Real-World Applications for Virtual Fences – What Are Potential Benefits for Conservation?

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Real-world applications for virtual fences – what are potential benefits for conservation?

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Abstract

Livestock grazing can enhance biodiversity and ecosystem services in agricultural landscapes. In many parts of Europe, however, grazing has lost its importance, especially in the dairy sector. Large proportions of permanent grassland have been converted to arable land or intensified by fertilization and frequent defoliation. The disappearance of large herbivores and extensively grazed pastures contributes to the loss of structural, functional and biological diversity and ecosystem services. Modern technologies, which circumvent the cost- and labour-intensive installation of physical fences, could facilitate a precise spatio-temporal management of livestock and promote grazing. We reviewed the literature on the state-of-the-art of virtual fencing, focusing on the prospects of these technologies to enhance environmentally-friendly livestock farming. Novel virtual fencing technologies are expected to entail various ecological benefits, but this has rarely been tested in practice. Future experiments not only need to increase sample sizes and study periods to evaluate the long-term effectiveness of virtual fencing, but also need to be specifically designed for answering questions of conservation interest. Virtual fences have the potential to reconcile agronomic with ecological demands and bring livestock back into the landscape, but whether they will actually find broad application depends on further multidisciplinary research on animal welfare, agronomic, social and legal aspects.

Introduction

Grazing livestock has contributed to shaping the cultural landscape of Central Europe. Today, however, most livestock is housed indoors (Läpple and Sirr 2019), and conserved forages and concentrates have replaced grazed grass as the main components in the diet (Schingoethe 2017). To produce high-quality conserved forage, grassland utilisation has been intensified by frequent cutting, high fertiliser inputs and resowing, which has resulted in a significant loss of phytodiversity (Plantureux et al. 2005, Wesche et al. 2012). If milk is produced from pastures, management intensity and stocking rates are high in order to achieve high sward quality and little pasture remainder (McCarthy et al. 2016). This leads to short, uniform swards with taller vegetation exclusively located at excretion patches (White et al. 2001). Typical swards grazed by dairy cattle are therefore dominated by few plant species adapted to regular defoliation and nutrient input (van Dobben et al. 2019). By contrast, under extensive management, selective grazing leads to structural heterogeneity that can enhance phytodiversity and provide habitats for invertebrates in pastures (Jerrentrup et al. 2014, Tonn et al. 2019), but at the cost of reduced whole-sward forage quality (Bruinenberg et al. 2002). Hence, there is a trade-off between intensive grassland management and biodiversity and ecosystem services (Maes et al. 2012). Until now, few attempts have been made to harmonize the goals of intensive livestock production and biodiversity conservation.

In rotational grazing, pastureland is divided into paddocks, which are alternately allowed to rest between grazing intervals. Paddocks that are skipped during the grazing rotation can be essential nesting habitat for birds (Perlut and Strong 2011) and promote the local plant and invertebrate diversity similarly as tall patches within extensive pastures (Wrage et al. 2011). For example, ungrazed areas were shown to diversify and prolong the availability of floral resources for bees in Mediterranean rangelands (Shapira et al. 2020). In extensive mountain pastures, a biodiversity-friendly rotational grazing scheme, in which animals were removed from one paddock during the peak flowering period, promoted pollinators, while herbage mass and animal performance were similar to continuous grazing (Enri et al. 2017).

Given that current grazing systems rely on physical fences, rotational grazing schemes or temporal exclusion zones within pastures demand considerable extra effort and expenditures by the farmer. We propose that novel virtual fencing (VF) technologies could facilitate the implementation of biodiversity-friendly pasture management approaches independently of production intensity. To validate this assumption, we reviewed the literature, assessed the state-of-the-art of VF and identified research gaps concerning the potential of VF to allow for a flexible grazing management in accordance with environmental goals without the need for laborious fencing.

Methods

We searched for scientific articles related to VF in Web of Science using the following search string: TS = ((stakeless OR wireless OR virtual* OR fenceless) AND (fenc*) AND (livestock OR cattle OR cow OR goat OR sheep)). This initial search (last performed on 28 October 2020) resulted in 56 articles including reviews, original research papers and conference contributions. After screening titles and abstracts, we excluded any off-topic articles. We furthermore searched with Google Scholar using combinations of the above key words and checked references within articles and added missing articles to our initial list. From the resulting list of 58 studies, we extracted all papers that referred in any way to the topic of conservation.

Results

We found 27 papers that addressed potential merits of VF from a conservation point of view, although this was rarely the main focus. Most of the experimental work (17 studies in total) was conducted in Australia (eight studies), fewer studies came from the US and Europe (four studies each) and one paper reported on experiments in Africa. The majority of research focused on cattle. Only one study each tested VF in a conservation context with sheep or goats. A French study (described in two papers) included six horses but did not report any specific results for this species (Monod et al. 2008, 2009).

State-of-the-art of virtual fencing technologies

Modern developments of virtual fences for livestock use remote positioning techniques combined with a conditioned pre-warning signal and an aversive stimulus in order to prevent animals from crossing a border that is not physically present (e.g. Umstatter 2011). The stimuli are applied to the animal's throat or neck via electronic devices attached to a collar. The animal is supposed to stop or turn away from the virtual fence line at the sound of the pre-warning signal, otherwise the aversive stimulus, i.e. an electric pulse, is applied. The most advanced developments allow easy setting and moving of virtual fences via smartphone apps. Although the first advances to control animals without visible physical barriers had already been made in the 1970s (Anderson 2007), most VF systems today are still in the prototype phase.

