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Abstract

This study was conducted to determine the effects of the erection of the Makgadikgadi wildlife fence along the western border of the Makgadikgadi Pans National Park on cattle populations and livestock owners to the west of the fence. Cattle foraging behavior and movement patterns were recorded using GPS and focal observation methods to determine resource use and pressures affecting the populations. Interviews were also conducted in the area of Meno-a-Kwena camp to examine the effects of the fence on the economics of the local cattle industry. Signs of resource stress were found in the continued selection of poor quality forage, land degradation around boreholes, and movement patterns that pushed the water bearing capacity of the animals as they searched for quality forage. Interviews contradicted these findings to a certain extent, while extolling the good effects of the fence on cattle predation by wildlife and premium prices offered by BMC as a result of the fence's disease-controlling effects.

Acknowledgements

First, we’d like to give a shout out to Dr. Chris Brooks, who patiently taught us all we know about how to track cows in the bush and be good behavioral ecologists, and telling us amazing bush stories at night. We’d also like to thank him for giving us his beautiful 1985 land cruiser, the Blue Lotus, even though we had to push it a lot. To A.G., our translator, the protector of our well-being, driver, and very patient mechanic, an enormous hug is also due. All of our friends at Meno-a-Kwena camp kept us sane after hours of watching cows eat every day, kept us laughing, and made us feel safe when the lions were around. To David Dugmore, the owner of Meno-a-Kwena we owe a huge thanks for his donation of camping space to students over the years, and most importantly his deep involvement in community development. The Tswana families at the cattle posts were very careful not to laugh too hard at us while we followed their cows with stopwatches, GPS, and clipboards, and without their help we would have lost the cows many, many times. I intend to take them up on their offer of coming over for Christmas and bojalwa. Of course, where would we be in the world without the SIT gang; Simba, thanks for introducing us to Chris, Matts, thanks for helping me establish good will with the families of the cattle posts, and to our fellow wandering students, thanks for listening patiently to our complaints and supporting us in every thing, from cooking meals at Sedia to emotional break-downs.

I. Introduction

i. Distribution of Grazing Herbivores

The distribution of grazing herbivores at large spatial scales is determined predominantly by extrinsic constraints placed upon the animals by their environments. In semi-arid conditions, the distance to water is the main defining factor of distribution (Arsenault & Owen-Smith, 2002). In domestic animals such as cattle there are additional limiting factors, as they must remain close to the human settlements they are affiliated with, often returning to a kraal at night, and historically agropastoral settlements in Botswana are located in areas ideal for agriculture, not necessarily cattle grazing (Denbow & Wilmsen, 1986). For example, in Kenya it was shown that the greatest predictor of grazing intensity of cattle over an area was distance from their kraal, with distance to water then being the second defining factor (Coppolillo, 2001).

Within the framework of broad environmental and historical constraints, animals can be thought to select grazing patches whose location and species composition allow net energy gain from feeding to be maximized, a model known as optimal foraging theory. According to optimization theory, herbivores have evolved feeding strategies that increase their reproductive fitness through maximum energy extraction from foraging (Houston & McNamara, 1999). ‘Prey’ items available in the animal’s environment are ranked according to their net energy content (Catania & Remple, 2005), mitigated by the digestive efficiency of consuming them (Westoboy, 1974) and the energy required to acquire them. The selection of ‘prey’ in grazing herbivores is highly complex due to the non-discrete nature of grazing swards and the variable distribution of vegetation type along gradients of soil quality and other abiotic environmental factors (Georgiadis &

McNaughton, 1990). According to optimization theory, cattle would save energy by moving as little as possible in search of food, assuming a homogenous environment of forage. As this is not an accurate assumption, the energetic benefits of pursuing higher quality forage in terms of nutritive content and digestibility may outweigh the energetic costs of locomotion, distance from water, and risk of predation (Duncan, 1983). The selection of feeding patches by animals within the optimization perspective therefore defines their population distribution within the overarching constraints imposed by the environment. Changes in the distribution of a population are indicative of changes in resource availability and composition, and limitations in specific resources, such as water or nutritious grasses, are reflected in the distribution of a population.

ii. Patterns of distribution in resource limited environments

In semi-arid conditions where water is a limiting factor, grazing herbivores have been shown to display a central-place foraging pattern centered around the limiting resource (Coppolillo, 2001). Grazing is observed to be focused radially outwards from a waterhole, as animals must return to the waterhole after time intervals defined by the intrinsic constraints of their physiology in terms of water retention and thermoregulation (Twine, 2002). In conditions where availability of quality forage is limited, grazing ungulates may attempt to compensate by expanding their grazing radius. Yet, in arid environments they are limited in the distance they can travel by their central-place foraging strategy. Animals may also compensate for resource limitations by eating a greater total biomass of forage of lower quality to meet their energy needs, thus decreasing their degree of selectivity in what they consume and increasing their intake rate (assuming that time constraints are unaffected by quality forage availability)

(Edwards *et al*, 1994). This contrasts with feeding behavior in times of plenty, as when high-quality forage is abundant wild herbivore populations and cattle both show a high degree of selectivity (Ego *et al.*, 2003). Browsing on shrubs and woody plants rather than grasses is of lower digestive efficiency for cattle, but if quality forage resources are limited within the grazing radius permitted them by water and predation constraints they may acquire up to 34% of their diet from browsing (Rees, 1974). In populations of wildebeest, kongoni and cattle in Kenya, the decrease in available forage associated with dry season conditions caused all species to increase the browse components of their diet by 100%, and cattle always consumed twice as much browse as wild herbivores (Ego *et al*, 2003). Resource limitation in populations of cattle is therefore reflected both in patch selection through rate of intake, degree of selectivity, and nutrient content, and in overall herd movements through forage radius in central-place foragers.

iii. Resource-based conflict

Guilds of wild herbivores in African ecosystems have evolved together in such a way that strong competition for food has generally been eliminated and resource partitioning occurs at many scales within their shared habitat. This equilibrium of sorts is established by the elimination of strong competitive interactions through competitive exclusion and the consequent extinction or niche specialization of involved species (Connell, 1980). In fact, these indigenous animals have been shown to facilitate one another's feeding behavior. Grazing by one species may make grass more accessible to other species depending on their body size or feeding morphology. One species may also consume specific parts of plants unpalatable to others, making the effort required to feed less for the secondary feeder, or stimulate grass regrowth for future grazers (Jersey-Fitzgerald, 1974).

