Wildlife movements over the Trans-Kalahari Transportation Corridor: A challenge to obstructive fencing in general and the Trans-Kalahari Railway specifically

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Summary

- This report was motivated by the assumption that the proposed Trans-Kalahari Railway may also have wildlife-proof fencing proposed along its route.
- The existing Trans-Kalahari highway following the Trans-Kalahari Transportation Corridor (TKTC) has wildlife-proof fencing spanning both sides of the road along some sections, while other sections remain open with no fencing at all.
- During November-December 2014, we quantified wildlife movements across the TKTC by interpreting animal tracks through the unfenced sections of roadway that bisect Wildlife Management Areas (WMAs).
- We found two hotspots for wildlife movement: one where the TKTC bisects GH10 and GH11 WMAs (northern wildlife corridor), and a second where it bisects the area of SO1, SO2 and KW6 (southern wildlife corridor).
- Granted the limited sampling period, we found that there occurred on average 52 large antelope crossings over the road in the north corridor, and 42 crossings in the south corridor, during each 24 hr period. Extrapolated this amounts to ***more than 30,000 large antelope crossings over the TKTC annually***. Most wildlife road crossings occurred at night when traffic volume was low, and the frequency of wildlife-vehicle collisions at present traffic volume is very low.
- GH10 and GH11 WMAs are particularly important as they comprise the most pristine wildlife habitat along the length of the TKTC and thus the only place remaining where the most disturbance-sensitive antelopes (gemsbok and eland) cross the road on a daily basis. This is a pinchpoint of functional wildlife habitat connectivity between the two great Kalahari protected areas: Central Kalahari Game Reserve and Kgalagadi Transfrontier Park.
- Closing these remaining sections of the TKTC with wildlife-proof fencing would effectively split the Kalahari ecosystem into two pieces in terms of free-ranging Kalahari antelope populations. Besides causing potentially massive mortalities along the new fences, such an obstructive barrier would severely undermine the long-term conservation of antelope populations that rely on large-scale movements to access patchy resources in a drought-prone ecosystem.

- ***Most importantly, with the exception of certain small species (e.g. tortoises), wildlife movements are generally not threatened by a railway line itself, but rather by any associated fencing that goes along with it.***
- We suggest three possible motivations for erecting wildlife-proof fencing along the proposed Trans-Kalahari Railway: a) protect trains from wildlife and livestock, b) protect wildlife from trains, and c) protect livestock from trains.
- Providing examples from other parts of the world, we argue that both a) and b) are negligible risk or inconsequential; thus, the only reasonable motivation for wildlife-proof fencing would be to protect livestock from being injured and killed by trains.
- We conclude that complete fencing along the TKTC would be a fruitless effort with severe negative consequences for free-ranging wildlife populations, and therefore unacceptable to Botswana. If the proposed Trans-Kalahari Railway proceeds, presently unfenced sections ought to be kept unfenced.

Introduction

According to the "Last of the Wild" data[1], Botswana's Kalahari including the Central Kalahari Game Reserve (CKGR) in the northeast, the Kgalagadi Transfrontier Park (KTP) to the southwest, and the expanse of Wildlife Management Areas (WMAs) and sparse settlement in between the two parks together comprise the largest least-disturbed ecosystem remaining south of the Sahara. Another underappreciated fact: wildlife can conceivably walk between Two Rivers and Kuke corner, a straight-line distance of nearly 700 kilometres, before encountering a man-made barrier that hinders their travel. This is more than double the distance of either the famed Serengeti wildebeest migration in Kenya-Tanzania, or the Nxai Pan-Chobe zebra migration recently called the "longest in Africa"[2]. Veterinary cordon fences do not intrude into this southwestern quarter of Botswana as they do fragmenting the rest of the country.

Figure 1 *An animal's view over the Trans-Kalahari Transportation Corridor - remarkably, where sections remain unfenced as here, this tarred road is the most substantial 'barrier' to wild animals moving between Two Rivers and Kuke corner, a distance of nearly 700 kilometres.*

The 2012 Department of Wildlife and National Parks (DWNP) aerial survey verifies the fact that this CKGR-KTP corridor ecosystem supports the great majority of free-ranging gemsbok, hartebeest, eland, springbok and ostrich remaining in the country, plus a sizeable proportion of kudu and wildebeest. Unfortunately, aside from aerial surveys, limited wildlife research capacity in Botswana has tended to focus in the north. Research has not kept pace with demand for up-to-date information on wildlife populations and their movements.

In 1989-91 Bonifica[3] showed Kalahari wildebeest undertaking seasonal movements between CKGR and breeding grounds in Kgalagadi. Since then few collaring studies, that have not specifically targeted wildlife movements through the CKGR-KTP corridor system, have been inadequate to give us a picture of more recent wildlife movement patterns. Deploying GPS or radiocollars on wild animals is expensive and invariably limited to exceedingly small samples. It is unlikely that a particular animal will travel between CKGR and KTP, especially over short periods of observation.

