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Can virtual fences reduce wombat road mortalities?

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ABSTRACT

Roadkill is a worldwide issue that can cause local population extinctions. In Australia numerous species are affected, however the bare-nosed wombat (*Vombatus ursinus*) is particularly vulnerable due to its preference for disturbed habitats. Collisions with motor vehicles causes significant damage to the vehicle and sometimes the driver, as well as wounding or killing the wombat. Virtual fences are light and sound-based devices, originally developed in Austria that can be used to reduce roadkill through mitigation. They have had mixed results. In this study a virtual fence was installed along a 1.5 km stretch of road in semi-rural NSW, Australia, with the aim of reducing wombat roadkill through the use of this form of mitigation strategy. The number of roadkilled wombats was counted before and after the fence was installed in March 2020. Prior to the fence being installed 23 wombats were killed and after the fence was installed six wombats were killed. Along Old Bega Road, outside of the fenced area 64 wombats were killed pre-fence installation and 17 post fence installation. Bare-nosed wombats are semi-fossorial ecosystem engineers with an important role in the ecosystem and despite being listed as Least Concern are readily impacted by roadkill. Virtual fencing implemented in regions that have high wombat roadkill rates may aid in reducing road deaths and species conservation. However, we recommend that more research is required to assess virtual fencing, as a roadkill mitigation strategy, including an investigation into a larger number of species in a range of different habitats.

1. Introduction

Roads have negative impacts on animals worldwide. These negative impacts can be indirect, due to habitat fragmentation, physically restricting animal movements, or aid the spread of exotic species (Trombulak and Frissell, 2000). Roads can also directly impact animals through death and injury as a result of vehicle collision (see Trombulak and Frissell 2000 and references within).

Mitigation strategies for reducing roadkill include erecting fences to prevent animals crossing roads, building underpasses and overpasses so animals can cross safely, erecting warning signs for drivers and clearing vegetation along roadsides (Romin and Bissonette, 1996; Dodd et al., 2004; Taylor and Goldingay, 2010; Bager and Fontoura, 2013). Virtual fences have recently been used as mitigation strategies to reduce roadkill (Fox et al., 2019). A virtual fence creates a barrier, or a boundary within the landscape, to alter animal behaviour (Umstatter, 2011). It was originally designed to contain domestic pets, and later, livestock (Anderson, 2007; Umstatter, 2011). It can also be used to deter wildlife from crossing roads when a vehicle is approaching. Virtual fencing is placed along the roadside and is activated by approaching vehicle headlights. On activation the device emits sound and light (LED lights) stimuli that alert and repel animals from crossing the road (Wildlife Safety Solutions, 2020). The advantage of virtual fencing compared with standard fencing is that it is not a physical barrier and animals are still able to move through the habitat.

In Australia, a three-year virtual fence trial in Tasmania along a 3.2 km stretch of road found that roadkill was reduced by over 50% (Fox et al., 2019). In contrast, Englefield et al. (2019) found that roadkill rates were reduced by 21 to 57% depending on the species, along a 4.5 km stretch of road over 126 days. Englefield et al. (2019) specifically investigated the rate of roadkill for Bennett's wallabies (*Notamacropus rufogriseus*), Tasmanian pademelons (*Thylogale billardierii*) and common

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brushtail possums (*Trichosurus vulpecula*), whereas Fox et al. (2019) investigated the impact on a wider range of marsupials, and other animals, including wombats.

Wombats are large semi-fossorial Australian marsupials that are commonly impacted by vehicle collisions (Roger et al., 2007). They act as important ecosystem engineers, especially in riparian zones. Their burrow building habits create microhabitats for other animals (Thornett et al., 2017; Old et al., 2018), whilst their soil perturbation has positive effects on vegetation growth patterns (Borchard and Eldridge, 2011). Additionally, turning over soil increases soil health and rotates nutrients trapped in lower layers of soil, improving the filtration of water, which increases soil moisture (Fleming et al., 2014). The bare-nosed wombat (*Vombatus ursinus*) is regarded as Least Concern on the IUCN red list, however the total population size is unknown (Taggart et al., 2016; Thorley and Old, 2020). Furthermore, despite their IUCN listing, bare-nosed wombats are threatened by a range of factors including vehicle collisions (Taggart et al., 2016; Thorley and Old, 2020).