Based on linguistic and archaeological evidence, cattle were introduced to southern Africa in the early centuries AD, (Denbow & Wilmsen, 1986), and are therefore no strangers to the wildlife of the area. However, their evolution has followed a sufficiently distinct path to allow strong resource overlap and high potential for competitive exclusion of indigenous herbivores. Overlapping resource use does not directly indicate competition without evidence of detrimental effect on reproductive success of one of the species involved (Field, 1972). However, the potentially damaging ecological effects of livestock grazing are diverse. Through the active selection of specific plant species by livestock and the differential vulnerability of those species to grazing or trampling, livestock may greatly alter the plant community structure of an area and both directly through consumption or indirectly affect resource availability for indigenous herbivores and the viability of the habitat for future resource productivity (Fleischner, 1994). The dietary overlap between cattle and indigenous herbivores in South Africa, while present throughout the year, increases during the resource-limiting dry season (Ego *et al.*, 2003). Zebra herds in Makgadikgadi Pans National Park of Botswana were observed to travel to the ends of their physical endurance in search of forage, potentially due to the presence of cattle in their preferred foraging areas close to water holes (Brooks, 2005).

iv. Livestock-wildlife conflict and the effects of fencing

Conflicts of interest between the livestock industry and conservation are occurring throughout the African continent and with increasing intensity as human populations continue to expand. In countries highly dependent on beef for export and the daily sustenance of people in rural areas, the interests and distribution of livestock have a large impact on conservation. The killing of livestock by large predators, predominantly lion and hyena and the trampling of crops by elephant have pushed for the division of wildlife from human populations, either by eradicating wildlife deemed ‘invasive’ through culling or illegal poisoning and shooting of animals by livestock owners or creating physical barriers such as fences. The traditional methods of fencing to prevent crop raiding and livestock kills by wildlife are stone or thorn barriers, however electric fences are much more efficient at deterring wildlife.

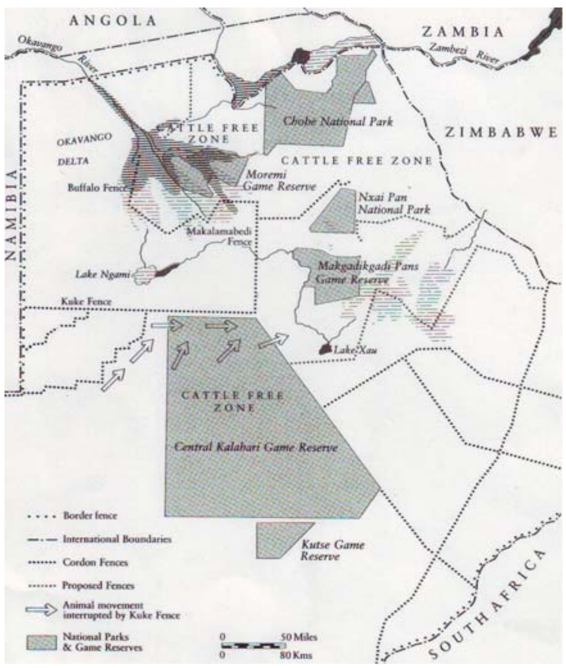

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Figure A: Map of Botswana cattle zones and fences

In the 1950’s, the government of Botswana began building such fences to prevent the spread of foot and mouth disease from buffalo to cattle, allowing export to the EU at a premium price (Darkoh and Mbaiwa, 2002). The Kuke fence along the northern border of the Central Kalahari Game Reserve caused the deaths of 65,000 wildebeest in 1983, as the animals attempted to migrate north to the Okavango delta, only to meet the fence and death from thirst and starvation. Mortality of migrating animals through fence entanglement, dehydration, malnutrition, and starvation are common results of the partitioning of such an ancient ecosystem. Migrating animals may also make detours into settled areas if fencing blocks their traditional routes, causing more conflict, as occurred in 1991 along the Makoro-Makoba veterinary fence with herds of hartebeest and eland. The concentration of wildlife into smaller areas by fences restricts gene flow between different wildlife populations and may not provide adequate land area to support the territory sizes demanded by certain species like jackal and hyena, causing mortality and resource stress (Kalikawe, 1997). However, the shooting of already small predator populations and the biological magnification resulting from poisoning of carcasses may be prevented by fencing in high-conflict areas. Where cattle and wildlife compete for forage resources, the exclusion of cattle from parks and wildlife management areas may act to reduce resource stress in indigenous grazing herbivores (Brooks, 2005). While fences are erected by government for the benefit of the people by reducing transmission of bovine diseases by buffalo, they may also cut off grazing lands previously available to cattle populations within wildlife areas. The effects of fencing on resource stress in cattle is yet unstudied, and the reaction of cattle productivity to fencing determines greatly in the future alignment alteration or destruction of established fences.

v. The Study Area: Boteti River, Makgadikgadi Pans National Park Fence

The Makgadikgadi Pans complex was formed eons ago by the drainage of the Zambezi, Okavango, Kafue, Lualaba, and Nata rivers, forming the enormous lake Paleo-

Makgadikgadi. With tectonic activity and subsequent landscape alteration, these rivers have changed course or disappeared altogether, leaving a huge depression and vast salt pans through inflow and evaporation. In present day, the area is an internal drainage basin for all of the water absorbed by surrounding areas, and groundwater is present within a few meters of the surface. The pans flood after the rainy season, and create Botswana's largest wetland habitat and possibly second RAMSAR site after the Okavango Delta. Soil around the pans is characterized as saline and nutrient poor, available only to halophytic grasses. The landscape is dominated ancient lake features, such as the ridges around Moremaoto representing the ancient lake shoreline, and is otherwise entirely flat. The Boteti river once ran along the western boundary of the MPNP, but has not flowed since 1991. While the riverbed is dry, underground aqueducts support rich growths of vegetation and woodlands within it (Parry, 1995). The riverbed is a key dry season water source for thousands of migrating Burchell's zebra (*Equus burchelli)* and blue wildebeest (*Connochaetea taurinius*) and the pans attract scores of migrating lesser and greater flamingoes (*Phoenicopterus spp.)* as well as supporting predator populations. Most migratory ungulates spend the dry season along the Boteti riverbed, and follow the rains east towards the pans, where they foal and spend the wet season (Brooks, 2005).

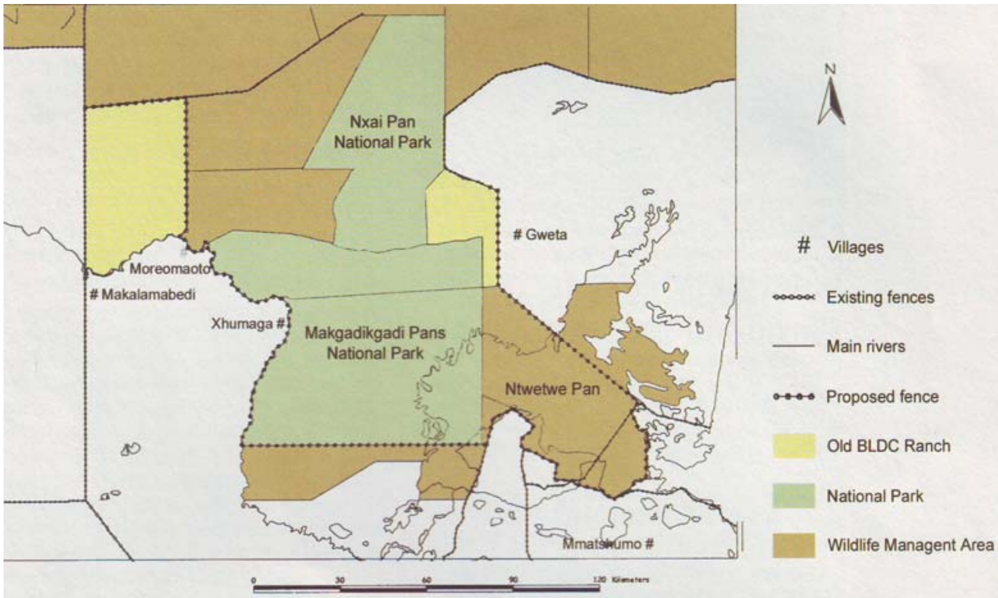

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Figure B: Makgadikgadi Pans complex and land use context map

In 2004, the government of Botswana constructed a 480 km fence along the Boteti riverbed in order to reduce conflict between wildlife in the Makgadikgadi Pans National Park (MPNP) and livestock living to the west of the park, at a total cost of 3.5 million pula. Before the fence was erected, predators would cross the dried river to prey on livestock, mainly cattle. Farmers would respond by killing problem animals, and this in turn affected feeding and social habits of predators, and the stability of the park's predator populations, which besides lion and hyena, include the endangered African wild dog and cheetah. In 2005, after the erection of the fence, a 45.1% decrease in the number of cows killed by predators, a 9.9% decrease in lion predation and a 28.7% decrease in hyena predation were reported by interviewed livestock owners (Gupta, 2005).