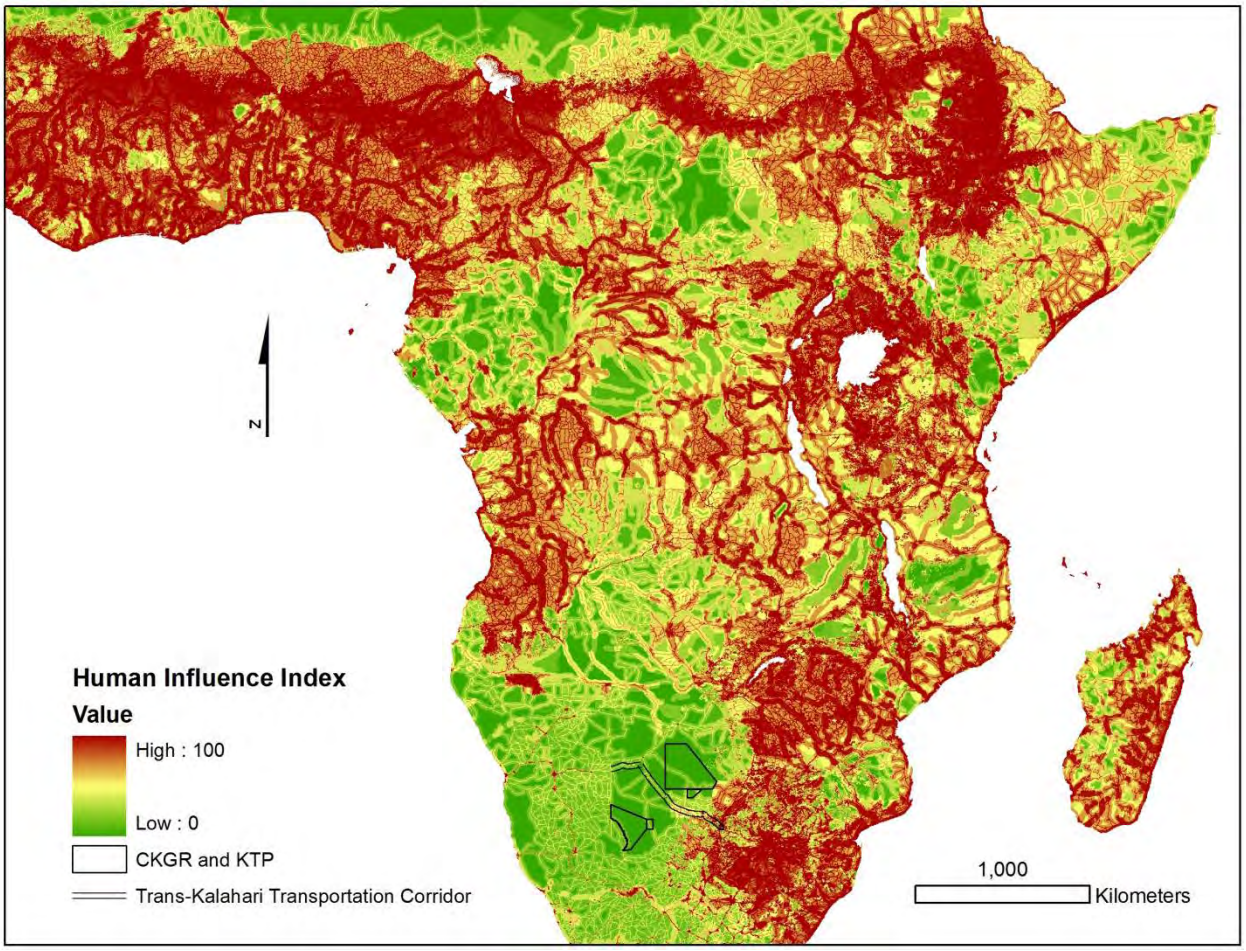

Figure 2 *A map displaying human influence on Africa's landscape highlights the fact that the Kalahari including CKGR and KTP (outlined) and the WMAs connecting the two, comprise the largest remaining least-disturbed area south of the Sahara. The Trans-Kalahari Transportation Corridor bisects this landscape. A continuous fence along it would sever the ecosystem, in terms of free-ranging wild antelopes, into two pieces.*

Over-reliance on such scanty data combined with the well-known and reiterated collapse of wildebeest in the 1980's[4,5,6] may dangerously direct us toward presumptions about an overall decline and contraction of wildlife in the Kalahari. This is not helped by casual observations along the A2 tarred road where livestock can be seen throughout from Jwaneng to Mamuno, while wild animals are rarely observed, even in sections of road that pass through the WMAs.

Lack of awareness of what lies just beyond sight from the tarred road in this under-researched region is reflected even within the scientific literature: statements such as "Only in northern Botswana, where no fences exist, do substantial herbivore movements persist"[7] are misleading and untrue. Such errors of omission perpetuate a myth that all of Botswana south of the Okavango Delta has already been fragmented like the rest of southern Africa.

Perhaps the consequences of these presumptions are best illustrated by the ease and rapidity with which fences have been erected in recent years along the A2 Trans-Kalahari highway. In light of this, and plans to develop the Trans-Kalahari Railway, it is prudent to understand present rates of large antelope movement, where these movements occur, and what the potential for future movements and wildlife recovery is before any decisions to increase fencing along the Trans-Kalahari Transportation Corridor (TKTC) are taken.

Figure 3 *Livestock is prevalent and visible all along the Trans-Kalahari Transportation Corridor, even in those unfenced wildlife corridor crossings within the WMAs, while wildlife is mostly invisible.*

Methods

To aid these knowledge deficiencies, we undertook a simple roadside animal track survey during November-December 2014.

Two unfenced corridors were selected that are thought to be the areas where most wildlife crossings now occur: a 94 km section between the KD/GH boundary (Palamakoloi) and Takatswaane, referred to here as the "North Corridor" bounded by GH10 and GH11 WMAs to the east and west respectively, and the 48 km section between Morwamosu and the eastern boundary of SO2, referred to here as the "South Corridor" which includes both SO1 Communal Grazing Area (CGA) and SO2 WMA. Note that the North Corridor continues unfenced beyond Takatswaane all the way to the Mamuno junction. However, cattleposts increase markedly beyond Takatswaane so this stretch was

not sampled. Note also that there is another sizeable unfenced corridor east of Mabutsane that was not sampled. Between North and South Corridors fencing is almost continuous besides short unfenced sections encompassing the villages Kang, Phuduhudu, and Morwamosu, a few narrow gaps (< 1km) between fenced farms throughout the Kang - Phuduhudu stretch, and a 5 km gap between Phuduhudu and Morwamosu.

We used a 4x4 to drive slowly (8-9 kph) along the A2 Right-of-Way (RoW) close to the edge of the bush. NK and !NB are two of four persons holding Master Tracker Certificates[8] in Botswana. They were perched on tracker seats scanning for large antelope tracks from the front of the vehicle, while DK drove. While driving, DK also recorded traffic passage rates along the highway. When a fresh track was encountered we stopped, determined species, the number of individuals and age of the spoor to the nearest 24 hr period, and interpreted the behavior of the animal(s) with respect to the tarred road - whether they hesitated, or walked slowly across, or went at speed in a gallop, or clearly deflected due to fright and failed to cross, and so on. Our work began in the morning but continued at any time during daylight hours, although between noon and 14:00 we often rested when heat and glare were most intense.

We managed to sample the South Corridor 3 times, and the North Corridor twice overall but 4 times in the two sections at either end where most wildlife movement occurs, as suggested ahead of time by NK and !NB. Total numbers of animals crossing the road per day were estimated as means of crossing frequencies within 24 hr periods, and 95% confidence intervals were calculated from pooled standard errors.

Results and Recommendations

Daily wildlife movements over the A2 tarred road

The Kalahari may appear devoid of wildlife if one is basing their opinion on direct daytime observations. We surveyed a total 455 km over 14 days, traveling slowly and often early in the morning, yet during that entire time we saw one hartebeest cross the road. However, through their tracks we recorded 630 large antelope crossings, and 150 more that either deflected or simply walked along the RoW but did not cross the road.

Table 1 Average numbers of wildlife movements over the A2 tarred road through two remaining unfenced sections named here "North" and "South" Corridors (see Appendix for locations) as determined from roadside track surveys in November-December 2014.

Species	Daily average crossings North Corridor	Daily average crossings South Corridor	Total daily average crossings over tarred road (95% Confidence Interval)	Estimated annual crossings or predicted number of movements disrupted by new fencing in one year (95% Confidence Interval)
Hartebeest	16	40	56	20,577
Kudu	19	2	21	7,769
Gemsbok	13		13	4,867
Wildebeest	2		2	831
Eland	1		1	402
Large antelope total	**52**	**42**	**94 (77 - 111)**	**34,446 (28,247 - 40,645)**

Every day about 94 large antelopes cross over the A2 tarred road through the North and South Corridors. This amounts to perhaps 28,247 - 40,645 crossings annually, or the predicted number of movements disrupted in one year if the Corridors were to be closed with fencing. The number of individual animals is somewhat less because some animals would have walked back and forth over the road and their tracks recorded more than once. Likewise, the predicted annual crossings are not individual animals but would include many of the same individuals making movements on different days.

The accuracy of these estimates is less important than highlighting the fact that 'many' animals cross the road on a daily basis. The true number that cross through the Corridors in any given year is likely to fluctuate depending on environmental conditions and could often be much higher. Our small sample captured day-to-day movements but not those infrequent mass-movements such as that on April 16 2014 when 400-500 eland were observed crossing over the road through the Okwa valley[9]. The Okwa is beyond Takatswaane - the arbitrarily defined northern limit of our North Corridor - and note that this single event already exceeds our predicted eland crossings in one year! Furthermore, we know that these daily average crossings are underestimates. Track detectability was not optimal because green-up had already begun along the RoW, obscuring visibility. An unknown number of tracks were missed and uncounted because there were 5 instances when DK spotted fresh tracks from the window that the trackers had failed to see, which means there were certainly others that went unnoticed.

Locations of wildlife movements

The locations of these crossings are illustrated in the Appendix. A few points are notable:

A narrow pinchpoint not more than 20 km wide appears to be the only remaining corridor through which gemsbok and eland cross the road on a daily basis. This is the wildest section that the TKTC bisects. Livestock rarely venture off the RoW and beyond 100 metres in either direction into GH10 and GH11 remains as undisturbed as the parks. It speaks to the intactness of the WMAs and reminds us that CKGR and KTP are linked through wilderness areas acting as viable wildlife habitats for even the most sensitive species.

