Second year report

Emily Bennitt

The ecology of African buffalo (*Syncerus caffer*)
in the Okavango Delta, Botswana

Introduction

The Okavango Delta is located in Northern Botswana between E 22.0° – E 24.0° and S18.5° – S20.5° (Heinl *et al.*, 2006). It is fed by the Okavango River, which originates in Angola, and runs through Namibia before entering Botswana in the north-western tip of the country. It passes through a valley known as the Panhandle (see Figure 1), then spreads out into several channels and waterways (Wolski *et al.*, 2006). The distribution of water across the Delta varies from year to year, and there is a current trend becoming apparent for increased water flow into the area used for this study, namely the south-eastern part of the Delta.

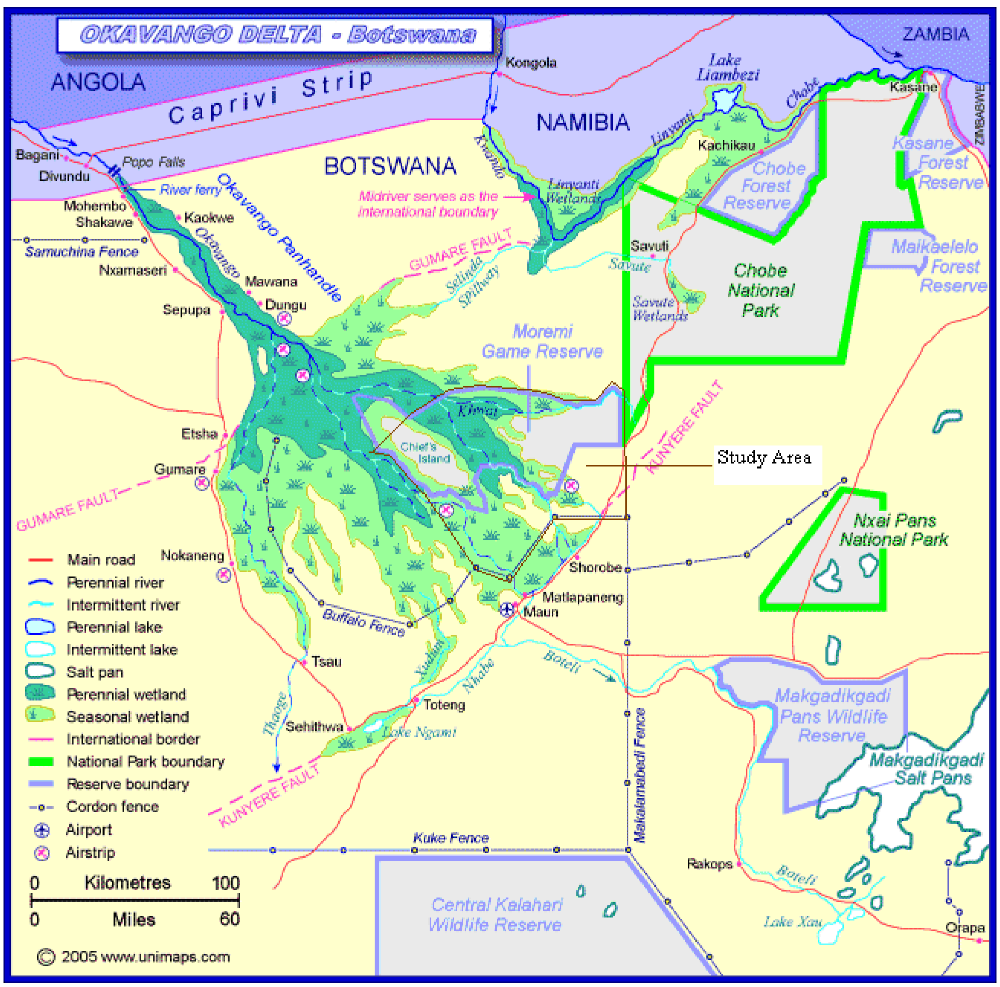


Figure 1: Map of the Okavango Delta, showing the study area
(Source: http://unimaps.com/okavango-delta/index.html)

African buffalo (*Syncerus caffer*) have been studied in several other sites across Africa (Sinclair, 1977, Mloszewski, 1983, Prins 1996), including the Chobe National Park in Botswana (Taolo, 2003). Information on the buffalo population of the Okavango Delta is sparse, mainly limited to aerial population counts conducted by the Department of Wildlife and National Parks (DWNP), as well as some previous work carried out in the Delta for the DWNP by Patterson (1979).

The current population of African buffalo in the Okavango Delta of Botswana, as estimated by DWNP (2006), is 30,000 animals in herds varying from fewer than 50 individuals up to reported herds 3,000 strong. These numbers, together with the large body mass of individuals – up to 700 kg for adult males and 500 kg for adult females (Sinclair, 1977) – suggest that buffalo play an important role in the ecosystem of the Delta.

Aims and hypotheses

- To monitor the demographics of a population of buffalo, including age and sex ratios, herd sizes and recruitment rates

  Hypotheses:
  1. Breeding herds will be female biased because males spend time in bachelor herds
  2. The recruitment rate will be positive
  3. There will be a fission-fusion society, with herd sizes and composition changing continuously

- To determine the extent to which buffalo use different habitat types and how this varies with season

  Hypotheses
  1. Certain habitat types will be favoured over others
  2. Preferred habitat types will change with season
  3. Herds will show seasonal home range use, defined by habitat composition

- To quantify the nutritional requirements of buffalo in the Okavango Delta and to determine whether the population is resource-limited during any season

  Hypotheses:
  1. Buffalo will not be resource-limited at any time of year
  2. Grass species with high leaf: stem ratios will be selected
  3. Buffalo will be more selective in areas with higher quality forage

- To compare movement patterns of buffalo herds at different scales

  Hypotheses:
  1. Herds will move randomly within patches
  2. Herds will move in a linear fashion between patches
  3. Herd will move rapidly and in a linear manner between seasonal home ranges

- To identify triggers for long-distance, seasonal movements

  Hypotheses:
  1. Herds will move from floodplains to woodland at the start of the rainy season, and the reverse at the end of the rainy season
  2. Movements will be between similar areas from year to year
  3. Changes in forage quality and rainfall will be the main triggers for movements

These aims are summarised in Figure 2. The text boxes shaded in blue represent targets for which sufficient data are being collected. Those shaded in yellow represent targets that are proving to be difficult to reach. The reasons for these difficulties will be discussed in the chapters below.

