both the annual and perennial species occurs primarily during the wet season.

Method

Vegetation transects

Vegetation transect lines were established in four focal areas of the eastern Hoanib River catchment (Fig. 1). The major permanent water source, either borehole, wetland or spring was the chosen point of origin for the transects in all of the focal areas. Two 7-km transects were taken from three of the water sources. Only one southern transect was taken at Kaross due to a large number of watersources in the northern section of the park. The direction of each transect was deliberately chosen to exclude the influence of any other water point. At nine plots, geology and geography permitting, data were recorded at 0 m (water source), 500 m, 1, 2, 3, 4, 5, 6 and 7 km along each of the transect lines. Plots were assessed for vegetation species and abundance by the Zurich-Montpellier method (Table 3) (Braun-Blanquet, 1932; Mueller-Dombois & Ellenberg, 1974; Werger, 1974; Bonham, 1989; McAuliffe, 1990). All fertile specimens of trees, shrubs, grasses and forbs were submitted to the National Botanic Research Institute (NBRI) of Namibia for identification.

Two surveys (wet and dry season) were undertaken at each of the plots along the transect lines. The wet season in the Hoanib River catchment can begin as early as October and finish as late as April the following year. For the purposes of this study,

Table 3. *Zurich-Montpellier abundance scale and the corresponding % abundance for vegetation analysis in the Hoanib River catchment, north-western Namibia*

Zurich-Montpellier abundance scale	Percentage abundance (%)
0	0
+	0–1
1	1–5
2a	5–12·5
2b	12.5–25
3	25–50
4	50–75
5	75–100

the wet season is named in the year that the last rains fell. For example, if the rains began in the October 1999 and ended in April 2000, this period would be referred to as the 2000 wet season. The dry season is the period from April (or at the end of the last rains) and the end of October (or the start of the first rains).

Field sampling technique

The site selection, representativeness, homogeneity, structure, plot size and plot form were based on Werger (1974). The minimum plot size for all plots was 50 m × 50 m, in normal heterogeneous vegetation areas. However, along riverbanks where vegetation is not as evenly dispersed, 100 m × 25 m plots were used to ensure that all plant communities were represented. In all cases plot size was 2500 m^2. The location of each plot was obtained via a Geographical Position System (GPS). The same plots were used for all surveys.

In the study area it was not always possible to identify individual species when surveys are conducted in either the dry season or during low and variable rainfall years as many species either loose their foliage or have reduced growth forms. Complete species lists, as far as possible, were collected during the surveys.

According to Werger (1974) the density of individual vegetation species provides information on species dominance in an environment, especially when comparing transects and individual sites along a distance gradient. The relative importance of each species whether tree, shrub, grass or forb was visually assessed as a percentage of area covered by that species within that plot and recorded as a cover abundance scale (Table 3). Bare ground was recorded as a 'vegetation species', and equates to the lack of vegetation cover within a plot.

Only those species that were carrying leaf were identified and analysed. Those trees and shrub species that had become dormant during the dry season were not taken into account during the surveys. However, even species known to be deciduous were counted if they were carrying leaf at the time of the surveys.

Wildlife population data for Kaross and Hobatere were obtained from the Specialist Support Services (SSS) (1999) and domestic stock population data for Palmfontein and Otjokavare were obtained from Leggett *et al.* (2001*a*).

Statistical analysis

As physical conditions and land-use intensity varied across the focus areas, parametric statistics could not be applied to the data. Non-parametric statistic in the form of the

Kruskal-Wallis ANOVA/median analysis was used to test the significance of the observed four data sets for each of the transects.

Results

Vegetation species present

A summary of the number of species of trees and shrubs, grasses and forbs found in the transect plots are presented in Table 4. During the wet season there were similar numbers of tree, shrub and grass species in three of the four focus areas with only Palmfontein having a lesser number of species. Forbs, however, showed a different distribution with Hobatere and Otjokavare having almost double the number of species being observed at either Kaross or Palmfontein.

There was a marked decrease in the number of species of trees, shrubs, grasses and forbs carrying leaf during the dry season. The largest decrease in species numbers occurred in the grasses, where annual grasses species made up to 90% of the total observed species of grasses. Annual forbs suffered a similar decline in most focus areas to that of the annual grasses with the exception of Palmfontein where forbs species were observed in the dry season. It was observed that perennial forbs made up to 80% of the total observed forb species in this area. The number of species of trees and shrubs retaining leaf during the dry season was between 50% and 80% across the focus areas, though the amount of leaf retained was usually less than that observed that during the wet season.

