Opinion on the welfare implications of using virtual fencing systems to contain, move and monitor livestock

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Animal Welfare Committee
Nobel House
17 Smith Square
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The Animal Welfare Committee is an expert committee of the Department for Environment, Food and Rural Affairs, the Scottish Government and the Welsh Government. Information about the Committee may be found at: https://www.gov.uk/government/groups/animal-welfare-committee-awc

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Introduction

1. The Farm Animal Welfare Committee (FAWC) traditionally provided detailed expert advice to Ministers in Defra and the Scottish and Welsh Governments on the welfare of farm animals on farm, at markets, during transport and at slaughter. In October 2019, FAWC was renamed the Animal Welfare Committee (AWC) and its remit was expanded to include companion animals and wild animals kept by people, as well as farm animals. This enables it to provide authoritative advice, which is based on scientific research, stakeholder consultation, site visits and experience, on a wider range of animal welfare issues.

Scope

2. AWC has been asked to consider whether invisible fencing can be used without detriment to livestock health and welfare. Safeguards and conditions that could be set for those intending to use such fencing are considered including in conservation management such as in National Parks and Areas of Outstanding Natural Beauty and by farmers for managed grazing.

3. The farmed species for which invisible fencing systems using neck collars are currently available are cattle, sheep and goats. This Opinion is therefore limited to their use for these species. The Opinion does not address the use of electronic collars on any other species. Neither does it address leg bands, ear tags or other possible technology that in future might be used as part of a containment system.

4. Electronic collars may be used as part of an invisible fencing system to contain cats and dogs to stop them straying from their home sites and thereby reaching highways or other premises. In Wales, the use of any collar that is capable of administering an electric shock to a cat or dog is banned. A review of the scientific literature commissioned by the Welsh Government led to the conclusion that the welfare concerns related to these species did not justify the use on a balance between welfare benefit and potential harm.[1]

Definitions

5. In the present Opinion, key terms are used as follows:

- electronic collar: a band secured around an animal’s neck that is capable of delivering audio cues, an electric shock and in some cases a vibration, for containment, movement or training purposes
- invisible fence: a boundary that is produced by an electronic signal and that an animal experiences by means of an audio or vibration cue and potentially an electric shock administered via a collar, band or metal chain worn around its neck, that does not necessarily correspond with any observable landscape features

[1] Ruth Lysons, A review of recent evidence in relation to the welfare implications for cats and dogs arising from the use of electronic collars, 2015.

- buried loop system: an older and now largely obsolete type of invisible fencing system in which the boundary was marked and triggered by an antenna cable dug into the ground or lying upon the ground surface
- virtual fencing: an invisible fencing system that contains and/or excludes animals within boundaries that are set, managed and monitored remotely and in real time by technology
- fenceline: the invisible line that a virtual fence follows as set using a smartphone, laptop computer or similar device
- dynamic fencing: an application of virtual fencing in which the boundary moves frequently or gradually for grazing or movement management purposes
- electric pulse: a surge of electrical energy of short duration resulting from a potential difference across a conductor
- electric shock: a non-lethal electrical pulse that passes through an animal and is experienced as aversive
- goad: a stick, prod or stimulus, which may be electrified, that is used to spur or guide animals from one location to another

Climate change

6. Shifting weather patterns attributable to climate change are affecting all farmed species. These include high temperatures, rapid and unpredictable temperature fluctuations, high and low rainfall, strong winds, and increased sunlight and humidity. Future planning of grazing infrastructure will need to take these into account. Increased contingency planning will also be required to safeguard welfare against extreme weather events such as drought or flooding.

7. Animals kept outdoors are likely to require improved provision of shelter from direct sun, wind and rain. On some soil types, sustained intense rainfall increases the risk of deep mud, which accentuates the risks of disease and injury from slippage. If heavy rain is followed by a heatwave, poaching produces hard uneven ground that further increases injury risk. Shorter stocking periods and lower stocking densities may mitigate these effects and protect soil structure. Local microclimates may either reduce or intensify climate change impacts. These general welfare aspects of climate change, which have different effects on different farmed species, are further addressed in the relevant sections of this Opinion.

Background

8. There has long been a need to contain livestock in order to manage grazing, prevent damage to land, avoid animal injury and separate animals from humans. The majority of containment is on land that is privately owned or rented by livestock keepers. Livestock on common land, or in hill and upland areas, may be contained to a lesser extent, to prevent them accessing settlements, highways or other potentially dangerous areas.

9. Livestock contained within blocks of owned or rented land are also increasingly fenced to control grazing for soil health and/or environmental management purposes and to control fodder intake. This may require temporary boundaries that may need to be easily altered.

10. Containment traditionally required physical boundaries such as hedges, walls or 'post and rail' fences. Wire, including barbed wire and stock fencing, made boundary creation easy, facilitating land compartmentalization while remaining relatively permanent.

11. Electric fencing was developed and commercialized in the United States and New Zealand during the 1930s. Using fixed posts, it can now provide effective permanent containment over long distances and large areas using far fewer resources than post and wire fencing. From the 1990s, portable electric fencing has been in use to demarcate small areas on a temporary basis. Stainless-steel or aluminium strands are woven into plastic threads or mesh strips and attached at different levels to insulators on plastic posts that are pushed into the ground by hand and connected to a mains or battery power source. On some terrains, such a fence can be quickly transported, erected, dismantled and moved.

12. The power input to electric fencing needs to deliver sufficient energy at the point of contact for an effective electric pulse and shock. Modern electric fencing may include electronics to modify the charge sent along the fenceline and provide data on fence performance. However, factors such as fence length, wire type, the efficiency of return earthing, surrounding vegetation in contact with the fence, and moisture, all combine to potentially reduce the energy and therefore the strength of the shock delivered. Other variables relating to the individual animal include which body part comes into contact with the fence as well as the thickness and wetness of the coat or wool, which depend on breed, sex, age, season and management practices. The shock received by an animal is of short duration, but the energizer continuously repeats the pulse with a short delay of approximately one second. If an animal is unable to remove itself from an active electric fence, it may experience repeated shocks.

13. Erecting and checking wire fencing is costly in terms of materials and labour. Setting fences at the right height and tension requires time, appropriate skill and equipment.

14. The containment methods used for livestock are likely to impact on wild species. Traditional boundary systems such as hedges and stone walls have been shown to have positive effects on some wild animal species and biodiversity, creating wildlife corridors, shelter and habitats. However, wire fencing may block routes, or injure or trap wild animals that try to jump over it or push through it.

15. To provide effective containment, physical boundaries require maintenance and may become hazardous if poorly maintained. Animals may become entangled in broken wooden, wire or electric fences. Barbed wire fencing or stock fencing may, if inappropriately placed or poorly maintained, cause traumatic injuries. Barbed wire fencing is inappropriate if horses are also to be kept in the field area at the same time or at different times.

16. Where cattle are grazed on low lying ground that floods, traditional stock fencing could trap them and increase risk of drowning. Similarly, periods of heavy snowfall combined with strong wind can lead to sheep being buried in drifts against walls or fencing from which they are unable to escape.