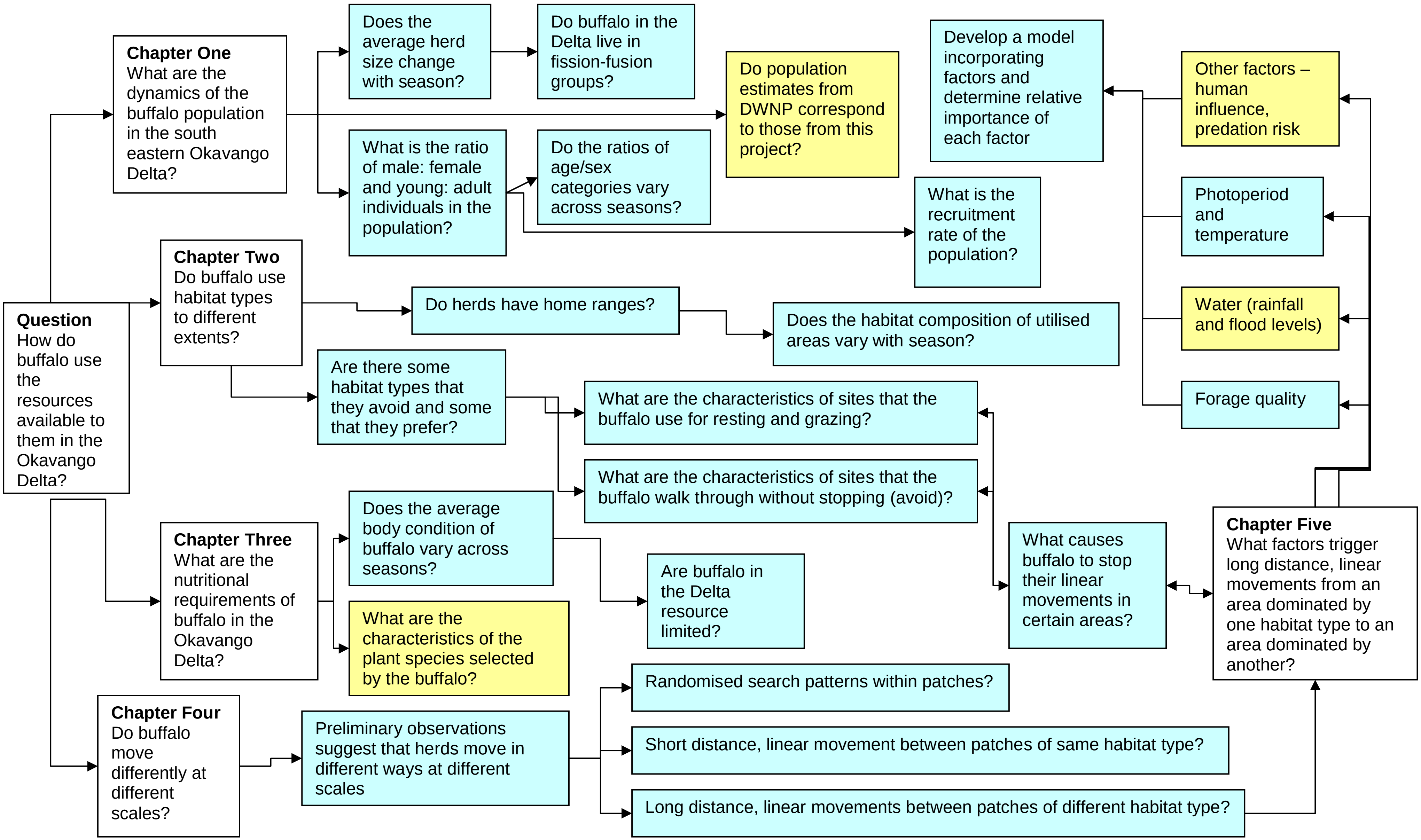


Figure 2: Flowchart of project plan

Methodology

A large proportion of data for my study come from eight GPS-enabled satellite collars that have been fitted to buffalo cows in several herds. These collars are manufactured by Televilt, and each weigh 1.8 kg, less than 0.5% of the animals' body mass. Each collar has been programmed to take a GPS fix every hour. These fixes are sent via satellite to a website that I can access, allowing me to monitor the animals' movements almost constantly. The collars also emit a VHF (Very High Frequency) signal enabling me to track and locate the collared animal using conventional telemetry equipment. Some GPS store-on-board collars were deployed, but all of these failed, and whilst I have been able to recover some of them, most have been lost.

Buffalo cows were selected because they form the core of the breeding herds, whereas bulls often leave them (Prins, 1996), and also because other studies found bulls to be adept at removing collars (Taolo, 2005). Each collared cow was darted by a qualified veterinarian, registered with the government of Botswana. Most were darted from a helicopter, but one has also been darted from a vehicle. The mean time from darting to the animal going down was 221.1 s (N=26, S.D.=106.2). The mean time between the animal going down and the reversal agent being injected was 523.9 s (N=26, S.D.=174.5). The mean time between the animal being darted and the reversal agent being injected was 745.1 s (N=26, S.D.=149.7). The mean time between the reversal agent being injected and the animal getting up was 110.2 s (N=26, S.D.=77.2). The mean total time between the dart being fired and the animal getting up was 855.3 s (N=26, S.D.=150.6). Different vets have used different combinations of drugs, the most frequent being 8mg of A3080, reversed with Naltrexone (N=21). The others were darted with a combination of 10 mg M99, 40 mg Azaperone and 5,000 i.u. Hyalase, reversed with 42 mg M5050 (N=5). The maximum time that an individual has been collared for is 16 months, but I have since tried to limit the collared period to one year in order to increase the sample size and avoid pseudo-replication.

I plotted every fix taken by the collars into Google Earth in order to determine the habitat that the cow was in at the time of the fix. Before plotting collar fixes, I recorded GPS coordinates in each habitat type then plotted them into Google Earth as a ground-truthing exercise. This yielded an accuracy of 90.7% (N=729). This was a more acceptable level of accuracy than the available habitat map, which frequently reached a level of less than 50% accuracy, depending on the area. I confirmed that Google Earth is itself a true representation of the Delta by recording the coordinates of the centres of 202 small pans (less than 10 m across) and plotting them in Google Earth. Every recorded coordinate was less than 10 m from the centre of the pan in Google Earth.

The Pathfind extension (Jenness, 2007) for ArcView GIS was used to calculate the distance between fixes. This information was used to determine whether the collared animal was resting (moving <50 m per hour), grazing (50 – 750 m per hour) or walking (>750 m per hour). These activity categories were assigned after observing buffalo herds to determine how far they moved in an hour when engaging in the above activities. All data were examined according to seasons, which were defined as the following: wet (December – March), early flood (April –

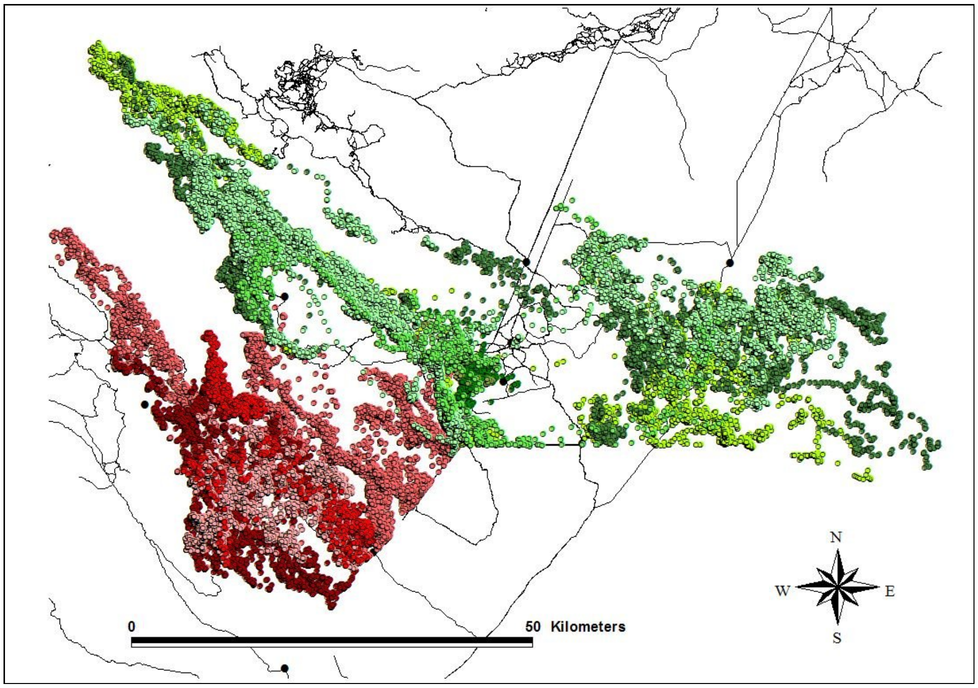
July) and late flood (August – November). Within each season, ten sites in each habitat/activity category were sampled.