Effect of land use

Examples of the abundance parameters are shown in Figs 2(a)–3(b). Similar abundance graphs were produced for each of the measured vegetation parameters namely cover abundance, bare earth, trees and shrubs, annual grasses, perennial grasses and annual forbs. The seasonal abundance of ground cover across distance gradients in the focus areas are shown in Figs 2(a, b), while Fig. 3(a, b) show the abundance of annual grasses. A percentage abundance scale was used in the graphing of the figures and each point on the graph represents an average value from the two plots at the same distance along the gradients.

Ground cover abundance in the focus areas decreased within 0·5 km of a water source to less than 12·5%. With increasing distance from the water source canopy cover increased to a maximum of 75%. There was no significant difference between the four focus areas during the wet season ($\chi^2 = 6{\cdot}218$, $p = 0{\cdot}102$), but there was a significant difference between the wet and dry season cover abundance ($\chi^2 = 18{\cdot}514$, $p < 0{\cdot}001$) in all areas. There was also a significant difference between the dry season ground cover abundance across/between the focus areas ($\chi^2 = 17{\cdot}714$, $p = 0{\cdot}005$). Otjokavare, Kaross and Palmfontein were observed to have a lower cover abundance (<12·5%) than Hobatere Game Park (12·5% to >75%).

There was little seasonal difference in the bare ground abundance between focus areas, however, there were marked differences between sites across the focal areas during the wet season ($\chi^2 = 11{\cdot}00$, $p = 0{\cdot}012$). All sites in the focus areas had >50% bare ground with Palmfontein recording the highest percentage per plot. During the dry season bare ground abundance increased in three of the four focus areas to be between 75% and 100% with the exception of Hobatere Game Park where the bare ground was between 50% and100%.

There was a significant seasonal difference in the tree and shrub cover abundance across the four focus areas ($\chi^2 = 34{\cdot}67$, $p < 0{\cdot}001$). The greatest difference in the tree

Table 4. *A summary of the number of species of trees and shrubs, grasses and forbs found in transect plots during the 2000 and dry season in the Hoanib River catchment, north-western Namibia*

	No. of species of trees and shrubs		No. of species of grasses		No. of species of forbs	
	Wet season	Dry season*	Wet season	Dry season	Wet season	Dry season
Otjokavare	36	18	24	3	76	10
Hobatere	30	19	27	6	70	32
Kaross	28	21	24	2	37	15
Palmfontein	21	17	14	4	35	29
Mean and STD (in brackets)	28·75 (±6·18)	18·75 (±1·71)	22·25 (±5·68)	3·75 (±1·71)	54·5 (±21·52)	21·5 (±10·66)

*Only those species that were carrying leaf at the time of the survey were included in the analysis.

