AFRICAN BUFFALO RESPONSES TO RISKS AND BOUNDARIES IN HUNTING, AGRICULTURE, NATIONAL PARKS, & URBAN LAND USES

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Abstract

Buffalo herds were radiotracked in Southern Africa through four land use types (LUTs) to see whether movements, much more extensive than the same species demonstrates in East Africa, were for resource acquisition or risk avoidance, and if selection was occurring at any scale. Potential costs (risks) to buffalo herds in each LUT included predation by humans and lions, and vehicular traffic on three types of roads and one railroad. Benefits were various amounts of forage and water available in each LUT through the 6-month dry seasons, and somewhat manipulated by land managers. A movement model was hypothesized to be non-random use of available human-managed units, at the change-of-land use-scale avoiding the more dangerous Agricultural area and Urban areas. Use was compared to random at several scales: herd distribution from monthly aerial survey at the landscape scale, down to the finest scale of individuals selecting plants to eat. Herds did not use the four LUTs randomly over the three year study. A clear preference for Agricultural and Urban LUTs weighed heavily against the hypothesis that risk was being perceived at that landscape scale. However at finer scales more explanatory distributions and movement behaviors were seen. National Parks and Safari Hunting areas were used neutrally in Zimbabwe but both avoided in Botswana, with a trend strengthening with each dry season's progression. This suggested a finer spatio-temporal step, that of half-seasons by country's LUT, which demonstrated a seasonal shift exhibited by these herds, to the east as the dry season progresses, through and around the northern side of the Panda fields, and into Zimbabwe. By August each year there were no large herds found in the Botswana side of the study area, more than 15 km south of the perennial northern rivers. Road crossings and vehicular collisions also increased during the busy tourist month of June, and were particularly high in a 38 km stretch of tarred road in Botswana's Northern Plains area all the months that buffalo herds were seen in Panda. This indicates the herds are using the Kazuma Depression as a corridor of movement for this seasonal shift between the agricultural fields and Zimbabwe's well-watered safari areas. If construction of something to facilitate this movement and mitigate some of the road carnage which involves humans, hippos, and other species as well, it would be a very large underpass in the previously wetland area of this depression. Raising the highway there would benefit the wetland habitat, the functioning of the vlei ecosystem, would slow down traffic and benefit all the mobile animal species.

Introduction

Ungulates in the savanna mosaics of southern Africa move extensively during the six-month dry season, into and out of land use types where human managers of the ecotourism industry want them to stay longer. The "Big 5" popular game species (elephant, buffalo, rhinoceros, lion, and leopard) are the third largest contributors to the GNP of Botswana and the second largest to Zimbabwe's, as they are the drawing cards bringing ecotourists to the region. These species also are known as dangerous game, conflicting with humans in the few densely settled areas surrounding the vast protected wildlife areas (Martin 1990), yet necessary for the 'wilderness experience' of the thrill-seeking non-residents. The border between Botswana and Zimbabwe is a narrow dirt road, undistinguishable from the many others in the region and allowing free passage of mobile mammals back and forth. In northern Botswana and Zimbabwe the large mobile game are internationally shared resources supplying both countries' ecotourism industries, and thus it is the goal of both countries' governments to maximize biodiversity, biomass and access by the high-paying tourist. Access requires some degree of good roads, trains and airports, as well as hunting quotas and fees that will be paid frequently. Non-consumptive tourism (photographic safari) can be nearly as profitable as safari hunting if the volume of low-paying tourists is high. Both Botswana and Zimbabwe devote large majorities of their land that is not suitable for agriculture, to these two land use types (LUTs): national parks (NP) for non-consumptive and Safari Hunting areas (SH) for consumptive ecotourism.