Prospects of virtual fences contributing to conservation purposes

Researchers envision ample scope for virtual fences to support conservation interests (Table 1). The literature unanimously expects that VF technology can facilitate the protection of environmentally sensitive areas, especially riparian areas (e.g. Campbell et al. 2019), but also forest regeneration sites (Quigley et al. 1990), moorland (Umstatter et al. 2013), protected habitats (Monod et al. 2009) or sites prone to soil erosion (Marini et al. 2018). Virtual fences could be used in difficult terrain and remote or large areas, where conventional fencing is unfeasible. Grazing could thus be reintroduced to formerly abandoned areas or where physical fencing is prohibited (Monod et al. 2009). In general, the increased spatial and temporal flexibility promised by VF is expected to bring along environmental benefits and improvements in natural resources management. Setting virtually fenced exclosures within a pasture could foster small-scale vegetation heterogeneity and provide habitats for rare species (Umstatter 2011). Moreover, moving virtual fence lines could avoid permanent grazing pressure in sensitive habitats. In this context, some studies point out that VF might not be fail-safe in keeping animals within the delimited boundary (Anderson et al. 2014). This might not be concerning or even beneficial in some cases because many habitats require a low level of grazing, but in other cases, this might be challenging because complete absence of large herbivores would be optimal for reaching certain conservation goals, e.g. survival of ground-nesting birds. Wild mammals would profit from

Table 1: Expected benefits of virtual fences for conservation mentioned in a total of 27 studies.

Study objective	No. studies
Protection of environmentally sensitive areas	20
Spatially and temporally flexible management of grazing pressure	14
Increased habitat heterogeneity and protection of rare species	10
(Reintroduction of) grazing in challenging terrain, large or remote areas	7
Reduced conflict with other land use (recreation, farming)	4
Unspecific ecological benefits, improved natural resources management	4
Wildlife-friendly (no fence-related mortality, no habitat fragmentation)	3
Landscape aesthetics	3
Weed control or grazing of crop residues	3

VF because the invisible barrier does not impede their dispersal (Jachowski et al. 2014). VF might also reduce conflicts between livestock grazing and other land use types, as they could prevent free-ranging herds from entering arable fields (Bello and Moradeyo 2019) or places highly frequented by humans, such as camping sites (Tiedemann et al. 1999). Generally, a landscape without conventional fences might be perceived as more natural and wild, which could enhance recreational experiences (Jachowski et al. 2014). Additionally, an effective VF system might open up opportunities to tackle specific conservation tasks, e.g. the control of invasive weed species by sheep or goat grazing (Fay et al. 1989). It might also allow for grazing of crop residues (Marini et al. 2018). Not yet mentioned in the literature is the idea to use arable fields oversown with cover crops later in the season as temporary grazing land. This could entail both economic and ecologic benefits, i.a. as cover crops are a valuable source of non-human-edible forage (Karlsson et al. 2018).

What has been tested so far?

Few studies have tested VF technologies in an applied conservation setting. In the early 1990s, researchers made promising attempts to exclude cattle from riparian zones on ranches in the US using an ear tag that emitted audio and electric stimuli when the animals approached remote transmitters within the exclusion zone (Tiedemann et al. 1999). The ear tag, however, appeared to be too heavy and fragile for long-term use. Another early VF technique, which relied on electromagnetic coupling between a wire and electronic collars emitting sound and electric signals, was tested from 1998 to 2003 with more than 100 cattle in French mountain pastures (Monod et al. 2008, 2009). While the system was effective in containing the animals, it still relied on a wire that had to be placed around the grazing area. Only with the advance of GPS technology VF systems became independent of any physical installations in the field (Butler et al. 2006). Investigating how to overcome limitations of short battery life, Ruiz-Mirazo et al. (2011) could show that discontinuous stimulation by VF collars was sufficient for discouraging cattle from using a specific area. The time animals spent in the exclusion area decreased by 97%, although the collar was turned on only 25% of the time. In contrast, deterring audio cues broadcasted by loudspeakers resulted only in an 18% reduction of the time cattle spent in an exclusion area (Umstatter et al. 2013). Using a recent pre-commercial VF collar, Campbell et al. (2019) tested if 10 cattle could be excluded from a riparian zone in Australia. After three weeks of free access to an area of >10 ha including a river, the cattle were restricted to a smaller area excluding the river by a straight virtual fence. The animals were properly contained by the virtual fence for 10 days except for four animals once intruding into the exclusion zone. When the fence was deactivated, the animals crossed the former boundary within 2 h. In a further study with the same type of collars, Campbell et al. (2020) showed that cattle could not only be contained by a straight but also by a contoured VF line. The animals were excluded for 99.8% of the time from an area with regenerating tree saplings during a 30-day period, despite higher forage availability in that area.

Conclusions

The scientific community generally anticipates that novel VF technologies for livestock management entail various environmental and ecological benefits. Results of first studies are promising, but experimental evidence for these expectations is still limited. Sample sizes, study periods and complexity of fence lines need to increase for a comprehensive evaluation of the suitability of VF for practical applications. To fully exploit the potential of virtual fences to benefit nature conservation under different agricultural production intensities, we call for further experimental and applied work to answer specific questions, e.g.: Can VF be used for implementing biodiversity-friendly rotational grazing? What is the minimum size of small virtual exclosures within a grazing area? How does the permeability of virtual fences affect the chances to reach specific conservation goals, i.e. do virtual fences offer sufficient protection from trampling to ensure breeding success of rare bird species? Finally, apart from focusing on ecological aspects, multidisciplinary research covering animal behaviour and welfare as well as agronomic, social and legal issues is required to ensure that virtual fences actually become widely applied—as a tool to reconcile agronomic with ecological demands and bring livestock back into the landscape.

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