17. If a stock fence or electric fence is damaged, one or more animals might escape, putting them at risk from external hazards. This might have negative welfare impacts on other animals and impacts on humans and property. Locating escaped livestock may prove challenging, especially in areas without other permanent boundaries.

18. Over the past decade there has been increasing interest in alternative containment systems used for grazing livestock. On sites where conservation grazing is used to restore and maintain priority habitats, installing physical fencing may not be legal, economic or practicable. These include common land and other previously unfenced areas where the land may have returned to scrub, thereby changing its biodiversity value and the character of the landscape and impeding public access. Such areas may be challenging for stockpersons to access and regularly locate and observe stock.

19. There is also interest in alternative containment systems to improve the management of outdoor dairy, beef and sheep grazing systems. These enable small grazing areas to be set up and periodically moved according to plant growth, prevailing ground conditions and weather.

20. In an early system, an audio cue and potentially an electric shock were triggered when an antenna cable dug into the ground or placed upon the ground surface was crossed by an animal wearing a receptor collar. This technology has now been superseded by systems using a digital signal. It is therefore no longer readily available although may still be in use in some locations. Instead, electronic collars that receive a Global Positioning System (GPS) signal are now commercially available and may be fitted to livestock as part of a system to control grazing location or movement. The collars may apply a series of audio cues, and possibly a vibration cue, potentially followed by an electric shock.

21. A further development in prospect is the use of dynamic fencing systems to assist or guide the movement of livestock on a farm or holding, such as dairy cattle from field location to collection ring before entering the milking parlour. The user may not be physically close to the stock but may control the system remotely and monitor the activity by image or geolocator signal.

22. AWC has been informed that, in the UK, there are currently over 140 virtual fencing users, mostly for cattle, but uptake is expected to increase markedly. Commercial systems are also in use in New Zealand, the United States and Australia. The use of electronic collars on sheep and goats in the UK is currently limited but growing rapidly. In Norway it has been greater.

23. AWC has gathered evidence from manufacturers, users and academic research relating to four virtual fencing systems, currently under development globally and in the early stages of commercialization in different global regions. It has also

directly observed virtual fencing in use. Evidence was presented of the use of these systems in a range of land usage contexts. Different virtual fencing systems have common elements but vary in their technology, capabilities and species suitability.

Legal context

24. Under the Animal Welfare Act 2006 in England and Wales and the Animal Health and Welfare (Scotland) Act 2006, all livestock keepers must ensure minimum standards of care for their animals and provide a suitable environment for their stock. It is an offence to cause unnecessary suffering to any domesticated animal and all reasonable steps must be taken to ensure that the needs of animals under the keeper's care are met.

25. The Welfare of Farmed Animals Regulations (WoFAR) (England and Wales 2007, Scotland 2010), Schedule 1, paragraph 2: animals kept in husbandry systems in which their welfare depends on frequent human attention must be thoroughly inspected at least once a day to check that they are in a state of well-being.

26. WoFAR, Schedule 1, paragraph 17: animals not kept in buildings must, where necessary and possible, be given protection from adverse weather conditions, predators and risks to their health and must, at all times, have access to a well-drained lying area.

27. WoFAR, Schedule 1, paragraph 18: all automated or mechanical equipment essential for the health and well-being of the animals must be inspected at least once a day to check that there is no defect in it. Paragraph 19 requires that, where defects in automated or mechanical equipment of the type referred to in paragraph 18 are discovered, these must be rectified immediately or, if this is impossible, appropriate steps must be taken to safeguard the health and well-being of the animals pending the rectification of those defects including the use of alternative methods of feeding and watering and methods of providing and maintaining a satisfactory environment.

28. WoFAR, Schedule 1, paragraph 25: All animals must either have access to a suitable water supply and be provided with an adequate supply of fresh drinking water each day, or be able to satisfy their fluid intake needs by other means.

29. The Codes of Recommendations for the Welfare of Livestock: for cattle (2003) and sheep (2000) in England, cattle and sheep (2010) in Wales, cattle and sheep (2012) in Scotland, and goats (1989) in England, provide guidance on how to comply with the statutory animal welfare requirements associated with domestic regulations, provide guidance on compliance and include elements of good practice. Livestock farmers, graziers and employers are legally required to ensure that all persons with any responsibility for livestock care are familiar with, and have access to, the relevant Codes.

30. Under these Codes, the use of electrical goads on adult cattle should be avoided as far as possible. If goads are used, there should always be sufficient space for an animal to move forward. The Codes for cattle, sheep and goats state that electric

fences should be designed, constructed, used and maintained so that an animal touching them feels only slight or momentary discomfort.

31. In 2010, the Welsh Government banned the use of any collar that is capable of administering an electric shock to a cat or dog, including boundary fencing systems.[2] The Scottish Government has issued guidance suggesting that using such collars on dogs to administer aversive stimuli may in some circumstances contravene the Animal Health and Welfare (Scotland) Act 2006.[3]

32. The Dogs (Protection of Livestock) Act 1953 prohibits dogs worrying livestock on agricultural land. 'Worrying' is defined as attacking livestock or chasing livestock in such a way as may reasonably be expected to cause them injury or suffering, or to cause abortion or loss of or diminution in produce. The Agriculture Act 1947, Section 109, defines 'agricultural land' as land used as arable, meadow or grazing land, market gardens, allotments, nursery grounds or orchards.

33. The Animals Act 1971, Chapter 22, Section 4 (covering England and Wales) and the Animals (Scotland) Act 1987, Section 1, make keepers of cattle, sheep and goats liable for any injury or damage caused to land as a result of them not being suitably controlled.

34. The Highways Act 1980, Section 155 (covering the UK), and the Roads (Scotland) Act 1984, Section 98(1), make it an offence to allow livestock to stray onto a road other than at a place where the road is running through unenclosed land.

35. The Civic Government (Scotland) Act 1982, Section 49, makes it an offence to suffer or permit any creature in one's charge to cause danger or injury to any other person in public, or to give such person reasonable cause for alarm or annoyance.

36. Under the Occupiers Liability Act 1984, a duty of care exists to any person on land.

Collar design parameters and associated infrastructure

37. A collar, neckband, chain or combination of chain and band is secured around the neck of the cattle, sheep or goat. For one manufacturer the collar breaking point for adult cattle is approximately 180kg of force.

38. A battery provides power to communicate with GPS satellites and, via the device provider's servers, to the livestock manager, and for the audio cue, electrical pulse and (if present) vibrator. In some designs, the device is charged by a solar panel linked to a battery buffer unit. In winter the battery may need replacing every 4–6 weeks, especially in northerly UK latitudes, if livestock are primarily grazing beneath a tree canopy or if audio cues or electronic shocks are frequently activated due to repeated contact with boundaries. Collars used in the UK are certified to IP67, an

[2] The Animal Welfare (Electronic Collars) (Wales) Regulations 2010.
[3] 'Dog training aids: guidance' (October 2018), at https://www.gov.scot/publications/guidance-dog-training-aids/.

international standard for waterproofing. Any moisture ingress would be likely to reduce charging capacity and performance.