This study was conducted in semi-arid southern Africa to deduce why buffalo (*Syncerus caffer caffer* Sparmann) were perhaps in serious decline in the region, or the alternative hypothesis, moving extensively and out of areas they had previously been found (and killed) in. Buffalo were believed to be in severe decline in Botswana in the early 1990's (D. Crowe and D. Gibson, pers. comm. 1993), while a similar decline was not noted in adjacent Zimbabwe (P. Mundy, pers. comm. 1994). As Botswana lowered its hunting quotas each year but Zimbabwe didn't, blame was placed on overhunting. There are no fences or any apparent barriers to prevent international movement of large mobile herbivores. Zimbabwe's national parks and safari areas are comprised of similar habitats to Botswana's, but provision water throughout the dry seasons. Preliminary study (Hunter 1994) showed that while many mammals appear highly mobile, there are no clear migrations in Southern Africa, but a higher degree of mobility than elsewhere exhibited by many mammals. Even wildebeest and zebra, which are clearly migrational in East Africa, seemed to move nomadically in the region (Joos-Vandewalle 1984) as did elephants, buffalo, eland, and perhaps other species. But the only telemetric study in the area was done with elephants and concluded that at least some subpopulations are "migrational" (Calef 1991 a,b).

Buffalo in East Africa, where two thorough studies of over ten years each have been conducted (Sinclair 1977, Prins 1996), are sedentery, herds defending riverine territories. In Southern Africa where most rivers run dry each year, herds were hypothesized to be much more mobile and non-territorial to search for water and forage as these resources disappear each long dry season. A telemetric study was needed in the region to see where herds were going, and whether they were avoiding any risks of mortality or disturbance along the way.

Risk-averse behavior is evident when herbivores forage in safer zones ('refuges') and avoid riskier forage resources. Two things are essential for the

hiding strategy to work: habitat heterogeneity to reduce predator visibility, and enough advance knowledge of predator locations to know when to move to the refuges (Skogland 1991). Refuges for ungulates us ually offer lower quality or quantity of forage, because of their heavy use (Noy-Meir 1981). In mid-risk level areas where ungulates have a choice of higher and lower quality patches, they often choose the lower quality, open patches that offer more predator-detection area (Festa-Bianchet 1988), but must forage there for longer time periods than in the higher quality but riskier patches. Larger ungulates have greater nutrient and biomass needs and thus must spend more time foraging, leaving less time available for predator detection & avoidance (Illius & Fitzgibbon 1994).

Thus foraging "refuges" can exist on any scale, from small patches to landscapes, and when humans are predators we affect several scales including the landscape. The distribution of predators and prey depends on their relative rates of movement. Each prey species probably has a unique scale of vulnerability to its predators. Where and when do buffalo herds take refuge from hunters or lions? Buffalo have earned their reputation as "the most dangerous land mammal in Africa" (Zimbabwe Hunter magazine Sept. 96) because they are the only ungulate known to frequently turn on, stalk and kill hunters. This did apparently happen to several hunters who wounded or missed in shooting at them, during the three years I was in the field. This behavior must be a response to a severe agitation that spreads throughout the herd somehow. There is a general belief that a buffalo herd is not at all disturbed to have one of its members cleanly shot, and often two buffalo can be taken in close succession from one herd. It is possible that greater disturbance behavior would be evidenced by a herd simply turning and moving away from the source. I documented from the spoor of herds this behavioral change from foraging movements to non-foraging 'milling' behavior. Buffalo are big enough (avg. adult mass 600 kg) to stand and fight, and do so often (Smithers & Skinner 1993, Estes 1993). This only contributes to their popularity as prey of humans and does not prevent the coordinated team of lionesses from taking adult buffalo often. Lions were considered ubiquitous and immeasurable across the entire study region. Human disturbance or mortality effects on buffalo were documented.

Elsewhere I report on herds' resource acquisition at several scales from the plant to the ecosystem (Hunter 1999), whether those resources are sufficient to support steady or increasing populations, and the actual population and social dynamics I witnessed in three years of tracking buffalo herds. Here I will report results on herds' movements between land use types, across roads and other potential barriers to movement, and their degree of recognition of the 'risks' posed by these human land uses (constructs, vehicles, and hunting behaviors). What buffalo herds recognize as risks, what were hypothesized to be and what actually materialized as risks of mortality or disturbance to buffalo turned out to be three different things .

Methods and Study Area

Land Use Types and their potential costs and benefits to buffalo

Botswana's only perennial river, the Chobe, forms its northern border and runs into Zimbabwe's northern border, the Zambezi, the only permanently flowing river in the northwestern quarter of that country. Since permanent water is a benefit that probably allows buffalo herds to remain sedentery, I chose to begin my study area 15 km south of that flowing river boundary, where herds are faced with a seasonal water shortage. Herds were marked by radio-collaring a mature cow found in the front of a cohesive group, more than 15 km from the river but less than 15 km from a boundary between two LUTs, and usually within 15 km of the Botswana/Zimbabwe border. All nine collared herds had access to all four LUTs and all ecosystems. The study area then was extended south, east, and west as far as buffalo herds could be tracked from fixed-wing and truck.