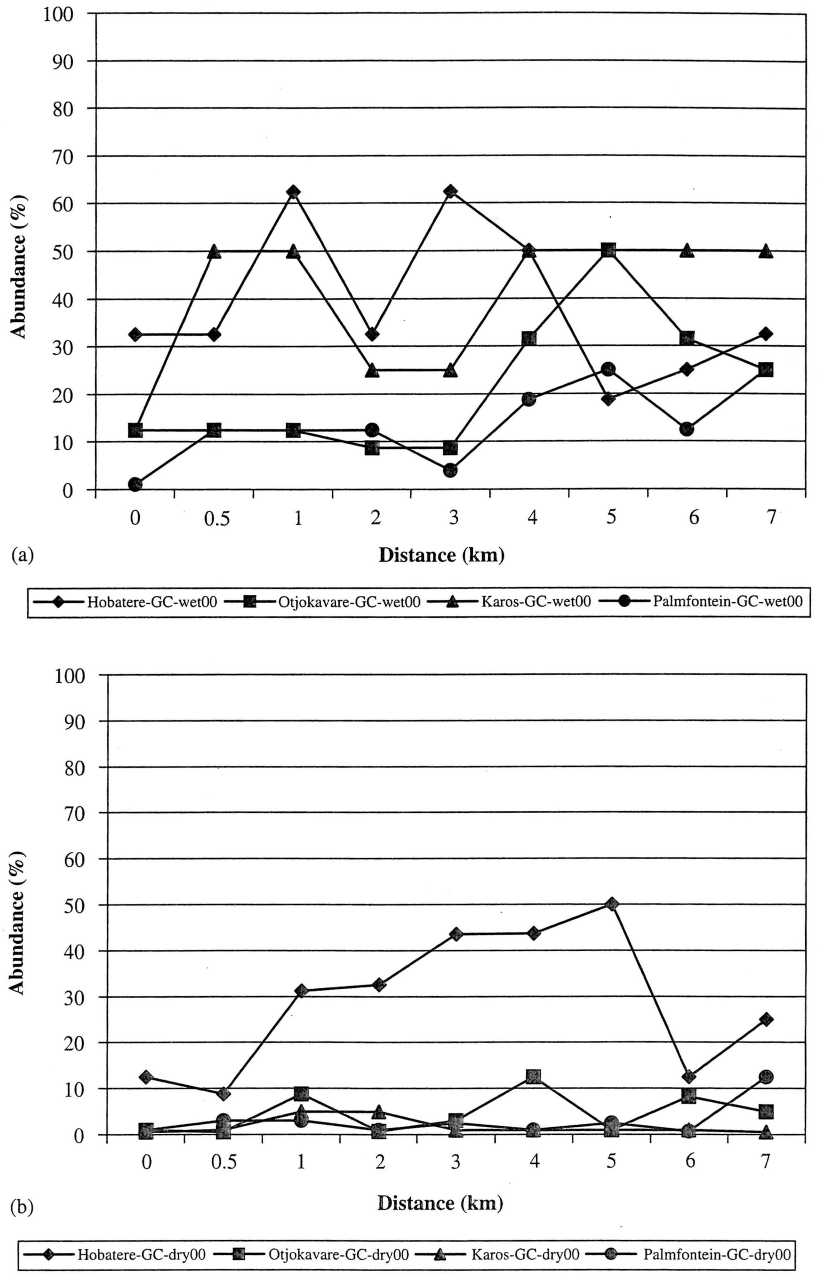
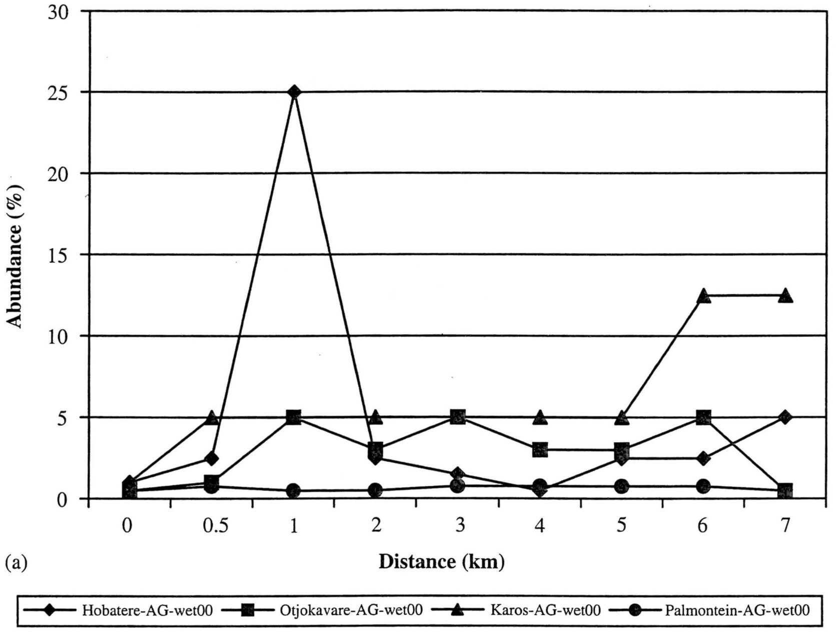
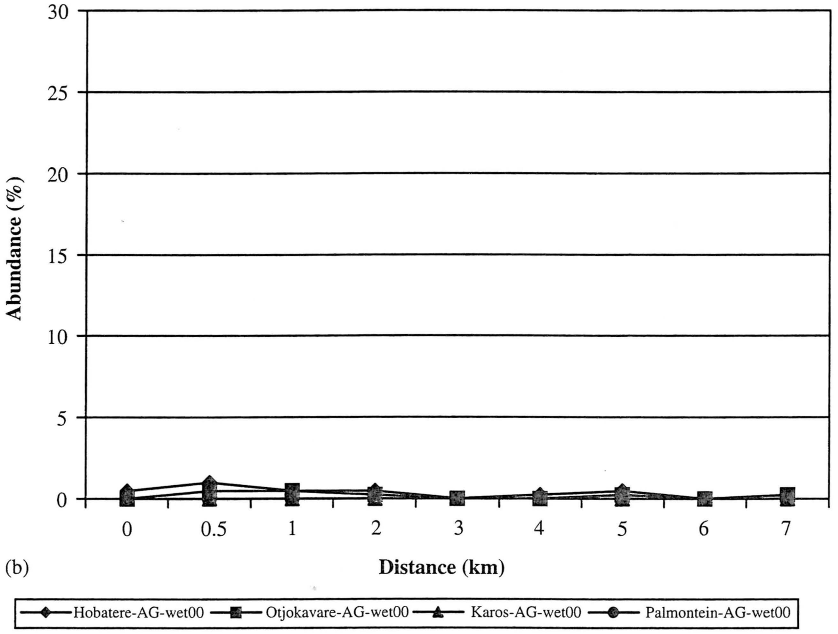