Within this pinchpoint there is a remarkable wildlife feature. At a particular location along the old calcrete Trans-Kalahari road, which parallels the new tarred highway, wildlife are utilizing the crumbling calcrete as they would typically use a mineral-rich pan. Nearby, an abandoned borrow pit has essentially been converted by frequent trampling, digging and gnawing into a major wildlife lick. There is an absence of natural mineral pans within this area of GH10/11, and this substitute appears to be a major attractant of importance for local wildlife. All 5 large antelope species come to this wildlife lick regularly, including herds of disturbance-sensitive eland, which appear to travel from the direction of CKGR and also cross the tarred road from GH11. When we typically hear about wildlife being lost and their habitats encroached upon, this is a remarkable story for Botswana: wildlife are reclaiming an abandoned road and borrow pit. We bring it to attention here because it ought to be considered in any railway construction planning. NK and !NB are particularly concerned about this unique and important wildlife feature.

Figure 4 *Wildlife lick on old calcrete highway located 130 metres from the new tarred road. All 5 large antelope species utilize this salt lick regularly. !NB (foreground) holds eland droppings in his hand while the sand embankment behind NK is riddled with spoor of an eland herd that visited recently from the east.*

Between Bere and Takatswaane, the TKTC bisects several fossil tributaries of the Okwa. These linear "molapo(s)" are important large antelope habitats and, according to NK and !NB, historical migration routes that draw wildebeest and hartebeest along the drainages between the northeast in CKGR towards the southwest in western Kgalagadi. It is here that the majority of radiocollared wildebeest movements were concentrated in 1989-91[3], and today's road crossings data mirrors these movements 25 years ago. That these movements still occur, however reduced they may be, is

important because this entire area south to Bere and Kacgae is slated to be imminently usurped by new fenced ranch developments according to Ghanzi Land Board[10].

The unfenced Southern Corridor encompasses not only SO2 WMA, but also SO1 CGA. And good thing it does. More than half of all wildlife crossings recorded, mostly hartebeest, were within the CGA rather than the WMA. Contrary to appearances on a land use map, unfenced CGAs in the Kalahari continue to be important wildlife habitats, not just as corridors, but as breeding habitats in those areas where human and livestock pressure (cattlepost densities) remain low enough. Large numbers of hartebeest within the Southern Corridor are consistently found year after year in the aerial survey records. Although we did not sample the Mabutsane-Sekoma section, it appears the same. A herd of 10,000 hartebeest were noted near Sekoma pan in 1963[11].

Wildlife are not only crossing the TKTC from one destination to another, they are utilizing the areas through which the TKTC bisects as foraging and breeding habitat. All 5 large antelope species were recorded with fresh calves. Wildebeest with young moved back and forth over the tarred road to the mineral lick in the North Corridor. Hartebeest nursery herds with up to 8 young meandered along the South Corridor RoW grazing, an indication that this area is among the best available range[12]. There are bull hartebeest with territories that actually include the tarred road; their dung middens are right on the RoW.

Figure 5 *A scrape and dung midden that marks the territory of a bull hartebeest. This one, in SO1 Communal Grazing Area, is only 14 metres from the A2 tarred road on the Right-of-Way. Unfenced CGAs remain active movement corridors and breeding habitats for wildlife. It is no coincidence that the best grazing areas have attracted people with their livestock.*

Probability of wildlife-vehicle collisions at present traffic volume

Botswana Police records of traffic accidents involving wildlife were retrieved for the North Corridor between Palamakoloi and Lone Tree - where the greatest wildlife crossing activity occurs.

Table 2 Traffic volume, reported wildlife-vehicle collisions, and collision probabilities within North Corridor between Palamakoloi and Lone Tree. Reported wildlife-vehicle collisions are those on Botswana Police record that have resulted in either an insurance claim, injury, or fatality. Estimates of traffic volume and antelope crossings include 95% Confidence Limits.

Estimated traffic volume per day between Palamakoloi and Lone Tree	Estimated vehicles passing over past 5 years	Estimated antelope crossings over past 5 years	Recorded antelope-vehicle collisions over past 5 years	Probability of vehicle driving between Palamakoloi to Lone Tree resulting in reportable wildlife collision	Probability that a large antelope crossing the A2 results in a reportable collision
613 ± 127	1,118,725	78,475 ± 6,693	5	1 in 223,745	1 in 15,695

About 613 motor vehicles travel the A2 between Palamakoloi and Lone Tree per day. Traffic volume was higher throughout daylight hours averaging 32 vehicles per hour, and generally low between 23:00 and 05:00 averaging 11 vehicles per hour. Between 19:00 and 06:00 during twilight and dark hours when most large antelope movements occur, the average interval between vehicles was 5 minutes and the longest interval was 30 minutes.

During the last 5 years, police records indicate that 5 separate accidents have occurred between vehicles and large antelopes. Over this same period about 1,118,725 vehicles travelled the same stretch of highway that perhaps 78,475 antelopes crossed over. Based on these statistics, motorists driving between Palamakoloi and Lone Tree have a 1 in 223,745 chance of striking a large antelope. Antelopes crossing the tarred road have a 1 in 15,695 chance of being struck by a vehicle. These are infrequent occurrences.

Kalahari wildlife needs large spaces

Table 3 Percentage of large antelope populations observed outside of protected areas (CKGR and KTP) in the central and southwest Kalahari in wet and dry seasons during aerial surveys in 1994-95 (reproduced from Thouless[13]) and the percentage of large antelope populations observed outside during the most recent DWNP aerial survey[14] in the dry season 2012.

	Eland	Gemsbok	Wildebeest	Hartebeest	Springbok	Kudu
Dry (1994-95)	26	36	34	44	61	
Wet (1994-95)	25	45	75	80	84	
Dry (2012)	35	33	65	53	59	80

It remains a fact that the majority of Kalahari hartebeest, wildebeest, springbok and kudu populations can be found *outside* of the two protected areas, rather throughout the vast WMAs and CGAs in between CKGR and KTP. Note also that these proportions have not changed in 20 years. Only eland and gemsbok, whose distributions are more strongly shaped by human/livestock pressure, have a majority of their populations within park boundaries, although a large proportion of both species reside outside in the WMAs too.

On a global scale the CKGR and KTP are relatively huge protected areas. But for free-ranging antelopes these are not big enough. Typical of semi-arid savanna regions, antelopes wander widely in response to local rainfall conditions instead of following more predictable migrations[15,16]. Free movement allows them to achieve much higher abundance levels than if they were restricted because they can access larger areas with seasonal forage[17]. It is long-recognized that the most productive wet season calving range lies *outside* of parks within the WMAs and CGAs which contain the greatest density of pans, an area known as the Schwelle[18,19,20].

Figure 6 *Large numbers of eland, hartebeest, wildebeest, gemsbok surge through the Wildlife Management Areas with the pulse of rainfall. Here is activity between KD2 and KD12 WMAs in November.*

Kalahari antelopes' instinctive urge to move in search of nutrition and moisture within their food overrides the alternative to stay and utilize permanent waterpoints. It is true that when forcibly confined within very small areas such as fenced game ranches these species can survive on dead grass if they are supplemented with both unlimited water and salt licks. But at the scale of protected areas they are reluctant to adopt sedentary habits just because a waterpoint is available, as they characteristically ignore several artificial waterpoints provided for them in the KTP outside of the Nossob.

During droughts their need for space increases. This urge to wander to meet their nutritional and moisture requirements is why populations cannot be sustained if partially-protected areas between the CKGR and KTP become inaccessible, why wildlife continues to die on fences especially during

drought years, and why increasing fencing throughout the CKGR-KTP Corridor will negatively impact populations, regardless of what artificial water is supplied in the parks.