39. A GPS unit operates using a standard chipset (group of electronic components in an integrated circuit) that communicates with satellite systems. Reception is likely to be poor in densely wooded areas, under trees and in deep gorges, meaning that there can be significant problems with accurate localization of fencelines set through these areas. Indoor functionality is severely limited.

40. An application on a computer or smartphone logs fencelines and manages responses, data communication, sensors and power.

41. A speaker within the battery unit or elsewhere on the collar can deliver an audio cue to the animal. On approaching the boundary, an animal may receive a given number of audio cues (typically an ascending scale or a tone increasing in volume) under given conditions within a given time period. The audio cue may be audible by other animals within earshot.

42. In one system a motor positioned on the inside of the neckband delivers a vibrator cue to prompt the animal to heed audio cues intended to guide it on a route from one location to another. Motors could potentially be placed on each side of the collar, enabling a vibration cue to be felt by the animal on one side or the other of the neck region in order to provide a directional stimulus.

43. Following one or more audio and/or vibration cues, if the animal does not respond appropriately, one or more electrical contacts on the inside of the collar or chains (acting as positive and negative electrodes) deliver an electric shock to the neck under the collar if the animal crosses the boundary. An animal may receive one or more shocks of a determined strength and duration. In one system the user may adjust the shock level downwards. In all systems on which AWC received evidence, there was a maximum number of shocks that an animal could receive as a result of any activation event. This number varied between systems although could be high (for example, during a virtual fencing training period, 20 shocks per 10 minutes).

44. So far as AWC is aware, no currently available virtual fencing system for livestock allows a human to deliver an intentional shock other than by moving a fenceline to an animal.

45. Instead of an electrical shock, it would in principle be possible to employ other aversive stimuli, such as a pushing probe, heat or spray. Use of positive stimuli might also be possible.

46. Control is provided via a smartphone, laptop computer or similar device. Sensors may communicate data to a server, to be interpreted to provide welfare-related information (for example, activity or immobility). This may be accessed by, or sent to, the livestock keeper’s device and a central monitoring location.

47. For designs where the battery and other hardware are situated on the upper side of the collar, a counterweight may be situated on the underside to help keep the collar in place. To reduce an energetic cost to livestock, the total collar weight should

be kept as low as possible. For two manufacturers the cattle collar total weight is 1.4kg and for one manufacturer the sheep collar total weight is 0.7kg. For ethical reviews of proposed livestock research studies, some UK institutions recommend that wearables such as collars be less than 2% of bodyweight. Current commercially available collars used in virtual fencing systems are typically within this range for their target livestock classes.

48. To fit the collar and to change the batteries as required, livestock need to be gathered and restrained. Appropriate handling facilities that minimize animal stress at handling need to be accessible or a mobile system needs to be brought onto the site. Increasing battery charging capacity reduces the frequency of livestock gathering for the purpose of battery changes.

49. Virtual fencing uses the Global Positioning System (GPS), which is more correctly termed the Geographical Navigation Satellite System (GNSS).[4] There have been significant advances in this technology. It uses a suite of satellite systems including, in the UK; GPS (USA), Galileo (EU), GLONASS (Russia) and potentially BeiDou (China).

50. All current virtual fencing systems are linked to remote servers (in the UK or elsewhere), an operating system and a long-term database.

51. Some difficulties have been reported with two-way communication on some sites, with variable mobile phone signal strength resulting in delayed or intermittent data transfer between the collar, remote servers and smartphone. All systems use GPS to provide location data and set boundaries. For collar to user/network communications, one system uses the mobile phone network while others employ a Long-Range Wide Area Network (LoRaWAN). These are privately-owned subscription networks with their own network identifications that use either masts or building-mounted antennae to communicate with the collars to increase accuracy and resolution by improving signal control and distribution. On environmentally sensitive sites, planning permission for antennae may be difficult to obtain.

52. Laptop software and a smartphone application provide the user(s) with screens and options to enable fenceline setup, fenceline changes and data management, including alerts for boundary challenges and breaches as well as livestock location, activity and, increasingly, data related to health and management.

53. Once fencelines have been uploaded, and provided that GPS continues to function, all current systems are able to maintain existing boundaries independently of remote servers. However, if the mobile signal is down or there is a dead spot, communication with the remote servers and smartphones is lost. In this situation the fenceline is maintained, but because the collar does not transmit location data the stockperson does not know the livestock location. One system partly addresses problems concerning dead spots by using Bluetooth short-range wireless technology to communicate with a user located close by to deactivate a collar or adjust the fenceline.

[4] In this Opinion, GPS is used generically for ease of comprehension.

54. Dealing with permanent or temporary dead spots, where mobile phone reception, or local LoRaWAN coverage, is poor or absent, requires good on-the-ground knowledge when setting fencelines.

55. Many of the stakeholders consulted by AWC emphasized the importance of user training. Currently, online technical support is complemented by in-person email and telephone contact. A setup site visit may be provided.

56. AWC has found it difficult to obtain collar operating parameters as some manufacturers regard these as commercially sensitive. Only one provider makes audio cue or electrical pulse data publicly available. For its system the audio cue is 82dB and the electric pulse is 0.2J and 1s duration for cattle and 0.1J and 0.5s duration for sheep and goats.

Virtual fencing as a means of containment and movement

57. While on pasture, livestock require shelter from adverse weather, such as prolonged direct sun, high winds, snow and heavy rain. Fencing of any kind can potentially limit access to shelter unless this is carefully planned. Virtual fencing allows users to change fencelines quickly. During severe weather events (for example, snow, heavy rain leading to flooding), when site access may be difficult or even impossible, the ability to change fencelines from a remote location could, with appropriate monitoring and use, enable livestock to move to safety.

58. Continual access to drinking water points within virtually fenced areas requires careful planning.

59. Virtual fencing allows a boundary and/or livestock to be moved without a human needing to be present on the site and potentially exciting or stressing livestock. However, when a user sets fencelines remotely the risk of mistakes (for example, not including a suitable drinking water source within the contained area) increases, unless the system can identify these and either prevent the user from making them or alert the user to them.

60. GPS accuracy and resolution are potential problems. Virtual fencing users report that a fenceline may drift by a couple of metres or more, such that a contained stationary animal receives one or more audio cues and potentially an electric shock. This could cause confusion and potentially distress. In addition, if a fenceline is placed close to water sources or shade, GPS drift could potentially prevent access to these, or allow access to areas of risk (for example, poisonous plants such as acorn or yew, hazardous land features or structures, or highways).

61. GPS accuracy may further reduce on slopes and in woodland. AWC is aware of reports of livestock experiencing inconsistent boundaries, with one animal receiving an audio cue or electric shock while an adjacent animal does not.

62. Good practice should involve ‘ground truthing’. This is where a boundary is set or verified by a user physically walking the boundary whilst carrying and listening to a collar and/or a smartphone with a virtual fencing application that accurately locates the

holder on the virtual fence map. This enables the checking of locations and fence function on the ground. In many settings, the background satellite maps may not be fully updated, and features such as fixed fencelines or drinking water troughs may not be visible and may also need ground truthing.

