Nature Conservation

Nature Conservation 57: 125–142 (2024)
DOI: 10.3897/natureconservation.57.116972

Research Article

The potential of electrified barriers to keep black bears out of fenced road corridors at low volume access roads

Marcel P. Huijser[1], Samantha C. Getty[1,2]

1 Western Transportation Institute, Montana State University, PO Box 174250, Bozeman, MT 59717-4250, USA
2 Current affiliation: Bell Museum, University of Minnesota, 2088 Larpenteur Ave W, St Paul, MN 55113, USA
Corresponding author: Marcel P. Huijser (mhuijser@montana.edu)

Abstract

Fences can reduce wildlife-vehicle collisions, but it is not always possible to fence over long distances, especially not in multi-functional landscapes. Side roads, driveways, and the need for access to agricultural fields all result in gaps in the fence. In some cases, wildlife guards or gates are installed at access points. However, gates usually require people to get in and out of their vehicle and they are often left open. Wildlife guards are typically only suited for low traffic speed, and while they can be a substantial barrier to ungulates, they are readily crossed by species with paws, including bears. Electrified barriers embedded in travel lanes can be a substantial barrier to both ungulates and bear species and while they can be suitable for higher traffic volume and speed, the costs are typically higher than for low volume and low speed roads. We explored the potential of low-cost electrified barriers to keep bears from accessing fenced road corridors at low traffic volume and low speed vehicle access points. As a first step, we conducted the study on private land at a melon patch that was a known attractant for black bears. We investigated the effectiveness of an electric fence and 5 different types of electrified barriers designed to keep black bears out of the melon patch. The electrified barriers included a swing gate, a standard bump-gate, a modified bump-gate with conductive netting, drive-over wires a few inches above the ground, and a drive-over mat. Trail cameras were installed at each access point to document approaching black bears and potential crossings into the melon patch. The swing gate, modified bump-gate, drive-over wires, and drive-over mat were an absolute (100%) or near absolute barrier (94.3%) for black bears while the standard bump-gate was a poor barrier (48.4%). Through a step-by-step process, the weak points of the electrified barriers at the vehicle access points and the electric fence around the melon patch were addressed. After addressing a weak point at a vehicle access point, the bears increasingly dug under the fence to enter the melon patch. However, eventually the melon patch became almost inaccessible to black bears. The number of black bears trying and succeeding to enter the melon patch at a particular location depended on how difficult it was to enter at other locations. This illustrates that fences and vehicle access points should be designed, operated, maintained, and monitored as a system rather than as individual features, regardless of whether the goal is to protect crops or to keep animals out of a fenced road corridor. The total number of black bear observations at the locations monitored with a trail camera, regardless of which side of the fence or electrified barriers the bears were on, was 95% lower in 2021 than in 2020. Combined with having no indication of a substantial drop in black bear population size from 2020 to 2021, this suggests that after the black bears were no longer able to enter the melon patch, they drastically re-

OPEN ACCESS

Academic editor: Cristian-Remus Papp
Received: 7 December 2023
Accepted: 30 April 2024
Published: 16 December 2024

ZooBank: https://zoobank.org/DEA7148F-3025-45F8-A0EF-626808955679

Citation: Huijser MP, Getty SC (2024) The potential of electrified barriers to keep black bears out of fenced road corridors at low volume access roads. In: Papp C-R, Seiler A, Bhardwaj M, François D, Dostál I (Eds) Connecting people, connecting landscapes. Nature Conservation 57: 125–142. https://doi.org/10.3897/natureconservation.57.116972

duced their presence in the immediate surroundings and reduced their effort to try and access the crop; the attraction of the melon patch and the habit of eating its melons was broken.

Key words: Access, coexistence, collision, conflict, crop, drive, fence, gate, highway, human, interaction, mitigation, roadkill, vehicle, wildlife

Introduction

Most wildlife mitigation measures along highways are aimed at improving human safety, reducing direct wildlife mortality, and providing safe crossing opportunities for wildlife (e.g. Ford et al. 2009; van der Grift et al. 2017). Fences in combination with wildlife crossing structures are probably the most effective combination of mitigation measures to achieve these objectives (Clevenger and Waltho 2000; Rytwinski et al. 2016; Huijser et al. 2021). For fences to be reliably reducing collisions with large wild mammals by 80% or more, at least 5 kilometers of road length needs to be fenced, including a buffer zone that extends well beyond the known hotspots for wildlife-vehicle collisions (Huijser et al. 2015; Huijser et al. 2016a). Collisions that still occur within or adjacent to the fenced road sections tend to be concentrated near the fence-ends (Huijser et al. 2016b; Plante et al. 2019; Huijser and Begley 2022). In addition, gaps in fences at access roads can result in concentrations of collisions inside fenced road sections (Sawyer et al. 2012; Cserkész et al. 2013; Yamashita et al. 2021).

Embedding barriers (e.g. wildlife guards or electrified barriers) in the travel lanes at fence-ends or at access roads can reduce intrusions into the fenced road corridor (Peterson et al. 2003; Gagnon et al. 2019; Honda et al. 2020). Gates are commonly used at gaps in the fence at low traffic volume access roads, but they are often left open, allowing wildlife to access the road corridor (VerCauteren et al. 2009; Sawyer et al. 2012). While single wide cattle guards or wildlife guards (2.1–3.0 m) can be effective for some ungulate species (VerCauteren et al. 2009; Huijser et al. 2015; Honda et al. 2020), double wide cattle or wildlife guards (4.6–6.6 m) consisting of round bars or bridge grate material and situated above a pit, are generally recommended for ungulates (Belant et al. 1998; Peterson et al. 2003; Allen et al. 2013; Cramer and Flower 2017; Gagnon et al. 2020; Kintsch et al. 2021). However, some designs, including guards that consist of flat bars, are less effective for ungulates (Reed et al. 1974; Kintsch et al. 2021), and single or double wide guards are not a substantial barrier for species with paws, including many mid-sized and large carnivore species (Allen et al. 2013; Clevenger and Barrueto 2014; Huijser et al. 2015, 2016b; Honda et al. 2020). Electrified mats or electrified guards can be a barrier for both ungulates and species with paws, but to prevent animals from jumping across the mat, they may need to be 4.6–6.6 m wide (Seamans and Helon 2008; Cramer and Flower 2017). Combinations of electrified barriers and non-electrified guards are also possible (Gagnon et al. 2020).