Figure 2. (a) Ground cover abundance observed during the 2000 wet season in transect plots from Otjokavare, Hobatere, Kaross and Palmfontein, north-western Namibia. (b) Ground cover abundance observed during the 2000 dry season in transect plots from Otjokavare, Hobatere, Kaross and Palmfontein, north-western Namibia.

and shrub abundance between the focus areas occurred during the wet season ($\chi^2 = 9{\cdot}04$, $p = 0{\cdot}029$). With the exception of the first 0·5 km around the water sources, the trees and shrub abundance was variable but ranged for all sites from between 5% and 50% (the majority of plots was between 5% and 12·5%). During the



(a)



(b)

Figure 3. (a) Annual grass abundance observed during the 2000 wet season in transect plots from Otjokavare, Hobatere, Kaross and Palmfontein, north-western Namibia. (b) Annual grass abundance observed during the 2000 dry season in transect plots from Otjokavare, Hobatere, Kaross and Palmfontein, north-western Namibia.

dry season there was no significant difference across the focus areas ($\chi^2 = 3{\cdot}90$, $p = 0{\cdot}272$) with all areas having low tree and shrub abundance of <5%.

There was a significant difference in the abundance of the 'dead grass' layer across the four focus areas ($\chi^2 = 9{\cdot}33$, $p = 0{\cdot}025$). Outside of the 0·5 km zone around the water source until approximately 4 km along the distance gradient, Hobatere was observed to have higher percentages of 'dead grass' than any other focus area, but after 4 km there was little difference in the abundance of 'dead grass' in any of the transects.

There was a significant seasonal difference in the abundance of annual grasses in all of the focus areas ($\chi^2 = 44{\cdot}80$, $p<0{\cdot}001$). During the wet season, there was a significant difference in annual grass abundance between focus areas ($\chi^2 = 16{\cdot}73$, $p<0{\cdot}001$). All sites showed low abundance of between 0% and 1% within 0·5 km of the water source. Outside of this zone, annual grass abundance was variable across the distance gradient in three of the four focus areas (1–22%), with only Palmfontein showing consistently lower abundance (1–5%). During the dry season the abundance of annual grasses decreased in all the focus areas to be <1%. Though there was still a difference in annual grasses between the focus areas ($\chi^2 = 16{\cdot}102$, $p = 0{\cdot}001$).

No seasonal difference was observed in the perennial grass abundance in the focus areas. However, a significant difference in the perennial grass abundance was observed between focus areas during the wet season ($\chi^2 = 22{\cdot}50$, $p<0{\cdot}001$). The abundance of perennial grasses was low in focus areas and never amounted to more than 1%.