Sampling sites used by buffalo involved throwing a 50 x 50 cm quadrat four times. Each grass species within the quadrat was recorded, together with its state (immature/mature/senescent); 5 measurements of leaf height; the proportional composition of each species; the percentage ground cover and whether it had been grazed or trampled. Samples of each species recorded were taken for the first year of data collection, yielding a sample size of 1,697. Financial and timing restrictions rendered the collection of additional samples unrealistic. When grass samples were taken, several tufts were cut within 5 cm of the ground and sealed into envelopes. These were dried in the sun before being taken in to the laboratory at the University of Botswana, where they were oven dried before being processed. The samples were separated into leaf and stem portions and weighed, then ground in preparation for analysis for nitrogen content.

A disc pasture metre (DPM) was dropped fifty times at each site to estimate biomass. The DPM consists of an aluminium disc that is dropped along a graduated aluminium pole, calibrated against known biomass measurements (Dorgeloh, 2002). Forty measurements of inter-tuft distances were taken per site. Canopy cover was estimated by walking ten metres in each cardinal direction from the GPS coordinate recorded by the collar and taking a photograph with a camera pointed straight upwards. The photographs were later loaded onto a computer and overlaid with a grid to visually estimate the percentage canopy cover for the site.

1. Population demographics

Prins (1996) described buffalo as living in fission-fusion societies, whereby stable herds split and come together again at intervals. Other studies have also been able to describe the buffalo population within their study area as several relatively distinct herds (e.g. Halley *et al.*, 2002). Data from collared animals indicate that buffalo in the Okavango Delta live in highly dynamic herds, with overlapping home ranges. There were two distinct ‘sub-populations’ within the study area that have had only a small degree of overlap since the project began: the Stanley’s herds and the Gomoti herds. The split between these sub-populations is shown in Figure 3.



<u>Figure 3</u>**:** Areas used by different sub-populations.
Shades of red represent Stanley's herds (four), shades of green represent Gomoti herds (four). Each shade represents a different animal over the course of a full year, although not all animals were wearing collars at the same time
(The cut-off at the bottom of the image is because of a veterinary fence)

Figure 3 shows that there was little overlap between the Stanley's and Gomoti herds, although there was plenty of overlap between herds within those areas. The collared animals in each area were never all in the same herd, although some came together for periods varying from a few hours to several months. This indicates that the fission-fusion patterns in the Delta were even more fluid than those elsewhere. Collared animals were not consistently seen in herds of the same size.

In Kruger National Park, buffalo have a three month peak for giving birth, with January being the month with the greatest birth rate (Ryan *et al.*, 2007). The wet season is also the time when mating occurs, given that buffalo have a gestation period of 340 days (Patterson, 1978). Buffalo bulls associate with breeding herds on a temporary basis, seeking mating opportunities from the end of the dry season until the beginning of the following dry season (Halley and Mari, 2004).

When a buffalo herd was found from a vehicle, the age and sex of at least 25% of the herd were recorded. The age categories were: calf (< 6 months), juvenile (6 months – 2 years), sub-adult (2 – 5 years) and adult (>5 years).

The identification of sex and age classes were based on the criteria outlined in Table 1, adapted from Sinclair (1977) and Prins (1996). The boss, a distinctive male feature, is a bony growth extending from the horns inwards to cover the top of skull.

Table 1: Criteria for determining age and sex classes of the African buffalo

Age	Sex	Boss	Horns	Body Size
Calf	Female	No	Small	Very small
	Male			
Juvenile	Female	No	Thin	Small
	Male	Grown up to halfway to central point, which is covered with hair	Thick	
Sub-Adult	Female	No	Thin	Almost fully grown
	Male	Grown over most of head, some hair in central point	Thick	
Adult	Female	No	Thin	Fully grown
	Male	Fully grown, no hair	Thick, some ridges	

Age and sex data from at least 1,000 buffalo in at least twelve different herds were recorded in each season. These data will be used to determine the ratio of males:females and of young animals (calves and juveniles):adult females and to compare variations in these ratios during different seasons, using chi-square tests. Figure 4 shows the distribution of age and sex classes in different seasons.

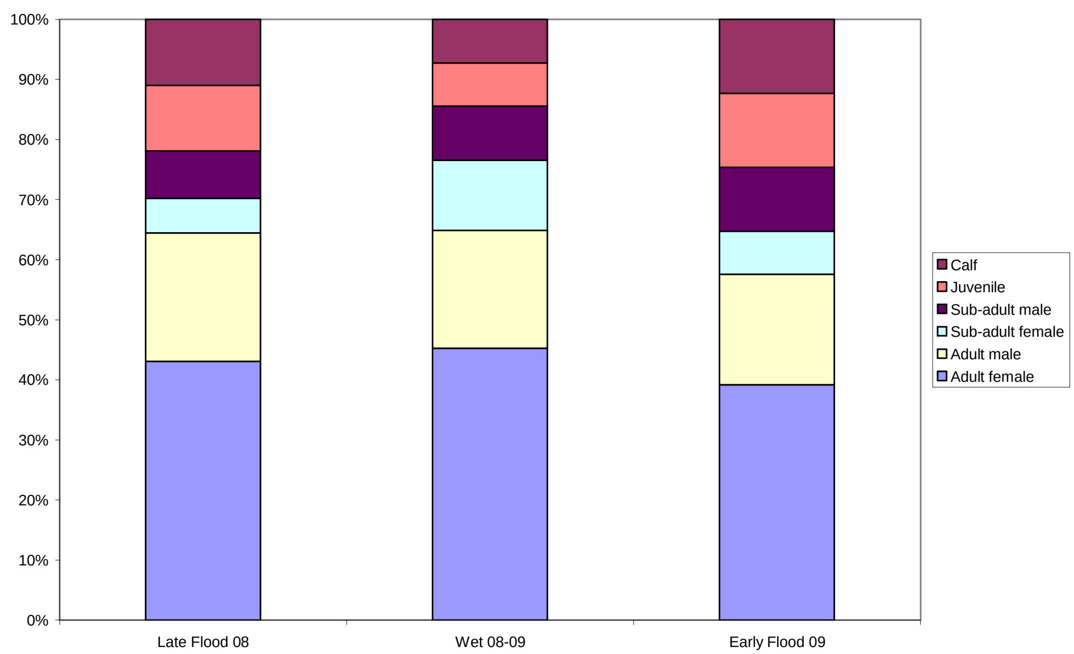


Figure 4: Age and sex distribution across seasons

Figure 4 indicates that there were a lower proportion of juveniles and calves present in herds during the wet season than during other seasons. This was in contrast to findings from other systems, where the wet season coincided with the peak birthing period (Ryan *et al.*, 2007). During the wet season, buffalo herds were often found in dense vegetation, which made accurate counts of the herd very difficult and only partial counts were possible most of the time. Dense vegetation could be the reason that fewer small animals were sighted. This will be investigated further.