Aerial systematic surveys of a 21,000km^2 region were conducted monthly, yielding distribution data on all large herds, not just marked ones, and a mapping of available waterpoints. Along the way tracking each marked herd from the ground, I would quantify plant and water resources and the potential risks in each LUT, being urban constructs, density of humans and their vehicles (cars, trucks, trains). While these risks would not change over time, benefits would: the amount of surface water and green vegetation (potential forage for a generalist herbivore) were mapped monthly from the air. Linear boundaries visible from the air were traversed on the ground with a hand-held GPS, then digitized onto a GIS. I developed the LUT coverage first as the simplest, and used the GIS to quantify the areas of each spatial unit; this work continues for ecosystems and habitats.

Monthly interviews with all land managers were conducted, to assess numbers of hunting clients, non-hunting tourists, vehicles, and buffalo deaths in each land parcel per month. Figure 5.2 summarizes the potential threats and benefits to buffalo breeding herds hypothesized to be occurring in each LUT as the study began. There was no previous research or planning done on the subject of wildlife injuries by vehicles in either country.

In a typical year between 400 and 700 mm of rain fall between October and April. By about July, all natural surface water in Botswana is dried up and in Zimbabwe, rivers are reduced to sporadic pools and only pumped pans remain available to wildlife. Zimbabwe invested much more extensively in all LUTs in the technology to pump water into mostly natural surface water holdings, called pans, changing them from seasonal to permanent. Pumped pans and dams in rivers are very numerous and dense in western Zimbabwe, while rare in Botswana. Note on Fig. 5.2. the seasonal portion of all rivers south of the Chobe-Zambezi system, leaving them dry except for a few pools at dams. Areas with no pumped or successfully dammed water were marked higher risk (cost) than those providing access to water. Costs and benefits were assessed per management unit per month, by the techniques in Table 5.1. All linear boundaries were measured on the ground with GPS , differentially corrected and digitized, then a GIS used to measure accurate areas of all available resources or the land use 'blocks', so that no assumptions had to be made about what numbers to compare use to with the standard chi^2 test (Neu *et al* 1974).

The study area centered on the international Botswana/Zimbabwe border because of the shared nature of this mobile mammal resource, and on the unusual agricultural land use, Mpandamatenga or "Panda". These commercial agricultural fields of either sorghum or sunflowers (high protein oil crops) were farmed by a few mostly South African farmers on subsidies from the Botswana government. While this small (336 km ^{2} Tbl. 5.2) LUT occurs only in Botswana, it is on the international border (4 to 60 km in) and is completely unfenced. The Panda fields take up two thirds of Botswana's only arable (basalt) soils, the remainder of the "Northern Plains" lying in the Kazuma Depression in Botswana's safari hunting region. The rest of Botswana is covered by Kalahari Sands and their typical open teak woodlands. Pure basalts flood seasonally into slippery deep anaerobic clay 'pans', then crack and churn as they dry, both through self-churning and the action of large animals' feet. Thus agriculture on these 'black cotton soils' is difficult and risky, as all machinery must be off the fields before the first rain, which can come anytime between early September and early November. Western Zimbabwe is predominantly covered by rocky skeletal basalts and granites, often mixed with some sand intrusions from the Kalahari, but that government has left the black basalt plains open for wildlife and even protected their half of the great Kazuma Depression with a small National Park (KPNP on Fig.5.2).

There remains an old annual problem, elephants and buffalo foraging in the fields at night throughout the growing season, which is the first half of the dry season (generally seeds are sown in April and harvested in June and July). Problem Animal Control (PAC, the shooting of animals by authorities not for financial profit) is conducted nightly by both farmers and the Department of Wildlife and National Parks (BDWNP), which is mandated to deal with it across the country and maintains a basecamp in or beside the fields. Any and all ungulates caught trespassing these unfenced fields can be shot, day or night. Local residents admit this often provides much of their meat for the year, with buffalo the most popular of 22 species of game. However, a new law in 1994 changed the rules slightly: the crop-defender cannot utilize the meat personally, it must be given to the BDWNP personnel nearby and then sold to the community. When extensive crop damage is done, the farmers claim recompense from the Government of Botswana as part of their subsidies.

