Fencing for wildlife disease control

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COMMENTARY

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RH: ‘Fencing for disease control’

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Abstract

1. Fencing is a contentious issue due to its impact on conservation. The Danish government aim to establish a 70 km fence towards the border of Germany and the agricultural ministry of Bulgaria erected 133 km fences along border with Romania to prevent spread of African swine fever by wild boar. The Norwegian government recently erected 24 km of fencing as part of combating chronic wasting disease among reindeer. Europe hence faces a new situation with fencing to limit emerging wildlife diseases. However, there is surprisingly little available scientific literature on the efficacy of fencing for controlling wildlife disease.
2. Fencing to combat disease include (1) 'perimeter fencing' aiming for containment and reducing likelihood of geographic spread, and (2) 'hot spot fencing' aiming to lower transmission rates within endemic disease areas. Critical limitations of perimeter fencing include: Numerous practical and construction details, differences in animal behavior relative to fences, animal contact along fences, placement relative to natural barriers, human infrastructure that disrupt continuous fencing, and mode of disease transmission including human aided disease spread.
3. Hot spot fencing is a potentially important way of reducing transmission of diseases once endemic, but require that materials and construction of fences are well thought through. A single fence breach does not have the same consequences as for perimeter fencing.
4. *Synthesis and applications.* Fencing as a tactic to mitigate disease appears appealing to politicians, but implementation uncertainty is considerable. We fear efforts may be futile unless more attention is paid to both practical and biological detail, and it seems urgent to build a more evidence based approach using experience from other sectors.

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42 **KEYWORDS**

43 African Swine Fever (ASF), Chronic Wasting Disease (CWD), fencing construction, animal
44 behavior and fences, adaptive management, disease mitigation.

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45 **1 | INTRODUCTION**

46 The issue of fencing is a contentious topic due to its impact on conservation (Hayward &
47 Kerley 2009; Bode & Wintle 2010; Woodroffe, Hedges & Durant 2014b; Linnell et al. 2016).
48 Fencing serves many purposes and the value is context dependent (Hayward & Kerley 2009).
49 Fencing of scattered islands of natural habitat and national parks in increasingly fragmented
50 areas of human development, as in Africa, serve conservation purposes (Pfeifer et al. 2014).
51 Large animals have extensive home ranges and areas surrounding national parks can serve as
52 sinks without fencing, with lion (*Panthera leo*) conservation as one well-known example
53 (Watson 2013). Fencing may also aid in containing large carnivores in rewilding efforts (Bull
54 et al. 2018) or to protect remnant and declining caribou (*Rangifer tarandus*) populations in
55 Canada (Cornwall 2016). However, fences are often for other purposes than conservation and
56 divide contiguous wildlife habitat (Woodroffe, Hedges & Durant 2014a), cut migration routes
57 (Osipova et al. 2018), and lower carrying capacity of the landscape (Boone & Hobbs 2004).
58 Indeed, the most common use of fencing to solve wildlife-human conflicts in Europe and
59 North America is along roads to avoid large mammal–vehicle collisions.

60 Two major concerns for wildlife health in Europe is the emergence of African swine fever
61 (ASF) among wild boar (*Sus scrofa*) spreading from eastern Europe and westwards (EFSA
62 Panel on Animal Health and Welfare et al. 2018) and of chronic wasting disease (CWD)
63 among reindeer in Norway (EFSA Panel on Biological Hazards et al. 2016). The economic
64 repercussions of spillover of ASF to swine production are huge, and the geographic expansion
65 of CWD was listed by a horizon scan as among the top 15 most important global issues for
66 biodiversity and conservation research in 2018 (Sutherland et al. 2018). The Agricultural
67 Ministry of Bulgaria erected recently 133 km of wire fences at the Romanian border to
68 prevent entry of wild boar and ASF (The Sophia Globe staff 2018). The Danish government
69 voted on 4th of June 2018 to establish a 70 km fence 150 cm high and 50 cm deep towards the

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border of Germany to prevent spread of ASF by wild boar (Reuters staff 2018). The Norwegian government recently erected 24 km of fencing as part of combating chronic wasting disease among reindeer in Norway, and extensions of fences are underway. Due to a diversity of adverse effects of fencing on ecosystems and economy, their use in combating wildlife disease should be evidence-based.