63. Virtual fencing works in the dark because it is not reliant on visual cues.

64. When setting fencelines, corners with obtuse (wide) angles reduce the risk of animal entrapment or bullying. In rotational grazing systems, a square paddock (with cut-off corners) may be optimal because it maximizes grazing efficiency and minimizes the distance walked over pasture, which in wet weather is likely to lead to soil damage including compaction and surface poaching.

65. Boundary crossing (escape) was reported to AWC as mostly due to exceptional events such as trespass, dogs, low-flying aircraft, thunder, lightning or the presence of unfamiliar vehicles. It may also be the result of livestock following a stockperson or due to bullying or confusion about the location of a water source. After such events, separated individuals or sub-groups are reported to return to the main herd.

66. In current virtual fencing systems, livestock that have crossed a boundary may return across it without experiencing audio cues or electric shocks, after which the collar automatically resets. This is not possible with physical fences and was also not possible with the buried loop system.

67. The electric shock function of collars may not be fully effective on sheep in full wool nor on very hairy cattle.

68. The collars manufactured for ordinary cattle use may not be appropriate for cattle with large neck girths (for example, mature bulls, where the neck girth exceeds the head size).

Adaptive multi-paddock (AMP) grazing

69. How grass leys and permanent pastures are grazed and managed over a season has a significant impact on both grass productivity and utilization (how much forage is produced and how much of this is eaten) and the nutritive quality of what livestock consume. A good intake of high-quality forage is typically associated with higher animal energy status, and therefore with improved abilities to maintain bodily functioning, growth, lactation and reproduction. It is also likely to support good rumen health because reliance on concentrated feed is reduced.

70. Because milk production is energetically demanding, dairy cattle have high energy requirements. Improved grazing efficiency and management are therefore likely to bring significant health, welfare and productivity benefits to dairy herds.

71. Traditionally, UK grazing has been ‘set stocked’, with stock allowed to access a large area of grazing for an extended time period. This can result in patchy grazing due to some less palatable plants becoming over-mature or trampled or lain on. Also, pasture contaminated with dung may be rejected. The continued presence of stock can result in soil compaction, which further restricts plant growth. In many cases, stock

will use a single entrance to access the pasture and may have access to just one or two water points. This can result in high-traffic areas, which (depending on soil type and weather conditions) may lead to poaching of the ground, and increased risk of udder infections and lameness (due to either hoof infection on wet ground or leg injury on uneven dried-out ground).

72. Paddock grazing and strip grazing are widely recognized as efficient grazing methods for dairy stock and are also increasingly used for beef cattle and some sheep flocks. Paddock grazing typically uses a combination of permanent and movable electric fencing (physical or virtual) to create a number of small paddocks that are grazed for a short time period (a few hours to a few days). Paddock size is often adjusted to match grass growth rates, weather conditions, livestock numbers and body condition. Strip grazing requires the regular movement of a front fenceline, typically every 12–24 hours, to allow stock access to a fresh strip of pasture within a field. In a virtual system, as one animal identifies, by the absence of audio cues, that a boundary has moved, others will follow. Once all animals have departed, the old pasture may be closed off and left to regrow.

73. Both dairy and beef youngstock may be grazed in fields at some distance from the main unit, and to reduce labour requirements are typically set stocked. Virtual fencing offers similar benefits in terms of better pasture management leading to improved growth rates.

74. When virtual fencing is employed in AMP grazing systems, the stock usually encounter boundaries more frequently than those extensively grazing a large area. Once the livestock have learnt the system, a small subset seem to continue to ‘test’ the virtual boundaries and receive more audio cues (and electric shocks) than others. Often two to three animals receive 30–50% of the audio cues in any given day, continually exploring the fenceline and grazing into the ‘audio zone’. These animals may be important for normal herd dynamics by leading the group into new pasture. Their behaviour may give them access to more forage, and AWC has seen some unpublished research that suggests a positive relationship between boundary testing and weight gain, but there are different views on the reasons for boundary interactions and peer-reviewed scientific research is needed.

75. Alternatively, some individuals receiving a disproportionately high number of audio cues and electric shocks may also be ‘slow learners’ or lower ranking animals that either wish to maintain a distance from more dominant herdmates or are pushed into the fenceline by them.[5] In addition, a few animals may be temperamentally unsuited to virtual fencing.

76. Virtual fencing may be used to manage feeding on winter crops (for example, stubble turnips, fodder beet, brassicas). This is usually challenging for conventional electric fencing systems due to heavier land and the supporting posts being knocked over as livestock uproot crops. Conventional systems also often suffer from management difficulties due to the grass or stubble ‘runback’ zone surrounding the

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[5] S Lomax, P Colusso and CEF Clark. Does Virtual Fencing Work for Grazing Dairy Cattle? *Animals* 9 (2019), 429; DLM Campbell, JM Lea, SJ Haynes, WJ Farrer, CJ Leigh-Lancaster and C Lee. Virtual Fencing of Cattle using an Automated Collar in a Feed Attractant Trial. *Applied Animal Behaviour Science* 200 (2018), 71–7.

crop area becoming fully grazed and so too soft and muddy to support livestock and keep them free from significant mud.

77. In all AMP grazing systems, care needs to be taken to provide access to shelter from adverse weather and shade from solar radiation.

Upland, rough and conservation grazing

78. In upland settings and on conservation grazing sites, conventional fencing may not be permitted or else be very expensive or impractical. In these locations, initial experience suggests that virtual fencing has considerable potential for managing stock location. In combination with GPS tracking to locate the stock on a site, it makes visual inspection easier to complete. Virtual fencing may also be used to keep stock away from neighbouring land and to discourage stock from approaching steep inclines, drops or bogs. It may also keep livestock away from rare or hazardous plants, ground-nesting birds in appropriate seasons, or historic or archaeological features.

79. AWC is aware of differences of view on whether all adult livestock in a herd or flock require collaring. It has been suggested that it may be possible to collar the majority of animals, including leading animals, with herd synchrony keeping uncollared animals with the group. However, there is a lack of research evidence on part-collaring. One study on a small group of sheep notes that, when two-thirds of this flock were collared, they remained together, but when only one-third was collared the uncollared animals moved over the boundary.[6] Most users AWC spoke to considered that collaring too few animals would result in the uncollared animals moving outside the boundary, leaving the collared individuals behind and causing them distress.

80. On ground with common grazing rights and on some farms, several livestock groups of the same or different species might be grazed in close proximity or together. Concerns have been raised about potential confusion if a virtually fenced group cannot follow or access other groups uncontained by such a system. It needs to be recognized that, on common ground, herds and flocks are self-forming and that different stockpersons may be responsible for individual animals within a single group.

81. On some open Commons or extensively managed grazing sites, stock may gravitate towards their preferred sites, which then become overgrazed. This may not be how the stockkeeper or site manager wishes the land to be grazed and they may expend considerable time regathering and moving stock. This is potentially stressful for stock. Although using virtual fencing to prevent stock moving to preferred sites restricts animal choice of grazing location, it could bring significant welfare benefits by reducing the need to gather stock in order to manage the grazing intensity around a site.

