WILDLIFE BIOLOGY

Research article

How fences communicate interspecies codes of conduct in the landscape: toward bidirectional communication?

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Wildlife Biology
2023: e01146
doi: 10.1002/wlb3.01146

Subject Editor: Nuria Selva
Editor-in-Chief: Ilse Storch
Accepted 7 September 2023

The fence provides two functions in wildlife management. First, it physically blocks, deters or impedes wild animals from access to protected areas or resources. Second, the fence signals impassability, danger, pain or irritation to animals through both of these pathways: the actual blockade and the signal of no access both communicates to wild animals that they should stay away, producing area effects which constrain animal mobility. The mere presence of a fence, while imperfect and potentially passable, can come to establish an area effect of avoidance. In this regard, fences are part of an interspecies communication on the basis of mutually understood signals in the landscape. In this paper, we consider how fences, both physical, such as walls, and virtual, such as 'biofences' that use sensory deterrents, signal danger or no access to wildlife, and with what practical and conceptual limitations. Through a framework of ecosemiotics, the communication of signals between wildlife and humans, we discuss the communicative role fences play in human–wildlife interactions. First, we outline the way in which ecosemiotics may be leveraged to manage human–wildlife conflicts by utilizing fences as signals. Then we explain miscommunication, and how this impacts the success of fences. Finally, we discuss the normative problems of attempting to signal to wildlife how to behave and where to be, and raise the need for bidirectional communication across species, such that wild animals are also seen as participants in negotiating space and access around humans.

Keywords: fence, semiotics, sensory ecology, wildlife management

Introduction

The fence against wildlife has proliferated in function and form throughout history. For example, directional fences corral wild animals onto wildlife underpasses, and restricting electric fences keep them away from agricultural crops or livestock (Umstatter 2011). There are also virtual fences whose sound, smoke or smell etc., deters wildlife and provides a *fence-like effect* despite lacking visible material presence (Hayward and Kerley 2009). Other fences may be the opposite: fladry and flags function as area markers to keep away wolves and coyotes (Musiani et al. 2003), but may in actual fact may be more symbolic, as these animals could easily pass the flags. In this regard, fences not only act as a physical barrier in the practical sense but, over time and through wild animal learning, they also communicate to wildlife *where they are and are not allowed* (Drenthen 2021). We thus argue that fences have a longer-term goal in wildlife management: they govern wildlife to 'play by the rules of the game', in shared landscapes. However, fences are imperfect and frequently fall short of this communicative role, resulting in miscommunication, unintended consequences of animal outsmarting them, or 'wrongly' learned lessons.

To understand the communicative properties of fencing, we take as our point of departure the semiosis of fences. Semiosis is the process of creating and transmitting meaning through the use of symbols or signs. In wildlife management, fences are part of a semiotic system of 'establishing physicality and giving meaning to [...] boundaries' (Mignolo 2020), by separating desirable protected goods from external threats. Yet the fence has yet to be seriously considered in the context of cross-species semiotics: often termed ecosemiotics (Brentari 2015). The communicative fence is predicated on the idea of wildlife correctly receiving (through their species-specific sensory capacities) and interpreting (through their cognitive capacities) the message that fence means stay away. This is typically achieved through, among other things, aversive conditioning by the fence's deterring technologies.

Taken further, an ecosemiotic understanding of fences in wildlife management may also promote the idea that wild animals have the ability to, over time, internalize codes of conduct in relation to not trespassing in certain areas, not predating on livestock, or refraining from raiding farmers' crops because of associations with past negative stimuli of various kinds. The widespread use of electric fences, repellents like waving flags or flaps, shrapnel, flashing lights, infrared radiation, olfactory and acoustic emissions in wildlife management, seem to support this basic idea – animals can learn and do not need to 'try' the fence anew every time for passability. They may learn this also through the observation of their conspecifics suffering pain or injury at a fence. But actually communicating to wildlife about standards of propriety over space also encounters some pragmatic and conceptual problems. The fence, as an ideal, does not always deliver.