We explored the potential of low-cost electrified barriers to keep bears from accessing fenced road corridors at low traffic volume and low speed vehicle access points. As a first step, we conducted the study on private land at a melon patch that was a known attractant for black bears (*Ursus americanus*). We investigated the barrier effect of an electric fence and different types of electrified barriers at vehicle access points in keeping the bears out of the melon patch. In the past, the farmer has seen up to 7 individual black bears eating melons in the patch at the same time (personal communication Cassie Silvernale). In 2019, before the electrified fence and barriers were put in place, the economic losses because of black bears were estimated at 5% of the crop or about 5,000 melons (Andrews 2020). Assuming a sale price of about US $5 per melon, this amounts to about US $25,000 in lost revenue per year. Eating melons with high sugar and carbon content can also be detrimental to the health of the black bears, e.g. through tooth decay. Furthermore, reducing conflict between farmers and bears in general can help build a willingness to co-exist in the same landscape (e.g. Wilson et al. 2017). Depending on the location, this may benefit both black bears and grizzly bears (*Ursus arctos*), as well as other species that are present in the area and that may eat commercial crops.

Methods

Study area

The main study area was a melon patch (about 8 ha) located immediately south of the Bison Range, about 3.5 km west of Ravalli, Flathead Indian Reservation, Montana, USA (Fig. 1). The melon patch was just north of MT Hwy 200, and just south of the Jocko River and the associated trees and shrubs in the riparian area. While the patch was dominated by different varieties of melons, there was also some corn planted along one edge of the field. An additional study site with a drive-over mat was located along US Hwy 93, just south of Ravalli (Fig. 1).

The electric fence and electrified barriers at the vehicle access points

A Non-Governmental Organization, People and Carnivores, built an electric fence around the melon patch in the summer of 2020 (Fig. 2). The fence was constructed before the harvest of the melons in 2020 with the intent of keeping black bears, and potentially also grizzly bears, out of the melon patch. In addition, electrified barriers were installed at 4 vehicle access points to the melon

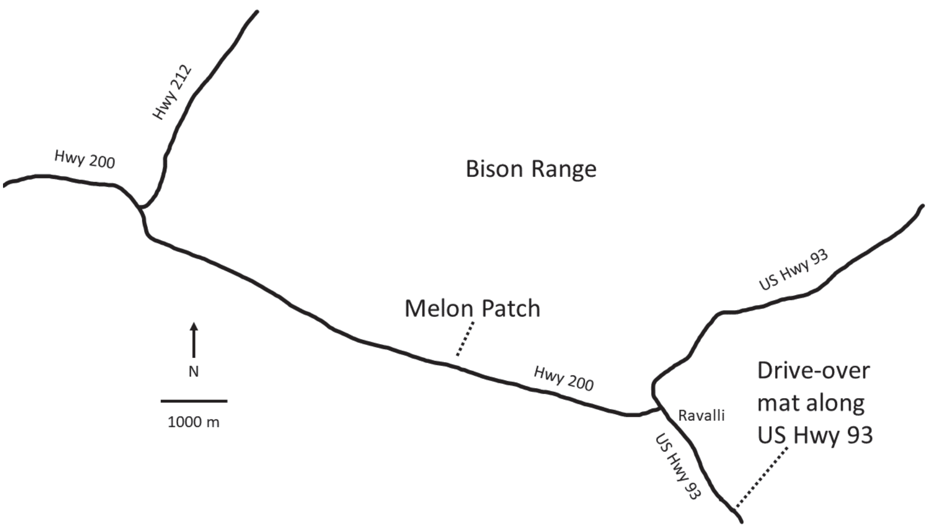

Figure 1. The location of the melon patch, and the additional drive-over mat, Flathead Indian Reservation, Montana, USA.

patch (Fig. 2). The electric fence consisted of 4 wires attached to composite fence posts made from polypropylene and wood (PasturePro®) (Fig. 3). This fence design is similar to those used by others to keep different bear species from accessing crops or other attractants (Huygens and Hayashi 1999; Otto and Roloff 2015; Khorozyan and Waltert 2020). Corner posts and braces, including at vehicle access points, were treated wood posts. The height of the fence was about 91 cm (Fig. 3). While the fence was designed to keep both black bears and grizzly bears out of the melon patch, it was not designed to keep other species from accessing the melon patch. Ungulates (e.g. white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), and elk (*Cervus canadensis*)) can easily jump this fence. The farmer sprayed herbicides along

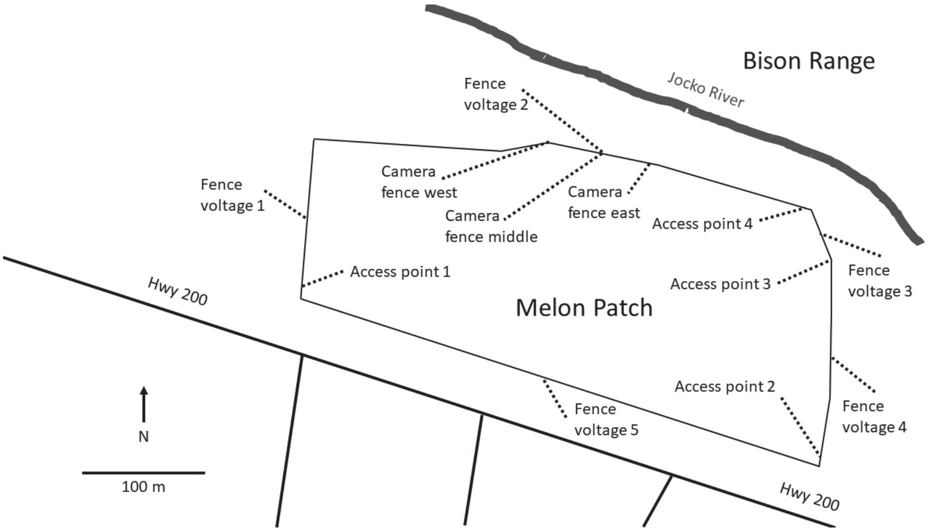

Figure 2. The melon patch (roughly 450 m east-west and 180 m north-south). The electric fence (solid black line around the melon patch), the 4 vehicle access points, the 5 locations along the fence where fence peak DC voltage was measured, and the location of 3 trail cameras where we suspected black bears were digging under the fence.

