

WILDLIFE BIOLOGY

Short Communication

No benefit in using rubber-coated wire to counter loss of voltage due to tall grass in large carnivore deterring fences

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Electric wire enclosures to protect livestock represent one intervention to mitigate negative impacts of large carnivores. However, appropriate fence construction and voltage level in the live wires are crucial to deter carnivores. To ensure that the voltage level remains sufficiently high, maintenances and clearing the wires from tall or growing vegetation is regularly needed. In this study, we investigate the performance of a fence wire coated with conductive rubber, claimed by the supplier not to short circuit and drop in voltage due to contact with e.g. ground and vegetation. We examine the voltage of the rubber-coated wire during contact with soil, ground, and wet vegetation and observed a voltage loss comparable to that of the standard metal fence wire. Our results imply that the rubber-coated wire does not perform better than a conventional metal fence wire when in contact with growing grass and other elements that usually short circuit an electric fence.

Keywords: electric fence, carnivore deterring fences, rubber-coated wire

Introduction

Wildlife populations and humans often cooccur in terrestrial ecosystems, leading to both positive or negative interactions for humans (Curtin 2009, White et al. 2017, Bhatia et al. 2020, Johansson et al. 2021, Flykt et al. 2022) and for the wild animals (Prange et al. 2003, Szott et al. 2019, Tyagi et al. 2019). Mitigating negative impacts from wildlife on human interests, such as predation on livestock, is a challenge to wildlife management globally. Not least is this the case in situations when conservation of threatened species relies on land sharing between humans and wildlife. Yet, for many interventions intended to mitigate the negative impact from large carnivores, further evidence of intervention effectiveness is still needed (Miller et al. 2016, Eklund et al. 2017, van Eeden et al. 2018, Oliveira et al. 2021).

Electric fences represent one intervention to mitigate the negative impact of large carnivores (Eklund et al. 2017) and can be highly effective in protecting grazing livestock from carnivore attacks (van Eeden et al. 2018, Khorozyan and Waltert 2020, Oliveira et al. 2021). However, to effectively deter carnivores, proper construction



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and regular maintenance are crucial (Nass and Theade 1988, Frank and Eklund 2017, Khorozyan and Waltert 2020, Oliveira et al. 2021, Schütte 2021, Honda 2022).

The barrier function of an electric fence is psychological rather than physical (Tolhurst et al. 2008, Phillips et al. 2012) as the deterring effect relies on the anticipated pain and discomfort caused by the electric shock (Fish and Geddes 2009) that an animal experiences when it touches a live wire. To be effective the fence should always be electrified, and the voltage must be sufficiently high to induce vigilance towards the electric fence. The voltage required to induce vigilance may differ between animal species (Honda 2021). The live wires must also be tense, as animal fur is a good insulator against electricity (Wooldridge 1983, Honda 2022) and high tension of the live wires induces electrification over the fur (Honda 2022).

Well adapted interventions to protect livestock from predation can facilitate animal owners' coping with large carnivore presence (Eklund et al. 2020). However, if interventions recommended by authorities or wildlife managers are inappropriate and ineffective, the consequence may rather be reduced tolerance and diminished trust.

Carnivore deterring fences often encircle large grazing areas, and to keep carnivores (e.g. wolves) from digging into the enclosure the lowest wire must be close to the ground. According to the recommendations for wolf and bear deterring fences in Sweden, the lowest wire should be no more than 30 centimetres above the ground (Fig. 1), and the voltage level in the wires no lower than 4500 volts (Frank and Eklund 2017, Ängsteg et al. 2021). Some experiments have indicated that a lower wire placement of approximately 30 cm and an upper wire at 70 cm were optimal for deterring bear (Smith et al. 2018) and that the minimum voltage should be 5000 volts (Smith et al. 2018, Alaska Department of Fish and Game 2023). An older study with polar bears also used the 30 cm distance for the lower wire while the voltage used was 8000 volts. These settings were effective for deterring polar bear (Davies and Rockwell 1986).

