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Full Length Research Paper

Dry season herbivore utilization of open grasslands in Lower Zambezi National Park, Zambia

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Utilisation of open grassland plains by large herbivores (≥100 kg) and harvester ants (*Messor capensis*) in Lower Zambezi National Park, Zambia was assessed every September from 1997 to 2007. A point intercept method was used to estimate percent cover for grass, shrub, bare, litter, herbivore droppings and presence of harvester ants in the Jeki open grassland vegetation community as indicators of range condition. Results showed a reduction in grass cover from 35% in 1997 to 10% in 2007 while litter remained stable. Incidence of herbivore droppings and harvester ants showed a decline while shrub cover and species composition of shrubs increased significantly. As grass cover and grass species composition declined, herbivore droppings and incidence of harvester ants also decreased. Unpalatable species such as *Vernonia* spp. were assumed to be signs of poor quality range. Increase in bush encroachment indicated heavy utilization by herbivores in the dry season when quality of range deteriorated as a consequence of over utilization of grass species. Further research is required to determine population estimates and grazing capacity of key herbivores such as buffalo (*Syncerus caffer*).

Key words: Range utilization, overgrazing, flood plains, valley floor, shrub encroachment.

INTRODUCTION

Lower Zambezi National Park and surrounding Game Management Areas (GMAs) are situated in Agro ecological zone I which is the driest ecological zone in Zambia receiving ≤ 400 mm annual rainfall in the valley floor and 800 mm on the plateau. In this ecological zone, droughts occur 61% of the time (Sichingabula, 1998). Drought occurrences particularly in the valley floor reduce availability of open water and forage for herbivores in the dry season (April/May to October/November). At this time of the year, most tributaries of the Zambezi River such as Chongwe, Musigiswa, and others flow intermittently such that from about September every year, they become sand rivers and any water in them is below surface and not directly available to most herbivores. Elephants *(Loxodonta africana)* are the only species that have the ability to dig down the sand river bed to the water level and in the process making water available to other species. Such water holes made by elephants are limited in number such that by September to October every year, the Zambezi River remains the only main source of water for herbivores (Kajuni, Chansa and Chivumba, 1998). The study assessed dry season grass cover, grass and shrub species composition, incidence of herbivore droppings and harvester ants (*Messor capensis)*, (Picker, et al., 2004), in the grassland plains of the Zambezi Valley floor every September during 1997 to 2007. It was reported that most of the valley floor was over grazed (Jarman, 1972) in the dry season, which led to decline of

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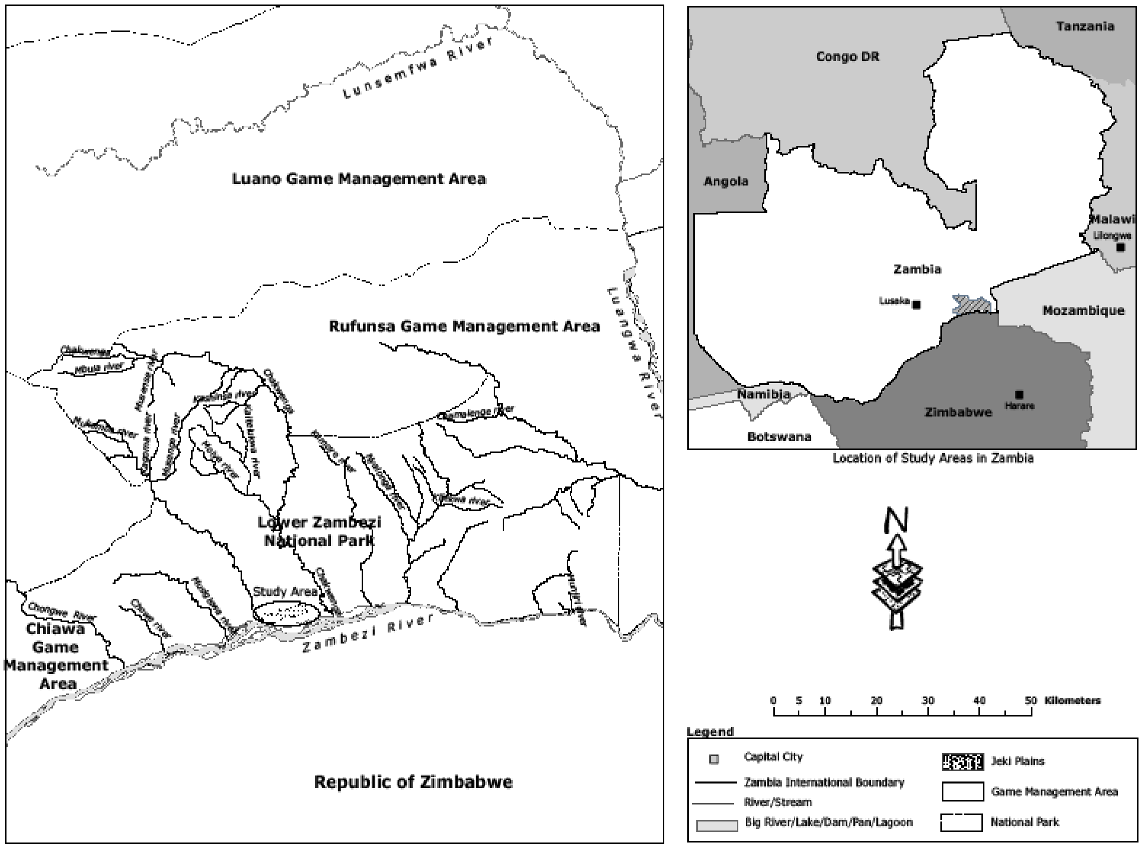