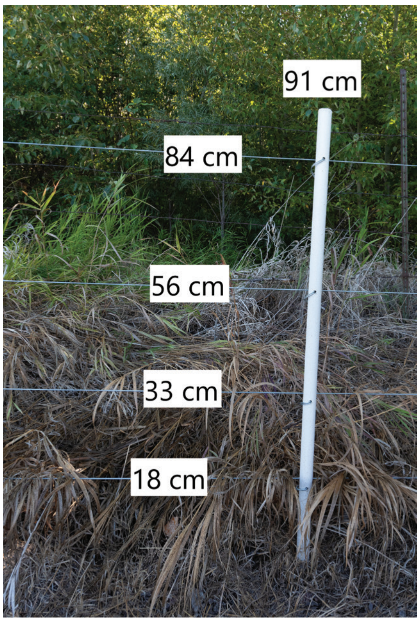

Figure 3. The approximate height of the non-modified electric fence and its 4 wires.

the fence to reduce voltage drop. At first, the 2nd wire from the bottom was a designated ground wire, with the other 3 wires being hot (i.e., carrying current). After 27 August 2020, the 2nd wire from the ground was made into a hot wire also, which meant that from then on, the current received by an animal depended on the contact points of the animal with the ground which varies with the conductivity of the animal itself, and the conductivity of the ground or vegetation. A solar panel, and associated battery and energizer powered the fence and all 4 access points. However, from 6 August 2021 onwards, access point 3 had the drive-over mat installed which was powered by its own solar panel and associated battery and energizer. The electric fence energizers are listed by the internationally recognized safety standards agencies (UL, CSA or IEC).

In 2020 and 2021, we evaluated 5 different electrified barrier designs at the 4 access points to the melon patch (Table 1, Fig. 4). The drive-through bump-gates were originally installed at 2 access points, but 1 of them was modified in 2020, and the drive-over wires barrier was replaced by a drive-over mat in 2021 (for exact dates see Table 1). In 2022, we continued to monitor only the swing gate at access point 2 and the drive-over mat at access point 3 (Table 1). We continued monitoring in 2022 to increase the sample size for the swing gate (from 9 in 2020-2021 to 23 in 2020-2022) and the drive-over mat (from 2 in 2021 to 3 in 2021-2022). Since the drive-over mat still had a very low sample size, data from a similar barrier design from the same manufacturer at a nearby site (US Hwy 93, just south of Ravalli) was added (Fig. 1). The electrified barrier along US Hwy 93 was monitored in 2022 and 2023 (Table 1). There were 2 black bears and 1 grizzly bear that approached this drive-over mat, bringing the total sample size for the drive-over mat design to 5 black bears and 1 grizzly bear (6 "bears" in total).

The fence and the 5 electrified barriers at the 4 access points to the melon patch were modified during the study. The most important modifications to the electrified barriers, start and end dates of the melon picking seasons in 2020 and 2021, and the associated evaluation periods, are summarized in Table 2. Note that melons were also a potential attraction to animals before the first pick of a season and after the last pick of a season.

Table 1. The electrified barriers and the periods during which they were evaluated.

Electrified barrier type	Brand, approximate costs (US$)	Location	Evaluation start-end 2020	Evaluation start-end 2021	Evaluation start-end 2022	Evaluation start-end 2023
Swing gate (modified with 4 hot wires)	Hutchison, $290 for gate only (excl. installation)	Access point 2	10 Jul – 12 Dec	28 Apr – 19 Nov	23 May – 15 Dec	None
Bump-gate (not modified)	Koehn, $180, (excl. installation)	Access point 1	10 Jul – 12 Dec	28 Apr – 19 Nov	None	None
Bump-gate (not modified)	Koehn, $180 (excl. installation)	Access point 4	10 Jul – 27 Aug	None	None	
Bump-gate (modified with netting)	Koehn, $180 (excl. installation, excl. netting)	Access point 4	27 Aug – 12 Dec	28 Apr – 19 Nov	None	None
Drive-over wires	Fully custom (Bryce Andrews, People and Carnivores), cost under $500 (excl. installation)	Access point 3	10 Jul – 12 Dec	28 Apr – 4 Aug	None	None
Drive-over mat	Crosstek™, $11,250 (incl. installation)	Access point 3	None	6 Aug – 19 Nov	23 May – 15 Dec	None
		US Hwy 93	None	None	23 May – 30 Nov	14 Apr – 12 Jul