Maintaining the function of electric fences thus requires extensive effort clearing the wires from grass and other

vegetation throughout the grazing season (Schütte 2021) since contact with vegetation, and in particular wet vegetation, causes short circuit and generally a significant loss of voltage in electric fences. A regular fence wire often requires farmers to cut grass under the fence several times per year to maintain voltage. A fence wire consisting of thin copper threads coated by electrically conductive rubber has been developed in Denmark and according to the supplier this wire will not short circuit when in contact with e.g. vegetation, ground, and water. The rubber-coated wire is claimed to maintain a stable voltage over long distances even if moist vegetation is in contact with the wire, reducing the need to clear vegetation along the fence. Due to this potential advantage, the rubber-coated wire has received substantial interest from farmers and authorities in Sweden to be used in the construction of large carnivore deterring fences.

In this study, we test the performance of the rubber-coated wire in conditions that normally cause short circuit and voltage drop in electric fences. Through experiments, we investigate how the voltage level is affected by contact with wet vegetation, soil, and ground, and how the rubber-coated wire performs in comparison to a standard fence metal wire.

Material and methods

We carried out four experimental trials (Fig. 2) in July 2021:

1. Control (free wire). The entire wire was mounted on fence posts, >70 cm above the ground, free from any contact with vegetation, soil, ground, water, or anything else.
2. Soil contact. The wire was mounted as in the control trial except for 2 m that were led through an excavated soil mound.
3. Ground contact. The entire wire was laid on the ground.
4. Wet vegetation. The wire was mounted on fence posts, <40 cm above the ground in tall grass. With this setting approximately 10–20% of the wire came into direct contact with wet vegetation.

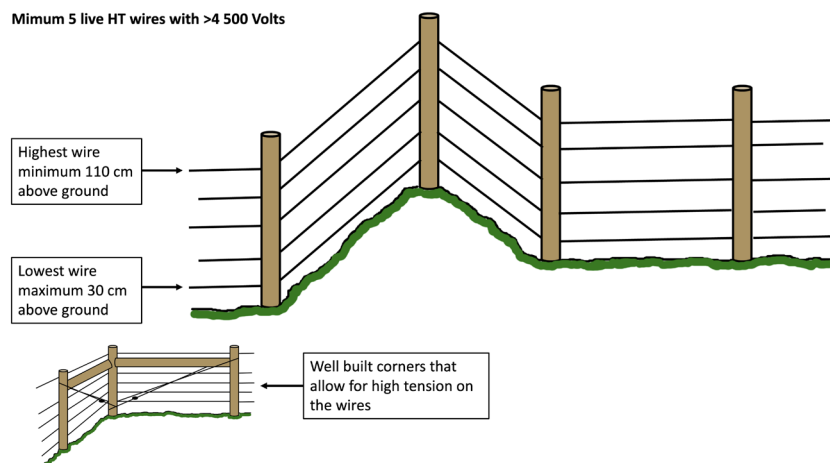


Figure 1. Schematic drawing of a high tensile wire fence to protect livestock against large carnivores (Frank and Eklund 2017).

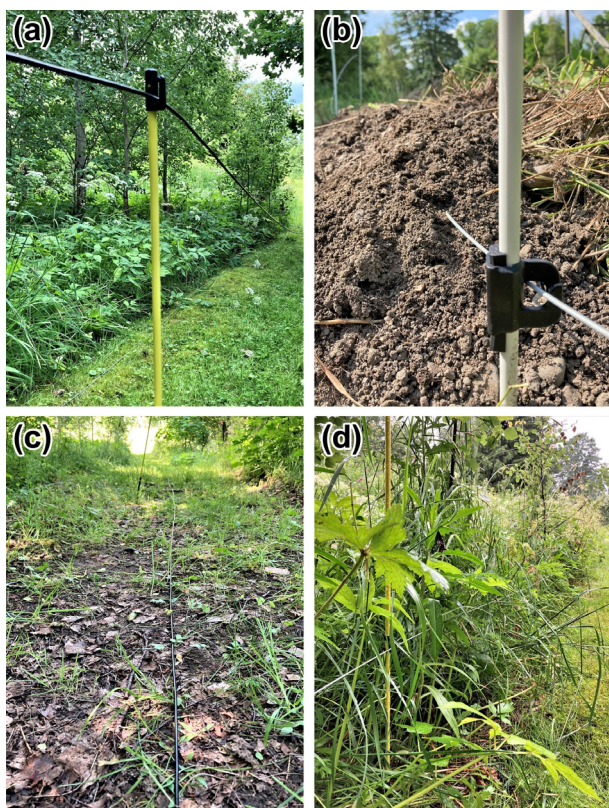


Figure 2. Photos illustrating settings of the different trials: (a) control (free wire), (b) soil contact, (c) ground contact, and (d) wet vegetation. Photo (a) and (c) shows the rubber-coated wire, and (b) and (d) the HT wire.

