Transforming Livestock Grazing with Virtual Fencing

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Introduction

Controlling where animals graze, obtain water, or rest is an age-old challenge of livestock husbandry. For more than 10,000 years this issue was addressed by intensive herding or with barriers made of sticks and stones. In the late 1800's as ranchers staked claim to the western lands of North America, they needed tools to set boundaries and control livestock on their lands. However, ranchers moving into the Great Plains encountered a prodigious shortage of lumber and stones. These ranchers grasped the value of a metal wire armed with sharp metal points and many styles of "barbed wire" were patented in the 1860's. Today, millions of miles of barbed wire fencing exist on rangelands across the globe.

The idea of an electrified fence was proposed in the 1800's, and a reliable electric wire was developed in the 1930's in New Zealand by Bill Gallagher, who later founded Gallagher Group Ltd© and began manufacturing electric fence equipment (https://am.gallagher.com/en-US/About-Us). Electric fence systems began to appear in the United Sates in the 1950-60s and have steadily grown in popularity. A significant advantage of electric over traditional wire fence is that it can allow for relatively rapid changes in pasture configuration facilitating adaptive, intensive, and targeted grazing methods.

In 1973, a new electronic approach to fencing was proposed to contain dogs (US Patent No. 3,753,421 Aug. 1973). This became the Invisible Fence© system, which is now used across the globe (https://www.invisiblefence.com/). This fence system involves an electronic device worn by the animal that delivers an electric shock when the animal approaches a boundary delineated by a radio frequency. Though designed for dogs, this system has been successfully used to contain livestock in a targeted grazing context (Fay et al. 1989).

When Global Positioning Systems (GPS) became widely available, Dr. Dean Anderson with the USDA Agricultural Research Service collaborated with a private electronics firm to patent a system where animal location was determined with satellite GPS signals (US Patent No. 6,232,880 May 2001) and controlled within a perimeter set on a virtual map. Based on this initial idea, GPS-based systems have been developed that allow ranchers to draw a pasture on a computer or mobile device to set virtual pasture boundaries. Livestock wear an electronic band/chain/collar around their neck and a sound is emitted when the animal approaches a virtual boundary based on their GPS location and an electric shock is delivered through the collar if the animal does not turn away from the boundary. Several companies offer GPS-based virtual fence systems including: Vence (http://vence.io), eShepherd (https://am.gallagher.com/en-US/new-products/eShepherd), NoFence (http://nofence.no/en/), Halter (https://halterhq.com), and Corral (https://www.corraltech.com). In the United States, Vence is the most widely available system, with on-ranch testing that started in 2019.

The Attraction of Virtual Fence

The idea that animals could be contained in a pasture or excluded from a specific area without wire and posts is alluring for several reasons. The development of an electronic containment system on grazing lands has been significantly motivated by the potential to reduce the cost of fence construction and maintenance. The cost of wire fence varies considerably depending on topography and access but expected costs to construct a multi-strand barbed wire fence range from $10,000 to $20,000/mile (NRCS-USDA 2020) and can cost considerably more in steep, inaccessible areas. The time and expense to build new and maintain existing fences is a significant enterprise expense and has fueled interest in electronic virtual alternatives.

Virtual fence will not replace the need for physical fences along property or unit boundaries. However, the ability to easily revise and move a virtual fence boundary will provide unlimited opportunities to develop cross fencing within a unit or pasture. Adaptable cross fences can facilitate a host of grazing options. These include management-intensive or holistic grazing methods, which rely on high stock density, small paddocks, and rapid pasture rotations. Virtual fence technologies could also facilitate grazing of crop residue and failed crops for forage (Lardy 2017). Many targeted grazing goals can also be accomplished with virtual fence. Livestock grazing can temporarily be concentrated in specific areas to facilitate weed control (Fay et al. 1989) or create fuel breaks (Boyd et al. 2022a).