The second smallest land use in the area is called 'Urban' (U) , devoted to human residence and including the usually associated small buildings, roads and other structures, and livestock which occur where humans put them. In ex- colonialized Zimbabwe, British gardens are popular, full of exotic flowers. Most houses in both countries are small mud buildings with either thatch or tin roofs. Powerlines and train tracks are other linear potential threats to movement by large animals.

Table 5.1. Methods used to assess and index risks, costs and benefits to buffalo in each managed land parcel each month.

- Hunting Records and observed hunts
- Observed behavior at roads and other potential barriers ("milling")
- Interviews with Land Managers (vehicle/client densities, hunting, manipulation of grass and H20)
- Interviews with Group Users by Participatory Rural Appraisal (meat availability)
- Roads and Tracks Kills Reported
- Density of Tourists, Vehicles
- (Parks Records & Pers. Obs.)

Table 5.2. Areas (km^2) of each of the four LUTs in the study area. An attempt was made to incorporate an equal amount of each LUT in the two countries, and to center the captures and thus study region on the only Agricultural land use, MPandamatenga in Botswana but right on the Zimbabwe border.

LUT	Zim	Bot	Study
Urban	204.4	347.0	551.4
Agriculture	0.0	336.0	336.0
Safari Area	5160.2	5912.0	11072.2
National Park	4025.0	4176.0	8201.0
Totals (km2)	9389.6	10771.0	20160.6

Safari Hunting (SH) Areas aim to give the luxury of a wilderness experience in style to the hunters braving the chase of big game, and paying many foreign dollars for the priviledge. Clients are guided by a Professional Hunter in small groups or often one on one. The tiny compounds of staff that support the cleaning of meat and trophies, the catering of food and lodging, etc. while trying to remain inconspicuous in the surrounding wilderness, and thus usually have only a small fence around the compound. Hunters are kept very low volume, one to four per professional guide, and escorted through the wilderness without seeing another human being. The policy in both countries is to use an open 4WD vehicle on dirt roads until a trophy animal is spotted, then to stalk and hunt from foot. Crews of cutters and bearers are brought in after a large animal is bagged. A network of dirt roads is necessary for access; in Zimbabwe's SH (Matetsi, Fig. 5.2), there are many waterpoints pumped and many roads connecting them all. Botswana's Safari Areas are much larger management units leased for shorter terms to the operators, so they have not been able to invest in any pumped waterpoints. The few dirt roads in that safari area go around the few natural, seasonally drying pans. Botswana's hunting quotas are set annually by the BDWNP; in 1997 they took buffalo off quota and put a few elephants on, implementing the downlisting they achieved at CITES in 1996. Zimbabwe's Department of National Parks & Wildlife Management (ZDNPWM) also sets annual quotas for all game species, but has not changed them in many years so it is unclear how much basis they have in the science of population dynamics.

National Parks (NP) are federally protected and share the goals in both countries of providing a safe place for all wildlife for the viewing pleasure of ecotourists. While they claim to want to maximize biodiversity, the visibility of the popular megafauna is more important to Parks staff. National Parks have been defined as places for wildlife providing all except fish safety from human predation, and actively excluding human users of natural resources, ever since the "Yellowstone Model" first defined the world's first National Park. This policy has been unfortunate for many indigenous human societies, as they are continuously evicted and excluded from areas rich in wildlife and other natural resources they traditionally used. Southern African NPs have been designated with less disregard for human residents, but after colonialism already had moved many subsistence societies (Cumming 1993). Botswana parks policy has been historically separate all wildlife from humans and their cattle, by means of elephant-proof fences. However the costs on game that must move to drink or for forage or refugia, the costs are too high, and the country reduced plans to build other fences. They are very expensive and require constant maintenance, so the fencing policy has been abandoned completely in Zimbabwe and is only successful in areas of low elephant density in Botswana (Thomas & Shaw 1991, Hoare 1992). There is only one small game-fenced area in the study region, a private hunting reserve in Matetsi. Each of the four national parks contains several housing compounds, small villages of huts surrounded by elephant-proof fences. These compounds were labeled Urban. The NPs exert virtually no limit on day visitors with their own vehicles, and overnighters are common in the dry season, limited only by housing (during the study, about 75/pm in the portion of Hwange National Park (HNP) studied). The season closes the basalt-based areas upon first rain, but leaves open the sandy-based areas, which is the majority of HNP and all of CNP, open all year. Although vegetation is thick during the rains, tourists again are found at high densities around Christmastime.