In this paper, we critically conceptualize the possibilities and limits to interspecies communication by considering semiosis of material and virtual fences. In particular, we engage with the fence as an imperfect conveyor of signals to wildlife, which sometimes has counterproductive outcomes because either the underlying reasons for the animal crossing this barrier are insufficiently addressed, or because we imperfectly understand the sensory capacities of that animal to get the right message from the signal. In applying ecosemiotics to fences in wildlife management, we aim to put sensory social sciences in dialogue with sensory ecology. We contend this is an instructive way of understanding and conceptualizing animal learning in relation to symbolic communication in the landscape.

We frame our arguments around use of semiosis to govern of wildlife (i.e. wild animals receiving a signal about the meaning of a landscape intervention and acting upon it in a way that managers have predicted), the miscommunication of signals (i.e. the signal may be poorly calibrated to resonate with the target wildlife species and/or give rise to undesirable adaptations), and finally the need to adopt negotiations into the management of human–wildlife interactions. By negotiations, we refer to ecosemiosis taking its point of departure in bilateral exchanges of communication between species, and not a one-way didactic communication from humans to govern wildlife mobility.

Semiosis in wildlife management

Semiosis denotes the process by which signs or symbols are used to communicate meaning between individuals or groups (Barbieri 2009). It involves three key elements: the signal, the object to which the signal refers, and the interpretation of the signal by the receiver. The study of bio-, eco-, or zoosemiosis emerged to understand how animals signal with one another and with humans using various channels for communication (Sebeok 1972, Farina 2012, Maran et al. 2016, Tønnessen 2016). While some still maintain that animals lack capacities for *culturally* learned symbolic communication (Scott-Phillips 2015), semiotics appears in increasingly frequent use to explain and inform interspecies signaling among species of various cognitive abilities (Hediger 2013).

In this paper, the ideal fence functions as a sign to govern where wildlife can and cannot be. Across the diversity of fences, material and virtual, the signals of the fence may be emitted through visual, tactile, auditory, olfactory or gustatory channels. They all contribute, ideally, to signifying an area/barrier as a no-go zone in ways that make sense to the particular species. It is because of the semiotic properties of a fence that its physical structure can be imperfect and porous, and yet still successfully signal to wildlife to keep out. Indeed, some fences may be practically passable for wildlife, but their symbolic presence, often visual manifestations, provides the functional deterrence.

For example, a ground fence armed with high flapping flags every two meters that ripple in the wind is not an obstacle to birds in theory (who, after all, can simply fly over it), but the effect is they treat it as a barrier (Månsson et al. 2012). Fladry corrals to deter wolves from livestock pastures have also been used successfully, both historically and in contemporary settings (Iliopoulos et al. 2019), even if their effectiveness wears off with time (Davidson-Nelson and Gehring 2010). In another example, a fence that was once material but has now decayed to become passable for wildlife, is shown to still constitute a barrier and govern wildlife behavior through a so-called site fidelity effect (Dupuis-Desormeaux et al. 2018).

Physical fencing is so prolific that there are few, if any, boundaries in the terrestrial landscape that were not signified by e.g. a border, a wall, or even a hedgerow at one point. Traditional physical fences are permanent in space and tend to persist through time. The boundary-enforcing effects of fencing are not limited to traditional material fences, and can also be achieved through deterrents which form a virtual fence, sometimes called a metaphorical fence (Hayward and Kerley 2009). The virtual fence is frequently lauded by managers and ecologists as a 'minimal' solution, not risking fragmentation of the landscape or visual pollution to humans (McInturff et al. 2020). It is also argued to provide greater precision, preventing non-target species from getting tangled up in wires and harming themselves.

Virtual fences typically attempt to govern wildlife by evoking 'fear' or 'disgust' responses that have been informed by past experiences of harm or adverse physiological effect, or 'taught' through animal-cultural learning (Laland and Janik 2006). The virtual fence is ostensibly invisible to the naked eye, but signals from virtual fences work in ways semiotically similar from conventional fences, in that they can be olfactory, tactile, visual, acoustic or even gustatory (Jachowski et al. 2014). The goal of this type of communication is for the signal to carry a certain meaning, which becomes known among wildlife communities over time through aversive conditioning, as an area to avoid.