In NSW Australia, bare-nosed wombats are among the top five species involved in vehicular collisions along with kangaroos, dogs, cattle and cats (NRMA, 2018). Wombats represented the second highest number of roadkills, after eastern grey kangaroos (*Macropus giganteus*), reported to a roadkill application in Australia over a three month period in 2019 (Englefield et al., 2020). Higher rates of animal collisions occur in regional townships in NSW (Burgin and Brainwood, 2008; NRMA, 2018). Our study therefore assessed whether virtual fencing could be used to reduce or prevent fatal vehicular strikes on bare-nosed wombats in regional NSW, specifically Nimmitabel in the Snowy Mountains.

2. Methods

2.1. Site

The site chosen for this study was based on roadkill records in the WomSAT database (WomSAT.org.au), an online database that allows citizens to record sightings of wombats across Australia (Skelton et al., 2019), as well as availability of local council funding for roadkill mitigation strategies to be implemented. The study site chosen to erect the virtual fence was a 1.5 km stretch of Old Bega Road, Nimmitabel NSW (Point A, Monaro Highway end, 0 km: 36° 30′ 55"S 149° 18′ 49″E; Point B, Kybeyan Road end, 1.5 km: 36° 30′ 44"S 149° 19′ 46″E). The road is a 22.7 km long single carriageway road located in a rural area of the Snowy Mountains region and has a 100 km/h speed limit. Both sides of the road consisted primarily of paddocks and grassland. The southern side of the road, nearest Kybeyan Road, consisted of bushland. Sheep and cattle were present in the paddocks adjacent to the study site.

2.2. Vegetation survey

Along the 1.5 km portion of Old Bega Road (study site) 12 transects were set every 150 m perpendicular to the road (Supplementary Fig. 1). The transects alternated on either side of the road, starting from transect 1 (0 km). Each transect was 25 m long and all vegetation was recorded 2 m either side of the transect line at 5 m intervals. A livestock fence bisected the transects on both sides of the road at approximately 7 m. Canopy cover (%), shrub cover (%), ground cover (%), and the dominant species of tree, shrub, and ground cover were identified (PlantNET, 2020; Plantyx, 2020) and recorded.

2.3. Wombats and roadkill data

Surveys of the road were conducted every two to three days and records entered into WomSAT (Skelton et al., 2019). The first recorded death within the study site occurred on the 26th June 2017 and surveys of the road continued until the 1st February 2021, hence roadkill data was collected throughout the entire study period. During the vegetation surveys (14th March 2020) wombat burrows and bolt holes along the study site were recorded and photographed.

2.4. Virtual fence

Wildlife Safety Solutions DD430 virtual fencing (iPTE, Traffic Solutions Ltd., Graz, Austria) was installed at the study site on 16th March 2020. The units were 160 mm × 74 mm × 48 mm and weighed 110 g (Wildlife Safety Solutions, 2020). The virtual fencing posts were installed along the study site every 25 m on alternating sides of the road. Each device was installed on a standard flex-base post and capable of operating in temperatures from −35 °C to 65 °C. The device uses a solar cell located on the top for power, but is only operational at night (Wildlife Safety Solutions, 2020). When a vehicle approaches, the headlights trigger the device to emit sound and light to deter animals.

2.5. Vehicular traffic monitoring

A Viasis 3003 radar activated sign (Via Traffic Controlling, Germany) was mounted on a roadside pole at the 0 km point (Monaro Highway end) and the 1.5 km point (Kybeyan Road end) of the road on the 18th March 2020 to measure the speed of vehicles travelling along Old Bega Road. The data was downloaded from the Viasis 3003 using Viagraph 5.3.2.0 (Via Traffic Controlling, Germany) in Microsoft Excel on the 20th May 2020 ($n = 63$ days). The data was logged as either arriving or departing from both the Monaro Highway (A) and Kybeyan Road (B) ends of the study site.

2.6. Data analysis

Numbers of wombats killed on the road were compared pre- and post-installation of the virtual fence. The vegetation data was analysed using an ANOVA to determine differences between transect canopy, shrub and ground covers using SPSS.

3. Results

3.1. Vegetation

There was a significant difference for canopy cover between transects, with transects 7, 8 and 10 having a higher portion of canopy cover compared with all other transects ($F_{11,71} = 3.024$ $P < 0.05$). These transects corresponded to the bushland area of the study site. Shrub cover was significantly higher at transect 7 compared to all other transects ($F_{11,71} = 10.198$ $P < 0.05$). The dominant shrub and tree species included silver wattle (*A. dealbata*), myrtle tea-tree (*Leptospermum myrtifolium*), scribbly gum (*Eucalyptus haemastoma*) and mana gum (*Eucalyptus viminalis*). Ground cover was not significantly different across transects ($F_{11,71} = 1.964$ $P = 0.05$). The commonly occurring ground cover species included weeping grass (*Microlaena stipoides*), dandelion (*Taraxacum officinale*) and warrego summer grass (*Paspalidium jubiflorum*). Poa tussock (*Poa labillardierei*), spiny-head mat-rush (*Lomandra longifolia*), common rush (*Juncus usitatus*), narrow leaf plantain (*Plantago lanceolata*), and broad-leaved dock (*Rumex obtusifolius*) were also recorded.