Figure 1. Location of Lower Zambezi National Park, Zambia.

most large herbivores. In light of the potential threats that may arise from global climate change, the suggested research activities were required to monitor range condition and trend for improved management of the Lower Zambezi ecosystem. This study was commissioned to evaluate indicators of range utilization by large herbivores in the dry season when water resources are very limited and suggested ways of ameliorating range deterioration.

MATERIALS AND METHODS

Study area

The Lower Zambezi National Park is approximately 4,092 km^2 in extent located at 15° 7' to 15° 44' South and 29° 10' to 30° 10' East (Figure 1). It is situated in Agro ecological zone I which is a low rainfall region of Zambia receiving about ≤ 800 mm on the plateau and ≤ 400 mm in the valley floor (Sichingabula, 1998). The vegetation communities in the Lower Zambezi National Park comprise riparian forest along the Zambezi River and major tributaries, woodlands which are subdivided into Miombo covering the plateau and escarpment making up over 70% of the area and Mopane on older calcareous alluvial soils along the valley floor and *Acacia* woodlands between Miombo and Mopane woodlands (Kajuni et al., 1998; Chanda , 1991). Grasslands are found mainly in dambos, marshes and on the Zambezi River flood plains which drain the area seasonally. The Jeki plains where the study was carried out is the largest at about 30 km^2 ha in extent (Kajuni et al., 1998).

Field methods

To determine cover of grass, litter, shrub, percent occurrence of herbivore droppings and harvester ants, a point intercept method was used (Brower and Zar, 1977; Walker, 1974). Shrubs considered in this study were those below 1 m high. A 1-m long and 1 m high wooden frame with 10 slanting wore pins placed 10 cm apart was used. The frame was placed over herbaceous plants at 1,000 randomly selected sites in the five hectare area of the Jeki plains and the pins were lowered vertically one after another, one at a time. Phenology and species of plant litter or bare ground touched by each pin was recorded. The frame was placed 1,000 times representing 10,000 sample points during the period 1997 to 2007.

All the hits were added together to provide the total number of hits for each individual species category. The final number of hits was expressed as percent of total number of pins. Incidences of harvester ants and herbivore droppings were also recorded for each sample point. The total number of harvester ant burrows per hectare was recorded in the five hectares sampled area. The amount of litter accumulated by harvester ants at each burrow encountered was collected and weighed using a digital solar scale with readings calibrated to the nearest 0.5 g. An excavation was made in the ground to collect the litter accumulated in 4, 395 burrows examined. Above ground and below ground litter collected was weighed together and classified as husks, seeds and soldier ant heads.

Table 1. Outcome of Chi-square test for percent cover grass, shrub, litter, bare and percent occurrence of herbivore droppings and harvester ants (figures show probability at which differences are significant: = 95% **, NS = Not significant, n = 8).