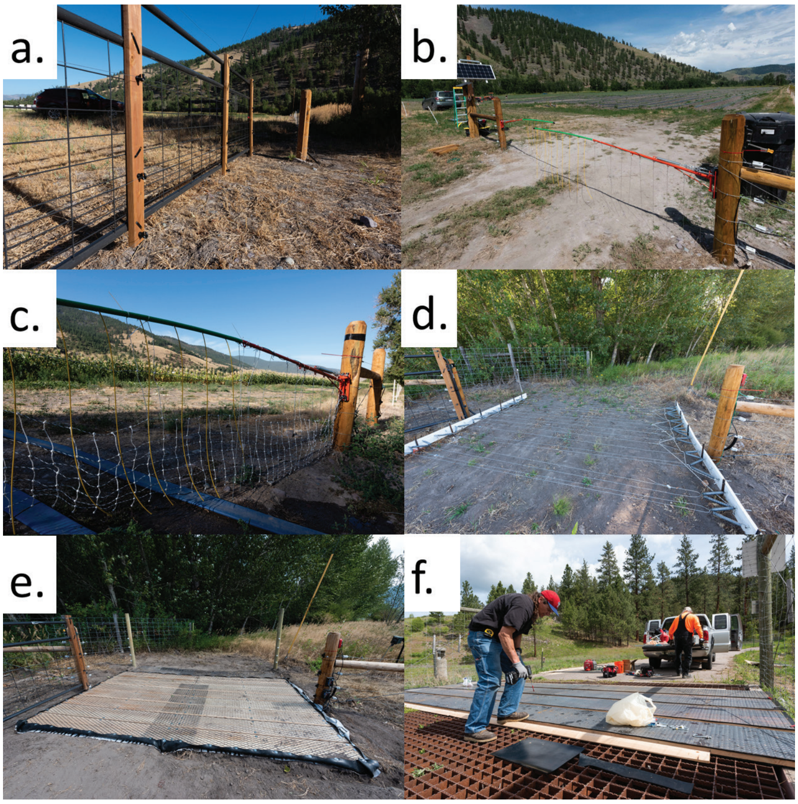

Figure 4. The 5 electrified barriers at the 4 vehicle access points (**a–e**) and along US Hwy 93 (**f**) **a** The electrified swing gate (4.88 m wide, 1.37 m tall, about 18 cm gap between ground and bottom of gate). The wires are mounted at 15, 48, 97, and 140 cm above the ground. Installed at access point 2 **b** A drive-through bump-gate (not modified) (about 4.88 m wide, about 91 cm tall), with vertical electrified wires. The orange horizontal pole is metal and carries current. The green horizontal part is fiberglass and does not carry current. Installed at access points 1 and 4 **c** A modified drive-through bump-gate (with conductive netting) (about 4.88 m wide, about 91 cm tall), with vertical electrified wires and custom conductive netting (about 61 cm high) attached. Installed at access point 4 **d** The drive-over wires, about 4.34 m wide (post-post) and 3.10 m long. The 18 drive-over wires are about 18 cm above the ground and the gaps between the wires vary between 13-30 cm. There are "side-board" wires that angle toward the ground from the post along the sides of the barrier to reduce the likelihood of an animal bypassing the drive-over wires. However, these "side-boards" do not cover the full length of the barrier. Installed at access point 3 **e** The drive-over mat, about 4.34 m wide (post-post) and about 3.05 m long. On the far side, the habitat side, there is metal mesh on the ground, connected to a grounding rod (about 61 cm wide). This is followed by 8 sections of 25-28 cm wide expanded metal sheeting (alternating positive and negative (ground)) mounted on wooden planks. This drive-over mat is powered by its own solar panel, battery and energizer. Installed at access point 3 **f** The drive-over mat, about 7.36 m wide (post-post) and about 2.44 m long, installed at a gap in a wildlife fence for a low volume access road along US Hwy 93. The mat is positioned on a wildlife guard (bridge grate material). On the far side, the habitat side, the animals first encounter bridge grate material (about 66 cm wide) that is connected to a grounding rod. This is followed by a wooden ramp (about 20 cm wide) and 4 metal plates (each about out 51 cm wide, alternating positive and negative (ground)) mounted on rubber and wooden planks with about 6 cm gaps in between the metal plates, and another wooden ramp on the far side (about 20 cm wide). This drive-over mat is powered by its own solar panel, battery and energizer. Installed along US Hwy 93, just south of Ravalli (see Fig. 1).

Data collection

Each access point had a trail camera installed (Reconyx™ PC 900). The trail cameras fully covered the area up to 2 m in front of each access point. The 2 m distance from the access point was visible on each image based on the line between the trail camera's viewpoint and a stick with reflective tape on the other end. This allowed us to consistently evaluate the behavior of large mammals that approached each access point within 2 m. We evaluated whether the animals succeeded in accessing the melon patch by crossing the electrified barriers. Some large mammals were also detected further away from the access point, but those animals were not included in the evaluation of the effectiveness of the electrified barriers at the 4 access points. We also detected or suspected that bears were digging under the electrified fence at 3 locations (Table 3, Fig. 2), and we monitored these locations with trail cameras. Interestingly, these locations were all adjacent to the riparian habitat along the Jocko River and not along the roadside of MT Hwy 200 or adjacent agricultural fields. We replaced the memory cards in all trail cameras about once a month. We replaced the batteries (Energizer® Ultimate Lithium™) about every 3 months.

We measured the peak DC voltage (Stafix digital volt meter) of the electrified fence on each of the 4 wires at 5 locations for most of the trail camera checks before, during, and after the melon harvest seasons in 2020 and 2021 (Figs 2, 3). We also measured the peak DC voltage of the electrified barriers at the 4 access points during most trail camera checks before, during, and after the harvest seasons in 2020 and 2021 (Figs 2, 4). For the bump-gate designs at

Table 2. Major modifications to the electrified fence and vehicle access points and the start and end dates of the melon picking seasons in 2020 and 2021. The number of days relates to the length of each period with a particular set of conditions.

From	Until	Days (N)	Description of changes that applied to the period
10-Jul-20	7-Aug-20	28	Electricity turned "on" 10 Jul 2020, turned "off" 12 Dec 2020
7-Aug-20	21-Aug-20	14	Start melon picking season 7 Aug 2020, end 2 Oct 2020
21-Aug-20	27-Aug-20	6	Wires lowered a select locations, access points permanently "on"
27-Aug-20	9-Sep-20	13	Mesh added at access point 4, motion light fence west, 2nd wire from bottom hot
9-Sep-20	2-Oct-20	71	Additional post and a 5th wire at fence west and fence middle
2-Oct-20	12-Dec-20	23	No more melon picking for 2020 season
28-Apr-21	30-Jul-21	93	Electricity turned "on" 28 Apr 2021, turned "off" 19 Nov 2021
30-Jul-21	6-Aug-21	7	Start melon picking season 30 Jul 2021, end 14 Sep 2021
6-Aug-21	14-Sep-21	39	New drive-over barrier installed at access point 3 on 6 Aug 2021
14-Sep-21	19-Nov-21	66	No more melon picking for 2021 season

Table 3. The 3 fence locations (see Fig. 2) and the periods and associated number of days they were monitored with a trail camera in 2020 and 2021.

Fence location	2020		2021	
	Start and end date evaluation	Days (N)	Start and end date evaluation	Days (N)
West	6 Jul 2020 - 12 Dec 2020	159	28 Apr 2021 - 19 Nov 2021	205
Middle	27 Aug 2020 - 12 Dec 2020	107	28 Apr 2021 - 19 Nov 2021	205
East	6 Jul 2020 - 12 Dec 2020	159	28 Apr 2021 - 19 Nov 2021	205

access points 1 and 4, the peak DC voltage was measured for both the right and the left part of the gate. For the other barriers there was just 1 measurement. Though the peak DC voltage measurements only occurred during the trail camera checks - the voltage measurements were not continuous - the peak DC voltage readings showed whether the electric fence and electrified barriers were electrified at that moment. This indicated whether we could have expected the electric fence and electrified barriers at the access points to have discouraged bears from entering the melon patch since the last voltage readings.