3.2. Wombats and roadkill

Thirty-one wombat burrows were recorded during the vegetation survey, with seven showing signs of recent activity (as described in Old et al., 2019), as well as six bolt holes (Supplementary Fig. 2). The fence that bisected the vegetation transects showed some damage in places where it appeared animals were traversing through the study area. Incidental observations were made of feral pig (*Sus scrofa*) diggings and scats, as well as feral rabbits (*Oryctolagus cuniculus*) in the paddocks.

All wombats killed were recorded between 26th June 2017 and 4th February 2020 (Supplementary Table 1). Twenty three wombats (10

Fig. 1. Map indicating deceased wombats (purple markers) recorded on Old Bega Road, Nimmitabel NSW within the 1.5 km study site prior to the installation of a virtual fence (blue markers indicate the start and end of the fence). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Map indicating deceased wombats (white markers) recorded on Old Bega Road, Nimmitabel NSW within the 1.5 km study site after the installation of a virtual fence (blue markers indication start and end of the fence). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

males, 10 females and 3 sex not recorded) were reported killed prior to installation of the virtual fence within the 1.5 km fence area (Fig. 1).

The virtual fence was monitored from the 17th March 2020 to the 1st February 2021 post-installation ($n = 322$ days). Six wombats were killed within the fence area after installation. One of those wombats was found recently dead (but lacking rigour and bleeding) during the day (Fig. 2).

The ratio of wombats killed per month pre and post installation of the virtual fence was similar (Table 1). Outside the 1.5 km study site 64 (34 males, 22 females and 8 sex not recorded) wombats were reported as roadkill in WomSAT from 30th June 2017 until 17th February 2020 on Old Bega Road. Seventeen wombats (8 males, 7 females and 2 sex not recorded) were recorded as roadkill outside the fence area after

Table 1
Ratio of wombats killed per month on Old Bega Road, Nimmitabel NSW before and after installation of a virtual fence.

	Inside virtual fence	Outside virtual fence	Total
Pre-installation	0.7	1.9	2.6
Post-installation	0.6	1.7	2.3

installation (17th March 2020 onwards) (Supplementary Fig. 3; Supplementary Table 2).

3.3. Vehicle traffic monitoring

Mean vehicle speeds recorded on Old Bega Road were below that of the sign posted 100 km/h, 85% of the time (Table 2). However, records well above the signed posted speed limit, up to 139 km/h, were also recorded during the vehicle monitoring period. When vehicles were arriving from the Kybeyan Road end, mean vehicle speeds were lower than vehicles arriving from the Monaro Highway end, 37 km/h and 75 km/h, respectively (Table 2). The same was true of vehicles departing the study site. The Kybeyan Road turn off was in close proximity to the Viasis 3003 radar and is also a dirt road.

4. Discussion

Vegetation surveys confirmed the presence of plants known to be included in the diet of wombats (Casey et al., 2021), and the site survey confirmed numerous active wombat burrows were present. The virtual fence appeared to be minimally effective at reducing roadkill as six wombats were killed in the fenced area post installation. Compared to before the fence was erected the rate of wombats killed per month was almost the same.

Despite bare-nosed wombats inhabiting eucalypt forests, open grasslands and farmland (McIlroy, 1977; Buchan and Goldney, 1998; Evans, 2008), they often prefer disturbed habitats and are found in locations with high road densities (Roger et al., 2007; Crook et al., 2013). Our vegetation survey of the study site confirmed the site contained disturbed habitat, and the majority of the wombat burrows occurred along the roadside rather than in the paddocks. Significant differences were found in canopy cover and shrub cover across the transects. Differences in the vegetation cover were observed among transects because of the presence of bushland at the southern end of the study site where native shrubs and trees were present, whereas the northern area of the study site consisted of livestock paddocks/open grasslands. Furthermore, an abundance of native perennial grasses and preferred dietary items of wombats, such as *Lomandra*, *Poa* and *Juncaceae* were identified (Evans et al., 2006; Green et al., 2015; Casey et al., 2021). Thus, the habitat along the roadside at our study site is ideal for wombats, providing a suitable location for burrowing and foraging, and confirmed through our burrow surveys to have wombats actively living in the area.