2. Habitat use and home ranges

Resource selection varies according to the scale at which it is described (Johnson *et al.*, 2002). Use vs. availability patterns of selection will be used to determine habitat preference (Manly *et al.*, 2002). The proportion of each habitat type (grassland, dense mopane, open mopane, riparian woodland, secondary floodplain, tertiary floodplains and low mixed woodland) across the study areas will be determined by plotting a large number of randomly-generated fixes into Google Earth. This will be compared to the proportion of each habitat type within the home ranges of the collared animals. This in turn will be compared to the proportional use of each habitat type by the collared animals within their home ranges.

To date, a full year's worth of GPS data has been recorded by six collars on different animals (yielding approximately 50,000 GPS points), with another six currently collared. Some collars were on for less than a year, but will be included in the analysis if they were on for a full season. As of yet, the GPS points that will be used to estimate habitat availability have not been generated or plotted, but this is work in progress.

Plotting GPS fixes taken by collars into Google Earth has enabled me to compare habitat use between seasons. Only habitat types that the buffalo herds spent more than 10% of their time in were included in the analysis. The habitat composition of areas used by Stanley's and Gomoti herds were different, particularly in that one habitat type, Low Mixed Woodland (LMW), was barely present in the Stanley's area but covered a large proportion of the wet season home range used by Gomoti herds. For this reason, habitat use by the two subsets was analysed separately. The only habitat type that was used to a similar extent across all seasons was grassland. Herds spent significantly more time in dense mopane and open mopane during the wet season and significantly more time in floodplains and riparian woodland during both the early and late flooding season (Chi-square, $P<0.001$). For Gomoti herds, low mixed woodland was only used during the wet season, to a similar extent as grassland.

Distances between each GPS fix taken by the collars showed which activity (walking, resting or grazing) was being undertaken at the time of the fix. Occasionally, herds would walk in a certain direction, then turn around to end up close to the same point for successive fixes, which would be falsely interpreted as resting behaviour, but these occasions would be sufficiently rare within a large dataset such as this one as to have minimal impact on this method of activity determination.

Different habitat types were being used more for certain activities than others, e.g. herds spent significantly more time resting in woodland habitats, and significantly more time grazing in open habitats compared to the overall time spent engaged in each activity across the season (G-test, $P<0.001$). Characteristics of sites used by buffalo herds for each activity in every habitat were recorded, according to the protocol described previously. Laboratory technicians at the University of Botswana are being employed to sort and analyse grass samples, but progress has been slow and it may be difficult to obtain results within the current time frame.

Harris *et al.* (1990) described a home range as “a more or less restricted area within which an animal moves when performing its normal activities”. Halley *et al.* (2002) described buffalo herds in Chobe National Park, Botswana, as having defined home ranges with minimal overlap, particularly during the dry season. GPS fixes obtained from collared animals in my project suggested two levels of patterns. The areas used by collared animals within the Gomoti and Stanley’s areas overlapped significantly, although the overlap between these two different subsets was small (see Fig. 3). Core areas of use within the home ranges of each collared animal varied, as did the extent of the area covered by individuals. These differences will be examined and potential causes of such differences will be identified.

Herds in the Stanley’s area utilised similar areas during the wet and flooding seasons, although the habitats that they preferred did change. Herds based in the Gomoti region during the dry season had a distinct wet season home range that was approximately 30 – 50 km east of the dry season home range. Figure 3 shows these seasonal home ranges, separated by a zone that was avoided, visible in the centre of the figure.

Borger *et al.* (2006) found that using kernel methods to calculate home ranges produced the most accurate results. The Local Convex Hulls Homerange Generator extension for Arcview 3.x (Jenness, 2007) will be used to generate polygons and a kernel method will be used to define home ranges and identify any periodic differences in their size and extent.

3. Nutritional requirements

There are several reviews of techniques for dietary analysis (Homolka and Heroldova, 1992; Henley *et al.*, 2001; Parker and Bernard, 2006). Analysis of the contents of stomachs and rumens is only possible from deceased animals, which were not available for this study. Micro-histological faecal analysis, although highly accurate (Henley *et al.*, 2001), is very time-consuming and costly. I examined sites recently used by buffalo to determine which species were grazed by the herd. Grazing produces characteristically clean cuts on the stems and leaves of the grasses.

Grass samples of each species found in sites used by buffalo herds were taken, together with information on whether or not they had been grazed. Selection for certain species over others will be quantified using methods described by Manly *et al.* (2002). The physical and chemical characteristics of these samples will be compared to the properties of baseline samples that are currently being assessed by a colleague from the University of Bristol, Hattie Bartlam-Brooks. Crude protein is the main limiting factor for African buffalo (Smallegange and Brunsting, 2002), so nitrogen content of grass samples will be determined. The University of Botswana is limited in terms of staff and time, so I will be analysing these samples myself after the end of my fieldwork.

When herds were visited to collect population dynamics data, each animal's body condition was scored, according to a scale adapted from Prins (1996):

1 Very poor – ribs and spine clearly visible, ridge on shoulder blades
2 Poor – ribs visible, flank, tail base and pelvis concave
3 Moderate – ribs just visible, pelvis less concave
4 Good – ribs not visible, flank not concave
5 Excellent – fat ridges on neck, convex body contours

The body condition of individuals in the study population is being recorded throughout the period of field work. Chi-square tests have been carried out on the first year's worth of data. These show that, for almost all age and sex classes, the body condition scores varied significantly with season ($P<0.001$). The only exception to this was for sub-adult females between the wet and early flood seasons ($P=0.573$). The lowest body condition scores were observed during the late flood season, and the highest during the early flood season. Buffalo were eating annual grasses high in nitrogen content throughout the wet season, stocking up their body fat for the early flood season, and it then decreased to its lowest level during the late flood season.

Across the seasons, chi-square tests showed that the body condition scores of the various sex and age classes were significantly different ($P<0.001$), except for sub-adult females and juvenile males ($P=0.201$). The category with the highest mean body condition score was the juvenile females, whereas that with the lowest was the adult females. Adult females invest energy in their young, so they were expected to be the category with the lowest body condition (Prins, 1996).

Fresh faecal samples were collected and will be analysed for nitrogen content, which reflects the quality of forage consumed. Samples from ten different pats were collected from each herd and kept separately. Faecal samples were collected from a minimum of twelve herds per season. Nitrogen content will be compared between individuals within herds, between herds within seasons and between all herds in different seasons. These comparisons will be carried out using a series of chi-square tests. I will be carrying out the analysis of faecal samples after the end of my fieldwork.

4. Movement patterns at different scales

Johnson (1980) defined four orders of scale that can be applied to movement patterns and habitat selection. These were adapted by Johnson *et al.* (2002) to include the landscape scale, the patch scale and the feeding site scale. Several studies have interpreted movements according to these different scales and found that the effect of specific factors can vary in intensity according to scale (Johnson *et al.*, 2002; Gustine *et al.*, 2006).

Results to date suggest that buffalo movements follow several patterns, which are thought to be related to patch use and the scales at which buffalo perceive their environment. Figure 5 shows some of the movements of a collared cow over several days.