Data analyses

Voltage

For most of the trail camera checks during the melon harvest seasons in 2020 and 2021, we calculated the average peak DC voltage for each of the 4 wires of the fence based on the 5 measurement locations. In addition, we calculated the average peak DC voltage for each of the 2 sides of the 2 bump-gates at access points 1 and 4. The peak DC voltage of the barriers at access points 2 and 3 was always based on a single measurement.

Barrier effect

Each barrier design at a vehicle access point was evaluated for its barrier effect on black bears through counting the number of black bears that were recorded in the area up to 2 m immediately in front of each access point and calculating the percentage of bears that were deterred. If a black bear was recorded within 5 minutes of the previous event involving a black bear, it was considered the same bear and it was counted and evaluated as 1 event. However, if there was evidence (e.g. based on body size, hair color) that these were different individuals, then it resulted in 2 events. If more than 5 minutes passed between consecutive black bear observations, then these were considered different events, regardless of whether it involved the same bear. We reviewed the images and calculated the percentage of black bears that successfully accessed the melon patch (undesired result) vs. the percentage of black bears that were deterred (desired result, equivalent to the barrier percentage).

Breaking the addiction

Modifications to the barriers at the vehicle access points and the fence were recorded and grouped into different periods (Table 2). The absolute number of black bears accessing the melon patch in each period was calculated for each access point and for each of the 3 fence locations that were monitored with a trail camera. Since the periods varied greatly in length, the black bear counts were standardized for the number of days in each period. This analysis shows potential increase or decrease in black bears accessing the melon patch, and the locations of the intrusions in association with the modifications to the barriers at the vehicle access points and the fence. In addition, we counted the total number of black bear events inside and outside the fenced melon patch recorded by the 7 trail cameras, regardless of the distance to the fence, vehicle access point or trail camera, per month for both 2020 and 2021. This analysis showed potential differences in the attraction of the melon patch and whether the black bears' habit of trying to access the melons was broken.

Results

Voltage

When measured, the peak DC voltage on the fence was almost always 7–9 kV and very similar for the 4 fence wires (Fig. 5). The 2nd wire from the bottom was a ground wire until 27 August 2020, hence the lack of voltage measurements before that date. In general, the 2 bump-gates (access points 1 and 4) had lower peak DC voltage (usually between 4–6 kV) than the barriers at the other 2 locations (usually between 7–10 kV) (Fig. 6). Note that the measurements in 2021 at access point 3 related to a drive-over mat with its own power source that was independent from that of the fence and the 3 other access points. Also note that the peak DC voltage at the end of November in 2021 was lower everywhere.

Barrier effect access points

All the bears that were recorded at the melon patch were black bears; there were no observations of grizzly bears at this site. All the black bear events related to single animals; there were no events involving multiple black bears (e.g. a sow and cubs). Four out of the 5 electrified barrier designs for access points were an absolute (100%) or near absolute barrier (94.3%) for black bears (Fig. 7). However, the bump-gates that were originally designed for cattle were a poor barrier for black bears (48.4%). Based on the images from the trail cameras, the bears usually passed in between the vertical electrified strands, and thus minimized contact with the wires. After conductive netting was attached to the bump-gate at access point 4, the bears no longer passed through that bump-gate (100% barrier) and

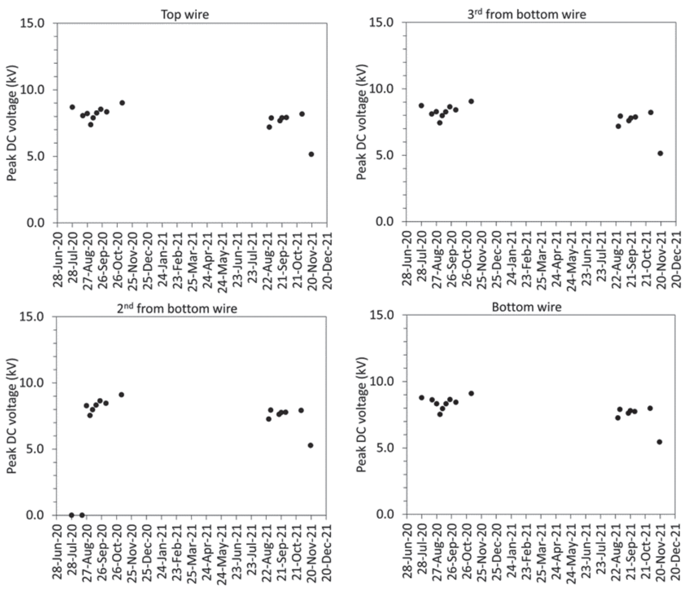

Figure 5. The peak DC voltage on the 4 fence wires before, during, and after the harvest melon seasons in 2020 (point groups on the left) and 2021 (point groups on the right).

