Effects of culverts and roadside fencing on the rate of roadkill of small terrestrial vertebrates in northern Limpopo, South Africa

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SUMMARY

We tested the effectiveness of low-level roadside fencing to direct wildlife towards existing culverts beneath the road (underpasses) in order to reduce road deaths of small terrestrial vertebrates. While our results showed a reduction in roadkill count (from eight to one) along the stretches of road where we installed barriers (from an average of 0.33 roadkill/day/km to 0.04 roadkill/day/km), this decrease was not significant, possibly due to the small number of dead animals detected across all sites. Our trial highlights the challenges in acquiring robust evidence for roadkill reduction interventions and, given the small sample size, we were unable to elicit firm conclusions for this study. We therefore propose further testing of the efficacy of roadside fencing to reduce roadkill.

BACKGROUND

Various roadkill reduction measures have been implemented around the globe to reduce animal deaths on roads. Fencing is a favoured method for mitigating the impacts of roads on wildlife in Europe and America, but it has the drawback of limiting landscape connectivity for wildlife. Mitigation measures connecting wildlife habitats by way of wildlife crossing structures can overcome the barrier effect of fences. These potentially prevent collisions between animals and vehicles, and include underpasses that make use of existing infrastructure, such as road culverts and drainage lines (van der Ree *et al.* 2007).

In this study, we tested the effectiveness of low-level road-verge barriers in directing wildlife towards existing culverts. This trial was conducted along a 12.3 km section of paved road in northern Limpopo Province, South Africa (22°27'47"S, 29°18'30"E), previously identified as a roadkill hotspot by Collinson (2013). The roads in this area have a number of irregularly-placed culverts to allow water to flow under the road, either to prevent flooding on the road, or to allow continuation of natural water flows. The culverts are made from concrete and are approximately 2 m in diameter, and are therefore well-suited as road underpasses for small terrestrial vertebrates. Here we report on the effectiveness of two types of road-verge barrier to reduce roadkill mortality: (i) a disturbed section of road verge that incorporated a 30 cm deep trench (~2 m from the road verge) dug for 200 m on either side of the culvert, to assess whether disturbance alone would be enough to deter animals from crossing the road, and (ii) a low-level roadside fence barrier in combination with under-road culverts. We targeted only small terrestrial vertebrates since larger species, such as greater kudu *Tragelaphus strepsiceros*, require different mitigation measures (for example, larger crossing structures).

ACTION

We ran our trial in the hot/wet season (10 January–25 February 2015; Viljoen *et al.* 2008) as this is when roadkill rates are highest (Collinson 2013, Collinson *et al.* 2015).

Before starting our trial, we used a Garmin eTrex Global Positioning System (GPS) to map the location of all culverts and drainage structures (n = 17) along the 12.3 km road section. This section formed a contiguous length of single carriageway paved road with no major junctions or intersections that would lead to variable traffic volumes along its length.

Pre-intervention surveys: A single observer, who was also the driver, drove at speeds of between 40–50 km/h, using the protocol of Collinson *et al.* (2014) for roadkill detection. We drove the road section daily for 20 consecutive days (10–29 January 2015), starting at least 1.5 hours after sunrise (sunrise range 05:24–05:55 h) so that glare from the sun would not affect driver ability to see roadkill (Collinson *et al.* 2014). We only counted roadkill carcasses if we detected them on the road, and we excluded carcasses on road verges due to potential detection bias (Guinard *et al.* 2015). At each carcass, we took a photograph to verify identification, and recorded the GPS location to avoid recounts on consecutive days.

Installing fencing: Our study design was contingent on the location of existing culverts: we were not able to use all of the culverts due to the irregularity in distances between them (range between culverts: 20–150 m). Entrance gates to private properties and a riverbed further decreased the choice of culverts to be selected for mitigation (Figure 1).

