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Warning systems triggered by trains could reduce collisions with wildlife

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ABSTRACT

Ecosystems are degraded by transportation infrastructure partly because wildlife mortality from collisions with vehicles can threaten the viability of sensitive populations and alter ecosystem dynamics. This problem has attracted extensive study and mitigation on roads, but little similar work has been done for railways despite the occurrence of wildlife–train collisions worldwide. We propose a method for reducing wildlife losses on railways by providing animals with warning signals that are triggered by approaching trains, particularly in areas of high strike risk. Analogous to the warning signals provided for people at road–rail crossings, our system emits flashes of light and bell sounds approximately 20 s before train arrival at the location where the system is deployed. Learning theory predicts that animals will associate these warning signals with train arrival if the warning signal (conditioned stimulus) consistently precedes train arrival (unconditioned stimulus). We tested two designs for a warning system: one that detects passing trains and wirelessly relays this information to warning devices further along the track, and one that integrates detection of trains at a distance with warning signals in a single device. The most reliable design detected passing trains with magnetic or vibration sensors and relayed the information to warning devices. We have developed an affordable and publicly available prototype of this design that can be built for a material cost of US$225. With refinement, this technology could become an inexpensive means of protecting wildlife and people around the world from fatal train strikes wherever strike risk is known or predicted to be unusually high.

1. Introduction

Wild animals interact with transportation networks in complex ways. Through habitat loss, fragmentation, and degradation as well as direct mortality, the abundance of many species is reduced near roads (reviewed by Fahrig and Rytwinski, 2009; Benítez-López et al., 2010; Rytwinski and Fahrig, 2012) with potential to alter community composition and ecosystem dynamics (van der Ree et al., 2015). Although the effects of roads on wildlife are typically negative, some species have been found to increase in abundance near roads (e.g., Morelli et al., 2014; Fahrig and Rytwinski, 2009) while others are attracted to the vicinity of roads despite high risk of mortality (e.g., Nielsen et al., 2006). Strikes on railways have received less attention, perhaps because they present less risk to people (Langbein, 2011; Morse et al., 2014) or because railways are less prevalent than roads (Dulac, 2013). Nevertheless, train strikes have been associated with population effects (reviewed by van der Grift, 1999; Seiler et al., 2011; Dorsey et al., 2015) and animals are sometimes struck more often on railways than on adjacent roads (Huber et al., 1998; COST 341 Management Committee, 2000; Waller and Servheen, 2005). Additional incentive for strike reduction on railways applies for sensitive or threatened populations and charismatic, keystone, or culturally important species.

The best methods for reducing wildlife–vehicle collisions on roads are often impractical on railways. Collision reduction is increasingly achieved through the installation of wildlife exclusion fencing and crossing structures, which can reduce the frequency of wildlife–vehicle collisions by up to 80% (Clevenger et al., 2001) while maintaining habitat connectivity (reviewed by Glista et al., 2009). These road mitigation measures are costly, however, and despite the consumptive, passive-use, and management values of animals killed by vehicles (Boyle and Bishop, 1987; Conover, 1997; Schwabe and Schuhmann, 2002), mitigations may be less

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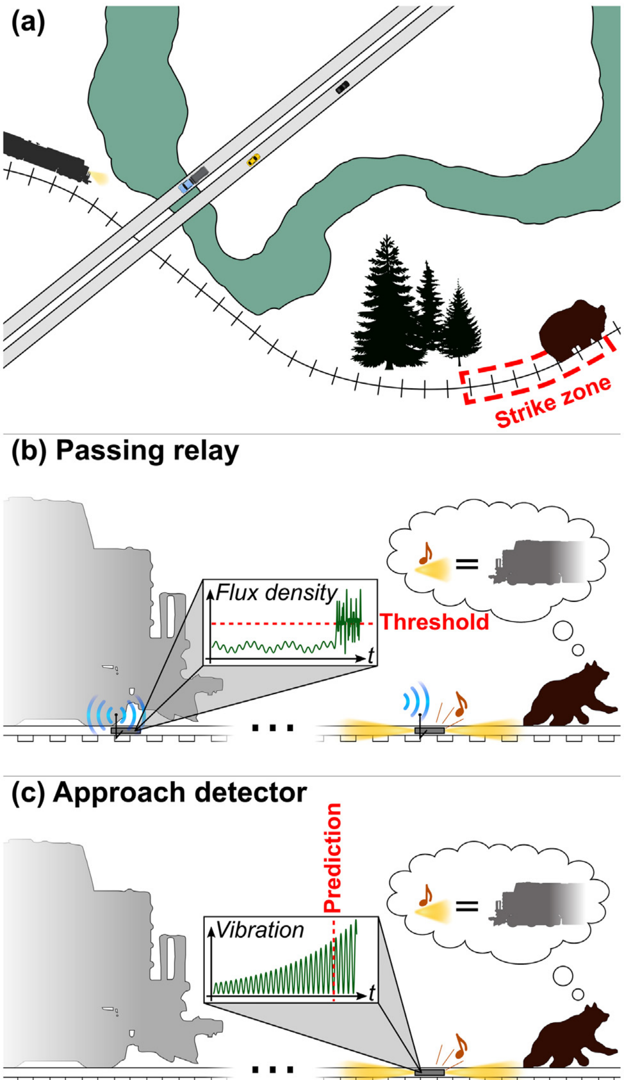