An EA was conducted by Scott Wilson Kirkpatrick and Partners, but comprised mostly desk-work and its recommendations were not adhered to by the government (EIA, 2004). By the current alignment, most of the Boteti riverbed is fenced outside of MPNP, due to the interests of people and livestock owners living in the area, but to the great detriment of wildlife. The EA suggested that the fence be zig-zagged along the riverbed to allow equal partitioning of water resources for livestock and wildlife, but individual parties were unwilling to sacrifice their land to the fence, despite the opportunities for eco-tourism on tribal lands inherent in being included within the park (David Dugmore, interview). Indeed, in the Management Plan published for MPNP, it was suggested that any fencing projects be conducted only along areas of intense conflict, such as from Khumaga to Meno-a-kwena, and not along the entire riverbed (Ferrar, 1995). While the recommended fire breaks have been put in place to prevent wildlife being trapped against the fence in the instance of veld fires, the push for more boreholes on the inside of the park has been very slow as funds in DWNP are lacking. It has been suggested by David Dugmore, owner of Meno-a-Kwena tourism camp, that the drilling be taken on by private tourism interests rather than the government (David Dugmore, personal interview).

Monitoring of wildlife mortalities along the fence in 2005 reported high incident of zebra deaths, and in mid-January 254 zebra, 131 of them juveniles, died in one week from exhaustion and dehydration as they trekked back to the Boteti riverbed due to bad rains in the East, only to have the fence blocking their water access. Oddities of fence construction, specifically large loops, confused zebra and caused them to go in circles along the fence, eventually resulting in death. While providing protection from dangerous predators, the fence also prevented cattle from straying into MPNP for grazing. Gupta (2005) found that 49.6% of those interviewed in the Makgadikgadi area said that access to grazing lands had decreased since the fence’s construction and that there was no benefit to having the fence. As the actual effect of the fence on feeding ecology in cattle is as yet not understood, the primary goal of this study is to determine the effects of fencing on resource use by and health of cattle whose grazing areas have been reduced by it. Brooks (2005) found that before the fence, cattle grazed inside MPNP, but not further than 6km from their kraals, and competition between livestock and wildlife was asymmetrical, with no negative impact on cattle. Since the exclusion of cattle from within the park, vegetation has become more abundant and more wildlife is visible during the day around waterholes. While a solution was necessary to avoid the escalating livestock-wildlife conflict in the area, it was calculated that the total cost of building the fence, including maintenance, could have compensated for cattle losses several times over if put aside in a compensation fund (Dr. Chris Brooks, personal communication). The poor alignment of the fence has aggravated the already inherent issues of fencing wildlife areas. The negative effects include lack of water for wildlife, wildlife mortality, the destruction of natural migration routes, decreased livestock grazing lands, and the loss of CBNRM tourism opportunities. However, as stated earlier, by excluding cattle from the park the fence may decrease resource stress in wild herbivore populations (Brooks, 2005) and may have economic benefits for the local cattle industry.

Though designated as a wildlife conflict fence and not a disease prevention fence, the Makgadikgadi fence is a double electric fence that meets the standards of effective protection from FMD, pending approval of a parliamentary proposal to include this area as a FMD-free zone (Gupta, 2005). Such approval would allow farmers living to the west of the Boteti Riverbed to fetch premium prices from the Botswana Meat Commission (BMC), which has an effective monopoly on beef export (Darkoh and Mbaiwa, 2002) in Botswana. Gupta (2005) states that beef export is primarily pursued by wealthy ranchers that own large herds, and small-scale farmers will only occasionally sell beef to municipal butcheries. The second goal of this study is to investigate the potential economic gains from the inclusion of small scale farmers in the export business as made possible by the Makgadikgadi fence.

II. Methods

i. Behavioral and Distribution Analysis

In order to determine the post-fence feeding behavior of cattle, a herd was located each morning from a specific cattle post in the area (CP1), and an adult individual selected at random from the herd. To offset any confusing factors of physical condition, individuals in unusually bad condition were not selected for observation. Juveniles were also avoided to account for differences in feeding behavior between adults, who form the bulk of a herd, and their young. As female cattle tend to be given preference to better forage by males, a female was selected for observation. This same bovinette was found every morning and observed for the three hour period from 9am to noon. Observed behaviors were documented for five minute intervals, with a five minute rest period in between each interval. Scan samples were conducted twice an hour, in which the total number of individuals visible in the herd and the total number engaged in feeding activity were noted, as well as a GPS fix of the individual's location. Feeding behavior as defined in this study is any action resulting in food acquisition, excluding movement between patches of forage. In the afternoon, a random group of cattle were selected, an adult female individual selected, and the same methodology applied from 3pm to 5:30pm, as by around 5:15 all cattle observed tended to stop feeding and begin walking back to their kraal. GPS fixes were also obtained for key resource locations, such as waterholes and boreholes.

ii. Diet Composition

The composition of selected grass swards and browsed plants was determined by walking into the approximate center of the herd and throwing out a 50x50 cm quadrats.

This was done randomly twice an hour, and a GPS fix was taken from the center of the quadrat to get an idea of relative vegetative distribution. Within each quadrat, the relative amounts of perennial versus annual grasses were recorded, the number of live grass tufts was counted, the number of dead grass tufts, the percent cover of annuals, perennials and herbs, the overall percent cover of live vegetation, the height of the sward, and the inter-tuft distance for living tufts were recorded. All of these measurements contribute to an understanding of cattle preference for certain grazing patches over others and account for resource availability and the occurrence of browsing behavior.

iii. Interviews

A total of eleven interviews were conducted with livestock owners or cattle post hands in the area surrounding Meno-a-Kwena tented camp. Cattleposts were located by sight from the main tarmac road, by our guide in the bush from CP1, and by following cattle in the afternoons back to their kraals. The area in which interviews was conducted was minimized by the continual break-downs of the blue lotus, our sweet ride. Upon arriving, a GPS fix was made of the cattle post, and questions concerning the economics of cattle ownership, the population dynamics of the cattle in question, the health and predation risks of the cattle, and the changes in both these areas brought about by the erection of the fence were posed with the aid of our interpreter. Interviews were also conducted with key leaders in the area, the kgosi of Moremaoto and the owner of Meno-a-Kwena tented tourist camp, David Dugmore.