We determined that a distance of 200 m on either side of each culvert would allow us to apply our intervention to nine culverts. Two treatments (disturbance only, and barrier) and a control; (Table 1, Figure 2) were each randomly applied to three of the nine culverts. To choose these, we used pre-intervention roadkill counts to identify the nine 400 m segments with the highest number of kills (total length, 3.6 km; Table 2). We used a randomised block design to dispense treatments to avoid the possibility of assigning a single treatment to the three culverts with the highest likelihood of roadkill. Implementing the treatments took seven days (30 January–5 February 2015). Approximate cost of the roadside fencing was 7500 ZAR (40 x 1 m x 50 m Knittex Barrier Net, MultiNet (PTY) LTD 2017).

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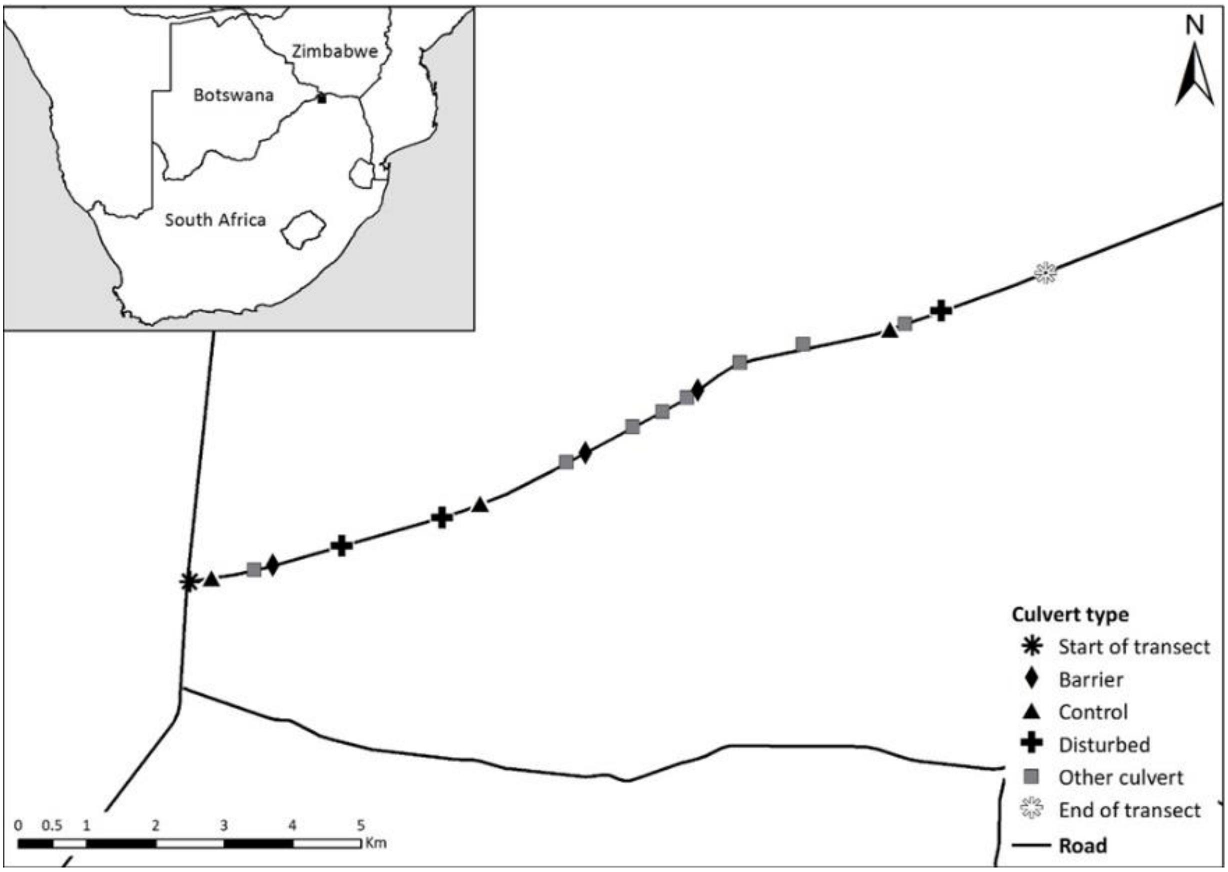

Figure 1. A schematic diagram showing transect start and finish and the location of the 17 culverts along the 12.3 km section on the D2662 paved road. Each culvert has been coded to show the treatment applied (barrier, control, disturbed or other (i.e. not used in the study)). Inset map shows location of study (black square).