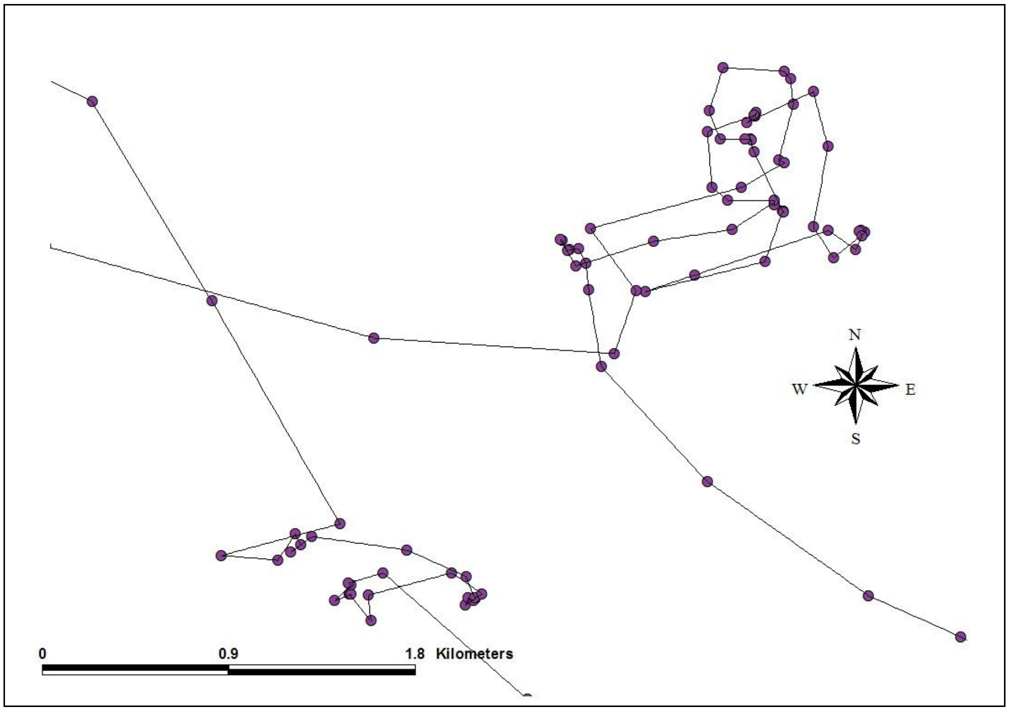


Figure 5: Some movements of B37 between 8th September and 11th September, 2009. Each point represents one hourly GPS fix taken by the collar.

Two patterns are visible in Figure 5: relatively random, short distance movements associated with foraging; and longer distance, more linear movements associated with moving between foraging patches. Fractal analysis has been used in several studies to examine movement patterns at different scales (Doerr and Doerr, 2004). Fractal analysis extrapolates movements at one scale to movements at other scales. This process assumes that there is a fractal dimension *d* that is constant at all scales. Turchin (1996) suggests that the fractal dimension may change continuously with scale, and advocates the use of random walk models to describe animal movements instead. These methods will be further researched to determine which is most appropriate for the data obtained from the buffalo.

The third type of movement that has been observed is large scale movement from one seasonal home range to another, which occurred in a highly linear manner, with collared animals (and associated herds) often covering upwards of 2 km per hour. Figure 6 shows one such movement.

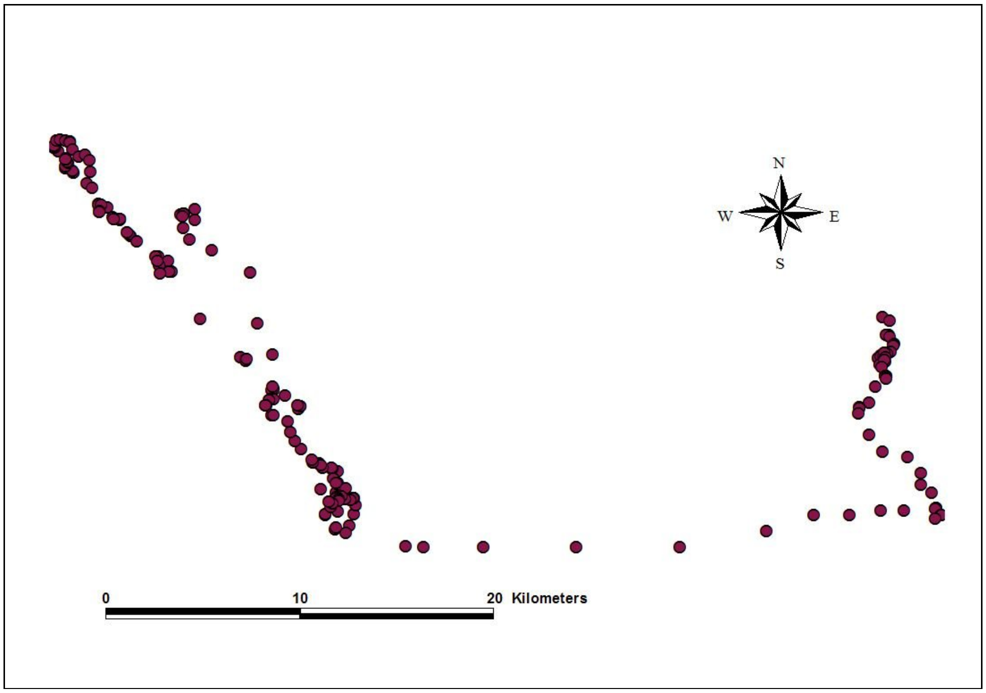


Figure 6: Movement of B77 from flood season home range (west) to wet season home range (east) between 16th November and 25th November, 2008

Data generated by the collars were used to determine activity levels at different hours of day and to compare these between seasons, as shown in Figures 7 – 9. These activity patterns stem from one full year's worth of data from four buffalo cows, and from several months' worth from animals whose collars failed before they were on for a year, or who had not yet been collared for a year. These graphs have been generated from data from six individuals in the wet season, four individuals in the early flood season and six individuals in the late flood season. More data are being collected, to give a total expected sample size of thirteen individuals per season, spread out across three years. Only one of each season's worth of data will be used from each collared animal, in cases where the collars were on for more than one year. Each collar having been programmed to take one fix per hour, this will yield approximately 38 ,000 fixes per season.

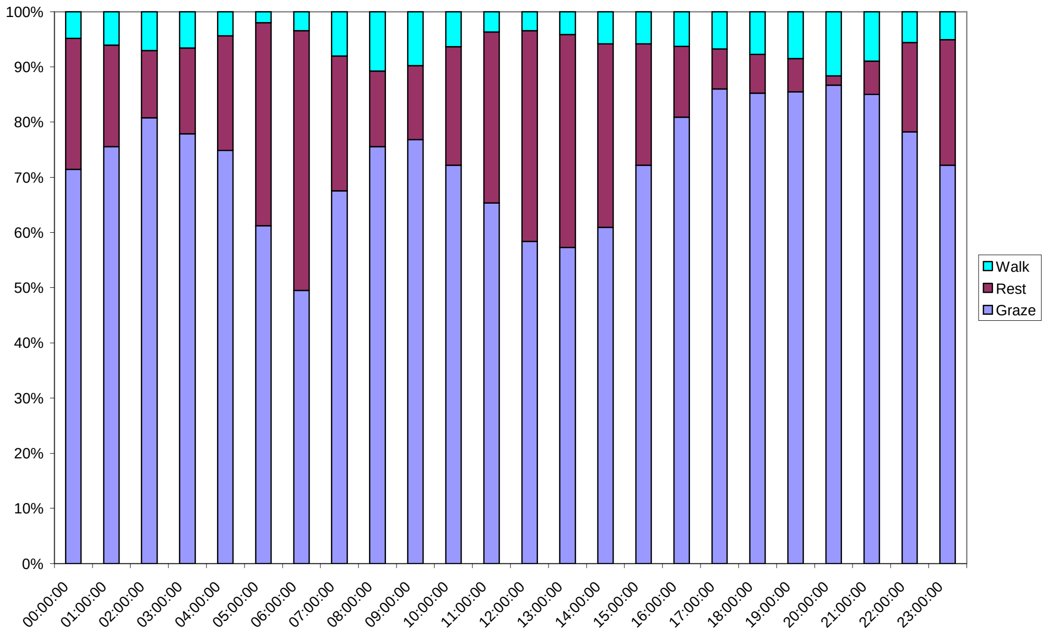


Figure 7: Activity patterns of buffalo during wet season (2007-08)