III. Results

i. Movement Patterns

The cattle we observed during the morning walked straight to a water source after being released from their kraal at 8am. On the first two mornings, they trekked 2-3 km to a natural waterhole. On the second morning, the waterhole was dry, yet they returned the following morning nonetheless. On the third morning, the cattle left the kraal and headed in the opposite direction, towards a borehole in the dry Boteti riverbed, where water was pumped for them. Although cattle were not followed on the fourth day due to transportation issues, the owner followed them and reported that they had returned to the original, now very dry, waterhole. On our final day of observations, they repeated this action and went straight back to the same waterhole. For GPS coordinates of movements, taken every half hour, refer to Appendix III.

ii. Foraging Behavior and Forage Selection

Cattle during both morning and afternoon follows spent significantly more time grazing than browsing, with a browsing to grazing ratio of 0.37 in the afternoon and 0.08 in the morning. For averages of all behaviors observed during morning and afternoon follows, see Appendix I and II.

Figure 1*: Morning time-budget of cattle*

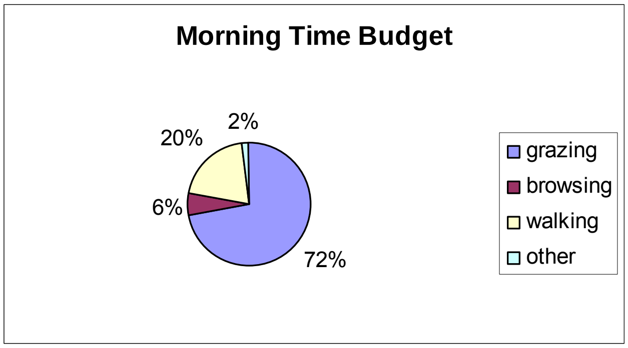
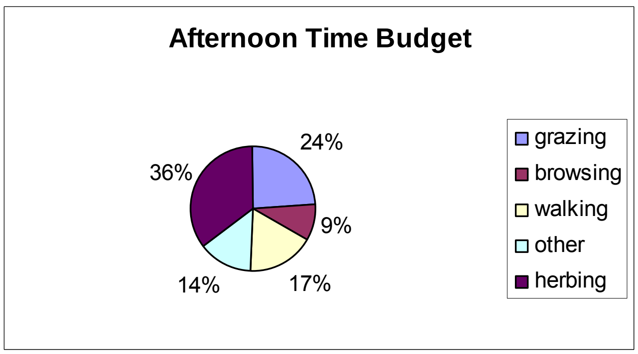


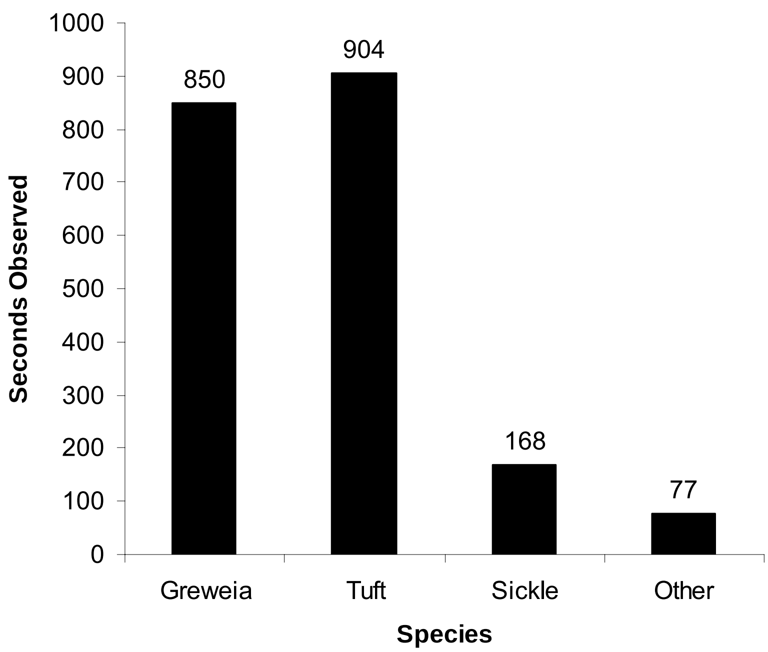
Figure 2*: Afternoon time-budget of cattle*



There was a distinct difference in vegetation from one side of the large tarmac road to the other, with a much greater percent cover of grasses on the waterhole side than that of the riverbed and borehole, as revealed in table 1. It is important to note the effect of resource availability on the separation of observed behaviors between morning and afternoon follows, as all but one of the morning follows occurred predominantly on the waterhole side of the tarmac, whereas all afternoon follows occurred predominantly on the borehole side. Around the waterhole, cattle were seen walking for 4% of the time, while cows spent 34% of their time (7.86 times that observed on the waterhole side) walking on the borehole side. Cows observed on the borehole side spent 9.3% of total observation time browsing (with a browsing to grazing ratio of 0.23), compared to 5.1% seen on the waterhole side (with a browsing to grazing ratio of 0.08).

On both mornings and afternoons, cows were observed browsing on seven species of plants: Kalahari tuft bush (*Rhus tenuinervis*), *Grewia bicolor*, sickle bush (*Dichrostachys cinerea), Acacia mellifera*, wild sage (*Pecheul-loeschea leubniziaea*), Kalahari apple-leaf (*Lonchocarpus nelsii*), and *Acacia erioloba*. Figure 3. gives the total time observed browsing on the most common species. *Grewia* and Tuft were the most preferred species, followed by sickle bush.

Figure 3: *Relative browsing time of browsed plant species.*



Quadrats were used to determine ground cover, and locations were dictated by where the cattle were foraging. The averages for morning and afternoon are given in tables 1. and 2., respectively.

Table 1: Morning quadrat averages

	11/26/2006	11/27/2006	11/28/2006	11/30/2006
Number of Tufts	27.50	23.40	25.80	13.80
Number of Dead Tufts	2.25	1.20	9.00	3.71
Number of Sprouts	25.50	24.00	11.20	27.57
Percent Cover (live)	11.25	11.00	12.00	14.00
Percent Herb (of live cover)	27.50	30.00	18.00	9.28
Percent Perennial (of live cover)	11.25	52.00	0.00	82.15
Percent Annual (of live cover)	61.25	18.00	82.00	8.57
Percent browsing material (of live cover)	0.00	0.00	0.00	0.00
Inter-tuft Distance (cm, where tufts present)	8.39	13.30	14.00	16.61
Sward Height (cm, where tufts present)	6.70	5.32	7.92	7.06

***Table 2**: Afternoon quadrat averages.*

	11/26/2006	11/28/2006	11/29/2006	11/30/2006
Number of Tufts	0.00	0.75	4.25	2.50
Number of Dead Tufts	9.66	10.25	18.75	9.50
Number of Sprouts	0.00	0.25	8.75	14.25
Percent Cover (live)	2.16	5.25	5.25	5.75
Percent Herb (of live cover)	100.00	77.50	75.00	86.25
Percent Perennial (of live cover)	0.00	12.50	0.00	0.00
Percent Annual (of live cover)	0.00	0.00	25.00	13.75
Percent browsing material (of live cover)	0.00	10.00	0.00	0.00
Inter-tuft Distance (cm, where tufts present)	7.95	21.90	25.65	19.40
Sward Height (cm, where tufts present)	6.53	2.80	4.90	3.80

All morning data for quadrats were recorded on the waterhole side of the road except for 11/28/2006 and small parts of 11/26/2006 and 11/27/2006. All afternoon data were collected on the borehole side except for the beginning of the observation period on 11/30/2006. Quadrat analysis between sides of the tar road revealed that the borehole side had an average percent cover of 7.22%, while the waterhole side exhibited an average percent cover of 12.54%. The borehole side consisted of mainly herbs (61% of ground cover), and annual grasses (35% of ground cover) dominated perennial grasses (2.2% of ground cover). The other side of the road was markedly different with 20.4% of ground cover described as herbs, and perennial grasses (67.7% of ground cover) dominating grass cover over annual grasses (11.9% of ground cover). Furthermore, the borehole side had much more dead grass than the waterhole side with live to dead ratios of 0.94 and 6.44, respectively.