Post-intervention surveys: After installing the treatments, we drove the road section for the following 20 consecutive days (6–25 February 2015), using the same methods as described in the pre-intervention surveys. We then conducted a pairwise before-and-after comparison for each of the three treatments by calculating the difference in total roadkill counts between the two 20-day data collection periods. We used a non-parametric Friedman test (*K* related samples) to determine whether any differences varied significantly among treatments. This approach reduced the effects of geography, season and climate. We used Vassarstats (Lowry 2015) to conduct all statistical analysis.

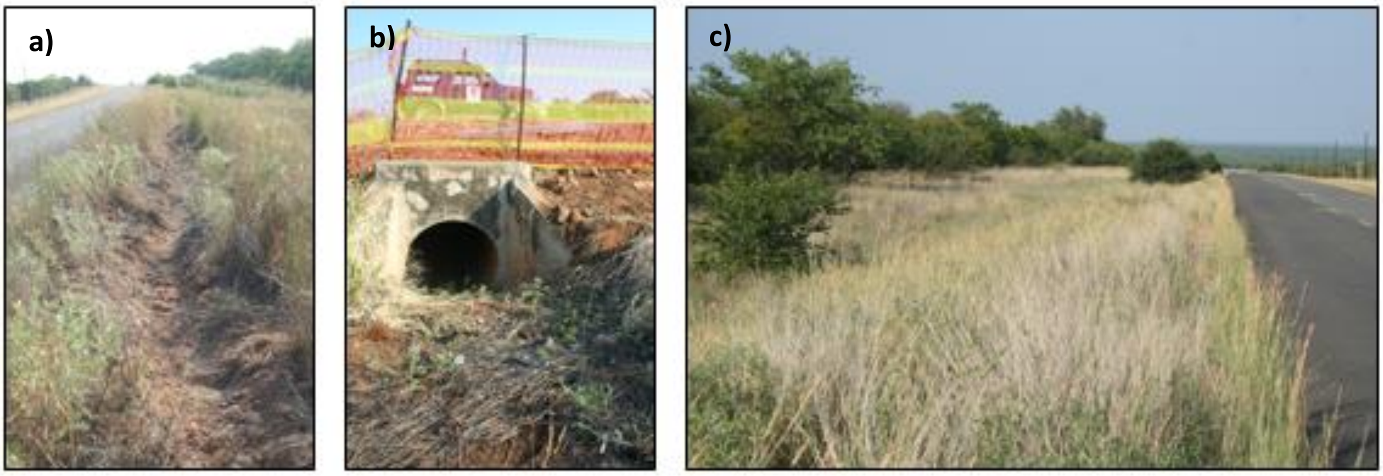

Figure 2. The two treatments (disturbance only (a), and erected fencing (b)) and a control (c) administered on the either side of the culvert on the D2662.

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Table 1. Treatments applied to 200 m on either side of selected culverts on the D2662 paved road, northern Limpopo Province, South Africa

Treatment	Description
Disturbed area	A 30 cm deep trench (~2 m from the road verge) was dug for 200 m on either side of the culvert (Figure 2a).
Barrier	A low-level fence (approximately 2 m from the road verge) was erected for 200 m along both sides of the road on either side of the culvert. Fencing (Knittex Barrier Net, MultiNet (PTY) LTD 2017) was 70 cm in height at a 45° angle from the ground, to prevent species from hopping, jumping or climbing over the fence onto the road. In addition, 30 cm of the fence was buried beneath the ground to prevent digging, provide more stability, and lessen the risk of potential theft. Metal stakes (every 10 m) held the fence in place. The end of the barrier (fence end) was bent at an angle of 45°, back towards the fence for a length of 2 m. This was to prevent animals, upon reaching the fence end, being directed onto the road (Figure 2b). The fencing is made from knitted polyethylene with threads running in various directions, making it impermeable to small vertebrates.
Control	No mitigation was applied (Figure 2c).