Alternatively, virtual fence is a promising technology to reduce or eliminate livestock grazing in ecologically important areas such as riparian zones (Campbell et al. 2018). Virtual fence has also been applied to facilitate restoration and revegetation in forest regeneration sites (Campbell et al. 2020), and recently burned areas (Boyd et al. 2022b). It has also been suggested that virtual fence could reduce human-livestock conflicts by keeping livestock out of areas with high value to humans such as recreation sites (Wolf et al. 2017) and historically important or archaeological sites. Virtual fences would also reduce loss of livestock and impact on grazing management plans when gates are left open by cyclists, off-road vehicles, hunters, or other recreationists (Wolf et al. 2017).

Virtual fence also offers solutions for wildlife friendly livestock containment. The removal of physical fences would reduce habitat fragmentation and eliminate fence-related stress, injury, and mortality for many wildlife species (Jakes et al. 2018). Virtual fences may also benefit wildlife by reducing livestock activity in nesting or brooding areas (Bleho et al. 2014).

Several of the currently available virtual fence systems offer additional benefits beyond animal containment or exclusion. Some systems allow ranchers to view animal locations within a pasture, making it easier for them to check the herd. Systems such as Vence also collect health attributes that allow ranchers to monitor and locate injured or ill animals.

Effectiveness of Virtual Fence

The idea of containing livestock with an auditory warning followed by a small electric shock instead of a physical fence may sound unattainable or ridiculous. However, in the last several decades dozens of studies have been conducted to demonstrate that the premise of a virtual fence is feasible. One of the first attempts to electronically contain livestock was accomplished by Fay and colleagues (1989) using electric shock collars designed for dogs to successfully contain a group of six goats for 12 days. Quigley and colleagues (1990) also showed early success by training four steers to stay within a virtual boundary in just four days also using remote dog training collars.

In more recent research, a virtual fence was used to exclude ten angus heifers from entering a riparian area in a small pasture for ten days (Campbell et al. 2018). Likewise, 20 angus cows were contained in a pasture and restricted from grazing a recently burned area in a 14-day trial (Boyd et al. 2022a). Another group of 20 cattle were excluded from an area of regenerating saplings 99.8% of the time during a 44-day trial (Campbell et al. 2020) and 30 lactating dairy cows were contained in virtual pastures >99% of the time in a 10-day trial (Langworthy et al. 2021). Though research has revealed general success in containing animals, non-compliance is also observed and 100% containment after training is seldom demonstrated.

Virtual Fence Failures and Challenges

Beyond carefully controlled experiments, virtual fence systems have demonstrated varying success in active ranching operations across the globe. The results of on-the-ground applications of virtual fence reveal that the greatest source of failure appears to be the loss of the neck collar devices. There are several reasons why collars may come off the animals after they are applied. Some collars may have been initially fitted and mounted too loosely, allowing the animal to rub or shake the collar off. Other collars may have been appropriately fitted, but a loss in animal weight caused the collar to loosen and the collars were subsequently lost. Certain collar designs have electrical contacts that can be inverted to point away from the animal if the collar is rubbed, so the animal no longer receives the electrical stimulus resulting in non-compliance. Finally, some collars simply sustain damage from the animal, causing them to disengage and fall off.

Other challenges voiced by livestock producers include the time required to install and manage a virtual fence system. Some producers have noted that significant time is required to learn and become proficient with the computer user interface needed to set virtual fences and track animal locations. Producers also noted that it takes considerable time to prepare the devices for deployment and get collars attached appropriately to animals. Some devices also require an occasional battery change, another substantial time commitment especially in larger herds of animals. Finally, it has been noted in the early field applications that recovery efforts to find lost or damaged collars and replace them on the animal are another significant time investment. Aside from the time for the producer to learn and launch the system, another potential challenge to implementing a virtual fence is the time required to train animals to understand and respect a virtual boundary signaled by an audio cue and modify behavior to avoid a potential electric shock. Fortunately, animals tend to require only a few electric stimuli before learning the relevance of the audio cue warning and to turn away to avoid the aversive electric stimulus (Umsatter 2011). Protocols can 0:31 be implemented to train animals in groups rather than individually, making the application of virtual fence to a herd or flock more feasible.