Comparing observations to quadrat data shows that in the morning, browsing time increased as inter-tuft distance increased (figure 4.), and browsing time decreased as sward height increased (figure 5.).

Figure 4*. Browsing time versus inter-tuft distance in the mornings.*

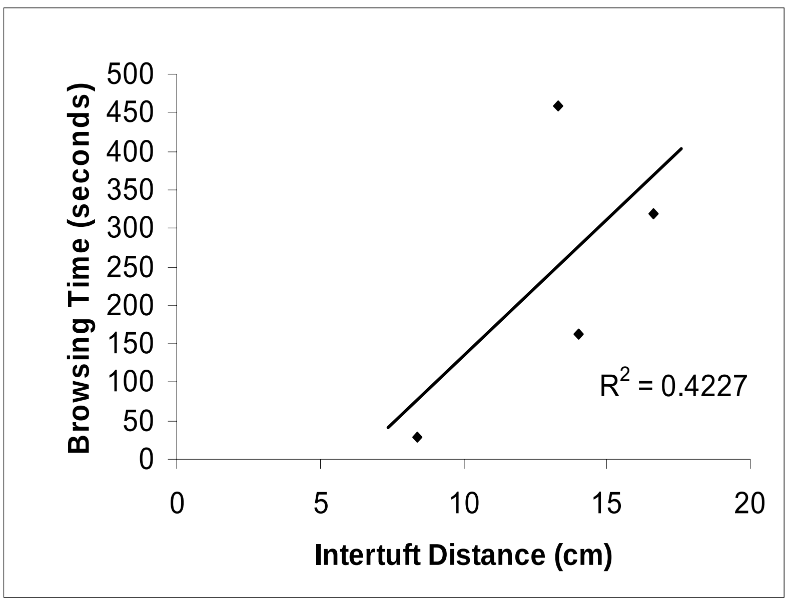
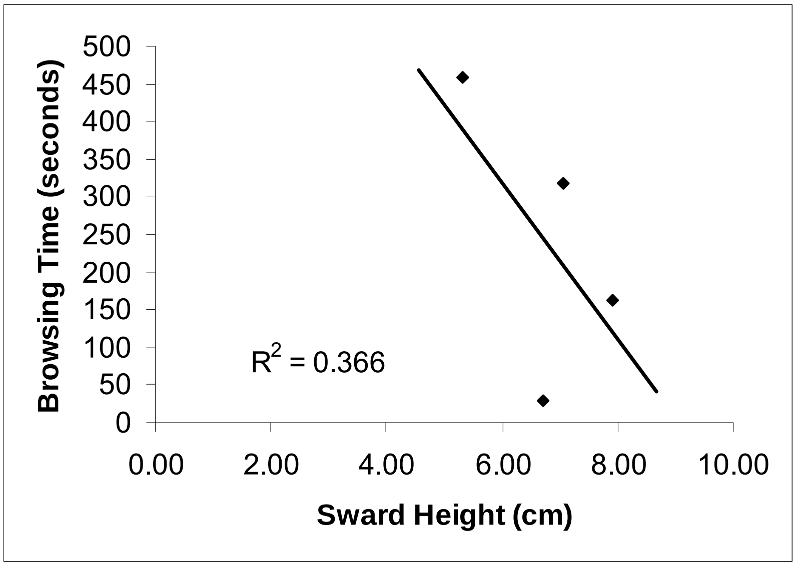
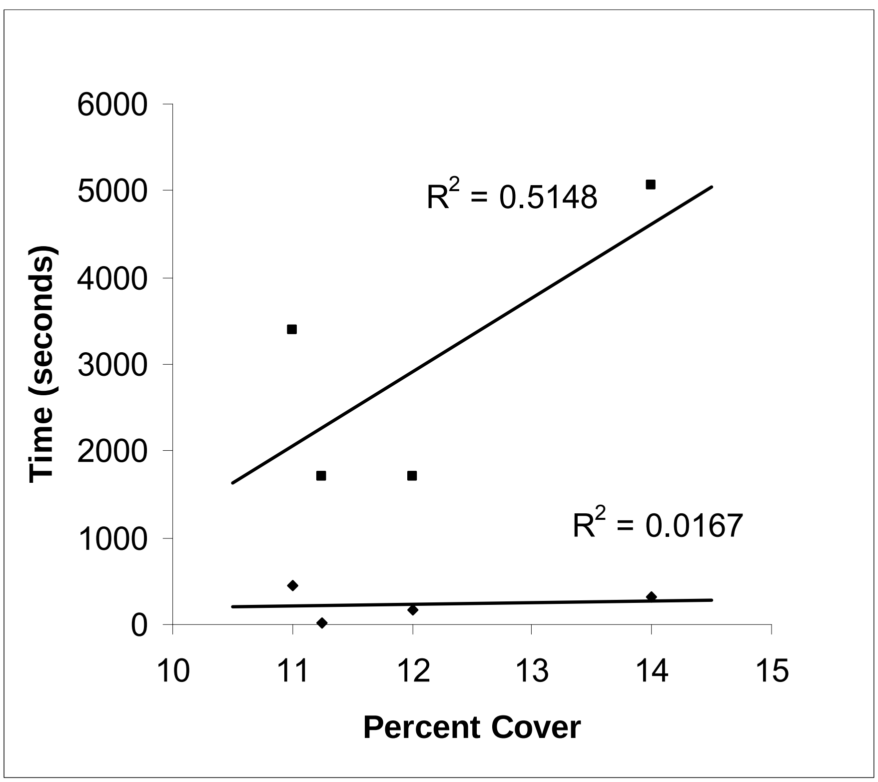


__Figure 5__. Browsing time versus sward height in the mornings.



In addition, as percent cover increased in the mornings so did grazing and a slight, yet insignificant increase in browsing is also observed (figure 6.).

__Figure 6__. Browsing and grazing versus percent cover (■ = grazing, ♦ = browsing).



iii. Interview Results

Interviews were conducted around the Meno-a-Kwena camp to determine the effects of the Makgadikgadi game fence on cattle productivity and economic viability. Of the 11 farmers interviewed, 10 raised cattle. Herd size in the study area ranged from 50 to 400, with smaller scale farms located closer to the riverbed than the larger operations. Cows were reported to walk between 5 and 20 km while foraging, and 2-3 km for drinking water. The average growth rate of herds was 19.37%, where 6 out of the 11 cattle-posts interviewed provided enough data to calculate growth rates.