Known causes of wildlife decline

Of the large Kalahari antelopes, eland, gemsbok and springbok are under the most poaching pressure. They are the tastiest and the easiest to kill without firearms. Wildebeest and hartebeest have comparatively tasteless meat, and the former is dangerous to hunt while the latter is too fast for horses. Yet eland and gemsbok populations have shown signs of stability and even recovery[19,20] while wildebeest and hartebeest have undergone the most dramatic reductions.

Unfortunately, for practical reasons, the Government may have little control over poaching in the Kalahari. The area over which the activity occurs is vast; not only the remote area settlements, but mainly the myriad smaller informal settlements - the cattleposts spread extensively throughout CGAs and encroaching into WMAs. We can only guess uncertainly at the affect that background levels of poaching throughout the Kalahari has on wildlife. By contrast, the Government has control over fences and the damage they cause. We know that fences have resulted in huge disruption and mortalities to free-ranging antelopes. They are the single identifiable cause of mass die-offs in wildebeest and hartebeest especially. It is a rather false hope for mobile Kalahari wildlife to recover as a result of a hunting ban while simultaneously permitting increased fencing that prevents those animals from accessing their seasonal habitats.

What then would proponents of fencing the TKTC hope to accomplish? What could be the motivation for obstructing wildlife movements through the CKGR-KTP Corridor system?

Motives for fencing

There are three possibilities:

a) Protect train from obstructions

Unlike highway motor vehicles whereby wildlife and livestock collisions are a serious threat to human life and property, freight trains literally bulldoze through animals in their path with little consequence to the locomotive or its operators. There's a growing number of examples illustrated on YouTube[21]. Train derailments due to animal collisions were rare events of the past; typically only light axle-loading passenger trains are affected. Coal-bearing freight trains are among the heaviest in the world, and engineering effective cattle-guards on the front of the locomotive further negates such risk.

Canada has two trans-continental railways spanning 40,000 km[22] and passing through several national parks and wilderness areas larger than the Kalahari. Of 1,284 main-track derailments

that have occurred over the last 10 years[23], only a single record was caused by an animal. That was due to a moose carcass which was frozen solid to the tracks thus acting like a large boulder. "Soft-tissued carcasses" by contrast do not pose much risk of derailment according to train operators[24].

More than 160 elephants have been killed in train accidents in India since 1987[25]. Although passenger trains have been affected none of these accidents have derailed a freight train, even after impacting a herd of 15 elephants[26], and it is doubtful that the world's largest land animals can do so. Clearly the largest oxen and eland pose a miniscule threat to a Trans-Kalahari freight train, and although elephants have been wandering down into the southern Kalahari more frequently in recent years, fencing does not stop elephants in any case.

b) Protect wildlife from train

Given wildlife's demonstrated ability to avoid traffic on the A2 tarred road, the large number of animals that continue to cross through unfenced corridors, the continued mortalities along the Trans-Kalahari where fencing has been erected and well-documented mass mortalities on other fences, we predict that the cumulative damage caused by a fence obstructing natural wildlife movements would be excessively greater than direct deaths due to collisions with trains.

Just as wildlife are successfully avoiding motor vehicles on the A2, they should have even less difficulty avoiding the much noisier and infrequent passing of trains. As in other places where heavy freight rail passes through wilderness areas such as Canada, large wildlife species cross railway tracks readily, and mortality becomes a challenge mostly when grain spillage, carcasses or vegetation attracts animals onto the railway[27,28] and animals have difficulty escaping due to deep snow conditions[21].

Consider a wild landscape in western Canada (comprising 3 national parks) bisected by 202 km of railway (30% longer than combined North and South Corridors) wherein freight trains (25-35 trains per day, up to 2 km long each) kill about 27 large ungulates per year[28]. Wildlife in the Kalahari have less reason to be attracted to a railway. Contrast the predicted 28,247 - 40,645 large antelope movements disrupted per year if North and South Corridors were to be fenced, and mortalities due to drought-induced mass movements that would be huge.

c) Protect livestock from train

Perhaps. By process of elimination this appears to be the only reasonable motivation. Compared to wildlife, livestock are less adept at avoiding collisions and a certain level of livestock mortality will be unavoidable. Presumably, these will be treated in the same manner as highway accidents in that untended livestock remain their owner's responsibility and the train operator is not liable for livestock injuries and deaths. It is also worth noting that the presently unfenced wildlife corridors have low livestock densities and would result in the least issues compared to other areas through which the rail passes. Given the exclusion fencing

erected already along particular sections of the TKTC and the entire Kang-Hukuntsi highway, we have a precedent to predict how effective railway fencing might be at excluding livestock:

Efficacy of fences along Kalahari roadways

Fencing the TKTC was considered a viable solution for keeping large animals off the tarred road[29], and the same might be assumed for the railway. Laudably, certain sections were left unfenced to permit wildlife movements, and as the present data reveal, these wildlife corridors are working. What about the sections that have been fenced?

A casual survey along the Trans-Kalahari in 2013 between Takatokwane east of Letlhakeng through to Palamakoloi revealed that of the 89 gates installed in the fence to permit off-highway access, 35 were left open and 3 were missing. Since then, these fences have decayed rapidly and there are gaps where cattle apparently pass through in volumes.

Figure 7 *Fencing, although well-intentioned, has clearly not prevented livestock from accessing the Transportation Corridor or colliding with automobiles. In some cases these fences may be exacerbating the problem when animals become trapped between the fences.*

If there is funding only to build fences but not to constantly monitor and maintain them, then they are a doubly-wasted investment. Even one hole or one gate left open negates the purpose of the

fence. It is possible these fences have reduced the number of livestock on the RoW, but it is equally possible that they exacerbate the problem, concentrating livestock between the fencelines. Now that several years have passed since fence erection along the Trans-Kalahari and Kang-Hukuntsi, it is perhaps time to evaluate them. Whether more or less animals, it is obvious that exclusion fencing along these highways has not kept livestock off roads, nor eliminated collisions with motor vehicles. Likewise, there is no certainty a fence will keep livestock off of a railway or whether it would make the problem worse.

At the same time these fences have failed to keep livestock off the roads, they continue to succeed in disrupting wildlife movements. For example, in June 2013 along an 8.5 km section of A2 fence north of Kang, 56 hartebeest were observed trapped, dying, and dead as a direct result of the fence[30]. An unrecorded but presumably larger number met a similar fate on the further 42.5 kilometres that this fence continues until the KD-GH boundary at Palamakoloi. Together this 51 km stretch of fence along the highway north of Kang is particularly damaging as it encroaches upon the core of wildlife activity in the North Corridor. It will surely continue to cause considerable wildlife mortalities if it is not deactivated.

Figure 8 *Kudu entangled to death in the Kang-Hukuntsi highway fence. This fence, and some sections of Trans-Kalahari fence such as that between Kang and Palamakoloi, frequently cause wildlife stress and mortality. The "wildlife-friendly" section of the Kang-Hukuntsi fence still traps large antelope and may be an uncrossable barrier to their young.*

A note from the co-authors

Since the end of Special Game Licences, NK and !NB, of the older generation, have refrained from hunting large antelopes. One can begin to appreciate how difficult this is to bear when one realizes how fundamental hunting is to their identities. Over the same period they've witnessed increasing encroachment by outsiders establishing new cattleposts, from which some of those people continue to poach with apparent impunity. The location of cattleposts precisely determines the remarkably narrow corridor through which gemsbok and eland continue to pass regularly. Any farther north towards Lokalane, or south towards Palamakoloi, these animals either avoid and/or are eliminated. Deactivation of the old cattlepost at Palamakoloi and the fence from Kang to Palamakoloi would enlarge the space available to these two species most sensitive to human disturbance and open up a more direct route for wildlife to move between CKGR and KTP.