Related to animal training, another challenge that will affect the application of virtual fence is the portion of animals that appear “untrainable” and do not respond appropriately to the audio cue or electric shock. While research has quantified this non-compliance as low, ranchers testing virtual fence systems have confirmed that a few animals seem to be unresponsive to the sound or electrical stimulus. Even among well-trained and responsive animals, a virtual boundary may become less effective as forage availability becomes limited (Langworthy 2021), through social facilitation of peers (Keshavarz et al. 2020), or by uncollared calves who have left the virtual pasture (Boyd et al. 2022a). Ultimately, all animals in a herd may need to be collared, and non-compliance with virtual fence may become a culling criterion for producers.

Potential stress or weight loss by animals in a virtual fence system have been a concern. Several studies have examined potential acute and chronic stress effects of containment by a virtual fence system. Few studies have detected any changes in stress indicators over short- or longer-term use. The lack of negative physiological or neurological effects, assessed in a variety of ways across several studies, indicate that the welfare impacts of virtual fencing on cattle and sheep are minimal. However, continued assessment of animals in virtual fence systems over a longer term should be conducted to confirm these initial conclusions.

The current cost of virtual fence is highly dependent on the system being used, and the number of communication base stations required. It is difficult to generalize, but recent costs for the Vence system would include $10,000- $12,000 for each radio gateway (or communication base station) and an additional $35 subscription fee for each cow collar. The number of radio gateways required varies depending on topography, but generally one to three are needed. Costs of other virtual fence systems were not readily available at the time of this writing. Though the cost of virtual fence will undoubtedly decrease with technological advances, it is currently not a low-cost technology.

Future Developments and Necessary Understanding.

After decades of research and refinement, several virtual fence systems are now on the market and being tested on the range. However, these current systems are still largely in the prototype and real-world testing phases. Much is yet to be learned to hone the idea of virtual fence into a highly efficacious system for grazing animals. Virtual fence systems are clearly effective for livestock species including cattle, sheep, and goats. However, virtual fence systems have not been widely tested for horses (Janicka et al. 2022). A greater understanding of differences between breeds, ages, and sexes within species relative to their response to virtual fence is needed to develop effective virtual fence systems.

Developing effective and ethically appropriate virtual fence systems will also require deeper understanding of the role of animal experience and training. Initial training procedures for virtual fence systems have been applied but more research and understanding will lead to more efficient training protocols that require the application of fewer electrical stimuli to the animal. Several studies have examined the types of visual or audio cues that are particularly salient as warning cues (Umsatter et al. 2015). However, we still know little about how to combine these external cues to hasten animal learning.

The current virtual fence systems rely on large batteries which must be mounted on the animal in a way that can tolerate the weight. Therefore, current technology options involve devices attached to collars or bands mounted on the neck to deliver audio cues and electrical stimulation. Some systems are solar powered (i.e., Corral) while others rely solely on battery power (i.e., Vence). Though the neck can sustain devices of considerable weight, preliminary research at the University of Idaho indicates that lower levels of electrical stimulation are required to elicit an animal response when delivered to the ear compared to the neck. In 1999, an electronic ear tag device was found to be effective (Tiedemann et al. 1999). However, this device weighed 113 grams and the authors indicated that it was too heavy for an ear-borne device in rangeland settings. However, with advancement in battery technology, an electronic ear tag device may become feasible.

The path for effective virtual fence for grazinglands is being paved. As we learn more about animal behavior, we will be able to more effectively select and train animals to adapt and live within virtual pastures. Advances in electronic, battery and communication technologies will provide more effective and less expensive systems. Robust virtual fencing technology could, like barbed wire over a century ago, be a catalyst that transforms livestock operations and improves economic and environmental sustainability for ranchers across the globe.

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