Boundary Dynamics

If the majority of a herd was seen on (crossing) a road, the LUT for that location was marked Urban, regardless of the LUT in which the road lay. Road crossings were also reported to me by residents along the two tar roads in the region, and by the Pandamatenga Wildlife Dept. personnel who recorded all vehicle/wildlife collisions. From my own frequent driving of the roads I estimate that about ten% of all herd crossings were reported to me or witnessed by me. I drove the international border from Kazungula (Zambia border) to the northern edge of HNP on three occasions, marking all buffalo spoor crossing it.

In the case of the Victoria Falls Safari Lodge which lies on the edge of Zambezi NP with nothing marking the boundary, the NP LUT was defined right up to the manicured lawn around the hotel itself, where "Urban" began. So the hotel's pumped natural pan for wildlife, while officially on private ground, was called NP because no hunting was allowed there and there was nothing distinguishing it or separating it from the park. The pan lies 300 meters from the hotel balcony. Since there was nearly constant watching for herds from this balcony ('The Buffalo Bar"), location of buffalo herds at that pan could be considered a continuous record, if someone were there to check on the counts and recording of each occurrence of a herd. I used only counts and sightings of collars made by myself or a trusted official. Herds often would drink at the pan, then go eat at the lodge - the lawn or the thatch roof!

Table 5.3. Methods of Assessing Risk of Disturbance to Buffalo

All Early Dry		LUT Ag	NP	SH	U	Total	P Used As Avail?	All AI >100		LUT Ag	NP	SH	U	Total	P Used As Avail?
Risk	1		73	1		74	**3E-06**	Risk	1		27			27	**0.0094**
	2			124		124	**no*** **		2			38		38	**no****
	3	17			16	33			3	1		1	6	8	
		17	73	125	16	231	Total			1	27	39	6	73	Total
% used		7.36	31.6	54.1	6.93	100		% used		1.37	37	53.4	8.22	100	
% avail.		1.67	40.7	55	2.73	100		% avail.		1.67	40.7	55	2.73	100	
Zim. Early Dry		LUT **Ag**	**NP**	**SH**	**U**	Total	P Used As Avail?	**Zim. AI >100**		LUT **Ag**	**NP**	**SH**	**U**	Total	P Used As Avail?
Risk	1		64	1		65	**0.30488**	Risk	1		23			23	**0.0006**
	2			91		91	**yes**		2			37		37	**no*****
	3				7	7			3			1	5	6	
		0	64	92	7	163	Total			0	23	38	5	66	Total
% used		0	39.3	56.4	4.29	100		% used		0	34.8	57.6	7.58	100	
% avail.		0	42.8	55	2.2	100		% avail.		0	42.8	55	2.2	100	
B & B/Z Early Dry		LUT **Ag**	**NP**	**SH**	**U**	Total	P Used As Avail?	**B & B/Z AI >100**		LUT **Ag**	**NP**	**SH**	**U**	Total	P Used As Avail?
Risk	1		9			9	**3.7E-43**	Risk	1		4			4	**2E-25**
	2			33		33	**no*****		2			1		1	**no*****
	3	17			9	26			3	1			1	2	
		17	9	33	9	68	Total			1	4	1	1	7	Total
% used		25	13.2	48.5	13.2	100		% used		14.3	57.1	14.3	14.3	100	
% avail.		3.1	38.8	54.9	3.2	100		% avail.		3.1	38.8	54.9	3.2	100	

- Hunting Records and observed hunts
- Interviews with Land Managers
- Interviews with Group Users by Participatory Rural Appraisal
- Roads and Tracks Kills Reported
- Density of Tourists, Vehicles (Parks Records & Pers. Obs.)