Parameter	Year								Percent cover and occurrence		
	1997	1998	2000	2002	2003	2005	2006	2007	χ^2	P-value	Significance
Bare	30	30	15	20	20	18	20	10	36.24	0.001	**
Grass	35	35	30	25	18	15	10	10	34.27	0.001	**
Shrub	10	15	30	32	37	43	45	60	54.20	0.001	**
Litter	25	20	25	23	25	24	25	20	1.39	0.250	NS
Herbivore droppings	65	61	63	45	30	15	13	11	102.36	0.001	**
Harvester ants	95	93	96	70	55	30	22	15	136.15	0.001	**

RESULTS

Grass cover and species composition

There was a reduction in grass cover and species composition (Table 1). In 1997 grass cover was 35% comprising 14 grass species, *Brachiaria* spp., *Cenchurus ciliaris, Chloris guyana, Cynodon dactylon, Dactyloctenium aegyptium, Dactyloctenium* spp., *Digitaria* spp., *Echinochloa* spp., *Eragrostis* spp., *Panicum maximum, Pennisetum* spp., *Phragmites* ssp., *Setaria* spp., and *Sporobolus pyramidalis.* Between 1997 and 2007 percent grass cover declined significantly from 35 to 10% in 2007 ($P < 0.001$). Number of grass species per site also declined from 14 to 11. Three grass species, *C. ciliaris, P. maximum* and *D. aegyptium* were totally eliminated from all study sites by 2007 (Table 2). Seven grass species, *Brachiaria* spp., *C. guyana, Dactyloctenium* spp., *Echinochloa* spp., *Eragrostis* spp., *Pennisetum* spp. and *Setaria* spp. were reduced to less than 10% incidence. Only four species *Digitaria* spp., *Phragmites* spp., *C. dactylon* and *S. pyramidalis* maintained percent incidence of between 15 and 65% (Table 2). The results also showed that *Chloris*, *Cenchurus, Dactyloctenium*, *Eragrostis* and *Panicum* species had decreased and might be eliminated by heavy grazing.

Shrub cover

In 1997, shrub cover was 10% with only eight species recorded, *Faidherbia albida, Acacia tortilis, Balanites aegyptiaca, Cassia obtusifolia, Trichodesma zeylanicum, Acanthospermun hispidum, Vernonia* spp. and *Sonchus* spp. In 2007, the shrub cover increased to 60%, which was higher than any cover category (Figure 2) ($Y= 6.4762x + 4.8572$; $R^2 = 0.9553$), with the addition of five species namely; *Adansonia digitata*, *Borassus aethiopium*, *Diospyros* spp., *F. albida* and *Trichilia emetica*.

Litter and herbivore droppings

Litter from dry grass and tree leaves remained relatively stable from 25% in 1997 declining slightly to only 20% in 2007 (Figure 2). Herbivore droppings declined during the period 1997 to 2007, from 65% in 1997 to 11% in 2007 (Figure 2).

Harvester ants

The incidence of harvester ants declined from 95% in 1997 to15% in 2007 (Figure 2). The number of burrows per hectare also declined significantly ($P< 0.005$)from 605 in 1997 to 255 in 2007. The mean per hectare during the period 1997 to 2007 was 400. Each burrow had a mean weight of 300 g of litter giving a mean of 124 kg litter per hectare (Table 3). The mean above ground grass husks during 1997 to 2007 comprised 97% with only 3% seeds. On the other hand below ground, 75% of the litter was grass seeds. The remaining 25% comprised of heads of dead ant soldiers piled up in a separate chamber. The below ground proportion of grass seeds to dead soldier heads remained relatively constant during the period 1997 to 2007 ($P>0.005$).

DISCUSSION

Shrub encroachment

The results obtained in this study during the period 1997 to 2007 showed that shrubs such as *Vernonia*, *Sonchus, Ocimum canum* and *Acanthospermum* spp. which are unpalatable to the grazers displaced grasses in many sample points of the study area. This was caused by aggregation of herbivores in the dry season in the open grasslands. Increased frequency of grazing and intensity on palatable grass species reduced plant vigour which became easily out competed by less palatable shrubs as also reported by Western (1975) and Jarman (1972). Unpalatable species of shrubs (Vernon 1983) such as *Acanthospermum* spp, *Sonchus* spp., *Vernonia* spp., *Sida alba* and *Euphorbia* spp., replaced palatable grass species namely *Chloris* spp., *Cynodon* spp., *Dactyloctenium* spp., *Echinocloa colona*, *Eragrostis* spp., and *Panicum* spp., *Phragmites* spp., *Echinocloa* spp.,

Table 2. Percent of species occurrence of grass and shrub in the study area and the years in which some species were eliminated from the sites and emergence of others.