A total of six wombats were killed after the virtual fence was installed. The ratio of wombats killed per month was only slightly lower after the fence was installed (0.7 and 0.6 respectively). One wombat was killed during the day post-installation of the fence, as evidenced by the lack of rigour and active blood loss occurring on observation. However, the DD430 fence was inactive when the wombat was struck because it uses an internal daylight sensor to automatically turn on before dusk and switch off after dawn (Wildlife Safety Solutions, 2020).

Our study focused on one nocturnal species, hence there is the potential for diurnal animals to continue to be struck at the site despite the fence being in place. However, Fox et al. (2019) despite reporting a reduced roadkill rate of between 50 and 90% for more than one species using the same virtual fencing suggested the virtual fence still may be utilised to temporarily reduce roadkill rates of diurnal species.

A study conducted by Hobday (2010) in Tasmania found wildlife were better detected at speeds between 54 and 83 km/h using high beams. High beam headlights could detect Tasmanian devils (*Sarcophilus harrisii*) at 60.8 m, almost double the distance when using a low beam at 33.9 m (Hobday, 2010). Mean speeds through our study site were within those suggested by Hobday (2010) as more effective at reducing roadkill, however, the sign posted speed limit, and maximum speeds recorded were above 100 km/h. Thus, road speeds on Old Bega Road are not ideal for reducing roadkill and vehicles are exceeding the recommended speed limit.

There are differences between the road types surrounding the study site. These differences in road types were affecting the speeds at which vehicles were arriving and departing the study site. Kybeyan Road is a dirt road and the intersection ('T' intersection) between this road and Old Bega Road is close (~300 m) to the end of the study site. Hence vehicles turning into or out of Kybeyan Road would have been reducing (or accelerating) their speed at this end of the study site, compared to the Monaro Highway end.

Hobday (2010) also concluded that detection distance was significantly related to the brightness of the fur, not the size of the animal. Hence, the detectability of bare-nosed wombats likely varies because of the range of coat colours that occur in the species, almost black to white (cited in Wells (1989).

Although virtual fencing appears promising, further studies are still needed as the results can vary. We were unable to replicate the results of Fox et al. (2019). Likewise, Englefield et al. (2019) failed to replicate the 50% to 90% reduction in roadkill rates observed by Fox et al. (2019), despite the 4.5 km stretch of virtual fencing along the Tasmanian highway and roadkill counts being conducted daily in the fenced area. Although the fence was split into six sections and monitored over 126 days, one of the most significant differences in the Englefield et al. (2019) study is that there was no pre-installation monitoring period, sections of the fence were simply turned on or off. This divided monitoring into five periods with before, control, impact and after occurring simultaneously (Englefield et al., 2019). Despite these differences in methodology, the trial by Englefield et al. (2019) still recorded a 13% to 32% reduction in roadkill rates; however these results were lower than the 50% to 90% reduction claimed by Fox et al. (2019).

One further limitation of our study is the relatively short distance (1.5 km) of the fenced area compared to Fox et al. (2019) (3.2 km) and Englefield et al. (2019) (4.5 km). Future studies should be conducted over a longer distance. Additionally, we do not know the numbers of wombats that entered the study site when a car was coming, was subsequently alerted, and therefore avoided being killed, hence future studies should utilise cameras to view animal behaviour and interactions with the virtual fencing.

The preliminary findings of this study suggest the fence at this site was minimally effective at reducing numbers of wombat deaths from

Table 2
Vehicle speed on Old Bega Road, Nimmitabel NSW at the site of a virtual fence study site, 18th March - 20th May 2020.

	Mean vehicle velocity (km/h)	Maximum vehicle velocity (km/h)	Vehicle velocity 85% of the time (km/h)
A arrive	75	139	97
A depart	78	139	95
B arrive	37	119	62
B depart	46	131	71

A is the Monaro Highway end of the study site. B is the Kybeyan end of the study site.

roadkill. Hence, virtual fencing may provide suitable mitigation strategies to reduce wombat roadkill rates, however further data is needed. We recommend investigating additional installations in areas with high wombat road mortality, different habitat types and differing lengths of fence to further test the viability of virtual fencing in reducing wombat roadkills. We also recommend additional mitigation strategies are used in combination with virtual fences to ensure roadkill is reduced.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoleng.2021.106414.

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