NK and !NB possess a genuine conservation ethic, often not as evident in the younger generation. They want to see wildlife recover to numbers that they remember. They continue to sacrifice and they continue to play their part, with hope that the day will come that they can once again benefit from wildlife in their WMAs.

Conclusion

Contrary to an increasingly accepted view, free-ranging Kalahari wildlife have not collapsed beyond recovery nor contracted to the two protected areas. At any time a huge proportion of total populations are to be found outside of the KTP and CKGR in the semi-protected wildlands in between. This is a positive story for Botswana. It says something about the state of the corridors and health of the overall CKGR-KTP ecosystem. It hints that wildlife continue to seek their wet season core breeding areas outside the parks and that major movements can continue to protect populations during times of drought when animals need to wander widely to meet their needs.

Hopefully it can be realized that an unfragmented ecosystem with free-ranging wildlife movements at this scale has become rarer than diamonds. It is a wilderness gem of untapped natural value. Botswana's neighbors can no longer boast this; they've long resigned to fences and fragments. Some like to claim the huge growth in populations of privatized 'wildlife' on game ranches as a great conservation success, but it is a tragic compromise at best. Whether these enclosed, behaviorally-modified animals can still be called 'wild'-life is questionable - they are qualitatively different from Botswana's free-ranging herds.

The semi-arid KTP and CKGR, and by extension the Kalahari WMAs, will never compete on the same terms as the great game-viewing parks such as Etosha and Kruger. It is rather the wilderness quality, and the quality of wildlife - however low in density and diversity - as populations that are still unfenced and free to move naturally as they've always done, that attract people here. Quality, not quantity. If those aspects are maintained, then the value of the Kalahari to Botswana's tourism development will only increase with time. Within WMA's, remote area settlements are expecting to

depend upon healthy wildlife populations for their future development. Denying wildlife seasonal access to WMAs would predictably force land use towards its default form in the Kalahari - poorly managed livestock expansion.

Botswana has the best opportunity in southern Africa to conserve a functional ecosystem including antelope migration - its most area-demanding natural process - in the long term. Closing the Trans-Kalahari Transportation Corridor with continuous fencing would effectively sever the system into two pieces, reducing seasonal pulses of antelope movement to zero. Such a decision would also resolutely relinquish the opportunity to reconnect historical migration routes to permanent water and forage in Botswana's north. The return of erstwhile magnificent Kalahari herds may not be out of reach if the CKGR can be re-linked through a corridor to Makgadikgadi. Wildlife could, in the not so distant future, move freely once again from one corner of the country (KTP) to the other (Chobe) along the rainfall gradient.

Large numbers of wild antelopes continue to cross the A2 tarred road on a daily basis. A new Trans-Kalahari railway line would be an inconvenience for wildlife; but they will adapt to cross it, and most will avoid trains. It is encouraging that wildlife are not endangered by a railway line itself, but rather by any associated fencing that goes with it. Likewise, the Trans-Kalahari railway is not threatened by the presence of large animals both wild and domestic. Freight trains can be protected from potential damage and engineered so that there is negligible risk of derailment from such obstructions.

When considered carefully, we are forced to conclude that motivation for fencing the Trans-Kalahari railway cannot be more than to protect untended livestock. Erection of extensive ungulate-proof fences has been a political culture in Botswana and may be viewed as an easy solution by some parties regardless of the facts. So far in the Kalahari, exclusion fencing has not kept livestock out of the corridor nor off the road. The economic cost, but moreso the opportunity costs of increased fencing are great. Much in terms of wildlife and Botswana's hopes pinned on future tourism is at stake. The best hope at helping free-ranging Kalahari wildlife persist and even recover in the long-term is to let them move. Are Batswana willing to give this up in order to save cows and donkeys?

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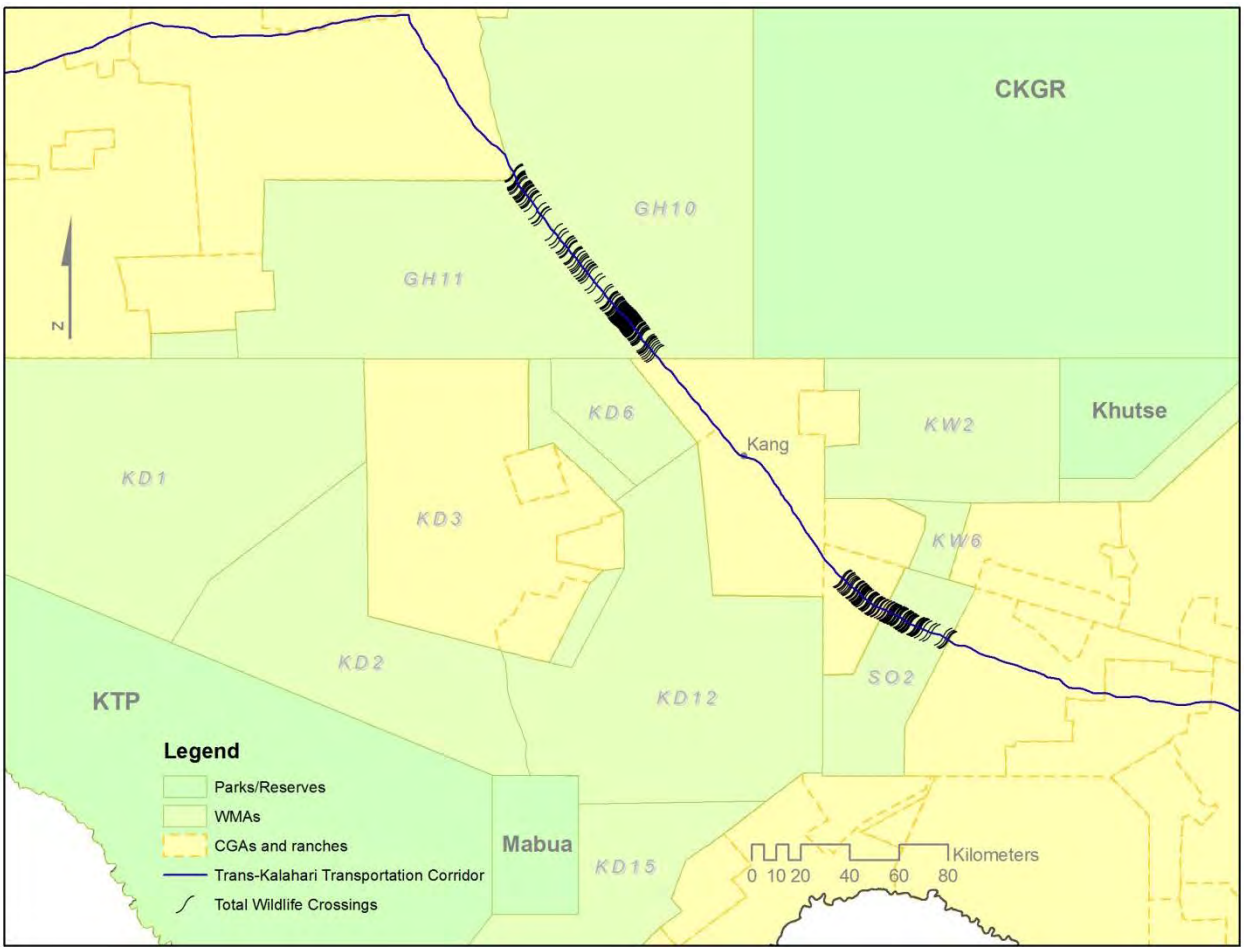
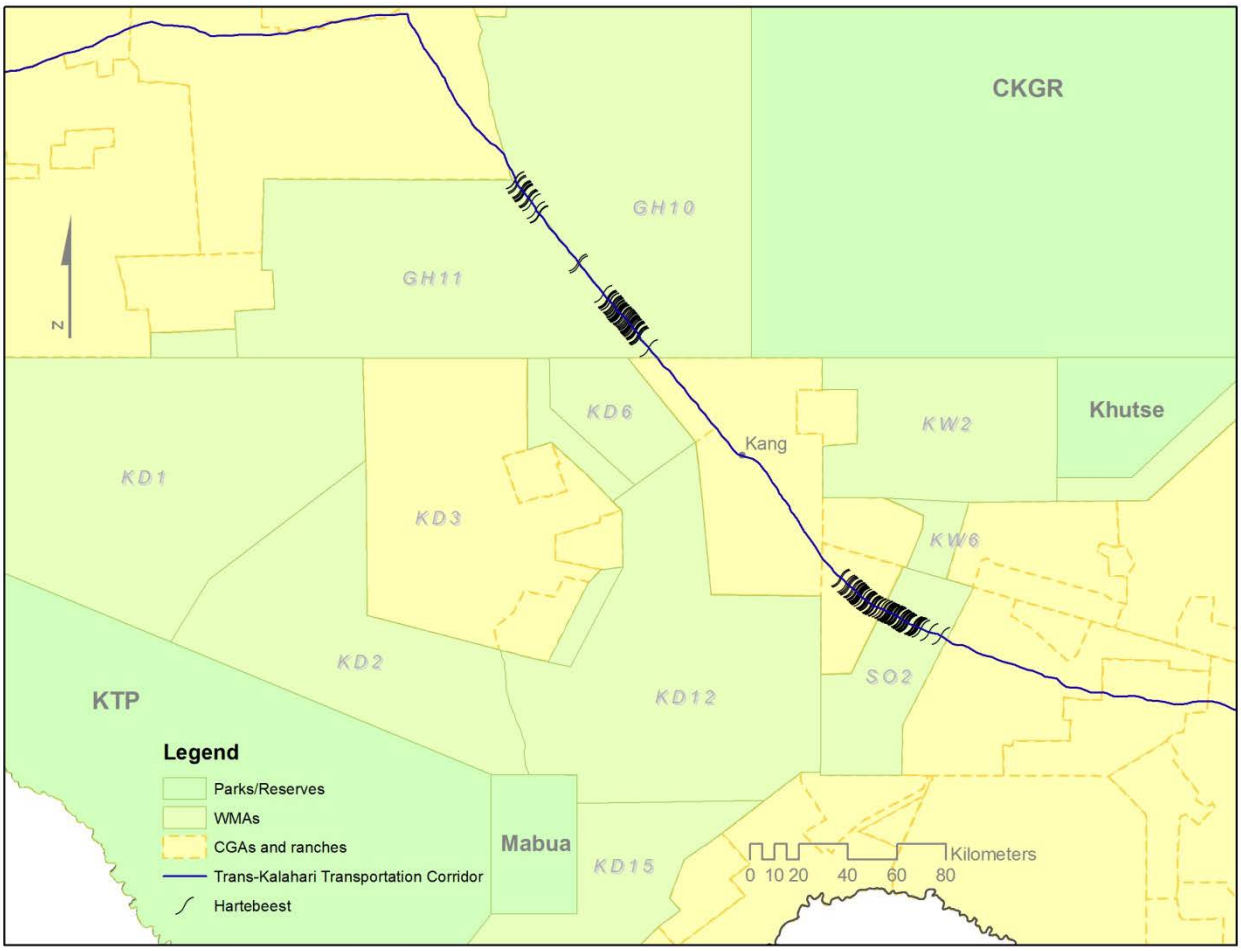
Appendix: Maps of Wildlife Crossing Locations