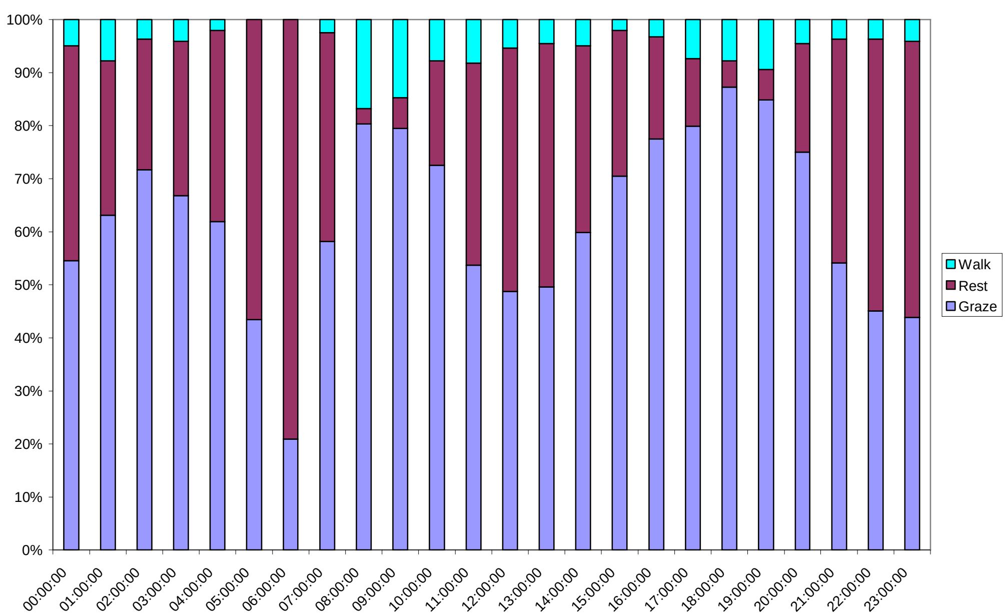


Figure 8: Activity patterns of buffalo during early flood season (2008)

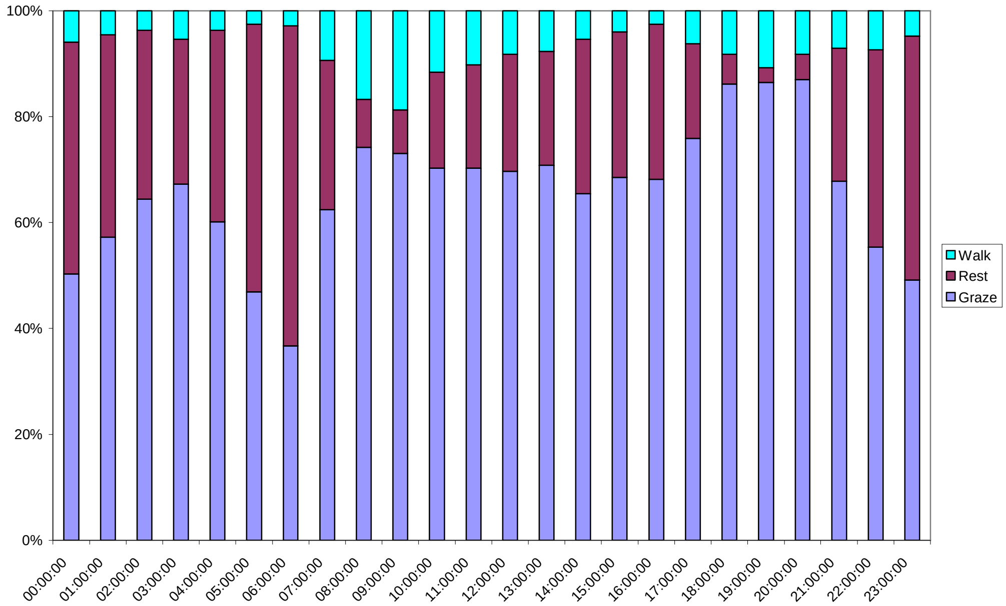


Figure 9: Activity patterns of buffalo during late flood season (2008)

The general trend was the same in each season: the hour most often used for resting was 06:00, there were also resting peaks between 11:00 – 14:00 and during the middle of the night. In between these were peaks in grazing and walking, showing a similar pattern to that found elsewhere, e.g. Kruger National Park (Ryan and Jordaan, 2005).

The early flood season showed the biggest contrast in activity peaks. During this season, buffalo spent significantly more time resting than during other seasons (G-test, $P<0.001$), spending 31.3% of their time resting (N=4), compared to 25.3% (N=6) and 26.7% (N=6) in the wet season and late flood season, respectively. The early flood season was also the time of year when their average daily movement was lowest, at 6.43 km (N=4), compared to 6.91 km (N=6) and 7.55 km (N=6) during the wet season and late flood season, respectively.

This coincided with their peak in body condition (see Chap. 3), and could be related to the quality of the forage that they were consuming. The nature of this relationship will become clear when analysis of grass samples from that period has been completed.

5. Triggers for long-distance movements

Across Africa, migrations occur in many different systems, for example in the Tarangire system in Tanzania, described in Bolger *et al.* (2008). Migrations should take place when the benefits of moving to an area outweigh the costs associated with travelling to that area (Alexander, 1998). Migrations are often associated with gaining access to higher quality forage, but can also be related to nutrient levels or access to water (Voeten, 1999). It makes sense for different animals in the population to move at different times, since when one herd leaves an area, there is less competition for food, so it may be beneficial for some herds to leave later (Alexander, 1998).

Anecdotal reports of buffalo movements in the Okavango Delta have described seasonal movements between floodplains in the flood season and areas dominated by mopane woodland in the wet season. These reports have been supported by findings to date. The habitat types found in the wet season home range produce large quantities of high quality annual grasses during the wet season. There are also numerous pans within the landscape that are full during the rainy season, removing potential constraints associated with daily water intake.

At the beginning and end of the rainy season, GPS fixes sent by the satellite collars were monitored closely. When a large scale movement was detected, the path taken by the herd was followed. At every GPS fix recorded by the collars along the path, vegetation samples were taken and the characteristics of each site were recorded as described previously. Ten sites used for grazing or resting within three days prior to the movement were sampled, as were ten sites used for grazing or resting within three days following the movement. Records of rainfall levels and temperatures were collected from several areas within the entire home range used by the buffalo (including wet and flood season home ranges). Day tables will be used to record changes in photoperiod. These data will be incorporated into a multivariate functional model that will be used to predict which combination of factors will trigger a seasonal movement by buffalo in the Okavango Delta.