When signaling is effective, to the extent that the animal interprets a signal as desired by humans and adjusts its behaviors accordingly, we may see so-called 'area effects' where some spaces are avoided out of fear (Parsons et al. 2018). Studies show that virtual fences have the potential to have as strong of a semiotic effect on wildlife as physical fences, but without the visual manifestation. Pschera (2016) writes of transmitter-equipped elephants: 'should one of these tuskers venture too close to a farm or village – will send a text message to the rangers, who can then quickly locate and redirect the animals. Elephants are so intelligent that they take note of these rebukes – or interactions, when it really comes down to it – and avoid these virtual fences in the future' (p. 85).

In order for virtual fences to be successful, the signal must be received or interpreted by the receiver as desired. This often means relying on the receiver's prior knowledge and experience and the context in which the signal is occurring. Sensory signals are often used for this purpose. For example, chemical odors that are associated with stress or trauma from poisoning may trigger aversive memories and one may avoid proximity to these odors (Parsons et al. 2018). Signals of a virtual fence can become activated upon motion sensor detection, emitting for example shrill noises, infrared radiation (as for reptiles), ultrasound (bats and rodents), sounds of human voices or dog barks, flashing lights or air cannons that eject shrapnel-like particles to deter geese. Innovation of fences, and in particular fences with deterrents, has been driven also in part by the need to reduce wildlife collisions at highways, railroads and other traffic (Babińska-Werka et al. 2015), but also to protect farms from crop-raiding (Widén et al. 2022). For deterrents to be effective, they need to be controllable and predictable for animals, so that they are temporally and spatially related to a threat (e.g. an oncoming train) in order to enforce the learning and reduce overexposure and habituation (Bhardwaj et al. 2022). But like any other signal, there is always the possibility for miscommunication and for message transmission to fail.

Miscommunication – failures of symbolic communication?

Morizot (2022) suggests that misunderstandings between species – over territories, property and access rights and the understanding of signifiers, can provoke a diplomatic crisis. It is 'an inability to interpret an ethos, an inability to communicate in a common code or to develop adaptive modes of interaction.' (p. 12). To explain such failures in semiotic terms, one can talk about miscommunication through faulty signaling. We summarize three main ways this can fail.

First, and straightforwardly, the signal may simply be poorly calibrated to the target species' by, for example, having insufficient knowledge about what triggers them. While the perceptual abilities of the animal may remain the same over time, their response may differ across certain time periods, given investment in activities like brooding, nesting, mating, foraging, caching or hibernating (Stevens 2007). As Elmer et al. (2021) summarize of this sensory calibration: 'Not only do we need to predict what sensory cues and signals an animal will respond to at a particular time, but also how that animal will respond in its given condition and environment' (p. 18).

Månsson et al. (2012), for example, found that fencing to keep out geese and cranes from bodies of water were most effective during their molting and brooding periods. For that reason, a deterrent that uses a pain stimulus – like an electric fence – may be effective to repel a target species from crops during summer months: a deer or wild boar's risk assessment of the fence changes to 'it's not worth it' when food is plentiful. But such a deterrent may lose its effectiveness the scarcer food becomes, and hence what is on the other side of the fence becomes considerably more attractive and worth the risk. Iliopoulos et al. (2019) found that wolves test electric fladry fences more boldly when their hunger levels increase. At other times, elephants defy electric and chili fences (Mutinda et al. 2014).

This leads us to the second form of miscommunication, a failure to understand and address the underlying reasons why wild animals may persist in defying fences. These reasons are not always reducible to static species motivations or fluctuating hunger or hormone levels, but may change depending on *external* circumstances like rising water levels, seasonal changes, and climate change.