82. In conservation areas such as Sites of Special Scientific Interest, long-term grazing quality and range may be improved by containing livestock in certain areas for set periods. For example, *Molinia* (purple moor grass) has the capacity to mature rapidly and is unpalatable once large tussocks form. However, cattle are good at

[6] D Marini, R Llewellyn, S Belson and C Lee. Controlling Within-Field Sheep Movement Using Virtual Fencing. *Animals* 8 (2018), 31.

breaking it up with their hooves, and grazing it, if they can be contained in the areas where this grass grows, especially at times of year when it has higher digestibility.

83. On open Commons and upland extensive areas, the appropriate placement of virtual fencelines is potentially challenging. Awareness of natural water sources and their reliability, suitable natural shelter from the elements (such as valley bottoms or rocky outcrops) and potential natural hazards such as bogs or flash-flooding spots requires a great deal of local knowledge and regular inspection.

84. AWC is aware that virtual fencing is currently being used to keep cattle and sheep off roads (thereby reducing the risk of road traffic accidents) and away from known stressors (for example, car parks, public rights of way, dogs).

85. In locations accessible by the public where virtual fencing is used in preference to natural barriers or physical fencing, there are limited opportunities for walkers with dogs to be alerted to their legal obligations in the presence of livestock.

86. In publicly accessible locations, virtual fencing also easily allows an increased separation distance between livestock, and walkers and dogs, according to seasonal needs such as lambing and calving.

87. The increased availability and popularity of virtual fencing systems may encourage people who lack sufficient livestock knowledge and experience to keep grazing ruminants on the land they manage, such as for some rewilding projects and conservation grazing sites. This is likely to have welfare implications.

Livestock movement

88. The livestock that need to be moved most frequently for production purposes are dairy cattle. These are typically milked twice daily and brought from the field to the milking parlour. How this is done varies. Best practice is typically to open the gates and allow the cows to walk to the parlour at their own speed, with a farmworker rounding up ‘stragglers’ remaining in the field partway through milking.

89. The milking process (including the movement of cows to and from the parlour) demands considerable staff time and some farms lack sufficient space to segregate milked and unmilked animals. On farms with staffing or space pressures, cows are likely to be rounded up and driven to the parlour by a farmworker on foot or a quad bike. Often when cows are driven, the stragglers are encouraged to walk at a pace greater than they would otherwise choose. This has been associated with increased risk of locomotor disease and, if animals are lame already, with pain and stress.

90. Dynamic fencing (i.e. virtual fencing used dynamically) could potentially be used to gather cattle for milking by at least three methods:

1) A front boundary is moved forward with a creeping rear boundary driving cattle forward, similarly to an automated backing gate.

2) A front boundary is moved forward with a creeping rear boundary following the last animal in the line as the group moves closer to the parlour.

3) A vibrator cue followed by audio cues simultaneously activate on the sides of the collars of all animals in a group according to an animal-specific algorithm to guide them to their destination. The audio cue is different from any cue used for boundary control purposes.

91. AWC is aware that dynamic grazing for cattle is in the process of commercialization by some virtual fencing providers outside of the UK. With reference to the preceding paragraph

- Method 1) leaves open the possibility of cattle boxed into a corner of the field or track receiving repeated audio cues and an electric shock. Moreover, use of a shock to encourage forward movement is effectively goading, which although legal is prohibited by UK farm assurance schemes.
- Method 2) potentially allows a trapped animal to be rescued without receiving an electric shock.
- Method 3) is in use outside of the UK and evidence received, together with video that AWC has viewed, suggests that it could be successfully employed.

92. AWC has not seen any evidence of how cattle respond to a creeping rear boundary and is concerned that future providers and/or users might misuse this. Unlike with other virtual fencing applications, there is not necessarily an action–signal–response event series. A cow standing still could potentially receive an audio cue followed by an electric shock. This is likely to confuse cattle and cause stress, because the direction in which they need to walk to avoid further cues, and potentially another electric shock, may not be apparent.

93. For mob management purposes, virtual movement systems may potentially be used in conjunction with virtual fencing by dividing one livestock group into smaller groups or by combining several smaller groups into a single larger group. This may be useful for optimizing use of available grazing. Animal movements may be scheduled in advance.

94. Some farm assurance schemes (for example, Red Tractor, which covers the large majority of dairy farms) prohibit the use of goads on all species. RSPCA dairy standards do not permit goads to be present or used on any site. None of the virtual fencing systems currently available for use on farms allows an operator to goad individual animals. Any system that permitted this, such as might be developed by new entrants into the market, would be likely to expose animals to a high level of risk of stress and harm.

95. Dogs, or humans on quadbikes, may be used to gather and/or move stock, especially sheep. Poorly trained dogs or inexperienced human gatherers are likely to cause them significant stress.

96. It is foreseeable that virtual fencing will be used to gather livestock from large remote areas for handling, sorting or transport. The potential future integration of drone technology with virtual fencing and location monitoring may encourage this. Risks could be presented if stock are gathered with no human oversight. For example, without human intervention stock might become ‘trapped’ by natural landscape features as the fenceline moves and receive an electric shock. In some situations, they

might also break out of the fenceline and could become separated from the group, with no intervention available until the farmer arrives from a potentially long distance and time away.

97. Systems currently in development may be usable to draft one or more individual animals out of a group for husbandry, production or veterinary purposes.

Youngstock at foot

98. Any collar needs to be appropriate for an animal’s weight and size. As a juvenile grows, suitable handling facilities need to be available for fitting and adjustment. AWC is aware that collars designed for sheep and goats are sometimes used on calves with apparent success, and that pet collars have sometimes been used on sheep and goats for containment purposes. These may have welfare implications.

99. The voltages and currents used in some of the virtual fencing units now on the market may induce greater pain and distress in small and young animals than in fully grown and mature animals.

100. Some users report successfully running virtually fenced suckler cows with uncollared calves within a larger, conventionally fenced area. This gives calves the freedom to ‘creep feed’ forward onto fresh pasture, thereby promoting their growth and reducing the duration of feeding stress on dams, which is likely to be greater in conservation and upland areas with lower quality pasture. As well as feeding away from their dams, young calves are typically highly motivated to re-join their dams behind the virtual boundary. Some users describe cows accepting separation without anxiety. Others report that a few dams have become distressed when older calves (about six months old) become more independent and stray further from the boundary. In this situation, one or more cows may break through the boundary to join their calf and in so doing receive an electric shock.

101. AWC has been unable to obtain any UK evidence regarding the virtual fencing of ewes or doe goats with youngstock at foot.

Training livestock to use the system

102. If stock are to be effectively and safely contained behind any electric fence, they need to be introduced under supervision and trained to recognize that the fence will deliver an aversive stimulus when crossed. This requires a learning period.