A significant seasonal difference was observed in forb abundance ($\chi^2 = 5{\cdot}675$, $p = 0{\cdot}017$). The abundance of forbs was at its highest during the wet season with little difference in abundance across the focus areas ($\chi^2 = 4{\cdot}58$, $p = 0{\cdot}205$). The greatest abundance of forbs was observed around the water sources (between 5% and 12·5%) in two of the focus areas, Kaross and Palmfontein, while the abundance of forbs around Hobatere and Otjokavare water sources remained low (<1%). At 2·0 km along the distance gradient the abundance of forbs in all focus areas was approximately the same (<1%). During the dry season the abundance of forbs decreased in most of the focus areas with little difference between focus areas ($\chi^2 = 2{\cdot}55$, $p = 0{\cdot}465$).

Discussion

Impact of different land uses on vegetation

There was little observable difference in the impact on the abundance of vegetation from either domestic stock or wildlife during the above average rainfall of the 200 wet season. All four focus areas exhibited similar abundance for vegetation during the wet season. These observations are supported by Kruger (1998), who reported that stocking rates for domestic stock appeared to have no significant influence on the percentage basal cover and frequency of occurrence of grass species over a 7-year period in the Camel Thorn Savannah of eastern Namibia. In this environment, changes in seasonal rainfall appeared to have a significantly greater impact on basal cover and grass species. Du Plessis *et al.* (1998*a*, *b*) reported, however, that it was impossible to distinguish between the effects of high wildlife grazing intensity and climatic cycling in Etosha National Park.

During the dry season only Hobatere Game Park of the focus areas showed an observable difference in the abundance of vegetation close to the water source. All other areas showed a decline in abundance of vegetation. This is probably due to the ability of wildlife to move seasonally into and out of the game park. This movement reduced the pressure on the land during the dry season resulting in the higher vegetation abundance at this time. This observation is supported by Behnke & Scoones (1993) who state that an effective management method to circumvent stress caused by uncontrolled swings in productivity in non-equilibrium systems (adiabatic controlled) is to allow movement.

Distribution of vegetation in response to grazing pressure

The greatest change in the vegetation abundance and species richness occurred near the water sources in all the focus areas. During the wet season the width of this zone varied between the focus areas from 0·5 to 1·0 km. This area corresponded to the 'sacrifice' zone (Perkins & Thomas, 1993) and is caused by increased disturbance from trampling and intensive grazing, forming a distinct vegetation zone that is dominated by annual grasses and forbs. Similar effects have been reported by a number of authors including Lange (1969) and Pickup (1994). With greater distance from the water source very little difference could be observed in the abundance of vegetation in three of the four focus areas. Similar results to these were reported in the Kalahari desert, Botswana by Ringrose *et al.* (1997).

Of the focus areas, Palmfontein was observed to have the lowest vegetation abundance and diversity of species. This area has been subjected to intensive grazing and is traditionally used as a 'hard times' grazing area by pastoralists of the eastern catchment (Leggett *et al.*, 2001*b*). 'Hard times' grazing areas are only used when traditional grazing areas have been exhausted as they are characterized by poor-quality annual grazing (high percentage of perennial forbs) and inadequate water supplies for large numbers of domestic stock. This area generally supports relatively small numbers of domestic stock (approx. 800–1000, Leggett *et al.*, 2001*b*) during 'normal' rainfall years. However, during drought years when no other grazing is available large numbers of stock (up to 5000 individuals) are pushed into this area because it was the only remaining grazing (Leggett *et al.*, 2001*b*). The lack of tree, shrub and grass species in the area is probably a reflection of the intense grazing pressure to which this area has been subjected. According to Bayer & Waters-Bayer (1994), systems where annuals predominate in a seasonal rainfall pattern, grazing pressure will have an effect on rangeland yield. Further, with more herbaceous perennials, higher grazing pressure can lead to the replacement of perennial grasses by annuals. There appears to be a similar effect on woody species. While most woody species are well adapted to being defoliated, severe browsing or cutting can cause disappearance of woody species, affecting yields in subsequent years (Bayer & Waters-Bayer, 1994).