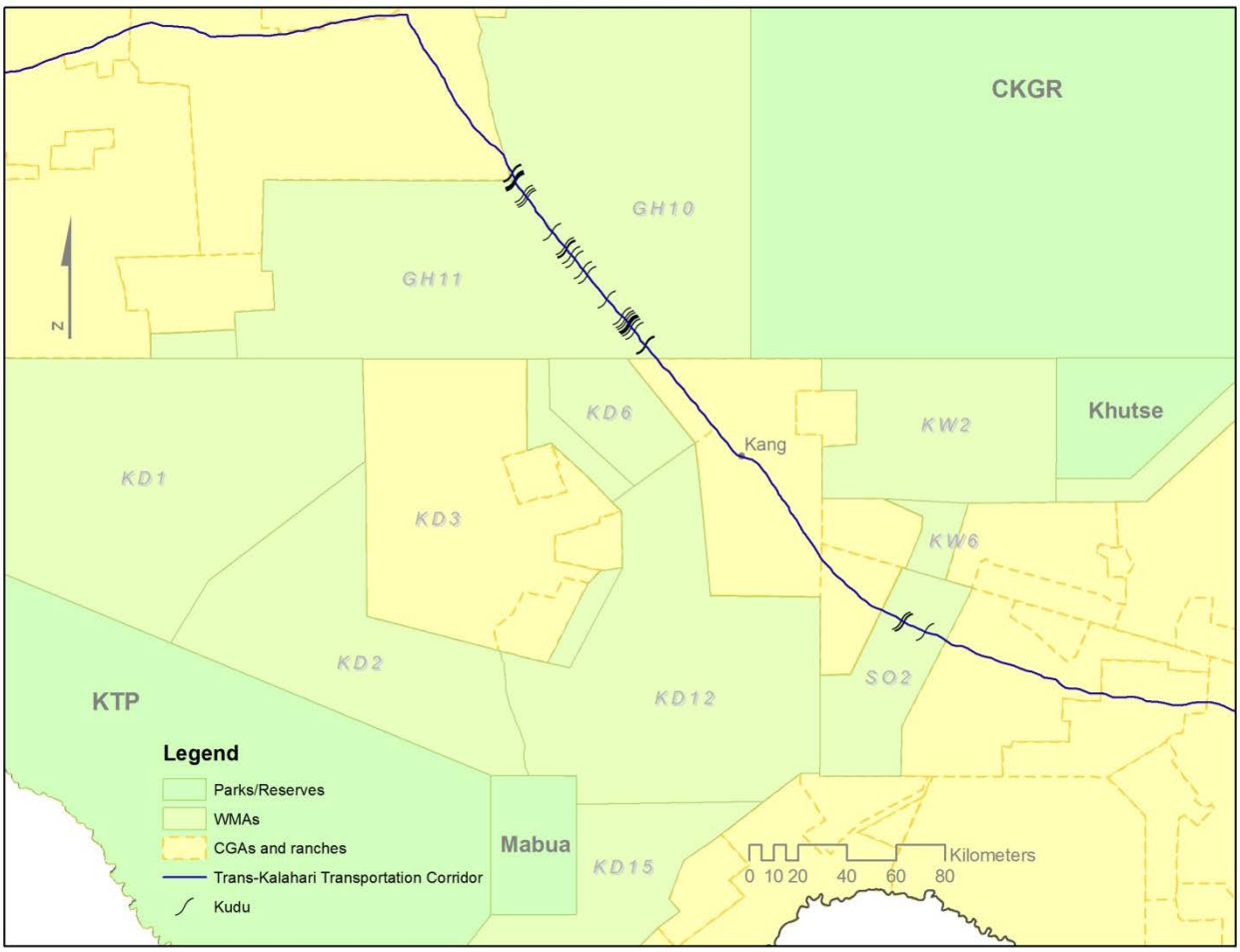
A1: Total Wildlife Crossings during the study period demarcating the North and South unfenced wildlife crossing Corridors