Species	**Years and % of occurrence, disappearance and emergence of species**									**Preferred site**
Grass	1997	1998	2000	2002	2003	2005	2006	2007	Rating	
Brachiaria spp	5	5	5	3	3	3	3	3	Heavily grazed	On wet soil under shade
Cenchurus ciliaris	30	28	30	30	15	10	0	0	Heavily grazed,	Near termite mounds, over grazed areas
Chloris guyana	3	3	3	3	3	3	3	3	Heavily grazed	On edges of dry river channels
Cynodon dactylon	47	50	50	50	48	48	48	48	Heavily grazed,	Was present mainly on all soils except on sandy soils. Resisted grazing pressure
Dactyloctenium aegyptium	30	25	15	5	2	1	0	0	Heavily grazed palatable	Common on sandy soils
Dactyloctenium spp	15	15	5	8	7	5	5	3	Heavily grazed	On sandy soils, on over grazed areas
Digitaria spp	15	15	15	15	15	15	15	15	Grazed	On island edges and near water
Echinochloa spp	10	10	10	10	10	10	10	10	Grazed	Common on wet areas only
Eragrostis spp	15	13	10	11	10	8	7	5	Grazed	On shallow soils. Was not usually grazed
Panicum maximum	35	35	3	3	1	0	0	0	Heavily grazed	On old river channels and banks. Heavily grazed
Pennisetum spp	10	10	9	7	10	9	7	7	Heavily Grazed	On edges of permanent water
Phragmites ssp	30	30	30	30	30	30	30	30	Grazed by elephant	On islands.
Setaria spp	15	15	13	10	10	10	7	7	grazed	Near termite mounds. Flower heads catching on clothes
Sporobolus pyramidalis	65	65	65	65	65	65	65	65	Very limited grazing	In many soil types. Generally avoided by grazers
Shrub										
Trichilia emetica	0	0	1	2	5	13	17	25	No record	
Faidhebia albida	10	17	30	35	62	64	66	71	Heavily Browsed	Particularly on old river channels
Diospyros spp	0		1	3	3	5	5	5	Browsed	Particularly near termite mounds and ant hills
Borassus aethiopium	0	5	5	10	15	15	15	16	Browsed by elephant	Was non selective but more common near stream banks
Acacia tortilis	3	3	4	4	5	11	15	19	Heavily Browsed	Was non selective, but was more common on dry river channels
Adansonia digitata	0	0	0	2	2	2	2	2	Browsed Fruits eaten	Showed no particular preference
Balanites aegyptiaca	1	1	1	1	1	3	3	3	Browsed	Found mainly on termite mounds and ant hills
Cassia obtusifolia	3	3	0	0	1	1	0	0	No record	Found in wetter areas
Trichodesma zeylanicum	7	7	3	0	0	0	0	0	Not browsed	Dry heavily grazed areas
Acanthospermun hispidum	21	2	18	23	25	13	11	9	Not browsed	Found on heavily grazed areas
Vernonia spp.	55	55	38	45	43	45	45	43	Not browsed	Found on heavily grazed areas
Sonchus spp.	11	8	11	5	5	0	0	3	Not browsed	Was common on dry river channels