CONSEQUENCES

Along the nine 400 m sections that were surveyed we detected a total of 38 vertebrate roadkill across both survey periods, comprising 20 different species (Table 3). After the application of the treatments we detected a reduction in the number of roadkill in both the barrier and disturbed treatments, while the roadkill count in the control treatments increased slightly (Table 2). Only one roadkill was detected along the barrier treatments after they were erected: this was a scrub hare *Lepus saxatilis* that was killed near the end of the barrier (18 m from the barrier end).

While our results showed an apparent decrease in roadkill count along the stretches of road where we installed barriers (from 0.33 roadkill/day/km to 0.04 roadkill/day/km; Figure 3), this difference was not statistically significant (Friedman's test, $\chi^2 = 0.1$, $p = 0.09$; $n = 8$).

DISCUSSION

Despite an apparent reduction in roadkill where the barriers were applied, our results were not statistically significant. This was most likely due to (i) the small sample size in our study design, which was unfortunately predicated by the configuration of culverts in our study site, and (ii) the type of data we collected which required the use of non-parametric statistics, which tend to have less power to detect significant differences. In hindsight, we should have extended our sampling period to allow for a more robust understanding on the true effects of the barriers.

Table 2. The number of small terrestrial vertebrate roadkill counted in two 20-day periods before and after the application of low-level roadside fencing and small trenches around existing culverts. Two treatments (disturbance only, and barriers) and a. control were each applied to three 400 m road lengths of a 12.3 km roadkill hotspot on the D2662 road, in northern Limpopo, South Africa, during January-February 2015.

MITIGATION	Pre-mitigation (20 days)	After mitigation (20 days)
Control	10	11
Disturbed	5	3
Barrier	8	1
Total	23	15

Furthermore, due to the positioning of the fencing above the culvert, we were unable to determine whether animals crossed the road in the unmitigated section and then moved towards the barrier; travelled along the barrier and then traversed the road at the barrier's end; or penetrated through the barrier, as in the case of the scrub hare as described in the results. This would have provided further insight into the barrier's efficacy but was beyond the scope of our trial.

We contend that this trial shows promising results. However, given the non-significance of the results of the trial, the small sample size, and the conservation implications of making a Type II error (i.e. failing to reject a false null hypothesis, in other words, failing to detect that barriers *do* reduce mortality and therefore not using them as a mitigation option), we propose that further monitoring is required to test this intervention. We recommend that the number of sites and/or the duration of monitoring be extended to provide more robust evidence on whether a combination of barriers and underpasses can reduce mortality of small terrestrial vertebrates. In addition, we propose further research that investigates the possible unintended consequences created by installing the fences.

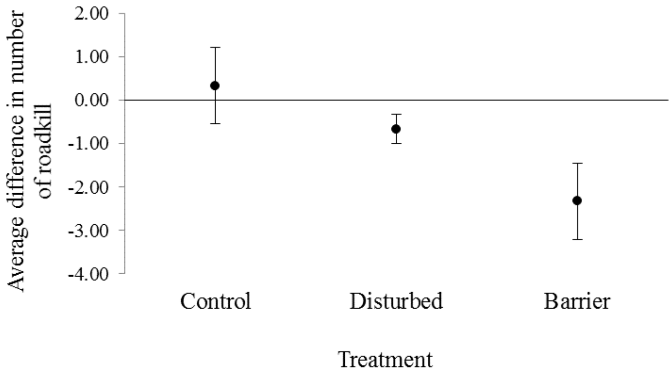

Figure 3. The average difference in number of roadkill counted in two 20-day periods occurring before and after the application of low-level roadside fencing to direct small terrestrial vertebrates to underpasses (culverts). Each treatment was applied to three 400 m segments of road (total 1.2 km) during February 2015. Error bars represent standard error.

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Table 3. The number of vertebrate species (excluding birds) detected as roadkill in the nine treatment sites (3.6 km) of the 12.3 km section on the D2662 paved road, pre- and post-intervention. The column labelled 'remaining culverts' indicates the number of roadkill found outside of the treatment and control sites on the 12.3 km section.