In terms of the economics of owning cattle in the area, of those interviewed, 70% owned the cattle they were caring for, and the owners of the two largest cattle-posts (CP4 and CP9, see Appendix IV) lived far away from Meno-A-Kwena. At the three largest cattle-posts, cattle sales ranged from 11-30 head of cattle per year to the BMC, while all others sold 6 or less. Small scale farmers said they rely on the BMC trailer to come to Makalamabedi for sales, and 100% of cattle farmers interviewed said they sold to the BMC. Forty-five percent of respondents reported that BMC prices have increased recently, and one man said that he expects to see prices rise by 40% in the next year. Only 30% of cattle farmers said that they sold to local butcheries, reportedly at P5/kg. Forty percent of the cattle-posts had paid workers to help care for the cattle, and each of these farms had at least 70 head of cattle. All farmers in the area augmented natural water holes with boreholes for drinking, and most used a communal waterhole in the riverbed, though the two largest cattle operations operated private boreholes close to their kraals. The petrol to run the borehole pump is paid for by local livestock owners, and costs approximately 100 pula per day to pump. The cost of setting up a borehole was reported to range from 750 to 11,000 pula, depending on method of construction.

The cost of maintaining the health of cattle in the area was also investigated. Only the four largest cattle-posts reported that they gave their cows vaccinations, though the costs of the vaccines were unknown. Feeding cattle food supplemental to forage was practiced by 30% of respondents and usually done to fatten the cows up before sale, not to maintain general health of the herd. One informant stated that there were too many cows living in the Boteti Area, and the land could not support all of them. He continued by saying that farmers in the area should sell more of their cows to avoid having them starve to death. However, 60% of those interviewed said their cows were eating the same or better than before the fence, and 30% claimed to have lost cows to drought/starvation in the past year.

Wildlife was the most common cause of death (40% claimed they lost cattle to predation in the last year) and all livestock owners with cattle wildlife casualties reported that wild dogs were the leading threat. Hyenas were also reported as source of predation. Wild animals generally targeted young calves, and the three smallest cattle-posts had the most devastating problems with predators—losing up to 20% of their herd to wildlife in the past year. Seventy percent of respondents reported that their cows returned to their kraals every night, usually to avoid added risk. Many people said that lions were a severe problem before the fence was erected, but there are almost no problems with them now; though one man said that they have the ability to dig underneath the fence. The effectiveness of the fence at deterring wildlife was deemed helpful but not perfect. The Kgosi in Moremaoto stated that the solar panels powering the fence were often stolen by people living in the area because the villages there are not on the electrical grid. David Dugmore corroborated this by stating that the fence rarely has a current running through it, though one of the researchers was electrocuted twice. Furthermore, he talked extensively on the inherent loss of grazing area caused by the alignment of the fence and about the potential economic gains that could be made from developing the tourism sector along the Boteti River.

IV. Discussion

The selection of forage by the observed cattle was dependent upon resource availability in the land area allowed them by the overarching constraints of their physiology and environment. While the quality of selected forage is a measure of stress in herbivores, movement patterns also provide a measure of resource pressure. The cattle herd we observed and tracked via GPS (see Appendix III for movement coordinates) every morning was distributed around two focal points: the kraal, and a water source, either the borehole in the riverbed or the waterhole. Such focus of movement around water is a defining factor of a population living in an arid environment where water is scarce, but availability of water for cattle in the Boteti region was relatively unaffected by the erection of the Makgadikgadi fence, as nearly the entire riverbed was fenced out of the park. This distribution pattern is not necessarily due to the fence but more likely to the fact that observations occurred at the end of the dry season, when water is at its most scarce. Once the natural water sources dry up, livestock owners are forced to pay for petrol to pump water from boreholes in the riverbed, which occurred once during our observation period.

Upon realizing that the waterhole was dry, the cattle's distribution changed entirely, as they had to walk in the opposite direction to access the borehole, and then wait in a line of competing herds, humans, goats, horses, and dogs to get to the water trough in the riverbed once pumping began. This limited the amount of time they had to forage before the heat of the day set in, and more snacking was observed on the way to the borehole than was observed on the way to the waterhole (personal observation). The availability of forage near the riverbed was much lower than that around the waterhole, at

34.05% grasses as opposed to 78.34% and an increase in dead grass (live to dead ratios of 0.94 as opposed to 6.44) which is of lower nutritional quality than green plant matter. According to figure 6, the time spent grazing increases with the percent cover of vegetation, as according to optimization theory the cattle will expend less energy moving from tuft to tuft if there exists a more continuous sward, and will therefore prefer areas with higher grass cover. The ramifications of this were observed when the cattle spent more time grazing during morning observations, which occurred predominantly on the grassier waterhole side of the road, and walked on the borehole side 7.68 times as much as on the waterhole side. The slight increase in browsing with percent cover can probably be accounted for by a correlation between browsing and grazing rather than browsing and percent ground cover. As is evident from figure 1 and 2, cattle spent a large amount of time grazing in both morning and afternoon observations, and are therefore more likely to be browsing in those same areas simply because they are spending more time there. Even though the waterhole was dry, the cattle went two days without water by returning to it the day after they visited the borehole, suggesting that the demands of quality forage outweighed those of water within this short time period. However, this assumes that the cattle remembered that the waterhole was dry and returned nonetheless for foraging purposes alone, and based on prior herbivore research that is not an unfair assumption.

The grazing lands within the national park are in close proximity to the boreholes of the riverbed, and would have cost less energy to reach in terms of walking and inefficiency of energy use due to water deficiencies. As these lands are no longer in reach, the cattle have been forced to walk a further distance from water to reach forage of any quality, and are at the same time pushing their physiological water constraints, an indicator of stress.

Cow browsing on Grewia shrub

In terms of foraging preferences, it’s obvious that cattle prefer grazing to browsing, as they spent a greater amount of their time grazing than browsing in both habitats, the waterhole and borehole sides of the road. Browsing was undertaken only as a second choice to grazing, as indicated by the plot of inter-tuft distance against browsing in figure 4. Browsing is only worth while if the time can’t be spent grazing, as in an environment with larger distances between tufts of green grass where energy must be spent walking between tufts and can grazing can therefore be augmented by browsing without detracting from grazing time. In figure 5 the negative correlation between sward height and browsing time suggests that in areas where grass is taller and therefore of greater accessibility and potentially biomass, browsing time drops. This is yet another indicator of the preference of grazing before browsing due to the differences in digestibility between browse and grasses. Indeed, on the borehole side of the road, in close proximity to a consistent water source, the browsing to grazing ratio was higher than that on the waterhole side, at 0.23 as opposed to 0.08, a highly significant increase.

In a forage-limiting environment, it would be seen that the location of good quality, continuous forage of the ideal height and biomass would be a prime decider of cattle distribution, with cattle expending great amounts of energy to reach such areas despite water constraints. In the Boteti region, the cattle population is showing such a distribution, though with water of primary importance due to the season. The fence has changed cattle distribution by limiting the availability of quality forage in good proximity to water sources, causing stress by forcing them to push their water bearing limits to the utmost and evoking energy costs associated with increased walking distances to forage, as observed by the return of cattle to areas of high quality forage but zero water availability during this study. The lower quality of forage in the areas around the riverbed borehole do not bode well for the sustainability of present cattle populations in the area. The high occurrence of dead grass matter and low recruitment of new, green annual grasses observed has probably been caused by high cattle traffic in the area, and is a sign of land degradation around the water hole and another corroborator of resource stress in Boteti cattle populations. Whether the condition of the area has changed since the erection of the fence is not within the ability of this study to confirm, but the decline in grazing area due to the fence has concentrated cattle impact to one side of the riverbed and could be the cause of the current state of the vegetation around the borehole. The impact of fencing on resource stress in local cattle herds varies, however, with the economic status and position of their home cattle-post.