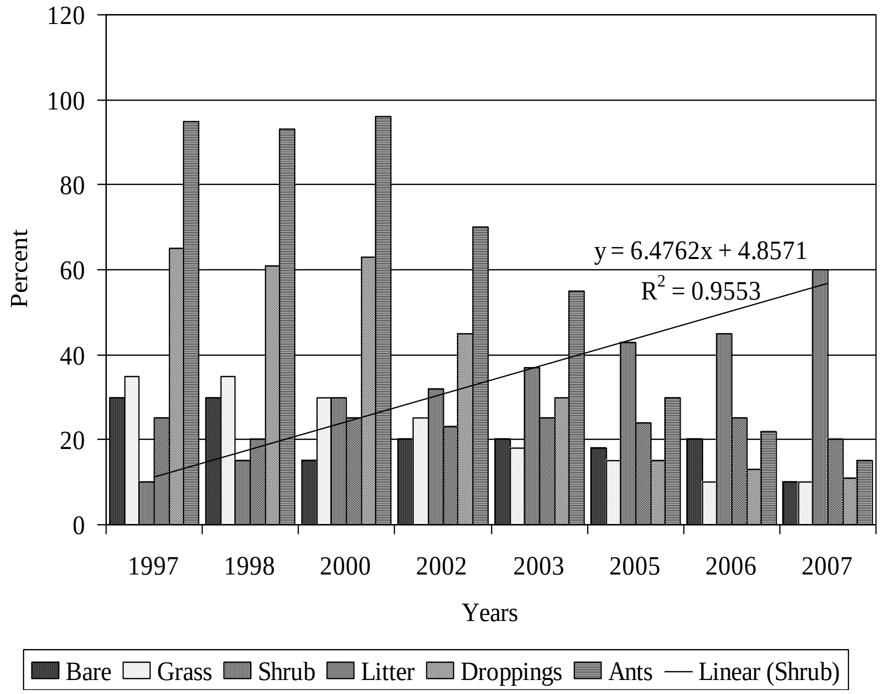

Figure 2. Change in percent cover of grass, bare, litter, shrub and incidence of herbivore droppings and harvester ants, during 1997 to 2007.

Table 3. Number of harvester ant burrows per ha, weight of litter in grammes and percent.

Year	Number of burrows	Mean weight in grammes per burrow	Total weight in grammes per ha.	Percent proportion of grass seeds below ground	Percent proportion of dead soldier heads below ground
1997	605	550	332,750	87	13
1998	650	600	390,000	90	10
1999	500	430	215,000	80	20
2000	355	250	88,750	83	27
2001	400	300	120,000	74	26
2002	550	430	16,500	70	30
2003	320	225	72,000	62	38
2004	255	140	35,700	65	35
2005	250	125	31,250	71	29
2006	255	135	34,425	73	27
2007	255	120	30,600	75	25
Mean	400	300	124,270	75	25

Below ground proportion of grass seeds to soldier heads.

Sporobolus spp., and *Chloris* spp.; however, persisted. Palatable species of grass could not withstand grazing pressure and were replaced by less palatable (increasers) and shrubs. The loss of grass species which were replaced by shrubs as range deteriorated increased species composition and cover of shrubs shown in Figure 2.

The results of this study indicated that open grassland plains were being encroached by shrubs and woody vegetation. We also suggested other factors exacerbating woody encroachment as being; lower numbers of elephants, which previously opened more of the woodlands through their feeding habits of knocking down trees and breaking branches. The numbers of elephants present in the National Park of 1,000 to 3,000 were far much lower than the > 5,000 individuals recorded in the 1970s (Mwima and Yoneda, 1995). The large herds of elephant kept woody vegetation under control. On the other hand, the implications of the removal of fire used by the Nsenga people when the reserve was established in the 1950s eliminated the slash and burn subsistence farming which played a significant role as a factor in the woodland dynamics of the area. This latter factor has not been well researched and understood. It is assumed that the combination of the reduction in elephant numbers, removal of the Nsenga people and the disruption of the natural flooding regime may have collectively accentuated encroachment of woody vegetation on former flood plains.

Incidence of litter and herbivore droppings

The amount of litter remained relatively stable becauseas litter from grass declined it was replaced by litter from shrubs (see Figure 2). Herbivore droppings also declined, which may have affected soil fertility in grassland plains. McNaughton (1985) and McNaughton et al. (1988) explained how herbivores affect primary production and regulate recycling balance through their dung output. Yet little attention is paid to their spatial and temporal variation in the incorporation of dung into the soi (Grimsdell, 1978). As palatable grass species are eliminated from an area, herbivore utilization of the area also declines which also reduces herbivore droppings.

Soil trampling by ungulates

In areas defaced of vegetation cover, trampling of hooves further hardened the soil, reducing water percolation and retention rates and increased water evaporation (Dunnet, 1997). This resulted in open plains being colonized by shallow rooted therophytes, which could not hold the soil together to prevent soil erosion which also contributed to range deterioration. The beneficial effects of large numbers of herbivores and their hooves observed in other natural areas with large numbers of large mammals such as the Serengeti National Park in Tanzania and Masaai Mara National Reserve in Kenya (Bell, 1971) is not felt in the Lower Zambezi area. This is because the herbivores in the Lower Zambezi National Park area, are largely resident except elephants which migrate seasonally otherwise the rest of the herbivores do not leave room for recovery of the range, while the ones in Serengeti migrate giving chance to the range to recover from grazing pressure.