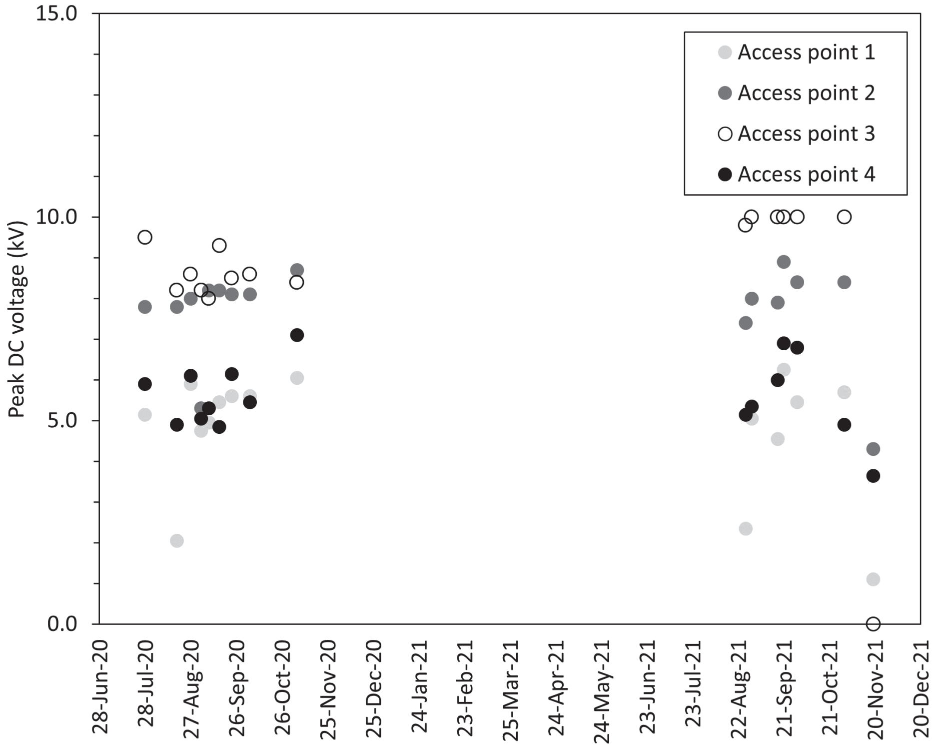

Figure 6. The peak DC voltage at the 4 access points before, during, and after the melon harvest seasons in 2020 (point groups on the left) and 2021 (point groups on the right). The measurements in 2021 at access point 3 related to a drive-over mat with its own power source that was independent from that of the fence and the 3 other access points.

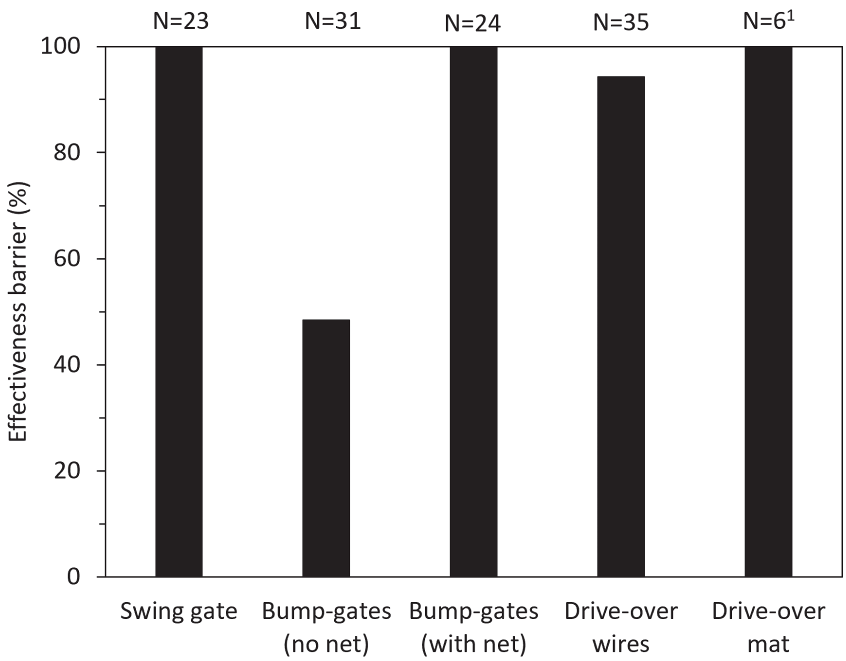

Figure 7. The effectiveness of the different barriers in keeping black bears out of the melon patch. N = number of bears (sample size) approaching the barriers. [1]Sample size at melon patch was 3 black bears, but the data were supplemented by additional observations (2 black bears and 1 grizzly bear, all single animals) at a similar mat nearby (US Hwy 93, south of Ravalli, see Fig. 1).

moreover, they did not even touch the electrified barrier. The same was true for the swing gate, drive-over wires, and drive-over mat; most bears that approached the barriers did not touch the electrified components at all. Two out of 35 black bears passed the drive-over wires above the ground (Fig. 7). Both intrusions involved a bear bypassing most of the wires by coming in or leaving from the side.

Breaking the addiction

At the 7 locations that were monitored with a trail camera, the number of black bear intrusions into the melon patch varied between 2.07 and 4.38 per day during the 2020 melon picking season (103 intrusions between 7 August 2020 and 2 October 2020) and was 0 per day during the 2021 melon picking season (0 intrusions between 30 July 2021 and 14 September 2021) (Fig. 8). Access point 4, the non-modified bump-gate adjacent to the Jocko River, and "fence west" accounted for most of the intrusions. After conductive netting was attached to the bump-gate at access point 4, black bear entries increased at "fence west" and at "fence middle" (Fig. 8). After fence modifications on 9 September 2020, almost no bears were able to enter the melon patch. There were only 2 black bears that entered after that date, and both did so through partially bypassing the drive-over wires at access point 3. We did not have any evidence that black bears entered the melon patch at any other location that was not monitored with a trail camera. The total number of black bears was highest in August through October (Fig. 9). The total number of black bear observations at any of the 7 locations monitored with a trail camera, regardless of the distance to the fence, vehicle access point or trail camera, and regardless of which side of the fence or electrified barriers the bears were on, was 95% lower in 2021 (N=24) than in 2020 (N=527).

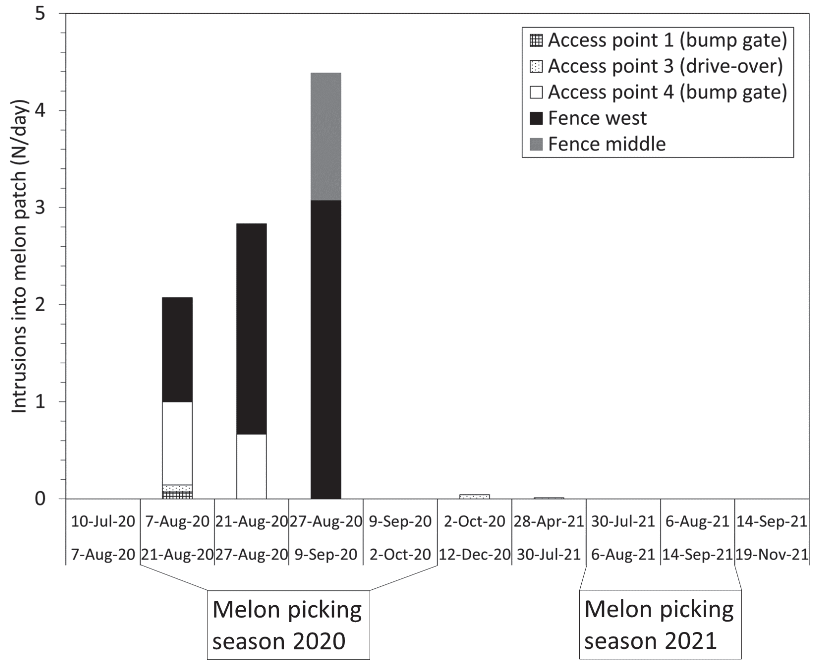

Figure 8. Black bear intrusions into the melon patch during different periods in 2020 and 2021. Note: No intrusions were reported at access point 2 (swing gate) and "fence east". Note: Access point 3 had drive-over wires 10 July 2020 until 6 August 2021 and a drive-over mat after 6 August 2021.