One of the most important factors is likely to be water availability. In the wet season home range, pans represent the main source of water. Proximity to pans and pan density in different habitat types will be incorporated into the model. Ideally, regular monitoring of pans throughout the wet season would be carried out to correlate rainfall and temperature (affecting evaporation) with the persistence of water in pans throughout the year. However, this would require fairly intense monitoring, which is not currently feasible in addition to other fieldwork. I am in discussions with the University of Botswana about a local Masters student taking on this aspect of the study. This process has been slow, and a suitable candidate was not found before the rains in 2009. Hopefully a student can be located before next year’s rainy season so that the data can be incorporated into the model before submission.

Collared animals have reacted in a variety of ways to the first rainfall, occurring typically in November – December. Some animals have initiated a seasonal movement immediately, whereas others have taken several weeks to respond. Those that left soon after the first rains often returned to their flood season home range when the rains ceased for several weeks. One such example is a cow that performed three seasonal movements before settling into the wet season home range (see Figure 10).

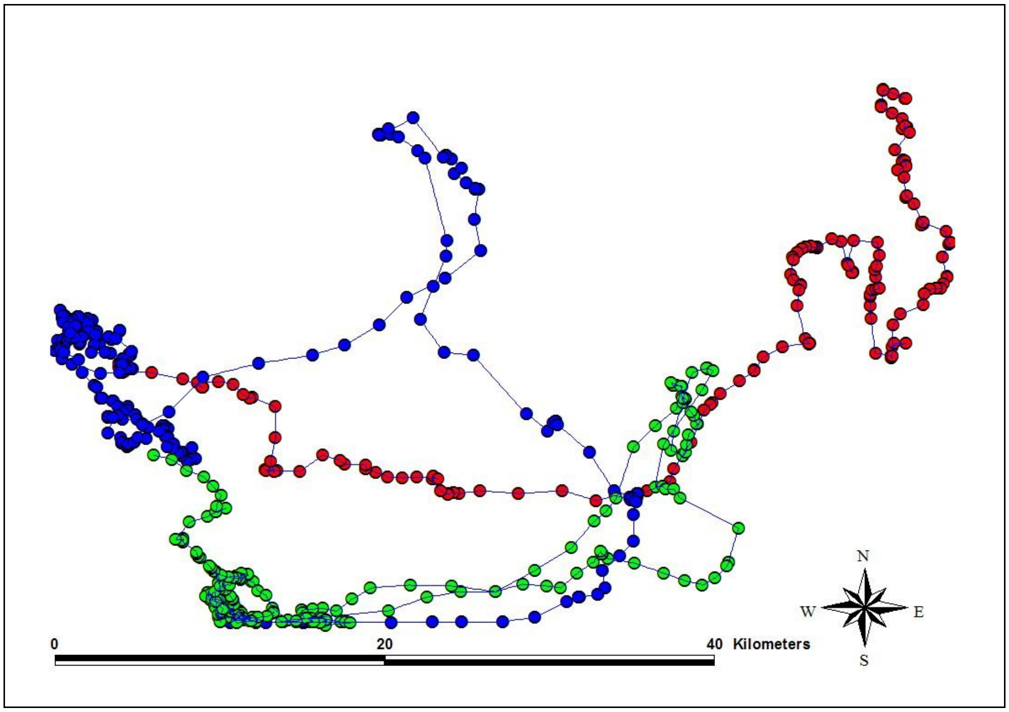


Figure 10: Long distance seasonal movements by B36. Different colours represent separate movements (green from 30th October – 5th November, 2009, then blue from 6th November – 12th November, 2009, and red from 17th November to 22nd November, 2009)

Discussion

The Okavango Delta is a unique system that is constantly changing, especially in terms of forage and water availability. Preliminary results suggest that these two factors are some of the most important in terms of influencing movements and behaviour of African buffalo. Buffalo require water on a daily basis to survive (Prins, 1996), but extensive flooding can reduce the area of available grazing. Understanding the mechanisms and causes of buffalo movements will broaden knowledge of the Delta ecosystem. The results of this study could therefore be applied to other species living in the Delta and help to predict the impact of future changes, such as those caused by climate change, on the species living in the Delta. The African buffalo is being used as a model species to gather information that can be applied to a broad range of species.

Satellite-enabled GPS collars have not previously been used on African buffalo, so the data being gathered will yield more detailed information than would otherwise be available. GPS fixes are being taken throughout the night, whereas other studies have relied on observations to collect night-time data (Ryan and Jordaan, 2005). Without these collars, locating buffalo herds would be very difficult, especially when they cover large distances, e.g. during seasonal movements, or when they spend long periods in inaccessible, highly flooded areas.

The Okavango Delta is made up of a dense mosaic of habitat types, linked to changes in water flow (Ramberg *et al.*, 2006). It is likely that buffalo respond to this complex system, utilising the diversity of available forage to their best advantage. This would include differentiating between habitat types according to season, as well as perceiving their environment on a number of different scales. Describing the mechanisms involved in buffalo movements and foraging selection would provide an insight into how animals optimise their foraging strategies.

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Third year work plan

December 2009	Follow paths of migrating herds and collect vegetation samples from ten sites used before, ten sites used after and all sites used during migration
January – March 2010	Collect data from 144 sites used by buffalo during wet season. Collect population dynamics data, body condition data and faecal samples from minimum of 12 herds, with combined total of at least 1,000 animals
April 2010	Follow paths of migrating herds and collect vegetation samples from ten sites used before, ten site used after and all sites used during migration.
May – July 2010	Collect data from 144 sites used by buffalo during early flood season. Collect population dynamics data, body condition data and faecal samples from minimum of 12 herds, with combined total of at least 1,000 animals

July - August 2010	End field work
Sept - October 2010	Analyse grass and faecal samples in laboratories of University of Botswana
November 2010	Remove collars and return to U.K. to begin writing up thesis
June 2011	Submit thesis

Thesis plan

Chapter 1 – Introduction

Main literary topic to be reviewed: Resource selection.

Resource availability varies across environments used by animals, in terms of water, shade, food, safety from predators, human disturbance levels. In order to ensure optimum survival strategy, they should select resources that will maximise fitness. Selection manifests itself across different scales – animals select specific food within a patch, select patches within their home range, select their home range within the landscape. In order to determine the level of selection and causes of variation, selected resources must be compared to available ones at all scales. This shows how animals perceive their environment so that important resources can be preserved and managed. Changes in resource availability caused by factors such as rainfall and flood levels should be reflected in the behaviour of buffalo. Do they use resources in a way that is optimal?

Chapter 2 – Methods

Summary of methods used in several chapters, not to be published as separate chapter, but incorporated into papers submitted for publication.

The project relies heavily on satellite-enabled GPS collars fitted to buffalo cows in several different herds. They have been fitted by a qualified veterinarian and programmed to take one GPS fix every hour, which is sent via satellite to a website that is accessible at all times. These fixes are used to calculate distances and bearings travelled along the path taken by the buffalo, and are plotted into Google Earth to determine habitat type.

Grass sampling uses measures of biomass, species composition and inter-tuft distances to describe sites. Samples are taken for separation into leaf and stem. The leaves are then analysed for nutrient content (especially nitrogen), as an indication of forage quality.

Chapter 3 – Population Dynamics

Age and sex composition of herds assessed across seasons to identify trends and determine health of population (recruitment rate). Publication target: Journal of Zoology.