All experimental trials were completed both for the rubber-coated wire and for a regular high tensile (HT) wire.

The wet vegetation experiment (trial 4) was carried out during rainfall, whilst the other experiments were carried out when the weather was sunny and the ground dry. In each experiment 135 meters each of the rubber-coated wire (PinaldoGuard Wire, PinaldoGuard, Denmark) and a galvanized steel high tensile wire with 2 mm diameter were used. The wires were mounted on 30 fiberglass fence posts with adjustable plastic insulators. An energizer (LME2304 fence energizer manufactured by Granngården, Sweden, for 230 volts from the mains and with 3.8 joule charging energy) was connected to the wires through a ten-meter-long Gallagher supply (lead out) cable. The grounding system consisted of two galvanized steel earth rods placed 5 m apart and 0.8 m into the ground. The rods were interconnected with a Gallagher supply cable that extended to the earth inlet of the energizer (Fig. 3).

In the control experiment (trial 1), the soil contact experiment (trial 2), and the ground contact experiment (trial 3) the fence posts were mounted in a line stretching over a lawn and continuing along a forest path with sparse vegetation and tree roots. The soil mound used in trial 2 was located halfway along the wire. In the ground contact experiment, the wire was placed on the ground about half a meter away from the posts. In the wet vegetation experiment (trial 4), fence posts

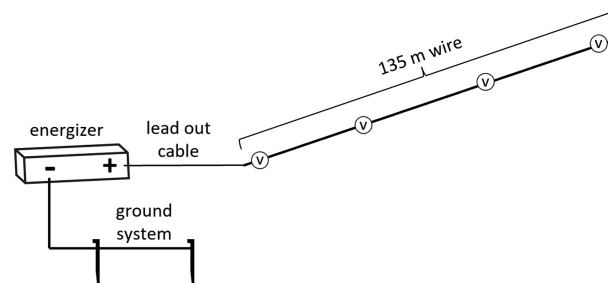


Figure 3. Illustration of trials. Voltage measuring points at 1, 45, 90 and 134 m are indicated with voltmeter symbols.

were placed outside the lawn and forest path in tall grass. The length and direction of the post line were identical to the other experiments, but the fence posts were moved 0.5–2.0 m to one side. The wire was mounted <40 cm above the ground to allow contact with the vegetation consisting of tall grass, herbs, and smaller shrubs. During the wet vegetation experiment special caution was taken not to trample down the vegetation to keep the test conditions equal for both wires. During the experiments the same post line was used in turn for both wires, the HT wire being tested first.

Voltage was measured with a Gallagher fence voltmeter at four measuring points along the wires: the first at 1 meter, the second at ~45 m, the third at ~90 m, and the fourth at 134 m (Fig. 3). An average value of voltage was calculated from the values obtained at the four measuring points, for each experiment and wire type. The average voltage obtained in the control trial (free wire) was used as a reference value indicative of the maximum voltage level. The average voltage level obtained in trial 2–4 were compared to the reference value of the corresponding wire type to assess voltage loss. Percentage voltage loss was determined by calculating the voltage as a percentage of the reference value and then subtracting the result from 100.

Results

The rubber-coated wire lost voltage due to contact with soil, ground and wet vegetation (Table 1). Moreover, the voltage drop was in the same order of magnitude as for the HT wire (Fig. 4). Hence, when exposed to different conditions, the rubber-coated wire did not perform different than the HT wire, i.e. it short circuited and lost voltage. Contact with wet vegetation caused a voltage drop of approximately 70% in both wires. The largest voltage drop occurred when the wires were placed directly on the ground, both wires then lost $\geq 90\%$ of the voltage.

Within each experiment and for each wire, the voltage measurements at the four measuring points were highly consistent. We did not detect a gradient with decreasing voltage further away from the energizer (Table 1).

Discussion

It is important for managing authorities to have access to results from independent studies of effectiveness in order

Table 1. Voltage measured for each wire and experimental trial, at four different measuring points, and on average. Measure 1, 2, 3 and 4 correspond to the voltage measured at 1, 45, 90 and 134 m from the wire's starting point.