2 | PERIMETER AND HOT SPOT FENCING

We searched the ISI database for the terms “wildlife” AND “disease” AND “fence” OR “fencing” and it yielded only 77 hits (13th of June 2018), and we found surprisingly little scientific evidence to the efficacy of fencing as aid in wildlife disease control. We can distinguish two types of fencing to combat disease; (1) ‘perimeter fencing’ aiming for containment and reducing likelihood of geographic spread, and (2) ‘hot spot fencing’ aiming to lower transmission rates within endemic disease areas. Perimeter fencing reduces the number of animals crossing and hence likelihood of disease spread. However, we identify several critical issues and limitations of fencing to control spread of wildlife disease: Numerous practical issues including maintenance, differences in animal behavior relative to fences, animal contact along fences, placement relative to natural barriers, human infrastructure that disrupt continuous fencing, and mode of disease transmission including human aided disease spread (Table 1).

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Table 1. An overview of construction detail to consider when planning fencing to limit disease transmission and spread. FMD=foot-and-mouth disease in cattle, buffalo and impala, CWD=chronic wasting disease in cervids, ASF=African swine fever in wild boar.

Parameter	Situation	Type of fence, construction detail	Example	Key issues	Reference
Disease status	Endemic (limit transmission)	Hotspot fencing	Mineral licks, haybales case of CWD	Construction for access for users still limiting wildlife access	Gooding & Brook 2014; Lavelle et al. 2015
	Epidemic (limit spread)	Perimeter fencing	FMD, CWD, ASF	Fence length, fence ends, river and infrastructure crossing, epidemic front, barriers	Vercauteren, Lavelle & Hygnstrom 2006
Mode of transmission or spread	Vector-borne	Fence not the solution?		Can vector pass fence?	
	Airborne	Two fence lines	FMD		Bode & Wintle 2010
	Direct contact	Two fence lines	CWD, ASF	Depending on host distribution (figure 1)	Vercauteren et al. 2007
	Multi-hosts	Fence not the solution?		Can smaller hosts pass fence?	
	Human mediated	Fence not the solution?	ASF	Information campaign	EFSA Panel on Animal Health and Welfare 2018
Host behavior	Digger	Dig fences 50 cm into ground	Wild boar, warthog	Erosion, river crossing	Lindsey et al. 2012
	Crawler	Bottom wire height	Mule deer, white-tailed deer, pronghorn	Effective lower height, consider topography	Burkholder et al. 2018; Jones et al. 2018
	Jumper	High fences	Red deer, mule deer, white-tailed deer, impala	Effective height, consider topography and snow	Sutmoller et al. 2000; Vercauteren et al. 2010; Burkholder et al. 2018
	Challenger	Electrification	Elephants,	Maintenance	Hayward &

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			lions, wolves, bears	costs considerable	Kerley 2009
	Swimmer	Shoreline fences, fence not the solution?	Wild boar, cervids	Water distance to pass, many wildlife species can swim a few km	

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93 **3 | A SINGLE FENCE BREACH**

94 All textbooks in combat of diseases include containment by aid of perimeter fencing, but this
95 is mainly examples from the livestock-wildlife interface. Perimeter fencing was used to
96 separate cattle from impala (*Aepyceros melampus*) and African buffalo (*Syncerus caffer*) at
97 the interface of the Kruger National Park to contain foot-and-mouth disease (FMD) (Jori &
98 Etter 2016). Together with the regular vaccination of cattle exposed to buffalo contact,
99 fencing proved important for limiting spatial spread (Dion, VanSchalkwyk & Lambin 2011).
100 Perimeter fencing also played a key role to limit FMD in Botswana (Mogotsi, Kgosioma &
101 Lubinda 2016) and fences offered protection of domestic pigs from retrieving ASF in Uganda
102 (Dione et al. 2015). However, the step from fencing livestock to fencing wildlife is a non-
103 trivial one. Fence-line contact may be sufficient for directly transmitted diseases, and this is
104 much more likely for wildlife of the same species, compared to separation of livestock and
105 wildlife with little interest for each other. CWD in North America appear to have spread over
106 fences from captive elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) to their
107 wild counterparts, and nose-to-nose contact from farmed to wild deer required for
108 transmission of CWD over fences is documented (Vercauteren et al. 2007). If disease
109 competent host species occur in dense populations on each side of a fence, a single fence-line
110 is unlikely to hinder disease introduction in the long term, as a single fence breach may be
111 sufficient for a complete failure to contain a disease (Figure 1A). Breakage of fences, and the
112 time between breakage and repair, was crucial for effectiveness of fences in the combat of