As the results from the interviews indicate, cattle farming practices in the Boteti region vary drastically based on scale. Large scale farmers are able to afford vaccinations, private boreholes, and workers to help maintain the herd. As discussed earlier, water was found to be a key factor in determining cattle distribution, and farmers capable of digging a borehole on the waterhole side of the fence are inherently better off as their cows will not have to walk far to find quality forage. The small scale farmers around Meno-a-Kwena operated a communal borehole in the riverbed, far away from the natural waterhole and the superior resources around it. The largest cattle posts in the area are located on the waterhole side of the fence, allowing easy access to the natural source of water. When this dries up (as we observed), these farmers will then revert to providing their cows with water directly at the kraal. Small scale farmers, however, are unable to maintain a balance of good forage and access to water for their cows because of the costs of maintaining a private borehole, resulting in overall unhealthier herds (personal observations). It is possible that the fence exacerbated this problem by cutting off grazing access close the riverbed on the park side. Before the fence was erected, cows going to the riverbed borehole would most likely not need to walk as far to find food and could spend more time grazing.

The divide between small and large scale farming practices is augmented by cattle sales and the prices given for meat. As stated above, 100% of respondents stated that they have sold the BMC in the past year. While small scale farmers sell fewer cows each year, they sell a higher percentage than their large scale neighbors. Two cattle posts maintaining a herd size of 50 heads of cattle sold 6 cows each last year (12% of their herd), compared to the largest cattle post with 400 heads of cattle which sold 30 cows last year (7.5% of their herd). Even though we were unable to determine how much any of the cattle owners made from sales to the BMC, it is likely that the large scale farmers received a much higher monetary return on their herds, despite selling proportionally fewer cows. This conjecture can be made by comparing the health of the cows between the operations. Furthermore, the BMC pays different prices per kilogram, based on the quality of the meat (see appendix V.). Since the cattle observed from the large scale operations showed superior overall health as well as weight, the BMC will most likely pay a premium price for this beef. The fence has already added significant value to all cows coming from the Boteti region, though the large scale farmers are able to take more advantage of these price increases than those with smaller herds.

Contrary to Gupta's (2005) findings, small scale cattle farmers around Meno-a-Kwena were not found to prefer selling beef to municipal butcheries. Only two cattle owners out of the 10 interviewed said they sold to them, and both did so in conjunction with selling to the BMC. This shows that all cattle farmers in the area are responding positively to the premiums offered by the BMC. One informant stated that local butcheries pay around P5/kg, regardless of size or quality, compared to the BMC prices where only the meat used for canning fetches a price lower than P5/kg. Small scale farmers, however, are constrained to sell to the BMC by their limitations on transportation. When word has reached the cattle posts that a BMC trailer is coming to the area, small scale farmers wishing to sell walk their cows to Makalamabedi (a distance of over 20km). Cows are sold to the BMC there, and farmers are again limited by the capacity of the trailer. Larger operations, on the other hand, are able to rent or buy trailers, allowing owners to decide when and how many cows to take to Francistown to sell.

The interviews also revealed that small scale farmers were more affected by wildlife than larger scale farmers. While everyone interviewed agreed that predation rates are substantially lower, those living closest to the fence (generally small scale farmers) still have problems with wild animals eating their cows. Before the fence was built, lions posed a great threat to cattle owners around Meno-a-Kwena, but only one respondent reported having trouble with lions, reflecting the fence's efficacy at deterring lions. Wild dogs were reportedly the biggest problem, presently roving in an unusually large pack of 15 and feeding predominately on calves. Informants said that wild dogs are able to dig underneath the fence, so it does little to protect livestock from these predators.

In terms of perceptions on forage quality, 60% of farmers said that their cows were eating the same or better than before the fence, despite a decrease in grazing access. David Dugmore, owner of Meno-a-Kwena camp, commented that the last rainy season was especially wet, and the cows were eating better compared to previous years which were drier. Three out of ten cattle owners interviewed said that they had lost cows due to drought/starvation in the last year. Deaths from drought/starvation could be common in this area at the end of the dry season, but could also be intensified by the decrease in foraging area caused by the fence. Combining drought with a smaller foraging area could quickly reduce the potential stocking rate in the Boteti region, and thus compromise the sustainability of the cattle industry.

V. Conclusion

Through focal observation of cattle in the Boteti region of Botswana along the Makgadikgadi wildlife fence, it has been found that local cattle populations are showing signs of resource stress due to a decrease in grazing area associated with the fencing off of the Makgadikgadi Pans National Park. A substantial amount of browsing and walking and lack of quality grazing in proximity to the riverbed boreholes which are frequented by the majority of local cattle herds was observed. Biases in the data may have arisen due to the time of day of observations, as they occurred during very hot hours, which may have affected foraging behavior, in the limited area and habitat in which random afternoon observations were conducted due to transportation issues, and from the effects of the researchers following the herds on their movement patterns. The fence was erected to help alleviate wildlife conflict between large predators and cattle, and in general it seems that livestock owners interviewed are happy with the results, and all cattle-posts which supplied enough information have herds showing a positive growth rate. However, the long-term impact of the decrease in grazing lands for the cattle, especially at stocking rates designed for greater land area, and all aggravated by already limiting water availability, may outweigh the positive effects of decreased predation.

While the fence has helped curb predation rates and created economic opportunities for all cattle farmers near Meno-a-Kwena, most benefits have gone to large scale cattle operations. Smaller scale operations were generally closer to the fence, leading to higher risk of predation than those further away, and a more dramatic decrease in grazing land due to fence alignment. These problems have been amplified by the constant economic constraints on small scale cattle operations, which have prevented these farmers from being able to adopt a more dynamic system of managing their cows based on market and resource conditions. Ecological factors such as drought demand the attention of cattle owners to adjust management practices in order to avoid overstocking and massive death rates. The welfare of the cattle in the future will determine any changes in the alignment or even presence of the fence, not necessarily the welfare of the wildlife within the park, depending on the degree of community-based tourism development that occurs in the next few years which the impending government-sponsored Makgadikgadi Management Plan may stimulate.

VI. Recommendations

The limitations associated with our cattle behavior data collection resulted mostly from the short time period of the project. To gain a more accurate impression of the current situation and the effect of the fence's construction on the cattle populations along the Makgadikgadi fence, a several-year monitoring project should be put into effect, so as to remove seasonal variations in rainfall and vegetative productivity from variations in resource use and availability caused by the concentration of cattle along half of the Boteti riverbed. Better communication needs to be established with cattle-posts, as a very limited number were within the reach of this study. Posts all along the fence should be taken into account, further north and south of the study area around Meno-a-Kwena, and further west towards the CKGR (for comparative studies in proximity to the fence). Future studies should include a more comprehensive method of quadrat analysis including nutrient content and ranking of different grasses and browsed shrub species. Pre-fence data, while unavailable for our use, does exist in all of the areas studied through this research, and a pre- and post- fence direct comparison is required to more definitively denote resource pressure. Manual GPS fixes and collar data should be used in conjunction with GIS software to track cattle movements and distribution to better understand constraints on the cattle population.