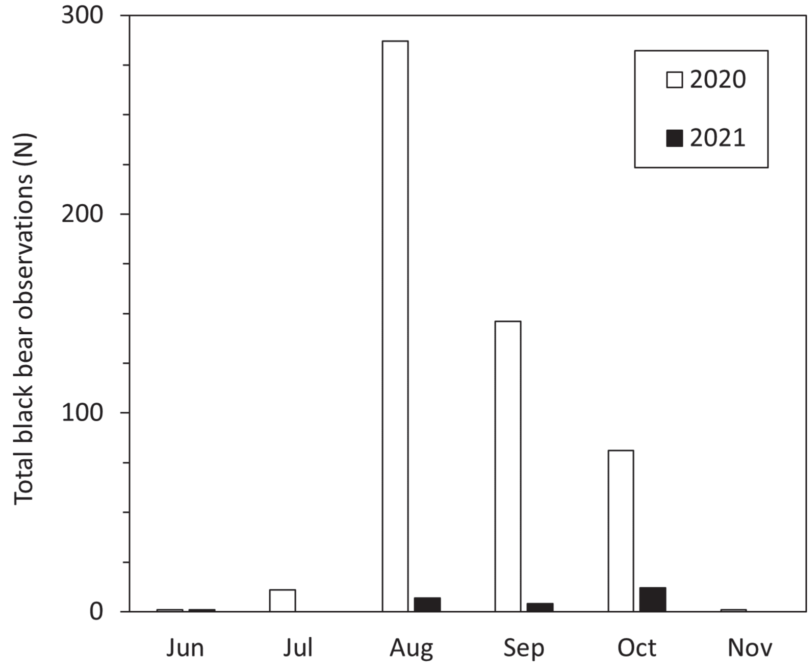

Figure 9. The total number of black bear observations, regardless of the distance to the fence, vehicle access point or trail camera, and regardless of which side of the fence or electrified barriers the bears were on, per month in 2020 and 2021.

Discussion

Voltage

In general, the peak DC voltage on the fence and at access points 2 and 3 was almost always 7–10 kV. However, the 2 bump-gates (access points 1 and 4) usually had lower peak DC voltage (usually between 4–6 kV), suggesting higher resistance of the materials or a short or voltage leak. The overall drop in peak DC voltage at the end of November in 2021 was most likely the result of moisture causing a voltage leak, or shorter days (not enough daylight to recharge the batteries) and lower temperatures (reduced capacity of the batteries). It is possible that there were additional voltage drops in between voltage readings, but if they were present at all, the peak DC voltage had recovered by the next voltage measurement.

Barrier effect access points

Four out of the 5 electrified barrier designs for access points were an absolute or near absolute barrier for black bears. However, non-modified bump-gates that were originally designed for cattle were a poor barrier for black bears as they deterred only about half of the animals. Adding conductive netting to one of the bump gates made it into an absolute barrier, however. This is likely because the netting results in more contact points with an animal for a longer time when an animal tries to lift the fence material and pass under. Changing electrified wires to electrified netting also made a fence a much greater barrier to European wild rabbits (*Oryctolagus cuniculus*) (McKillop et al. 1992). The drive-over wires were partially bypassed by 2 bears, emphasizing the need for tight fences along the full length of the sides of the barrier. Interestingly, most bears that approached an absolute or near absolute barrier did not even touch the barrier. This is consistent with other studies that reported that black bears and other large mammal species tend to stay away from electrified barriers, apparently because they know about its potential impact (Huygens and Hayashi 1999; Fischer et al. 2011; Otto and Roloff 2015; Teixeira et al. 2017).

Breaking the addiction

Through a step-by-step process, the weak points of the electrified barriers at the vehicle access points and the electric fence around the melon patch were addressed. The standard bump-gate at access point 4, and 2 fence locations (west and middle) were of particular concern. Interestingly, once the conductive netting was attached to the bump-gate at vehicle access point 4, the bears increasingly dug under the fence to enter the melon patch. However, from 9 September 2020 onwards, including during the melon picking season in 2021, the melon patch became almost inaccessible to black bears; the number of intrusions by black bear was reduced from 2.07–4.5 per day (2020 melon picking season) to 0 per day (2021 melon picking season). We found that black bears trying and succeeding to enter the melon patch at a particular location depended on how difficult it was to enter at other locations. This illustrates that fences and vehicle access points should be designed, operated, maintained, and monitored as a system rather than as individual features, regardless of whether the goal is to protect crops or to keep animals out of a fenced road corridor.

The total number of black bear observations at any of the 7 locations monitored with a trail camera, regardless of which side of the fence or electrified barriers the bears were on, was 95% lower in 2021 than in 2020. The farmer reported substantial reductions in melons lost to bears in 2021 compared to 2019 before the fence and electrified barriers were installed (100% reduction in losses; personal communication Cassie Silvernale). Although black bear activity in and adjacent to the melon patch was still relatively high in 2020, not nearly as much melon loss occurred because of bears in 2020 compared to 2019 (80% reduction in losses; personal communication Cassie Silvernale). The very substantial reductions in both black bear presence and melon losses after the installation of the fence and electrified barriers suggests that after the black bears were no longer able to enter the melon patch, they drastically reduced their presence and effort to try to access the melon patch. Apparently, the attraction of the melon patch and the associated habit of eating melons was broken. Note that based on direct observations of black bears by the authors, there was no indication of a population crash of black bears in 2021 in the immediate vicinity, or in the wider region (Montana Fish Wildlife & Parks 2024).