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FMD (Dion, VanSchalkwyk & Lambin 2011). Monitoring of disease status is necessary to detect and respond to disease introduction on the disease-free side of the fence. Using more than one fence line can markedly increase effectiveness (Bode & Wintle 2010) and limit fence-line contact (Figure 1C). Fencing is more likely to efficiently stop disease spread if it is at the distribution border for hosts, or that hosts are actively eradicated on one side of the fence, as fence breaches are not equally devastating (Figure 1B). In extreme cases, fencing is reversed and discussed to contain the few remaining healthy populations, as with cancer of Tasmanian devils in Australia (Bode & Wintle 2010).

Figure 1. Perimeter fencing is unlikely to work with (A) a single fenceline with hosts on each, while it is more likely to work with (B) host on only one side or with (C) double fencelines.

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4 | PRACTICAL DETAIL IS KEY

Construction details are critical (Vercauteren, Lavelle & Hygnstrom 2006), and in particular carnivore fences have developed in sophistication in Australia (Hayward & Kerley 2009). Animal behavior towards fences differs markedly. Some species challenge fences, some jump over, some crawl under, while pigs are notorious diggers and fences need to be dug into ground. Jumping by antelopes over perimeter fences was considered the main FMD infection risk to cattle (Sutmoller et al. 2000). Mule deer and white-tailed deer (*Odocoileus virginianus*) both jump over and crawl under fences (Burkholder et al. 2018), while pronghorn (*Antilocapra americana*) crawled under and were reluctant to jump fences (Jones et al. 2018). Experiments with white-tailed deer showed deterrence rates of 0% for fences ≤ 1.5 m, 14% at 1.8 m, 85% at 2.1 m, and 100% at 2.4 m (Vercauteren et al. 2010). We lack such data for European species. In Norway, 1.6 m height of fences was erected for wild reindeer to contain CWD. Though this is the standard height of fences in the semi-domestic reindeer husbandry, we regard this as too low for effective containment of wild reindeer. During winter 2018, 34 % of the 1.6 m high CWD fences was under snow and that 35 % was less than 1 m above snow providing limited barrier to reindeer (Figure 2B). Standard wildlife fences along roads in Norway is 2.5 m effective height for moose (*Alces alces*) and 2.2 m for red deer, roe deer (*Capreolus capreolus*) or reindeer (Statens vegvesen 2014). Hence, we need evidence based standardization of fence height across sectors.

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147 **Figure 2.** Norway has erected 24 km of fences to contain the CWD zone. (A) The fence end towards
 148 steep terrain has not worked as anticipated (photo Atle Mysterud), and (B) snow lead to low barrier
 149 effect during winter (photo Harald Skjerdal).

150 **5 | PLACEMENT**

151 Placement of perimeter fences is important. The front of epidemic disease spread are often
 152 uncertain and may change from decision to implementation. Barriers showing to limit gene
 153 flow are important predictors of disease spread (Robinson et al. 2013). Genetic structure has
 154 identified semi-permeable barriers like rivers and roads and limiting speed of spread of CWD
 155 in white-tailed deer (Lang & Blanchong 2012) and mule deer (Cullingham et al. 2011). Data
 156 deriving from GPS-collared wildlife can inform effective placement of fences. Fences along
 157 natural barriers to strengthen them, rather than along administrative borders as planned for
 158 ASF, are more likely to be effective. In the case of CWD in alpine reindeer in Norway, forests
 159 were assumed effective barriers, and the fences in alpine habitat follow the roads FV50 and
 160 RV52 that were quite strong barriers even before fencing. We should also take advantage of

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existing road fences when aiming to contain wildlife disease. However, many human infrastructures such as road intersections and smaller human settlements, but also lakes and rivers, will regularly require openings reducing their efficiency. Many wildlife species use roads for travel, especially during nighttime with low human activity. Related to this is the issue of fence length and challenges near fence ends. Short fences were less efficient in reducing wildlife–vehicle collisions, most likely caused by increased crossing frequency and hence accidents near fence ends (Huijser et al. 2016). In Norway, semi-domestic reindeer have crossed into the CWD contaminated zone at the fence end (Bergum 2018). Since the fence end towards a steep mountain was not as strong a natural barrier as anticipated (Figure 2A), the Norwegian Food Safety Authority will fence the 4 km gap and add another 8.7 km of fences towards the southeastern fence end. Part of the problems with snow covering CWD-fences (Figure 2) arose from suboptimal fence placement relative to local topography due to restrictions of landownership and livestock grazing rights. Legislation can hence limit optimal placement of fencing for disease control.