103. A trainee animal in a virtual fencing system generally has no physical boundary to associate with the audio cues and electric shock. It is unclear how far any individual animal uses visual cues in association with audio and potentially vibration cues to help learn the boundaries and avoid receiving a shock. Some research using specially designed collars has found the absence of visual cues problematic for stock moved to

a new area, with ongoing corrective reinforcement of the boundary by a physical means required.[7]

104. In virtual fencing systems currently used for livestock in the UK, an audio cue is generated as the animal approaches the virtual boundary. During training, animals learn that this cue, if not acted on, will be followed by an electric shock. After a few days of training, most animals are still likely to receive audio cues as they approach the boundary, but because they respond appropriately, the number of electric shocks markedly decreases, for some potentially to zero, demonstrating the ability of cattle to learn to respond to the audio cue.[8] However, in one study the mean number of electrical pulses activated by individual animals during training ranged from 1 to 6.5 per day, suggesting that successful containment may have a higher welfare cost for some individuals than others.[9] During training, virtually fenced cattle have been seen to respond more readily to the behaviour of herdmates than when no virtual fence was used, indicating that cattle observed the virtual boundary partly because of its observance by herdmates.[10]

105. Studies on sheep have indicated that situations with high predictability and controllability, such as those experienced when livestock successfully learn to avoid the aversive component of a virtual fence, result in a comparatively minimal stress response.[11] In one study, during a training period sheep approached the virtual fence significantly less during each of the successive training days, and behavioural responses to the electric shock tended to decrease in severity over time. This suggests that sheep are able to learn to respond to an audio cue.[12]

106. All virtually fenced livestock (including newly purchased or replacement animals joining an existing virtually fenced group) require a period of intentional training by the stockperson to

- become familiar with the weight and feel of the collar (especially immediately after fitting)
- experience the audio cue(s) and any vibration cue

[7] D McSweeney D, B O'Brien, NE Coughlan, A Férard, S Ivanov, P Haltone and C Umstatter. Virtual Fencing Without Visual Cues: Design, Difficulties of Implementation, and Associated Dairy Cow Behaviour. *Computers and Electronics in Agriculture* 176 (2020), 105613.
[8] S Lomax, P Colusso and CEF Clark. Does Virtual Fencing Work for Grazing Dairy Cattle? *Animals* 9 (2019), 429.
[9] PI Colusso, CEF Clark and S Lomax. Should Dairy Cattle Be Trained to a Virtual Fence System as Individuals or in Groups? *Animals 10* (2020), 1767. However, it is possible that not all these pulses were experienced by the animal.
[10] H Keshavarzi, C Lee, JM Lea and DLM Campbell. Virtual Fence Responses Are Socially Facilitated in Beef Cattle. *Frontiers in Veterinary Science*, 30 September 2020; MF Aaser, SK Staahltoft, AH Korsgaard, A Trige-Esbensen, AKO Alstrup, C Sonne, C Pertoldi, D Bruhn, J Frikke and AC Linder AC. Is Virtual Fencing an Effective Way of Enclosing Cattle? Personality, Herd Behaviour and Welfare. *Animals* 12 (2022), 842.
[11] T Kearton, D Marini, F Cowley, S Belson, H Keshavarzi, B Mayes and C Lee. The Influence of Predictability and Controllability on Stress Responses to the Aversive Component of a Virtual Fence. *Frontiers in Veterinary Science*, 30 November 2020.
[12] D Marini D, F Cowley, S Belson and C Lee. The Importance of an Audio Cue Warning in Training Sheep to a Virtual Fence and Differences in Learning when Tested Individually or in Small Groups. *Applied Animal Behaviour Science* 221 (2019), 104862.

- experience (if necessary) the electric shock that will result if they continue to move through the boundary
- learn that the aversive effect of the electric shock can be avoided by responding to the audio cue
- learn that the behaviour of herdmates can indicate the boundary location and, if it is moving, to where
- potentially learn that a stationary fenceline may be remembered in association with the physical landscape
- learn that a moving fenceline may shift at one time or dynamically
- (depending on the system) learn that their movement speed and direction effect how quickly following the audio cue that an electric shock is delivered

107. Training requires a controlled and predictable environment in which reliable virtual fencelines allow livestock to explore the effect of the audio cues and to discover how to respond in order to avoid receiving an electric shock. For virtually fenced cattle the training period is likely to last at least 5–7 days.

108. For dynamic fences used to manage feeding or movement, training is more challenging and for cattle may take 2–4 weeks, because of the complexity and number of cues that livestock need to learn. An animal becomes aware of a boundary move only on receiving a vibration or audio cue. The learned response of the animal based on a static boundary is to turn around in order to move away. However, turning may not reliably move an animal away from a dynamic boundary. Indeed, for a moving boundary coming from behind an animal, turning around will result in the animal facing and potentially walking into it and so receiving audio cues and then an electric shock. In this situation, animals are likely to turn round and round. This indicates confusion, potential stress and training challenges.

109. A few individual animals may not be able to adapt to virtual fencing and/or dynamic movement systems or may later lose the capacity to respond to them (for example, deafness in a system that uses audio cues).

Physical and mental welfare implications

110. If a collar worn by a livestock animal becomes caught on a tree or in undergrowth, this exposes it to an entrapment risk. The fact that it has not been reported as an issue suggests that current users are fitting collars correctly. In any case, to ensure that stock cannot suffer strangulation or become immobile, a collar needs to be breakable.

111. There may be direct abrasion from collars and there is some evidence of associated hair loss reported although without significant welfare impact. AWC is aware of isolated instances of skin damage, which is a welfare issue. This may arise from inappropriate collar application or collar damage, and failure to respond promptly when signs of these appear.

112. If collars are placed on growing livestock, they might become too tight if not regularly checked and loosened as needed (which requires gathering and handling), unless designed to expand with neck growth.

113. In designs where the main unit, including the battery pack, is suspended below the neck, when an animal is leaning down to graze, the pack knocks against the upper neck or jaw at each feeding movement. It has been suggested that this is not a significant welfare issue and AWC members have observed cattle wearing such collars grazing normally. However, the device may physically annoy the animal, even if carefully fitted to be appropriately tight.

114. With respect to faecal cortisol metabolite concentrations, research has found no differences between beef cattle contained for four weeks by conventional static electrical fencing and by fixed virtual fencing.[13] Concentrations decrease with time for all fenced cattle. This suggests that, compared with legally permitted fixed electric fencing, static virtual fencing does not have a differential effect on livestock stress. A study on sheep found that cortisol levels were not significantly higher in a trained virtually fenced group subject to predictable and controllable electric shocks than in a group that was subject to audio cues alone.[14]

115. However, other research has found that dairy cattle subject to dynamic virtual fencing for more than three days displayed reduced activity, grazing time and increased ruminating time and experienced increased stress as indicated by raised milk cortisol levels in comparison with a control group that were contained with physical electric fencing.[15]

116. As with a physical boundary, it is possible that poorly configured virtual fencing may provide bullying opportunities against lower ranking animals or make it harder for them to maintain a distance from dominant herdmates. In order to stop being bullied, these lower ranking animals may break through the virtual boundary and receive an electric shock.