In a recent example, beavers colonized a creek near a Dutch food forest, whereupon the farmer feared the beavers would consume his fruit and nut trees. In order to protect them, he wrapped them in chicken-wire fencing. The local water authorities were also concerned that the shift in water levels from the beaver damming would negatively affect farmer's interests. They decided to install a so-called 'beaver deceiver' device: a plastic pipe inserted through a beaver dam to ensure that water still continues to flow through the dam. In a move of escalation, this was not accepted by the beavers, who decided to build a new dam downstream, flooding the first dam, including the beaver deceiver. Apparently they failed to appreciate the reasons why beavers build dams. As precipitation changes, the beavers use the landscape differently, and hence drivers for felling trees vary.

In the third form of miscommunication, the signal may be adequately received, but the message not. In early ethology works, Smith (1965) distinguished between 'message' and 'meaning' in semiosis for this reason. As contended, an animal's reading of the message depends on its cognitive capacities, its past experiences, the context of the situation, and the configuration of its environment (Maran et al. 2016b). For example, what may be intended by a landowner as a signal for danger to deter the animal, may become functionally construed as invitation. Slovenian farmers express frustration over the failure of their use of fire to ward off wild boar from their fields, which instead becomes a signal that 'hey, there is food here' and acts as a spotlight directing boar to the crops (Kozorog 2022).

In other cases, bird effigies – like silhouettes of larger predatory birds to repel smaller birds from for example fruit fields – do not have the intended effect of keeping the target species away, because corvids try to attack the effigy instead. Here, the initial signal was correctly received but the response to the signal was not as predicted. Moreover, fences to keep out contagion or invasive species have sometimes promoted the movement of the very species they intend to keep out, such as invasive cane toads in Australia (McInturff et al. 2020). An angry cockatoo in Australia famously defiantly tore away anti-nesting spikes from a ledge so that it could walk freely. Barua (2021) discusses this phenomenon as one of 'repurposing' by animals of human infrastructures, using them in ways that become subversive to their original goals.

In the fourth and final form of miscommunication, the signal may simply be too broad and resonate with target and non-target species alike. Unless signals can be calibrated to specific species (which may be difficult), there may thus be collateral damage or bycatch. There is much research demonstrating this effect of fences, including exclusion fences for pests that end up deterring, harming the welfare or ecological integrity of endangered or protected species (Ferronato et al. 2014, Trouwborst et al. 2016). Collateral damage may also be associated with landscape effects. Fences erected for one purpose, such as Kruger National Park's fence aimed at controlling the spread of foot-and-mouth disease by blocking migration routes of elephants in the area, for example led to overgrazing in some areas and increased conflict with humans (Ferguson et al. 2012). In a famous case, predators sometimes use fence to hunt prey, cornering them and flushing them out. Rhodes and Rhodes (2004) found that prey species, including the kudu, are strategically chased by African wild dogs into fences, making some 81% of their kills within 20 m of this barrier, even though these zones made up only 1.7% of their total area.

Unlike physical fences, virtual fences can be adaptable in time and scape, only called into action in contexts when they are needed rather than standing permanently, which means virtual fences also provide something that physical fences cannot – a means of adaptive management that can be targeted in space and time and to species. In cases where management appears to 'fail' one can reframe the situation and address the signal as being miscommunicated. This is exemplified in, so-called 'rogue' or 'problem' individuals that appear to ignore signals designed for the average member of their population (Garvey et al. 2020). Triggered by hunger, animals can sometimes develop unforeseen alternative 'solutions': in Yorkshire, a group of hungry sheep found a way to outwit a 3 m wide hoof-proof metal grid meant to protect village gardens from being eaten, by learning to roll over them (BBC News 2014). Individual animals can sometimes learn these new solutions by observing and imitating humans: in a wildlife sanctuary in south India, where elephants learned to cross the deep elephant trenches that the forest department had dug to keep them away, by observing humans who use planks to cross the trenches, and quickly learn how to balance over these narrow planks and get across (Münster 2014). Mutinda et al (2014) also found that young elephants may be sent 'into' and 'across' both electric and chili fences by older elephants to test them. These cases represents some classic hallmarks of escalation and one-upping in wildlife management whereby animals outsmart, adapt, take over infrastructure designed to deter them (Krieg et al. 2020, Barua 2021). The typical response to animals outwitting fences is an attempt to redesign these fences (Koech 2021), or make intrusive interventions in animal lives, like detusking elephants if they use their tusks to outmaneuver fences, which in turn can prompt animals to find new ways to outsmart them.