Fig. 1. Concept for a train-triggered wildlife warning system. (a) Warning signals produced by trains are inconsistently available at some locations: light and sound from the train can be obscured, distorted, masked, or imitated by the surroundings. As a result, wildlife may be unaware of approaching trains or confused by the stimuli and become surprised when the train is very near. (b) The passing relay uses a sensing device to detect trains and relay triggers to a remote warning device. (c) The approach detector uses in-rail vibrations to detect trains at a distance and trigger integrated warning signals. For both warning systems, we rely on animals to associate the warning signals with train approach. Animals that have learned this association leave the track when the warning activates.

cost-effective on railways where strikes typically do not damage human assets (cf. Huijser et al., 2009). Exclusion fencing may also reduce animal access to beneficial foraging (Dorsey, 2011; Wells et al., 1999), travel (Hedeen and Hedeen, 1999; Kolb, 1984), and habitation (Moroń et al., 2014; Kaczmarski and Kaczmarek, 2016) opportunities along railways, and exclusion from these opportunities may be unnecessary where traffic intensity on railways is dramatically lower than on a typical road. As an alternative to exclusion fencing, road vehicle operators can sometimes avoid wildlife strikes by detecting animals and slowing down, especially if driver awareness is improved with warning signs or animal detection systems (Huijser et al., 2006). In contrast, train operators cannot change course and require minutes of warning time to slow safely. Systematic speed reductions reduce stopping distances and can often reduce wildlife strikes on both road (Gunson et al., 2011) and rail (Gundersen and Andreassen, 1998). However, speed reduction may be ineffective unless it is drastic (Rea et al., 2010), especially where deep snow, steep topography, or adjacent water bodies encourage animals to retreat along the track (e.g., Becker and Grauvogel, 1991).

An alternative approach to reducing wildlife–train collisions is to increase the probability that animals will leave the track after detecting an approaching train. For people and other animals, failure to detect an oncoming train can lead to a collision directly or via a maladaptive escape response (Lima et al., 2015), perhaps induced by panic. Such detection failures are especially likely if the visual or acoustic cues of an approaching train are obscured by vegetation, topography, or deep snow, especially around track curves, or if the cues are masked by competing stimuli from nearby roads and rivers (Fig. 1(a)). When these conditions occur in areas used frequently by animals, heightened collision risk presumably results. The risk of detection failures in these areas (hereafter, strike zones) might be reduced if warning signals were provided in advance of train arrival in a way that could not be obscured or masked. Animals could learn to associate these warning signals with train approach if the signals were provided at a consistent time relative to train arrival and if the signals differed from stimuli that occur in other contexts (Domjan, 2005). The warning signal need not be aversive because the close approach of a vehicle is, itself, an aversive unconditioned stimulus (e.g., Rea et al., 2010). Similar behavioural principles govern the logic behind road–railway crossing signals for people and were recently applied in a wildlife warning system (Babińska-Werka et al., 2015). Although effective, these systems rely on close integration with railway infrastructure and require expensive proprietary hardware. Lower-cost wildlife warning devices used on roads, such as headlight reflectors and deer whistles, are largely ineffective (D'Angelo et al., 2006; Valitzski et al., 2009). This may be because reflectors and whistles lack the spatial and temporal precision of association between the conditioned warning stimuli and the unconditioned stimulus of close approach by a vehicle.

Here, we describe an electronic system for reducing wildlife–train collisions that combines the precise signalling of active warning systems (e.g., road–railway crossing signals) with the flexibility of installation and affordability of passive warning systems (e.g., headlight reflectors). We tested two designs for such a system (Fig. 1(b) and (c)). One is based on paired but spatially separated devices in which the first device detects a passing train and relays that information to a distant warning device positioned within the strike zone (hereafter, the passing relay). The other is based on a single device positioned within the strike zone that predicts train arrival time from a distance and activates integrated warning stimuli at the desired time (hereafter, the approach detector). Both methods can be implemented with low-cost, off-the-shelf components, assembled with basic electronics tools, and installed without affecting railway infrastructure or operations.

2. Methods

2.1. Study area

The two methods were tested on a freight railway owned and operated by Canadian Pacific within Banff National Park, Alberta, Canada (hereafter, Banff) and Yoho National Park, British Columbia, Canada (hereafter, Yoho). This railway bisects the two parks, runs alongside the four-lane Trans-Canada Highway, and was the largest single source of direct human-caused mortality for grizzly bears (*Ursus arctos*) within Banff between 1990 and 2008 (Bertch and Gibeau, 2009). Black bears (*Ursus americanus*), wolves (*Canis lupus*),