Incidence of harvester ants

Harvester ants mainly feed on grass seeds, which they store in their nests in the ground. Towards the end of the season, soldiers of the harvester ants are killed by the minor workers and their bodies together with grass seeds are eaten up, but the huge heads are piled up in the chamber of the nest (Bertin, 1967). These heads together with the left over grass materials subsequently decompose releasing nutrients to the soil. Abandoned grass seeds germinate which assist in seed dispersal and maintenance of grass species composition, which later provide food for the ants and large herbivores. Therefore, as grass species and cover declined during the period 1997 to 2007, the incidence of harvester ant burrows and weight of litter buried in them also declined and may have subsequently disturbed the balance as harvester ants depend on grass for their sustenance while the grasses benefit from harvester ants that spread their seeds. In this study it was assumed that the mean number of 400 burrows per hectare was a minimum value for a healthy density of harvester ants in the Lower Zambezi National Park valley floor.

The activities of harvester ants which involves gathering of seeds and leaves for food is important in maintaining the ecological balance of grasslands. *Messor* spp. in particular, collect husk and seeds which they store in their nests and unlike other genera do not grow fungal gardens. Overgrazing by large herbivores on the Jeki plains of the Lower Zambezi National Park therefore, seem to have reduced food available to harvester ants and may have caused the decline in the number of harvester ant burrows and weight of litter per hectare. Fire, particularly late season (September – November) may also be a contributing factor to the overall reduction in grass litter which negatively affect harvester ants. The reduction in the below ground proportion of grass seeds to dead soldiers heads during the period 1997 to 2007 could be attributed to the reduced amount of grass litter available per burrow. It would appear that when grass litter is abundant the proportion of grass seeds to dead soldiers' heads is always skewed in favour of grass seeds and vice versa. Harvester ants are known to ferment grass seeds and eat them completely when the quantity is low. In seasons of food abundance they may eat the fleshy, edible appendages (the fat body or elaiosome) of certain specialized seeds which they also disperse in the process. During the seasons of food shortage, the dispersal of grass seeds may be reduced. In such years, all grass seeds are eaten and all soldiers are killed off by minor workers and their bodies eaten leaving their large heads in a separate chamber. This could be the reason why areas previously occupied by grasses were taken over by shrubs as no grass seeds were left to germinate during the subsequent rainy season.

Further research will be required to determine whether harvester ants select grass seed size, morphology and species in which case, it could be advantageous for a plant species to invest the total productive effort in a large number of very small seeds rather than in a few big ones. Only those species favoured by the harvester ants would succeed by virtue of being spread by harvester ants. Other species may be avoided by virtue of toxic seed constituents and may not benefit from the dispersal by ants. Seed size in its own right may also be a factor to consider. Ecologically, seed size is important in breaking dormancy. Therefore, being a small seed can only sample that part of the environment immediately adjacent to it, which is not necessarily representative of the generally prevailing conditions. In this study, we could not conclude with certainty the major causes of decline in the number of harvester ant burrows and weight of litter. It is therefore, important to investigate further the size, shape, internal structure, life span and number of seeds produced by each decreaser or increaser to determine their vulnerability to harvester ants and vice versa.

Influence of harvester ants on soil fertility

Grazers produce large amounts of dung and insects such as harvester ants also play an important role in nutrient recycling and seed dispersal by burying pieces of grass and seeds in the soil. Such litter later breakdown adding to the soil nutrient status. Such symbiotic relationship between harvester ants and grass has a beneficial effect on soil structure, soil nutrients, soil aeration, water percolation, and seed dispersal. This symbiotic relationship however, was being disrupted in the grassland plains of the Lower Zambezi National Park as shrubs took over most of the sites and the number of harvester ant burrows declined (Table 3). As the number of burrows declined the amount of grass seeds buried under ground also declined which reduced the regeneration potential of many grass species, some of which are grazed by herbivores.

The future of the lower Zambezi grassland plains

Grimsdell (1978) observed that open grasslands and woodland communities were in a state of flux whose major influencing factors were; climate, man, fire and elephants. In the Lower Zambezi area, it will be important to monitor and collect ecological data on a number of ecological factors such as; climate, man, fire, harvester ants, elephants and other large herbivores and many others. Subsequently, a summary of some of the key ecological factors to be considered in long-term ecological monitoring of the Zambezi Valley floor is provided below under recommendations.

RECOMMENDATIONS

Shrub encroachment

The study of encroachment of grassland plains by woody vegetation is critical in maintaining pasture and sustaining herbivores depending on them. In order to maintain quality pasture for herbivores, Zambia Wildlife Authority should provide guidance on the control of shrubs on open grassland plains.