6 | TRANSMISSION MODE AND HUMAN SPREAD PASS FENCES

Limited discussion has been devoted to mechanisms of disease spread for the effectiveness of perimeter fencing. Vector-borne and multi-host diseases involving smaller species will be difficult to control with fences. CWD have often spread by transport of farmed deer or possibly by hunters wasting contaminated parts of deer. The recent ‘jump’ of ASF all the way to wild boar in Belgium demonstrate fencing is unlikely to solve the problem of what is likely human mediated spread (Blenkinsop & Trompiz 2018). Contaminated pork products and the illegal disposal of carcasses, being eaten and infecting wild boar, are significant means of spread of ASF (Depner et al. 2017). Fencing will be futile if contaminated sausages are thrown away by tourists along the highways. There are currently signs along major roads in Germany aiming to increase public awareness. The Danish government aim to eradicate wild

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boar on the Danish side of the fence to avoid ASF in the economically important domestic pig industry (export of \$5.5 billion annually (Reuters staff 2018)) is therefore probably necessary, and a considerable challenge.

7 | HOT SPOT FENCING

Hot spot fencing are a potentially important way of reducing transmission of diseases once endemic, but require again that construction of fences are well thought through. A single fence breach does not necessarily have similar serious impact as for perimeter fencing. Mineral licks are hot spots for the prions causing CWD (Plummer et al. 2018). In Norway, mineral licks are mainly used for keeping livestock in a limited area rather than for nutritional purposes, but the agricultural minister is unwilling to cease the use of salt licks even within the CWD contaminated and adjacent areas. In Norway, the Norwegian Food Safety Authority therefore used more than 1 million Euro to fence around 600 salt licks (Figure 3). In this case, an opening large enough for sheep, but in theory too small for cervids was constructed. In practice, anecdotal evidence suggests that both red deer and semi-domestic reindeer have entered the fenced area (Bergum 2018). The construction of the openings meant for livestock need to be improved. Further, too small fenced areas around salt licks may still allow CWD transmission if not all the contaminated soil is contained and open for ingestion. Supplemental feeding of cervids is a common management practice, but typically not legal in CWD areas. However, ceasing feeding may significantly increase unintended feeding through stored forage for livestock. Hot spot fencing was efficient in reducing access to such feed both among white-tailed deer in Michigan, USA (Lavelle et al. 2015) and elk (*Cervus canadensis*) in Manitoba, Canada (Gooding & Brook 2014). Some individual deer tried at a low frequency to retain access to feed after fencing. Therefore, maintaining integrity of fences over time and closing gates at all times was essential for their efficacy (Lavelle et al. 2015).

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Figure 3. Norway has erected hotspot fencing of livestock mineral licks to reduce likelihood of CWD transmission (photo Atle Mysterud).

8 | CONCLUSIONS

The cost-benefit ratio of fencing in terms of money is one thing (Bode & Wintle 2010), but the full socioeconomic costs may not always outweigh the benefits (Thomson, Vosloo & Bastos 2003). Transmission of bovine tuberculosis among wildlife (white-tailed deer and elk) and livestock has created important risks for conservation and agriculture, but farmers dislike the idea of fencing Riding Mountain National Park in Manitoba, Canada (Brook et al. 2013). The degree of seriousness of a given disease clearly affect the public attitude towards management actions (Peterson, Mertig & Liu 2006), and the economic consequences of CWD, and even more so ASF, make fencing one of several actions likely to be implemented. As of today, we cannot say such perimeter fencing to combat wildlife disease is evidence-based. Fencing have several adverse effects on both target and non-target wildlife species. We therefore recommend that management actions involving fencing are evaluated scientifically,

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as its use is likely to increase with serious wildlife diseases spreading. This will provide management with knowledge that can be used when the politicians asks for solutions to eradicate or limit wildlife diseases.

Authors' contributions

AM conceived the idea and wrote the first draft, while CMR commented and further developed the draft.

Data accessibility

This paper does not contain data.

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