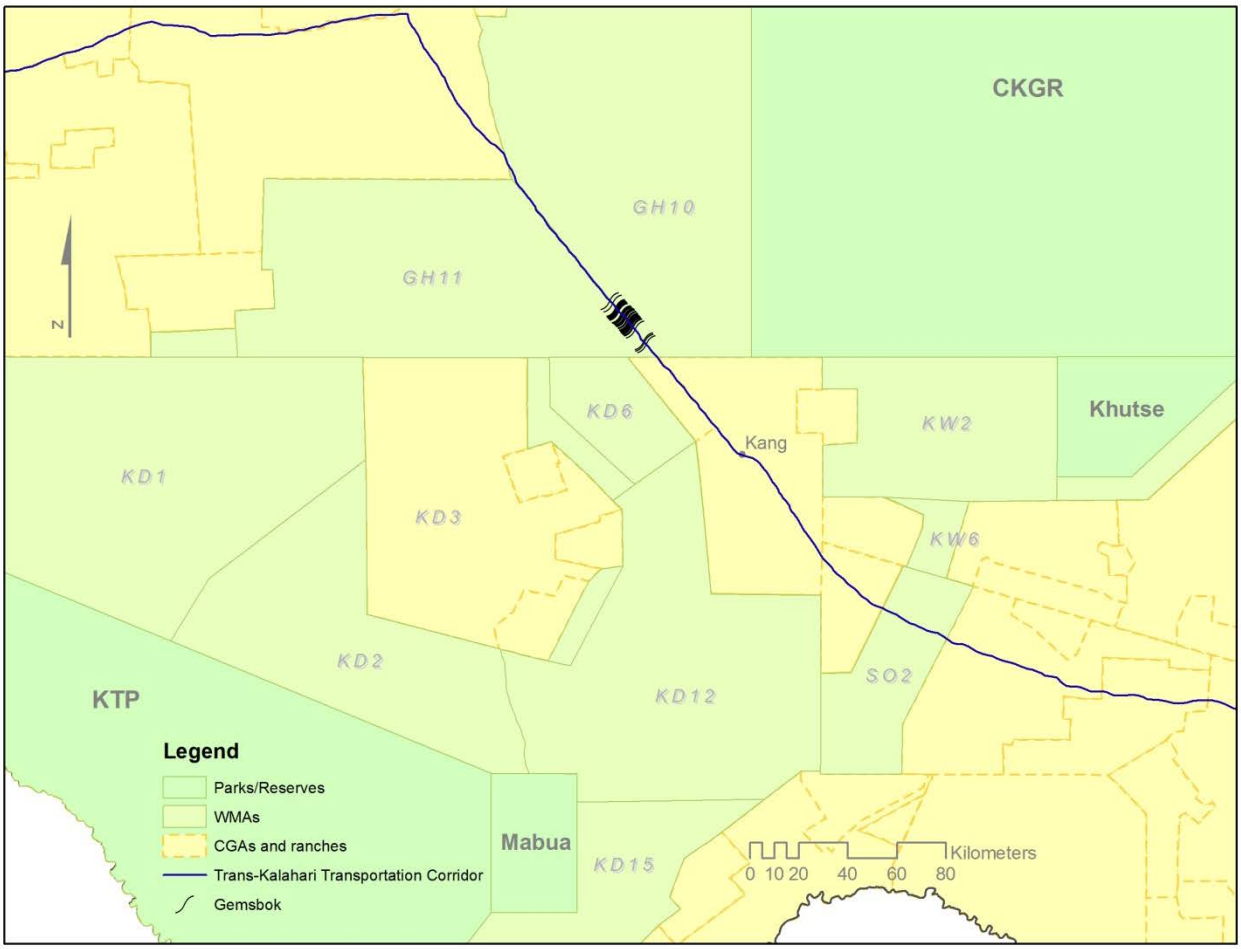
A2: Hartebeest Crossings



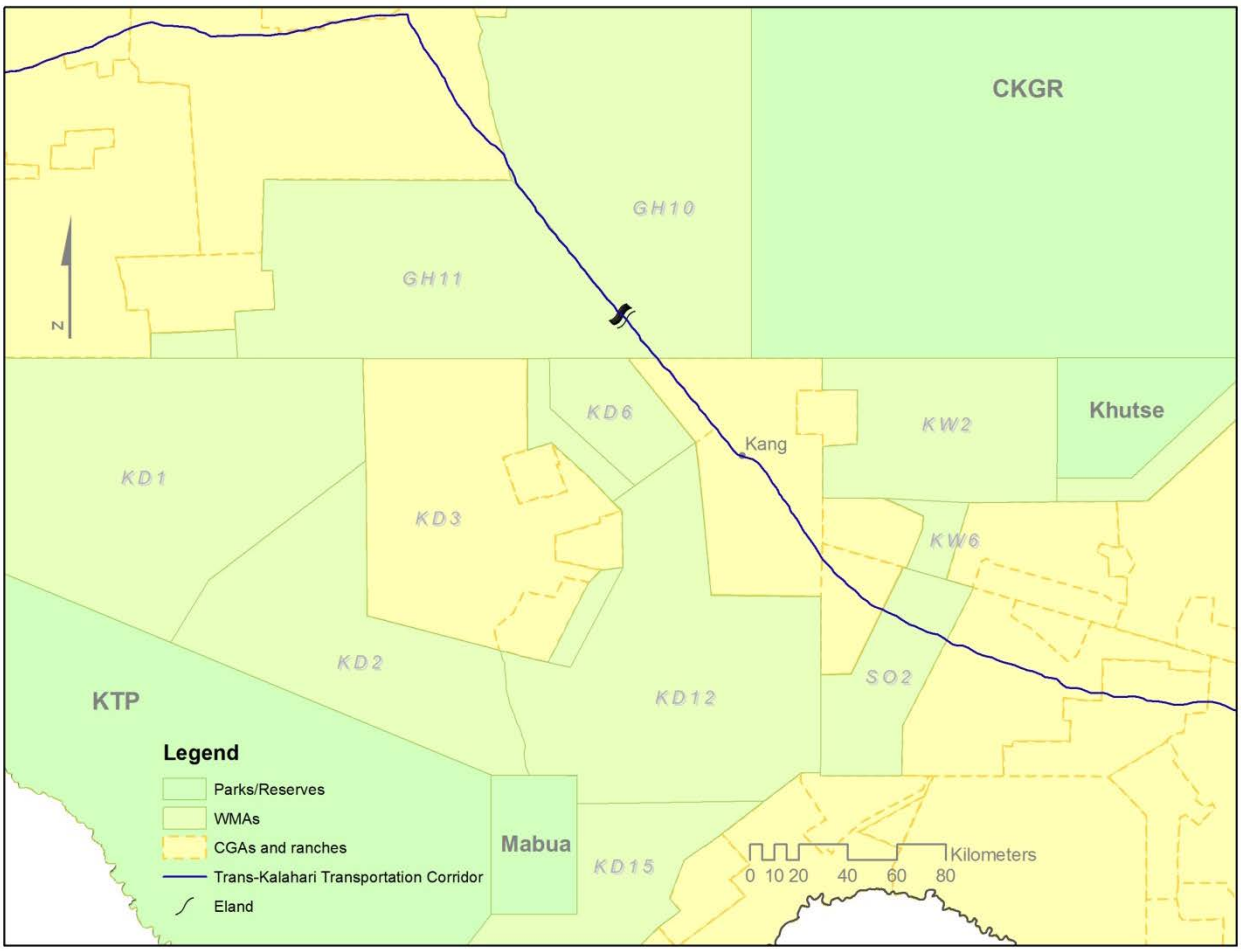
A3: Kudu Crossings



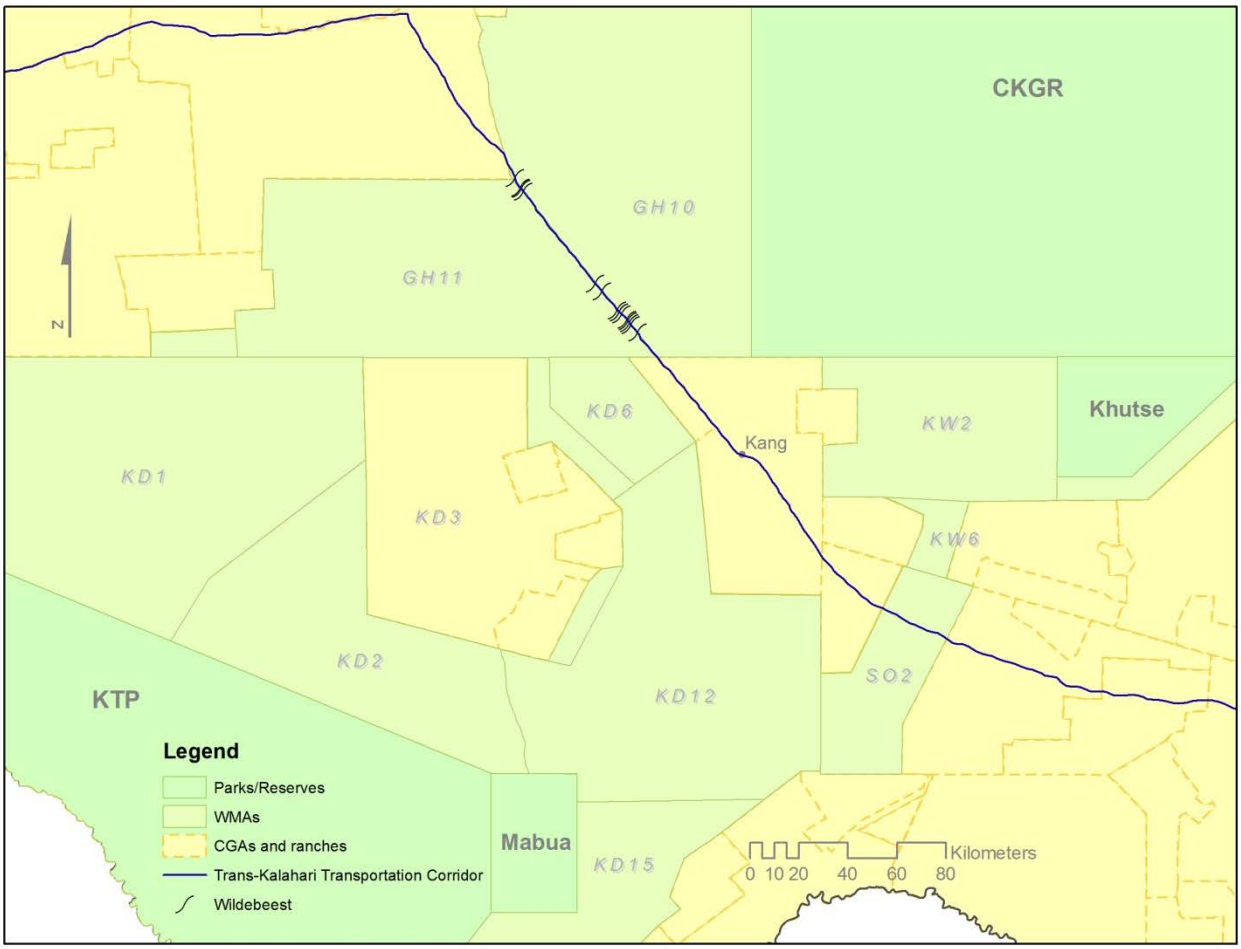