117. Automated notifications delivered to smartphones or other devices enable the remote monitoring of livestock and potentially prompt responses to problems. Monitoring that identifies individuals that are stationary for an extended period (due to for example, lameness, mastitis, imminent calving, being caught in a bog) may prompt rapid stockperson investigation. Monitoring that identifies individuals that move slowly or exhibit restricted ranging is likely to aid early identification of lameness or other causes of ill-health. There is also potential for rapid movements to be notified, such as

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[13] DLM Campbell, MJ Lea, H Keshavarzi and C Lee. Virtual Fencing is Comparable to Electric Tape Fencing for Cattle Behavior and Welfare. *Frontiers in Veterinary Science* 6 (2019), 445; also J Jeffus, RR Reuter, K Wagner, L Goodman and T Parker. Effects of Virtual Fencing on Cortisol Concentrations and Behavior of Beef Cattle. *Journal of Animal Science* 99 (2021 suppl. 3), 1–2.

[14] T Kearton, D Marini, F Cowley, S Belson, H Keshavarzi, B Mayes and C Lee. The Influence of Predictability and Controllability on Stress Responses to the Aversive Component of a Virtual Fence. *Frontiers in Veterinary Science* 7 (2020), 580523.

[15] M Verdon, A Langworthy and R Rawnsley. Virtual Fencing Technology to Intensively Graze Lactating Dairy Cattle. II: Effects on Cow Welfare and Behavior. *Journal of Dairy Science* 104 (2021), 7084–94. The study was conducted within a training period duration. It is possible that the differences identified would reduce over a longer period.

might be caused by low-flying aircraft, dogs or gathering by rustlers. Collar failure is also notified.

118. Monitoring that is currently provided by virtual fencing systems could form part of a systematic evidence-based continual welfare assessment. With further research and development, this could contribute to welfare data reporting to a consistent standard that may be useful to farmers, food business operators, herd health specialists, veterinary surgeons, regulators, retailers and consumers.

119. As systems develop, there is potential for additional animal sensor data to be communicated, analysed and provided in a user dashboard with superimposed satellite images of the current pasture, determinations of forage availability based on prediction or physical sampling, and weather warnings.

120. If provided and permitted by the system, members of the public may identify virtually fenced paddocks by scanning QR codes. With appropriate signage and guidance, this might reduce the incidence of dog attacks on livestock. However, some users have voiced concerns about members of the public being able to locate stock so easily, in case this exposes stock to risk of mistreatment.

121. There is a risk that the current high-quality (and relatively high cost) providers could be crowded out by cheaper alternatives providing containment but little or no additional monitoring.

Ethical analysis

122. The use of virtual fencing has the potential to maintain or improve livestock welfare. Nevertheless, an electric shock is fundamentally aversive and all virtually fenced stock are, like all stock contained by conventional electric fencing, likely to experience this, at least during training. To be ethically justifiable, all aversive stimuli must bring some clear welfare benefit that is not realistically deliverable by a non-aversive method.[16] In the medium- to long-term it may be possible to replace aversive stimulation with a positive stimulus. What the options for this might be, and how effective they might be, would require further research.

123. Within a virtual fencing system, the benefits and harms are unevenly distributed among the contained group. Slow learners and those that are inclined to test the boundary will experience more audio cues and electric shocks than those able to learn or choose to follow others or graze in areas at a distance from the boundary.

124. Some of the benefits of containment by virtual fencing in terms of improved grazing, such as improved soil structure and more abundant and diverse pasture and thus better nutrition, are long-term and therefore likely to be most fully obtained by future generations of the herd.

125. Virtual fencing and the monitoring associated with it is likely to increase the ability of keepers of livestock on remote and common land to exercise their duty of

[16] D Grumett and A Butterworth. Electric Shock Control of Farmed Animals: Welfare Review and Ethical Critique. *Animal Welfare*, in press.

care to their stock. However, remote data does not reduce the importance of human observation inspection and care of stock.

126. The use of a virtual boundary as a goad or creeping rear fence would be ethically questionable. GPS drift could also effectively function as a goad or 'uncontrolled shock'. The key distinction is between passive and active movement. A rear fenceline should follow livestock rather than be used to actively move or 'drive' them.

127. Large reductions in the use of physical stock fencing may have unintended ongoing negative welfare consequences including increased interactions with members of the public and more opportunities for dogs to attack or worry livestock.

128. The opening up of areas of countryside that were previously not able to be grazed (for example, common land) may result in new hazards and interactions between livestock, other animal species and humans.

Conclusions

129. Virtual fencing systems for livestock have several potential welfare advantages over conventional electric fencing. With appropriate provider safeguards and operator use, these include livestock nutrition, health and welfare benefits, and benefits to the land being grazed. These benefits are due to easy fenceline movement, the ability to apply audio and/or vibration cues prior to an electric shock, the ability of the system to deliver a known level of electrical pulse to an individual animal and associated monitoring functions.

130. In addition to containment and exclusion, systems may be used dynamically to move livestock from one location to another, to divide or combine suitable groups and to monitor location. Movement functions may either use a dynamic virtual fenceline or activate vibration or audio cues on the collar or neckband, delivering an electric shock if the animal does not respond to these. The welfare issues related to the use of virtual fencing are likely to vary according to context.

131. Virtual fencing systems are superseding previous loop-based invisible fencing, which had limited take-up. They have developed over the past 5–10 years with accelerated UK interest and take-up since 2019. There are likely to be ongoing improvements in collar design, battery lifespan and software functionality. Because the systems are new and developing, long-term outcomes are at present uncertain.

132. Before livestock are virtually fenced a training period is essential so they may become familiar with the cues given by the system and learn appropriate behavioural responses.

133. Additional sensors adding new data to the real time smartphone application as part of additional full herd management systems provide further uses and potential welfare gains by alerting livestock owners and/or keepers to potential health and welfare issues.

134. If held in the UK or accessible from within the UK under a duty of disclosure by a person other than the stock keeper, monitoring data could potentially be used as objective evidence of poor welfare or care as well as to demonstrate that welfare standards have been met.

135. Further research is needed to reliably assess the probability and importance of potential welfare gains resulting from virtual fencing, as well as the risk and magnitude of possible negative welfare impacts on livestock health and mental state.

136. Virtual fencing forms part of a shift in livestock management practices towards greater automation. If used in combination with other systems, such as automated milking, automated feed dispensing systems and drone observation, it could contribute to a highly technological management infrastructure in which ongoing contact with humans is greatly reduced. This may have unintended negative livestock welfare impacts.

137. Although virtual fencing, movement and monitoring systems have the potential to reduce ongoing human contact with livestock, they could also potentially improve the usage of stockperson time with livestock, reducing the time spent on locating and monitoring and increasing targeted engagement with welfare problems and issues.

138. Collars that are currently available are not suitable for lambs, kids or young calves, nor for farmed species other than cattle, sheep or goats. Further research would be required before the welfare implications of their use on other species could be considered.

139. There is significant scope for livestock welfare to be compromised if users of virtual fencing systems do not fully understand how the technology works, its technical limitations and how to respond in the event of problems.

Recommendations

140. The virtual fencing and remote monitoring of livestock should not replace regular human inspection.

141. Land managers and stock keepers should not rely on virtual fencing in preference to physical fencing in situations that are high-risk to livestock or humans (for example, to keep stock off a main road or railway line or away from a steep incline; to safeguard against biosecurity hazards).