	Measure 1 (kV)	Measure 2 (kV)	Measure 3 (kV)	Measure 4 (kV)	Average (kV)
Control (free wire)					
HT wire	10	10	10	9.9	9.98
Rubber wire	9.4	9.5	9.6	9.4	9.48
Soil contact					
HT wire	4.5	4.3	4.4	4.4	4.4
Rubber wire	3.9	3.8	3.8	3.8	3.83
Ground contact					
HT wire	1.1	1	0.9	0.9	0.98
Rubber wire	0.8	0.8	0.8	0.7	0.78
Wet vegetation					
HT wire	3.4	3.2	3.1	3.1	3.2
Rubber wire	2.9	2.8	2.7	2.9	2.83

to make informed decisions and recommendations to users. Identifying an absence of effectiveness can also prevent authorities and individuals from repeating the same mistakes over and over, resulting in waste of public and private resources.

In our experiments the rubber-coated wire did not perform better than a standard metal fence wire in terms of voltage loss and short circuit during contact with wet vegetation, soil and ground. The magnitude of lost voltage was similar to that of a metal wire. Our results suggest that the rubber-coated wire lose voltage when in contact with e.g. growing grass. Using the rubber-coated wire is thus not likely to reduce the effort needed to maintain voltage level and function of an electric fence throughout the grazing season.

A serious disadvantage with the rubber-coated wire is its low tensile strength, 400 N compared to 1100–1300 N for a standard HT wire. Animal fur is a good insulator against electricity and animals can evade an electric shock if they only touch the live wires with fur-covered parts of the body (Honda 2022). However, Honda (2022) effectively induced electrification over animals' fur by increasing the tension of the live wires. During a test of various electric fence types, Svensson et al. (2001) also found that captive lynx had to press the body hard against the wire to get a deterring shock over the fur. Wires that withstand significant tension are

likely a better option when electric fences are intended to deter furred wildlife species. Another drawback with the rubber-coated wire is the purchase price, which is more than ten times higher per meter compared to a regular HT wire.

This study contains only one replicate for each treatment. In practice, this means that we have not tested on several different locations or weather types. The main factor determining the voltage loss is to what extent the wire is ground. In the experiment we tested the effect of the most extreme treatments as well as more moderate ones. We cannot see any potential mechanism that would suggest that the function of the wires should differ significantly from other factors than degree of grounding.

High purchase cost, low tension strength, and no benefit of reduced loss in voltage when the rubber-coated wire is in contact with e.g. growing grass, means that we cannot recommend the rubber-coated wire to be used in fences intended to protect livestock from large carnivores.

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Author contributions

Eva Hedmark: Conceptualization (supporting); Data curation (lead); Formal analysis (lead); Investigation (lead); Methodology (lead); Project administration (lead); Validation (lead); Writing – original draft (lead); Writing – review and editing (lead). **Carlos Cardoso Palacios:** Conceptualization (supporting); Methodology (supporting); Validation (supporting); Writing – original draft (supporting); Writing – review and editing (supporting). **Jens Frank:** Conceptualization (lead); Funding acquisition (lead); Methodology (supporting); Project administration (supporting); Validation (supporting); Writing – original draft (supporting); Writing – review and editing (supporting).

Data availability statement

There are no additional data for this paper

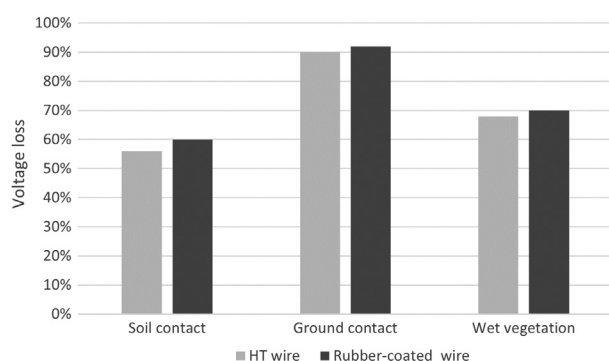


Figure 4. Voltage loss in HT wire and rubber-coated wire during contact with soil, ground, and wet vegetation, given as percentage of the voltage level measured in the control trial (free wire).

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