Monitoring changes in the flood regime

The upstream impoundments of both Zambezi and Kafue Rivers for hydroelectric power generation are of great consequence to the ecology and plant community distribution on the flood plains and islands in the Lower Zambezi National Park (Sichingabula, 1998). Zambia Wildlife Authority should commission a long-term study to assess any adverse impacts not only on plant communities but the gradual loss of river channels which are being colonized by wood plant species.

Disrupted flush floods and possible loss of soil fertility

Current records on rainfall indicate that Lower Zambezi area experiences more drought occurrences than any other area in Zambia (Sichingabula, 1998). The only area of the Zambezi Valley which experiences fewer droughts is around Lake Kariba possibly caused by the formation of a lake breeze system (Hutchinson, 1973) which seems to have minimized the drought vulnerability of this drought prone area. The remaining part of the Zambezi Valley is drought prone. The effects of drought and low rainfall in the Lower Zambezi National Park and the effects of the pre and post impoundments of the Zambezi River at Kariba and Kafue River at Itezhi Tezhi have not been assessed.

A long-term study will be required to determine the impact of these impoundments on the disruption of flush floods and sediment load deposition on the grassland plains as this is likely to reduce soil fertility. It is possible that due to reduced flooding frequency and intensity, a number of areas previously inundated with water are no longer affected by floods and have lost the sediment deposition previously brought about by the regular flooding regimes.

Removal of the Nsenga people and reduction of elephant population

The impacts of the removal of fire originally used by the Nsenga people in their slush and burn agriculture before the area was declared a reserve; the reduction of elephant numbers through poaching evidenced through out the African continent in the late 1970s up to the 1980s have not been critically assessed in order to understand their long term influence on vegetation dynamics in the Lower Zambezi National Park. Understanding the role of elephants in vegetation dyanamics will enable ZAWA to manage the vegetation communities in Lower Zambezi National Park in a manner that would maintain open grasslands for grazers.

Localised seasonal grazing by large herbivores

We noted in this study that shrubs and woody plants showed a significant increase (Figure 2). As a consequence of this change, most herbivores concentrated their grazing on few and smaller plains causing stress on palatable species of grass. The impacts associated with these changes must be studied in more details if management is to understand and manage the National Park based on empirical evidence and sound conservation goals. An effective way of managing the National Park would be to establish a long-term ecological monitoring program. Such a programme would check and document not only changes in vegetation as a result of those major influences introduced on ecosystems but also their effects to animal population dynamics.

Development of tourist accommodation facilities

By 2007 there were nineteen (19) lodges along the riverbank of up to 16-bed capacity. Some of these tourist accommodation facilities were close to each other, in some instances less than 5 km between them. The location of these facilities on grassland plains may have reduced area available to grazers. For instance, during construction phases of the tourist lodges, soil excavation is carried out (Sichingabula, 1998) which because of the fragility of the soils in the flood plain, may have accentuated soil erosion in those sites further reducing the extent of the open grassland plains available to herbivores. The policy of locating tourist facilities or any other infrastructure developments along the riverbank, open plains, islands and near multiple channels should be reviewed within the framework of mitigating their impacts in order to save the open grassland plain habitats and the herbivores which depend on them for their sustenance.

Range condition and trend

Oudtshoorn (1992) and Dunne (1977) outlined major criterion for characterizing range that is in poor condition with signs of erosion. To that effect, poor vegetation cover inevitably leads to accelerated soil erosion because it reduces the capacity of the range to absorb and retain water which results in exhaustion of the soil and hence reduced range ability to recover from herbivore use. In order to understand the relationship between height and weight of the different grass species in the mid Zambezi area with a view to estimating optimum range utilization, botanical inventories of plant species in the open plains and islands are required.

Additional studies to determine the correlation between height and weight for different grass species must also be undertaken. Such correlation would provide a means to estimate a minimum amount of vegetation cover that could be allowed in the open plains before irreversible range deterioration occurs. Such studies would provide standard forage utilization estimates in respect of height/weight for the different important grass species in the area. Particular attention should be paid to grazing lawns along the river bank and islands, as these are a result of deposited alluvial and as the rate and locality of this deposition is a function of river flow dynamics, monitoring should take place to assess the extent and changes in this key resource. Another area of future study should be the quantification of the abundance and distribution of vegetation communities and cover assessments over time.

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