A4: Gemsbok Crossings



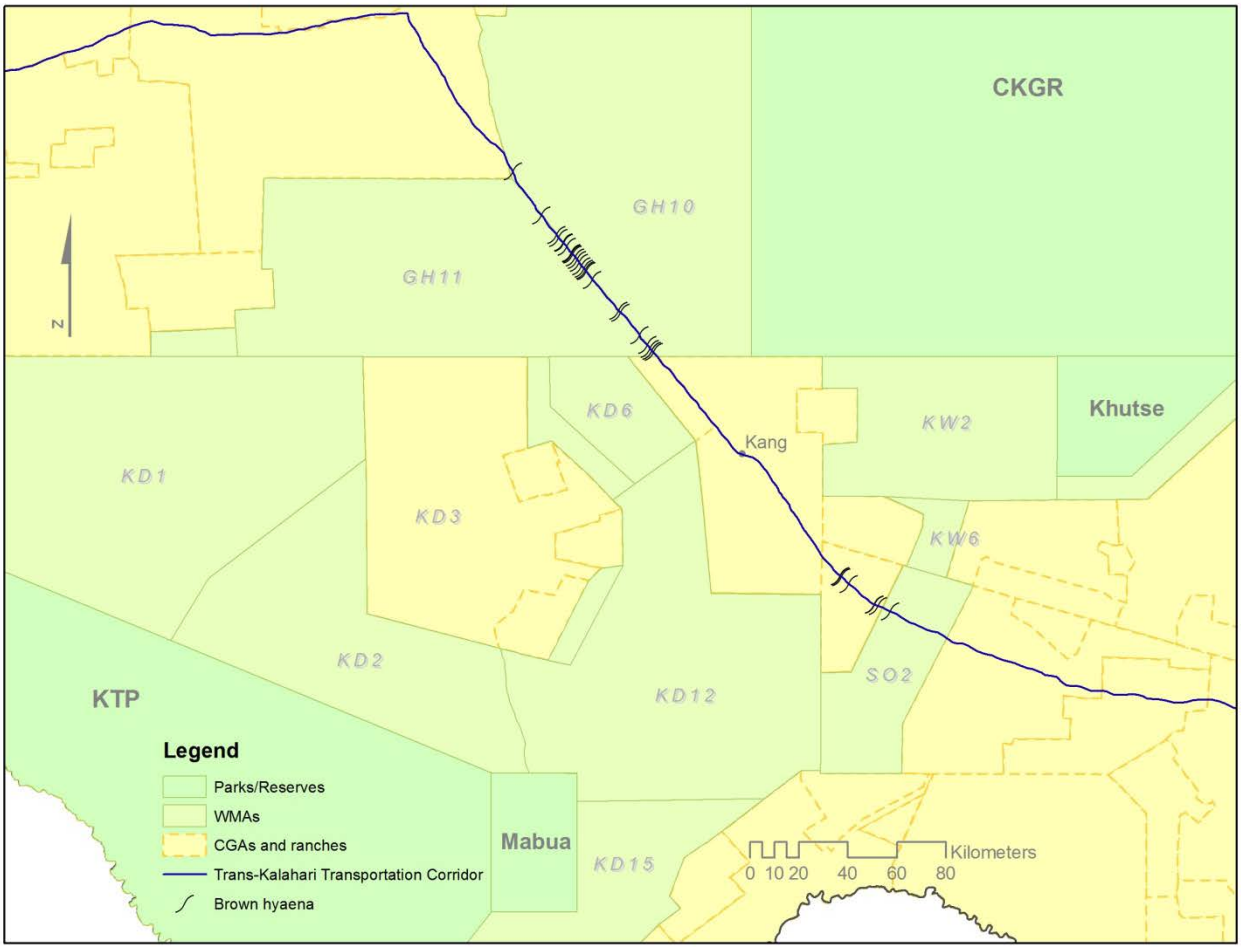
A5: Eland Crossings



A6: Wildebeest Crossings



A7: Brown Hyaena Crossings



A8: Cheetah Crossings