Such scenarios highlight where managers fail to capture an important aspect part of semiosis – that is communication between two parties. Wildlife management tends to be directional, so humans are often communicating or governing wildlife but are not receptive to communication from them. We argue for the need to incorporate negotiations in the process to improve management and to make full use of the dynamic technology that for example virtual fences offer.

Toward negotiation?

Management is often double-sided with both care and control (von Essen et al. 2023), and there may be examples where fences and deterrents can be said to benefit the interests of wildlife – such as for example, fences separating them from railroads, deterrents pushing them away from collision with wind turbines or other harmful environments (Machtans 2013). Wildlife management seeking to control wildlife mobility may be more likely to succeed when it draws on animal motivations rather than against them (Berger-Tal et al. 2011, Garvey et al. 2020, Bhardwaj et al. 2022), or a combination of the two (Cook et al. 2007). This has been suggested for use in for example species relocation projects, in which these animals may at first need to be 'guided' around for acclimatization and safety (Elmer et al. 2021). However, fences and deterrents in wildlife management overwhelmingly manifests humans 'project[ing] expectations onto the landscape, expectations that dictate judgments of which species belong in human-built spaces, and which do not' (Gordon 2022).

With further practical application of ecosemiotics in the landscape in wildlife management, research can make clear *what* the challenges are, and *how* they can be met, and *why* we should try to live together with them requires a normative view on human–wildlife coexistence, that focuses on moral questions. Initially, that will be a conversation of humans amongst each other. The implicit assumption of the common practice of fencing and other means, is that humans should seek to deter or control specific animal behaviors, whereby humans are the unilateral determiners of the terms of the contract over landscape access, space use and coexistence. However, if we take seriously the normative dimension of human–wildlife coexistence, this one-sided relation cannot be the whole story.

Rather than seeing interspecies communication as an attempt to *impose* a certain social contract, we propose to interpret it as part of a negotiation process over the use of shared space, or as a form of diplomacy using a sensory lingua franca (Morizot 2022). However, sometimes animals will refuse to behave according to the plan that was laid out for them. In that case, we argue, negotiations begin: the animal will respond, creating a new situation, and raising the question whether that new situation is acceptable to humans. Sometimes an 'opening bid' will not be accepted by animals. In that case the challenge is to find out why and seek a new arrangement that better meets the other's requirements.

In the abovementioned case of attempting to communicate to beavers to stay away from fruit trees in the Dutch town of Groesbeek, the process of interspecies negotiation between different users is partly demonstrated (Haverkamp 2023). Completely fencing off the fruit trees from the beavers has not been deemed feasible or desirable, given that beavers could easily dig under this barrier, and that wildlife can play important roles in pest control inside the forest. In this case, the farmer has established a willow tree buffer zone of 3 m that ostensibly offers beavers all they need, and takes away their motive for entering the forest and cutting down fruit trees (Willems 2023). Thus, the buffer zone can be seen as a fence-like opening bid in a negotiation process for finding co-existence.

In addition to this, to satisfy the beavers' need for managing water levels, the farmer pulls out some branches from the dam every week, allowing some water to pass through again, thus bringing the water to an 'acceptable' level for his food forest. In the following days, the beavers in turn repair that dam, forcing the farmer to remove some branches again a week later. We could interpret this as an ongoing battle between conflicting parties, but that would be too one-sided an interpretation. Indeed, the food farmer is happy to regularly repeat this relatively minor intervention to take the sting out of the conflict, and the situation seems to be manageable for the beavers in this way too. In this way, a dynamic equilibrium has emerged in the negotiation process that is acceptable for both parties, and requires an effort that can apparently be tolerated. There is a dynamic equilibrium not only because the situation requires constant active intervention by both parties, but also because this interaction is adaptive: beavers become allies of the farmers in times of drought (Rivierenland 2023).