The greatest challenges facing cattle owners in the Makgadikgadi region now that grazing area has been limited by the fence will be associated with over-stocking of an already drained landscape. Thus, management needs to be put in place to explain and implement better stocking rates in the area to prevent a crash in cattle populations. Supplemental water-holes must be made available to wildlife within the park, so that the area will continue to attract large numbers of wild herbivores and deter predators from digging under the fence and killing livestock, in addition to relieving stress on wild herbivore populations and sustaining community-based tourism efforts. There also needs to be a greater degree of communication and cultural awareness as well as understanding between conservationists and local livestock owners, as both the agro-pastoral lifestyle and the great herbivore migrations are ‘natural’ parts of the Makgadikgadi ecosystem.

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Appendix I. Morning observation totals (in seconds).

	11/26/2006	11/27/2006	11/28/2006	11/30/2006	Total
Activity:					
Grazing	1704	3396	1704	5062	11866
Herbing	0	0	0	0	0
Browsing	28	458	163	319	968
Walking	1025	266	1846	220	3357
Head Up	10	0	25	39	74
Resting in Shade	55	0	0	0	55
Social Encounter	127	0	0	0	127
Grooming	0	0	27	0	27
Total time observed	2949	4120	3765	5640	16474

Appendix II. Afternoon observation totals (in seconds).

	11/26/2006	11/28/2006	11/29/2006	11/30/2006	Total
Activity:					
Grazing	0	0	2216	545	2761
Herbing	1115	2919	0	0	4034
Browsing	377	0	356	298	1031
Walking	526	376	673	377	1952
Head Up	69	2	42	144	257
Resting in Shade	0	0	0	1257	1257
Social Encounter	0	8	0	6	14
Grooming	0	4	3	73	80
Total time observed	2087	3300	3290	2700	11377

Appendix III. GPS coordinates of cattle movements during morning observations.

11/26/2006
09:45: S20.34852, E24.30092
10:00: S20.34809, E24.30094
10:30: S20.34809, E24.30370
11:00: S20.34510, E24.31090
11:30: S20.34100, E24.31634
12:00: S20.34197, E24.32268
11/27/2006
09:00: S20.34973, E24.30358
09:30: S20.34949, E24.30088
10:00: S20.35085, E24.29931
10:30: S20.35058, E24.29819
11:00: S20.34800, E24.29885
11:30: S20.34640, E24.29955
12:00: S20.34136, E24.29810
11/28/2006
09:00: S20.34782, E24.33200
09:30: S20.33739, E24.31833

10:00: S20.33331, E24.31274
10:30: S20.32856, E24.30981
11:00: S20.32849, E24.30741
11:15: S20.32931, E24.30670
11:35: S20.33040, E24.30640
12:00: S20.33222, E24.30901
11/30.2006
09:00: S20.34665, E24.30081
09:30: S20.34568, E24.30216
10:00: S20.34773, E24.30131
10:30: S20.34682, E24.29983
11:00: S20.34800, E24.29943
11:30: S20.34765, E24.29874
12:00: S20.34586, E24.29918

Other Points:
Waterhole: S20.34872, E24.30027
Borehole: S20.35141, E24.33554
Meno-A-Kwena Camp: S20.32372, E24.31918
Makgadikgadi Fence Gate: S20.32504, E24.31576

Appendix IV. GPS coordinates of cattleposts interviewed.

CP1 S20.36109 E24.32179

CP2 S20.37222 E24.32574

CP3 S20.37441 E24.33627

CP4 S20.39175 E24.27732

CP5 S20.37613 E24.32939

CP6 S20.39292 E24.34985

CP7 S20.39417 E24.35594

CP8 Interview conducted at borehole

CP9 Interview conducted at borehole

CP10 S20.34717 E24.33221

CP11 S20.34718 E24.33222

Appendix V. BMC beef prices for 11/20/2006-11/26/2006 (source: www.bmc.bw)

PRICE STRUCTURE BY GRADE
LOBATSE AND FRANCISTOWN ABATTOIR

CATTLE **20-11-06 to 26-11-06**

SOUND		Weight range	Less than 200kg	200-205	206-210	211-215	216-220	220 +
PRIME	**SP**	Price	**10.74**	**15.81**	**15.91**	**16.01**	**16.10**	**16.27**

Prime Grade prices will change in line with beef prices in South Africa and the Pula/Rand exchange rate

SUPER	**SS**	**10.74**	
GRADE 1	**S1**	**9.99**	
GRADE 2	**S2**	**9.24**	
GRADE 3	**S3**	**8.22**	
GRADE 4	**S4**	**6.81**	
CANNING	**SM**	**4.11**	
CONDEMNED		**150.00**	**per head**

NB: These prices are in PULA per kilogram
There is no penalty for measles except on complete condemnation

Appendix VI. ISP Evaluation

The process of actually getting out into the field and self-directing data collection of any kind, much less behavioral observation data, was new to us. We have learned to use whatever resources are available to me to the best advantage, and modify strict research schedules when necessary for cultural reasons and out of consideration to the people involved by association with the research.

Our principal problems occurred through our inexperience in tracking animals in the bush and the continued break-downs of our vehicle. Our data is not of the quality it could be because of the minutes wasted trying to find our study subject or any cows in general. The car limited the distance we could travel and also caused bias in our data by forcing us to observe cattle in the afternoons in roughly the same area and habitat, as it could only go so far. However we learned a lot of patience and the tough side of field work while pushing the Blue Lotus, as well as a bit more about fixing cars. As stated earlier, we were forced by these limitations to adjust our research and take whatever we could get out of the situation.

Our methodology was prescribed mostly by our advisor, who wanted comparable data collected in a comparable fashion to similar data he had gathered previous to the erection of the fence. The interview methodology was entirely our own however, and we began by gauging the receptiveness of the livestock owners to speaking with us, always asking for permission and greeting informally before interviews. The use of a translator was key to this laid-back style of interviewing, which in a relatively un-interviewed area made people more conversant and willing to talk about sensitive subjects like wages and how much their cattle sell for.

Without Dr. Chris Brooks, our project would never have happened. He provided the vehicle, found a translator/driver for us, and came down to Makgadikgadi to set us up and train us in the fieldwork process. Awesome guy. However, his busy schedule meant that we did not get much practical assistance for data analysis and technological assistance in terms of GIS software, office space, and pre-fence cattle data that was initially to be included in the project. We made what we could with what we had access to, and learned to accept the limitations of our data and analysis. However, he has promised to help in any way possible if we wish to expand upon our data when we return to our respective universities, and has become a good friend.

Our major dead end was our GPS data. We took GPS points religiously, but because we now have no GIS access, were unable to draw any concrete conclusions from it. In the future however, we hope to use it, but not within the time frames of this paper and our stay in Botswana. Some interview time was wasted because the only people at some of the cattle-posts were visitors and did not know anything about the owner's cattle, limiting the amount of information we could get from them.