"Risk" of disturbance by humans both on foot and in vehicles was indexed after interviews with land managers across the study region (Park Wardens, gate keepers, hunting scouts, safari operators, professional guides, pilots, residents). Enough information was obtained on their density, duration, and activities of clients to assess an index of pressure monthly per unit. Their sightings of buffalo were however not used as locations, as they could not be confirmed or even sampling across the region as my surveys were. The ratings of "low, medium, or high" risk to buffalo herds were conservatively assigned after all locations were obtained (thus not biasing me into finding more or less in any risk category). They entail:

Low (1) = few cars and people in the unit ; in NPs = low season, in SH = no clients.

Medium (2) = hunting for buffalo in that unit for the majority of the month

(includes high density photographic tourists, always accompanied by an armed guide)

High (3) = any number of buffalo killed in that unit that month by humans or vehicles

(includes wounded and lost, as lions are very likely to finish off a wounded buffalo)

Humans are threats at both fine and coarse spatial scales, and the temporal season of disturbance is longer than the natural dry season of resource shortage. In residential areas it is all year long. In the ecotourism land uses, monthly changes in risks to buffalo were assessed at the scale of the management unit, where they could be regulated and measured.

Results

Buffalo were found to move greater distances and have larger home ranges than recorded anywhere else. The eight herds relocated sufficiently to assess these movements covered at least

Table 5.4. Used and available percentages of locations of buffalo herds in each of four Land Use Types: Ag = Agricultural, NP = National Park, SH = Safari Hunting, and U = Urban, any human consturcts like residential areas. The shaded boxes show significant differences. The table addresses at the top, the entire study area and 3 years (95-97). On the left is the early half of all dry seasons, and on the right the second half (AI = aridity index = days since rainfall). The second row covers all locations in Zimbabwe only (hence no Ag use noted there), and the last row is all the Botswana locations.

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the 20,000 km^2 surveyed and perhaps more, as three marked herds disappeared out of the study

area on different occasions. Herd movements and distribution were rarely random.
location data combined, herds used only Zimbabwe's LUTs in the early dry seasons (late wet, still green) randomly.

Discussion

Buffalo herds showed a clear preference for the sorghum and sunflower fields over all other forage resources available in other LUTs, despite the intense risk of getting shot in those fields, and the usually long treks from those fields to water. This food resource of course would increase in importance to herbivores as the greenness disappears from vegetation through the early dry seasons. Since western Zimbabwe has traditionally provided the only reliable dry season water, this movement to and from the fields to the east of them across Botswana's busiest highway. As vehicular traffic increases, so does mortality of all animals on this highway. Botswana's safari hunting areas were avoided by buffalo herds, weakly in the early dry and absolutely in the late dry seasons. This aversion could be partially due to high mortality on the wide road. Since the east/west seasonal shift seems to be quite a traditional one (occurring every year of the study and suggested by local hunters), passage across this road must be facilitated somewhere.

High frequency crossing areas were about ten km from the northeast corner of the fields up to the Kazuma Depression. This demonstrates that herds use the Kazuma Depression as a movement corridor, at least when they can access waterpoints near or in it. During the preliminary study buffalo were not seen to use this large open grassy " vlei" (local word for seasonally inundated grassland depression), and Botswana government was discussing expanding their agricultural operation into the northern plains (Cooper 1993). But the location data from this study shows a clear seasonal shift of herds west and into the open plains as each wet season began. The importance of protecting this valuable corridor for all the large mobile species to continue moving between Botswana and Zimbabwe cannot be understated. Protection by Botswana would involve not only abandoning expansion of agriculture there but also some sort of road crossing aid. Since the road lies on flat basalt which also acts as a seasonal wetland, I suggest the proper mitigation would be raising the road over an underpass, large enough for a herd of elephants to pass through (for a herd of buffalo I would suggest at least 80m wide). This would help restore the unique wetland of the Kazuma Depression and all the smaller animals which depended on it. It might also slow traffic a bit in that flat region where not many slow for wildlife. It would save many lives, human included, and would be a much more effective investment than fences or the costly choice, doing nothing. All the mobile animals are an internationally shared resource. Botswana is concerned about its buffalo population decline so might be willing and able to facilitate this passage into the adjacent N. Park, an improvement to the wetland that doesn't involve changing the land use from Safari Hunting but would allow more to get away…and return. Creative and planned landscape manipulations would probably be utilized by mobile mammals even more than the traditional pumped waterpoints and crop fields, and are necessary to reduce human/animal conflicts.