In other words, in some cases the inter-species communication is bi-directional, creating a negotiation process in which both parties can flourish, leading to a dynamic equilibrium. However, such a balance will always be provisional, if there is inherent tension between the parties' interests, changing circumstances (rising water levels, seasonal changes, climate change) may call for a re-negotiation. The creation and maintenance of such equilibrium will take time and effort, but more importantly, depends on one's normative stance towards coexistence with wildlife.

Conclusion

Using signals in the landscape to teach wild animals the codes of conduct or 'rules of engagement' (Hunold and Mazuchowski 2020) forms the basis for interventions and infrastructures in wildlife management. We explored the role of fences as signals in the landscape, and demonstrated how signaling can go awry in light of the many variables that govern how an animal will receive, interpret and respond to a signal. To this end, there remain other practical and conceptual problems with communicating to wildlife about codes of conduct in this way – enforced both by deterrents/punishment and lately also rewards. As we argued, a guiding fence put up by humans, protecting for example traffic against wildlife collisions and vice versa, will only be successful if one acknowledges the reason why an animal wants to cross the road in the first place. This was illustrated in the case of deterring beavers from fruit trees. But more importantly, we need to merge ecosemiotics and technical innovations in wildlife management also with a normative questioning of what it means to share landscapes with wildlife, and how such rules and preferences about space can be expressed. Innovating fence technology may be less about finding premises for coexistence than maintaining the separation of species in multispecies landscapes, even if some fences now also attempt to direct wildlife to sanctuaries. Our critique was that current approaches fail in acknowledging the two-way direction of interspecies communication, with humans ending up as unilateral 'teachers' of interspecies codes of conduct, on their terms. Demonstrably, a wildlife management approach, such as fencing, fails when the animals in question cannot accept the proposed terms, for instance because the proposed arrangement does not conform to their behavioral repertoire or does allow them to meet their essential needs. A sustainable solution to a conflict can only be reached if the basic needs of both parties are recognized.

Several insights may be imparted: first, we may helpfully think of for example buffer zones as an opening bid in negotiations for space between human and animal users. Second, not dissimilar to peace treaties, external circumstances may change, including water and vegetation affordances, hunger levels, and changing priorities of animals across seasons, and these necessitate finding a new equilibrium. In keeping with this metaphor, if a peace agreement between conflicting parties at war neglects the basic needs of one of the parties, it is inevitable that the peace treaty will eventually be breached. The important difference is of course the inevitable asymmetry in case of interspecies communication: humans will be responsible for finding a just and sustainable solution to the conflict with wildlife. Third, it is important to try to distinguish between failure of the signal to reach the animal on the one hand, and on the other hand, refusal of animals to accept the deal because the proposed spatial arrangement does not leave them enough space to live a flourishing life.

Acknowledgements – We are grateful to Annika Pohl Harrison and Michael Eilenberg at the School of Culture and Society – Department of Anthropology with Aarhus University for hosting the first author at a four-day fence symposium in 2022, which helped inspire and develop this paper. We also thank our reviewers for their insightful feedback on everything ranging from semiotics to fence design.
Funding – This paper was developed with support from the FORMAS-funded project 'License to Cull: Investigating the Necropolitics of Countryside Culling and Urban Pest Control.' (2020–2023) and The Dutch Wildlife Comeback: Dynamic co-management of human–wildlife interactions in the Netherlands (WildlifeNL).

Author contributions

Erica von Essen: Conceptualisation (lead); data curation (equal); formal analysis (main); resources (equal); visualization (equal); Writing original draft (main); writing - review and editing (main) . **Martin Drenthen**: Conceptualization (supporting); Data curation (supporting); Writing – original draft (supporting); Writing – review and editing (supporting). **Manisha Bhardwaj**: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Resources (equal); Visualization (equal); Writing – original draft (supporting); Writing – review and editing (equal).

Transparent peer review

The peer review history for this article is available at https://publons.com/publon/10.1002/wlb3.01146.

Data availability statement

This paper contains no new data.

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