Hypotheses:

1. Breeding herds will be female biased as males spend time in bachelor herds
2. The recruitment rate will be positive
3. There will be a fission-fusion society, with herd sizes and composition changing continuously

Compare herd sizes as well as composition across seasons. Buffalo show fission-fusion behaviour, with highly dynamic systems, herd sizes changing continuously and number of collared animals in one herd varying. Identify most common herd size in each season. Seem to be greatest in late flooding season, when waters recede and first rains start to fall, causing abundance of fresh green forage.

Compare ratios of males to females – in Chobe males are less often seen in breeding herds during early dry season (Halley and Mari, 2004). Compare ratio of young to adult females to identify possible breeding peak and estimate recruitment rate, showing health of population.

Chapter 4 – Home range and habitat use

Compare home range size and habitat composition between herds in same area (Gomoti or Stanley's) and between areas. Target publication: Journal of Applied Ecology.

Hypotheses

1. Certain habitat types will be favoured over others
2. Preferred habitat types will change with season
3. Herds will show seasonal home range use, defined by habitat composition

Home range size for animals within Gomoti and Stanley's areas respectively should be similar, but different between areas. Gomoti have seasonal home ranges, with wet and dry being in very different locations. Stanley's should be in fairly similar areas, but habitats will be used to different extents in different seasons.

Determine habitat composition within home range generally, and compare to habitat availability across entire study area. Also compare habitat availability within home range to habitat usage, with particular emphasis on seasonal differences.

Identify habitat types used at different times of day and for different purposes. Preliminary results suggest prefer to rest in woodland and graze in more open habitats.

Chapter 5 – Nutritional requirements

Quantify level of nutrients (esp. nitrogen) selected for by buffalo, and determine whether buffalo are limited by resources at any time of year. Target publication: Functional Ecology.

Hypotheses:

1. Buffalo will not be resource-limited at any time of year
2. Grass species with high leaf: stem ratios will be selected for
3. Buffalo will be more selective in areas with higher quality forage

Identify grass species selected by buffalo and describe in terms of leaf: stem ratio as well as nutrient content. Compare these characteristics between plants of same species at sites used for grazing/resting/walking, and between species grazed and avoided at different times of year.

Collect faecal samples and analyse for nitrogen content as indicator of nitrogen levels in forage consumed. Record body condition scores of individuals and compare values between age and sex classes, and between seasons. Determine whether these two measures provide similar results, and therefore whether one can be abandoned.

Chapter 6 – Movement at different scales

Compare movements within patches, between patches, and across landscapes. Target publication: Behavioural Ecology or Journal of Animal Ecology

Hypotheses:

1. Herds will move randomly within patches
2. Herds will move in a linear fashion between patches
3. Herd will move rapidly and in a linear manner between seasonal home ranges

Use data from GPS collars to examine distances and turn angles of movements and compare these between three scales (within patch, between patch and across landscape). Quantify average patch sizes, and relate these to herd size wherever possible.

Look at average distance moved in each season. Compare distances moved at night and during day to identify when most active. Break down activity levels into hours to determine when most likely to be resting/walking/grazing and relate to habitat use.

Look at return times to patches, determine whether there is a period of delay that is apparent more frequently than others. If samples allow, determine whether patches used several times with recovery period are re-used at optimum time in terms of vegetation quality.

Chapter 7 – Triggers for seasonal movements

Determine the importance of several factors in triggering observed long distance, linear movements between wet and dry season habitats. Target publication: Journal of Wildlife Management, Functional Ecology or Journal of Animal Ecology.

Hypotheses:

1. Herds will move from floodplains to mopane woodland at the start of the rainy season, and the reverse at the end of the rainy season
2. Movements will be between similar areas from year to year
3. Changes in forage quality and rainfall will be the main triggers for movements

Preliminary results show annual movements between wet and dry season home ranges, which have different habitat compositions, but movement only seen in Gomoti herds.

Monitor range of factors, including rainfall, NDVI, forage quality. Compare these factors in area left and area reached, as well as areas walked through on the way.

Construct model to determine which factors have an effect, and whether there is a threshold level for any of those factors that triggers a movement.

Chapter 8 – Conclusion

This project will determine the health of the buffalo population within the study area. It will also identify resources that are most important to buffalo herds and incorporate their conservation into a management plan for the Okavango Delta by submitting my results to the Okavango Delta Management Plan, as well as to the government of Botswana. Satellite GPS technology has not been applied much to buffalo, in the Okavango Delta or elsewhere, so will yield more detailed data on movements than have previously been available.

On a broader scale, this project will add to the understanding of how animals perceive and utilise their environment. The factors involved in habitat selection can be applied to a large variety of other herbivores, in the Okavango Delta in particular, but also in other ecosystems.

Budget

Secured funding is shown in bold.

University fees, over 3 years	**£10,000**
Field vehicle and accessories	**£7,000**
Fuel, over 3 years	**£6,000**
Vehicle maintenance, over 3 years	**£8,000**
Accommodation and food in Botswana, over 3 years	**£6,000**
GPS-enabled satellite collars (8)	**£24,000**
Store on board GPS collars (7)	**£7,000**
VHF receiver and antenna	**£500**
Downloading fixes from satellite collars over 2 years	**£8,000**
Darting fees to fit 15 collars, including helicopter hire	**£8,000**
Darting fees to remove 15 collars	£8,000
Laboratory fees, over 2 years	£2,000
Satellite phone	**£1,000**
Various equipment (GPS, camping equipment, binoculars)	**£3,000**
Return flight from U.K. to Botswana	**£1,000**
Living costs during 1 year write-up in Bristol	£10,000

Total budget	£109,500
Total secured	**£89,500**
Total being sought	£20,000

I received funding from the Harry Oppenheimer Okavango Research Centre (£18,000 in satellite collars, December 2007 and £7,000 in store on board GPS collars, August 2008), the Dulverton Trust (£5,000, December 2007 and payment of university fees equivalent to £10,000 over 3 years) the North of England Zoological Society (£1,500, July 2007), the Wilderness Safari Wildlife Trust (£6,000, January 2008; £3,000, January 2009), and Idea Wild (£500 in equipment, June 2008; £500 May 2009). I have also used my private funds and received funding from individuals (£10,000, January 2008). My accommodation, food and fuel are provided by Mr. Rodney Fuhr of the Squacco Heron Project, equivalent to £12,000 over 2 years. He has also helped with buying and fitting additional collars, contributing £16,000.

I have applied to numerous foundations and organisations for funding, including the Leverhulme Trust (twice), Philadelphia Zoo, Edinburgh Zoo, the Wildlife Conservation Society (twice), Seaworld and Busch Gardens, the Gen Foundation, the Wingate Foundation, the Tusk Trust, Zoo Boise, Oregon Zoo and John Ball Zoo.

I have received negative responses from all of these. I have also written letters to many companies and organisations requesting sponsorship, but received either negative answers or no response to my enquiries.

I have several applications pending, including from New Zoo, the Explorers Club and a continuation from Wilderness Safari Wildlife Trust. I am continuously seeking new funding opportunities and will be applying to several other foundations as deadlines approach. I have also organised fundraisers in Botswana and in the U.K. (by proxy).

I have put a web page online (www.okavango-buffalo-research.com) to promote my research and to try to generate funds, but have not yet had any responses. The African Conservation Foundation has agreed to include a page on my research on their website (www.africanconservation.org/content/view/1052/409/). I have produced leaflets that have been distributed around Maun and around some of the lodges that operate within my study area to attract tourists. I have offered to give talks to interested parties and am scheduled to do so within the next month.