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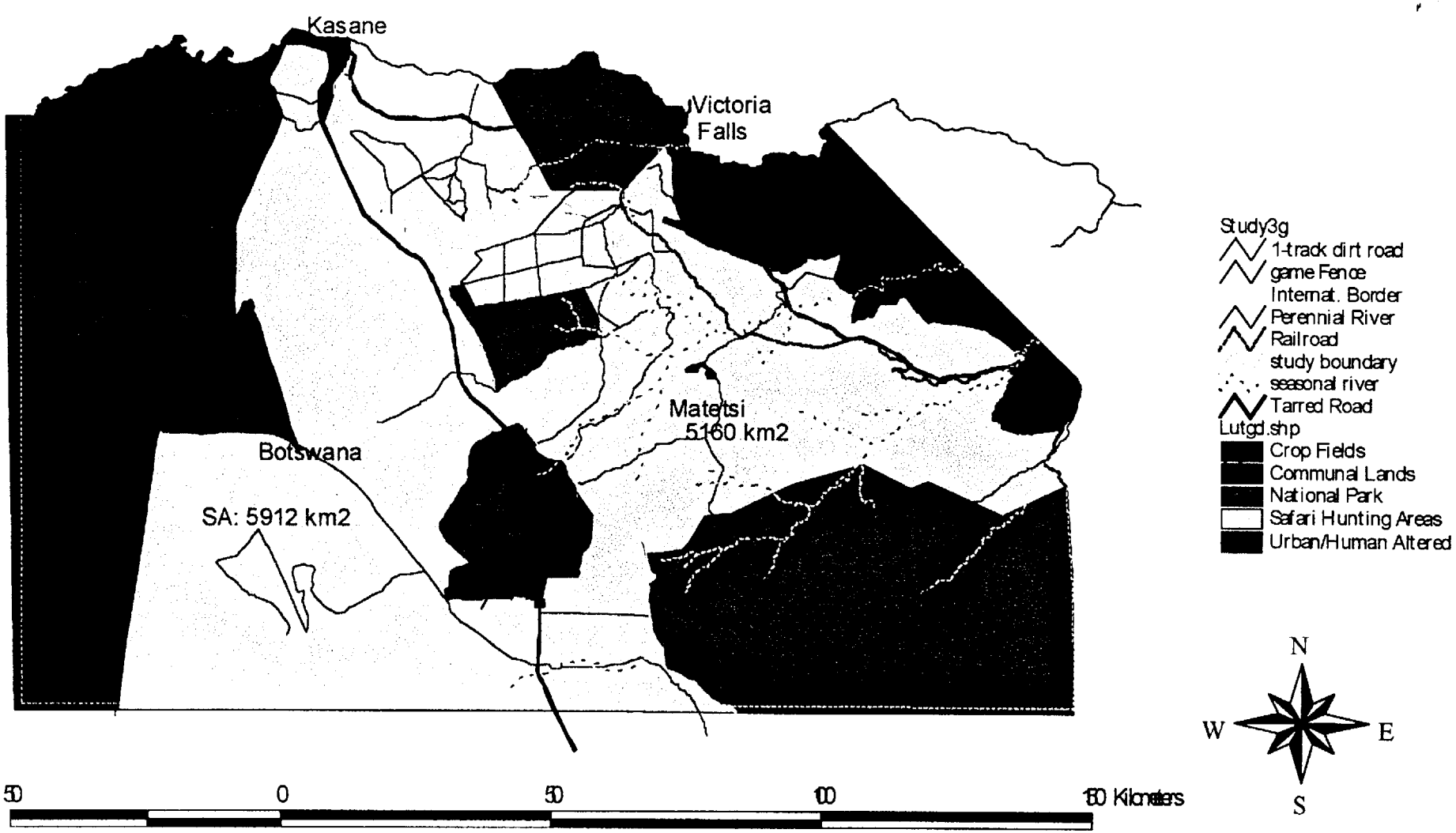

Figure 5.2. The Botswana/Zimbabwe border study area, with accurately measured Land Use Types and extent of all rivers, roads, tracks, and fences.