Seasonal abundance of vegetation under different land uses

There appeared to be a seasonal deficit of grazing for both domestic stock and wildlife in Kaross, Otjokovare and Palmfontein. Kaross is fully enclosed by an electric fence and no movement of animals either into or out of the 14,000 ha area is possible. Grazing pressure is maintained year round in this area. This situation is similar to that occurring in the communal areas around Otjokavare and Palmfontein. Although there are no fences, grazing pressure is maintained year round by domestic stock. During the wet season some of the domestic stock are kept close to the villages by pastoralists for monitoring purposes. During the dry season the domestic stock (particularly small stock) are limited in their movements by available water and tend to be concentrated around permanent water points and human settlements. As a result the vegetation in these areas does not get a chance to rest and recover. The lack of a resting period is believed to be responsible for the lower cover abundance during the dry season in these three areas.

Only Hobatere Game Park appeared to have available grazing during the dry season. This was due to a high abundance of standing 'dead grass' from the previous wet season as the abundance of trees, shrubs, annual grasses, perennial grasses and annual forbs was not significantly different from the other areas. The reliance on the previous seasons 'dead grass' is thought to provide significant nutrition for wildlife and domestic stock. Coppock *et al.* (1986) reported that livestock (in particular, cattle, goats, sheep and camels) survived for 6 months on the nutrition gained from dried stalks of the previous season's grass, seed pods and dried leaves in the arid Turkana region of Kenya.

In all the focus areas, the abundance of perennial grasses and available sources of browsing during the dry season were low. The abundance of perennial grasses and browse allows an ecosystem resistance and resilience to disturbance caused by intensive grazing and drought (Whitford *et al.*, 1999). Fynn & O'Connor (2000) reported that during 'average' or 'above average' rainfall years there does not appear to be reduction in domestic stocks performance (gain animal^{-1} and gain ha^{-1}) even at high stocking rates on heavily stocked rangeland. The ecosystem is essentially behaving as an 'annual' system, with primary production responding to seasonal rains. In the Hoanib River catchment below 'average' rainfall is normal and during drought conditions domestic stock are less productive at high stocking rates on heavily stocked rangeland (Fynn & O'Connor, 2000). If animals cannot migrate out of an area to another with better climatic conditions, a large percentage of the animals will die from lack of sufficient grazing and browsing rather than a deficiency of water. During the 1981–1982 drought approximately 90% domestic stock and 60–80% of the wildlife died in the Hoanib River catchment even though there were sufficient boreholes, springs and wetlands to support them (Viljoen, 1982). These episodic droughts enforce a natural 'resting period' on the veld. The vegetation is generally better adapted to drought and can recover at a more rapid rate than wildlife and domestic stock populations (Dankwerts & Stuart-Hill, 1988). Thus when the land is restocked after a drought period there is a natural resilience built into the ecosystem which allows populations of domestic stock and wildlife to increase until the balance is again disturbed.

Summary

Vegetation in each of the focus areas varied seasonally. Even with the abundant vegetation growth of the 2000 wet season there was an observable difference in species abundance and distribution. Where there was limited range for either domestic stock or wildlife, the effect on the abundance and distribution of vegetation appeared to be similar (Otjokavare, Erweë and Kaross). However, where animals were allowed a more open access to rangelands and seasonal movement their effect on distribution and abundance of vegetation was less (Hobatere).

The lack of perennial grasses and browse availability in all the focus areas indicates that the ecosystem does not have a great degree of resistance and resilience to disturbance caused by grazing animals and drought. Hence, significant mortality can be expected of domestic stock and wildlife during the next drought.

The implications for management from this study are that there appears to be merit in keeping an 'open range' system in operation allowing freedom of movement of wildlife and domestic stock during the wet and dry seasons. Although the 'high impact zone' appears to be relatively small around a water source, the addition of further water sources in an arid area would have the effect of intensifying grazing and browsing, possibly leading to an increase in this zone. What would probably be needed is a management option that would include a more appropriate distribution of water sources, together with a co-ordinated grazing management system that is highly flexible and adaptive.

We would like to thank Dr Mary Seely, Dr Joh Henschel and the staff of the DRFN for their help and assistance throughout the study period. In addition, we would like to thank the Ministry of Agriculture, Water and Rural Development for their continued support and the Ministry of Environment and Tourism for their permission to conduct the study in north-western Namibia. We also give our appreciation to Sida for funding the study, and to the NGOs and line ministries who have provided us with invaluable time, experience and effort. Most importantly, we extend our gratitude to the communities of the Hoanib River catchment.

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