Collar and system design parameters

142. Any collar placed on a livestock animal for containment or any other purpose should have a verifiable physical breaking point, which is reached before significant harm is caused to the animal wearing it, and be designed to be non-abrasive.

143. Any future significant weight increases in collars should be subject to welfare review.

144. Except for research purposes, no livestock animal should be double collared around the neck (for example, be fitted with a virtual fencing collar and a separate monitoring collar).

145. No virtual fencing system should be manufactured to allow a user to deliver an intentional electric shock to any individual livestock animal or group of animals.

146. Manufacturers should design all systems to set a maximum strength, number and duration of electric shocks that a livestock animal can receive according to strict parameters that a user may reduce, but not exceed. Electrical pulse strength should be the minimum necessary to control the individual animal, such as by means of algorithmic reduction, and should always be preceded by auditory and/or vibration cues.

147. Livestock that cross a boundary should always be able to return without experiencing an audio cue or electric shock while so doing.

148. Manufacturers should ensure that systems permit immediate cancellation of collar control by the user when inspection of livestock by the owner or other stockperson reveals adverse welfare effects.

149. Manufacturers should ensure that, in an emergency, all systems permit immediate remote cancellation of collar control by the user.

150. Battery capacity and solar charging capability should be sufficiently large to avoid livestock having to be brought into handling facilities frequently for battery replacement. Handling for this purpose should ideally be performed at the same time as other husbandry tasks requiring restraint.

151. Manufacturers should design applications used to set fencelines to require users to identify and prevent configurations that are likely to lead to welfare problems, such as lack of a drinking water point, exposure to hazards (such as lack of shelter from sun, snow or heavy rain), or the possibility of becoming trapped in a flooded area.

Collar and system use

152. Manufacturers should clearly specify the species, type, sex and age of livestock for which their collars and systems are designed.

153. Virtual fencing collars should not be used on calves aged under six months or on lambs or kids aged under four months. Research would be needed to support any alteration to these recommended minimum ages, including into psychological and developmental aspects.

154. The livestock owner or keeper is responsible for any consequences resulting from the use of virtual fencing.

155. Stockpersons should check collars used on growing youngstock frequently to ensure that they do not become too tight.

156. All persons using virtual fencing to contain or move livestock should receive full training and appropriate evaluation, including in welfare aspects, from providers.

157. Subject to further research, all weaned/adult livestock in a virtually fenced group should normally be collared. If one or more bulls is included in a virtually fenced area, an additional form of fencing should be required for safe containment.

158. Bulls should only be virtually fenced using collars manufactured specifically for them.

159. Prior to being virtually fenced, all livestock should be trained for a sufficient time period in a safe, controlled and predictable environment, taking into account their behaviour, temperament and site conditions.

160. If, during training or later, an individual livestock animal consistently fails to respond to the virtual system, the stockperson should transfer it into an alternative containment system. Virtual fencing systems should be able to identify such animals through monitoring.

161. Research should be undertaken to find livestock training methods that could replace the current use of aversive electric shocks. If these new methods are demonstrated to be reliable, electric shock training methods should be rapidly phased out of use on livestock.

162. A dynamic fenceline should move outwards in order to allow access to new pasture or other space and only move inwards when all livestock have vacated the area to be closed such that no animals receive any audio cues or electric shocks as a result of its inward movement.

163. In small containment areas without significant hazards, in order to reduce the risk of separation of dams from their young it is recommended that the virtual fencing function of collars on livestock be deactivated at calving and lambing, with only the monitoring function remaining in use. In large areas where potential hazards are present, it is recommended that the virtual fencing function not be deactivated at calving or lambing.

164. When dams with youngstock are virtually fenced within a larger area that is physically contained, a collar should be deactivated if the dam displays separation anxiety.

165. To avoid livestock receiving cues and potentially electric shocks, the virtual fencing function of collars should be deactivated whenever they are transported.

166. In case of GPS drift, water points and necessary shade and shelter should not be located close to a virtual boundary.

167. Manufacturers should design applications to prevent fencelines being set narrower than GPS resolution (for example, narrow corridors along tracks) and allowance should be made for GPS drift.

168. All current and future users of virtual fencing systems for containment and/or movement should have an alternative method or methods for providing these in place in case the virtual system malfunctions or fails.

Legal, regulatory and assurance aspects

169. Governments should review and clarify whether virtual fencing systems fall under the legal definition of an automated system used in the Welfare of Farmed Animals Regulations, and are therefore subject to the inspection, repair and welfare requirements in these Regulations.

170. Expectations for virtual fencing systems should be included in the Codes of Recommendations for the Welfare of Livestock for cattle, sheep and goats.

171. Manufacturers should publish electric shock parameters (voltage, energy, pulse duration and waveform characteristics) and acceptable levels should be included in the Codes of Recommendations for relevant species.

172. To guard against the risk of harm being caused to livestock, virtual fencing systems marketed in the UK should be manufactured to a consistently assured standard.

173. As the use of virtual fencing systems significantly increases, develops and diversifies, an approvals process may be needed.

174. The ownership of data generated by virtual fencing systems and access rights to it require legal clarification.

175. Farm assurance schemes should consider including specific requirements for virtual fencing, based on latest best practice, in their published standards.

176. If members of the public are likely to be legally on land where virtually fenced livestock are present, visible signage should be in place explaining the system.

Appendix 1: AWC Membership

*Peter Jinman—Chairman
Martin Barker
*Dr Andy Butterworth
*Richard Cooper
Dr Jane Downes
Dr Troy Gibson
*Dr David Grumett
Dr Maria Carmen Hubbard
Richard Jennison
Richard Kempsey
Dr Dorothy McKeegan
Dr Romain Pizzi
*Dr Pen Rashbass
*Prof Sarah Wolfensohn
Dr James Yeates

* = member of the Working Group for this Opinion

Co-opted members
Les Eckford
Dr Tony Waterhouse

Animal and Plant Health Agency
Joe Anzuino

Defra Animal Welfare Team
Daniel Grimwade

Appendix 2: Those who gave evidence and assistance

James Allen, AgFirst Waikato

James Allen, Heritage Graziers

David Attwell, Tracy May, Philip French and Russell Ashford, Dartmoor Hill Farm Project

Roger Beecroft, Legacy Grazing

James Daniel, Precision Grazing

Laurence Depuille, Margaux Goyenetche and Jean-Marc Gautier, Institut de l'Élevage

Emma Douglas, Pori Natur a Threftadaeth (PONT)

Charlotte Dring, Conservation Grazing Manager, Yorkshire Wildlife Trust

Halter

Martin Hartup, Head Ranger, Burnham Beeches

Keith Hopkinson

Brian Lavelle, Living Landscapes Manager, East Yorkshire Wildlife Trust

Skye Lindsay, Livestock Ranger, City Commons

Keith Luxford, Farming in Protected Landscapes programme, Defra

Tim Mallett

Nofence

John Phillips, Grazing and Landscape Project Officer, Epping Forest

Danny Squire, Senior Ranger, Birmingham City Council

Vence Corp

Sally Wallington, Dynamic Dunescapes Project Officer, National Trust