Experiences with operation and maintenance

All 4 vehicle access points had manual switches allowing farm personnel to walk through the electrified barriers without shocking themselves. However, shortly after the electric barriers were activated, the farmer realized that the switches were sometimes accidentally left in the "off" position. From 29 August 2020 onwards, all switches were permanently taped in the "on" position. While relatively inexpensive, the bump-gates required custom conductive netting to become a substantial barrier to black bears. The netting is subject to tearing and needs to be adjusted and reattached regularly (e.g. with zip-ties). In addition, there are tensioners for the 2 horizontal poles of the bump-gates. These also need to be adjusted on a regular basis to ensure that the 2 horizontal poles align and do not leave a gap in the middle. The horizontal poles are also subject to breaking; one of the poles broke after it got stuck in a bumper or wheel well of a pickup truck.

There were no operation or maintenance issues with the electrified swing gate. A design problem of the drive-over wires barrier was that the side fences were too short. Both intrusions by black bears involved the animals bypassing most of the wires above the ground by accessing or leaving the barrier from one of the sides. Barriers or "side-fences" that run tight along the full length of the barrier would likely address this issue and force bears, if they try to access the crop, to walk on top of, or in between, the wires above the ground for the full length of the barrier. In contrast, the drive-over mat has full side barriers that have a tight connection to the mat, and they do run the full length of the mat. Here, no large mammals were able to bypass the mat by coming in from or leaving at one of the sides. We did observe that the drive-over mat can kill amphibians and small mammals. Between 6 August 2021 and 21 November 2021, we found 1 dead western toad (*Anaxyrus boreas*) and 1 dead deer mouse (*Peromyscus maniculatus*) on the mat. Such unintended side effects may be reduced through making the habitat immediately adjacent to the barrier less attractive or inaccessible to small species, e.g., through ABS screens attached to the side fences of the barriers. There could also be a sensor installed that would only turn the electricity on after a large animal has been detected that is approaching the barrier from the habitat side.

For locations that are accessible to the public, such as along highways, warning signs and "turn electricity off" buttons may be required. These buttons should be associated with a timer and an indicator light so that the electricity will automatically turn on again, e.g. after a minute or so, and that confirmation is visible to the public. Note that some of the tested electrified barrier designs are not a suitable barrier to ungulates (e.g. swing gate, bump-gates). Wider barriers such as the drive-over mat or, though to a lesser extent, drive-over wires, are or can be, at least in theory, substantial barriers to not only species with paws but also ungulates (Fischer et al. 2011; Gagnon et al. 2019).

Conclusion

After modifications, a combination of an electric fence and electrified barriers at vehicle access points was able to keep almost all black bears out of a melon patch and break their habit of eating melons in the melon patch. However, bump-gates required custom conductive netting and frequent adjustments and repairs. The electrified swing gate was an absolute barrier to black bears and had no maintenance issues. However, this design still requires people to get in and out of their vehicle when opening and closing the gate, and therefore the gate may be left open. The drive-over wires barrier was a near absolute barrier for black bears. Nonetheless, its effectiveness can likely be improved if the side barriers run tight along the full length of the barrier. The drive-over mat performed well but has only a small sample size. The downside of the drive-over mat, and possibly also of the drive-over wires, is that these types of electrified barriers may occasionally kill small animal species (e.g. amphibians, reptiles, small mammals). Although the effectiveness of these barriers was investigated at a melon patch on private land, the results are applicable to low traffic volume and low traffic speed access points along fenced public highways. These electrified barriers are especially important along road sections where the purpose of wildlife fences is to also keep species with paws out of the fenced road corridor.

Acknowledgements

We thank the representatives of the funding organizations, as well as the representatives of the Federal Highway Administration and ARC Solutions for serving on the advisory panel. Many thanks to Cassie and Faus Silvernale from the Dixon Melon Farm for allowing us to conduct the research at the melon patch. Thanks also to Bryce Andrews and Stephanie Barron of People and Carnivores for the installation of the fence, the 2 bump-gates, the electrified swing gate, the drive-over wires and associated modifications and maintenance. We thank Tim Hazlehurst of CrossTek™ Wildlife Solutions for providing and installing the drive-over electrified mat, Dale Becker from the Confederated Salish and Kootenai Tribes for connecting us with People and Carnivores, Gina Kuebelbeck and Alexa Morris for helping with the field work, and Edgar van der Grift and Cristian-Remus Papp for critically reviewing an earlier version of this manuscript. Finally, we thank the Confederated Salish and Kootenai Tribes for their permission to conduct the research on the Flathead Indian Reservation.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

The research at the melon patch was funded by the following organizations: Alaska Department of Transportation and Public Facilities, Arizona Department of Transportation, California Department of Transportation, Iowa Department of Transportation, Michigan Department of Transportation, Minnesota Department of Transportation, Nevada Department of Transportation, New Mexico Department of Transportation, Ontario Ministry of Transportation, Oregon Department of Transportation, Parks Canada and Washington Department of Transportation through the Animal-Vehicle Collision (WVC) Reduction and Habitat Connectivity Transportation Pooled-Fund Project TPF-3 5(358). The research at the drive-over mat along US Hwy 93 was funded by the U.S. Department of Transportation, the Small Urban, Rural and Tribal Center on Mobility (SURTCOM), and the Montana Department of Transportation. Finally, we thank the US Fish and Wildlife Service for contributing funds for the electric fence.

Author contributions

Conceptualization: MPH. Data curation: SCG, MPH. Formal analysis: MPH. Funding acquisition: MPH. Investigation: MPH, SCG. Methodology: SCG, MPH. Project administration: MPH. Supervision: MPH. Validation: MPH, SCG. Visualization: MPH. Writing - original draft: MPH. Writing - review and editing: SCG, MPH.

Author ORCIDs

Marcel P. Huijser https://orcid.org/0000-0002-4355-4631
Samantha C. Getty https://orcid.org/0000-0002-5610-0241

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Barrier effect of electrified barriers to bears at the melon patch and the additional site with drive over mat along US Hwy 93, Montana, USA

Authors: Marcel P. Huijser, Samantha C. Getty
Data type: xlsx
Explanation note: Behaviour of bears in front of electrified barriers (cross or no cross into melon patch or fenced road corridor).

Link: https://doi.org/10.3897/natureconservation.57.116972.suppl1