CLASS	Species (common name)	Scientific name	Roadkill detected											
			Pre-mitigation						Post-mitigation					
			Control	Disturbed	Barrier	Remaining culverts	Road segments not associated with culverts	**TOTAL**	Control	Disturbed	Barrier	Remaining culverts	Road segments not associated with culverts	**TOTAL**
Amphibians	Eastern olive toad	*Amietophrynus garmani*	4	2	5	1	2	**14**	3	1	-	-	-	**4**
Total			**4**	**2**	**5**	**1**	**2**	**14**	**3**	**1**	**0**	**0**	**0**	**4**
Reptiles	Bibrons burrowing asp	*Atractaspis bibronii*	-	1		-	2	**3**	-	-	-	-	-	**0**
	Black-lined plated lizard	*Gerrhosaurus*	1	1	-	-	2	**4**	-	-	-	-	-	**0**
	Brown house snake	*Boaedon capensis*	-	-	-	2	2	**4**	-	-	-	-	-	**0**
	Common egg eater	*Dasypeltis scabra*	2	-	-	-	2	**4**	1	-	-	-	-	**1**
	Flap-neck chameleon	*Chamaeleo dilepis*	-	-	-	2	3	**5**	3	-	-	2	2	**7**
	Horned adder	*Bitus caudalis*	-	-	1	1	5	**7**	1	-	-		1	**2**
	Leopard tortoise	*Geochelone pardalis*	-	-	-	1	-	**1**	-	-	-	-		**0**
	Mozambique spitting cobra	*Naja mossambica*	1	-	-	1	4	**6**	1	1	-	-	1	**3**
	Peter's ground agama	*Agama armata*	-	-	-	-	1	**1**	-	-	-	-	-	**0**
	Puff adder	*Bitus arientans*	-	-	-	1	-	**1**	-	-	-	-	-	**0**
	Unknown reptile	Unknown	1	-	-	1	1	**3**	-	-	-	-	-	**0**
Total			**5**	**2**	**1**	**9**	**22**	**39**	**6**	**1**	**0**	**2**	**4**	**13**
Mammals	Black rat	*Rattus rattus*	-	-	-	-	-	**0**	-	-	-	-	1	**1**
	Black-backed jackal	*Canis mesomelas*	-	-	-	1	2	**3**	-	-	-	-	-	**0**
	Bushveld gerbil	*Tatera leucogaster*	-	-	2	3	10	**15**	-	-	-	-	-	**0**
	Multimammate rat	*Mastomys*	1	-	-	-	-	**1**	2	-	-	1	-	**3**
	Red veld rat	*Aethomys chrysophilus*		1		1	-	**2**	-	-	-	-	-	**0**
	Scrub hare	*Lepus saxatilis*	-	-	-	-	1	**1**	-	-	1	-	2	**3**
	Small-spotted genet	*Genetta genetta*	-	-	-	1	1	**2**	-	-	-	-	-	**0**
	South African pouched mouse	*Saccostomus campestris*	-	-	-	-	-	**0**	-	1	-	-	-	**1**
	Unknown rodent	Rodentia	-	-	-	-	-	**0**	-	-	-	1	-	**1**
	Tree squirrel	*Paraxerus cepapi*	-	-	-	-	1	**1**	-	-	-		-	**0**
Total			**1**	**1**	**2**	**6**	**15**	**25**	**2**	**1**	**1**	**2**	**3**	**9**
Total number of roadkill			**10**	**5**	**8**	**16**	**39**	**78**	**11**	**3**	**1**	**4**	**7**	**26**
Total number of identified species			**6**	**4**	**3**	**12**	**15**	**40**	**6**	**3**	**1**	**3**	**5**	**18**

Barriers impede crossing of the road, and thereby inhibit natural animal movement patterns, ultimately increasing population fragmentation. Further assessment of which species utilise the culverts, and how often, would provide an indication of the full usage of the culverts and the possible impacts of roadside fencing.

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