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Impacts of wildlife baiting and supplemental feeding on infectious disease transmission risk: A synthesis of knowledge

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ABSTRACT

Baiting and supplemental feeding of wildlife are widespread, yet highly controversial management practices, with important implications for ecosystems, livestock production, and potentially human health. An often underappreciated threat of such feeding practices is the potential to facilitate intra- and inter-specific disease transmission. We provide a comprehensive review of the scientific evidence of baiting and supplemental feeding on disease transmission risk in wildlife, with an emphasis on large herbivores in North America. While the objectives of supplemental feeding and baiting typically differ, the effects on disease transmission of these practices are largely the same. Both feeding and baiting provide wildlife with natural or non-natural food at specific locations in the environment, which can result in large congregations of individuals and species in a small area and increased local densities. Feeding can lead to increased potential for disease transmission either directly (via direct animal contact) or indirectly (via feed functioning as a fomite, spreading disease into the adjacent environment and to other animals). We identified numerous diseases that currently pose a significant concern to the health of individuals and species of large wild mammals across North America, the spread of which are either clearly facilitated or most likely facilitated by the application of supplemental feeding or baiting. Wildlife diseases also have important threats to human and livestock health. Although the risk of intra- and inter-species disease transmission likely increases when animals concentrate at feeding stations, only in a few cases was disease prevalence and transmission measured and compared between populations. Mostly these were experimental situations under controlled conditions, limiting direct scientific evidence that feeding practices exacerbates disease occurrence, exposure, transmission, and spread in the environment. Vaccination programs utilizing baits have received variable levels of success. Although important gaps in the scientific literature exist, current information is sufficient to conclude that providing food to wildlife through supplemental feeding or baiting has great potential to negatively impact species health and represents a non-natural arena for disease transmission and preservation. Ultimately, this undermines the initial purpose of feeding practices and represents a serious risk to the maintenance of biodiversity, ecosystem functioning, human health, and livestock production. Managers should consider disease transmission as a real and serious

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concern in their decision to implement or eliminate feeding programs. Disease surveillance should be a crucial element within the long-term monitoring of any feeding program in combination with other available preventive measures to limit disease transmission and spread.

1. Introduction

Many wildlife populations aggregate in small spatial areas in response to human modifications of the environment. A good example of such a modification is the placement of supplemental feed, either via bait, or natural or artificial forage within the native habitat of species. Supplemental feed is provided to wildlife across numerous parts of the world to address various ecological and socio-economic purposes such as alleviating winter mortality (Weidman and Litvaitis, 2011), increasing reproductive success (Robb et al., 2008b), controlling wildlife damage to crops and the environment (van Beest et al., 2010), reducing wildlife–vehicle collisions (Andreassen et al., 2005), controlling animal migration routes (Sahlsten et al., 2010), and optimizing hunting and tourism opportunities (Corcoran et al., 2013; Geisser and Reyer, 2004).

The effectiveness of wildlife feeding to fulfill the above mentioned factors is ambiguous and reviewed in more detail elsewhere (Putman and Staines, 2004; Robb et al., 2008a). Less well-known, and an under-appreciated biological problem, is the potential role of feeding and baiting on inter- and intra-species disease transmission risk. This is surprising as the risk of disease transmission and outbreak in native species has been recognized as one of the major threats to biodiversity around the globe (Daszak et al., 2000). In North America specifically, concerns have been raised regarding the ecological and economic impacts of such feeding practices following the emergence of chronic wasting disease (CWD) in free-ranging and domestic elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus hemionus*), black-tailed deer (*Odocoileus hemionus columbianus*), white-tailed deer (*Odocoileus virginianus*), and moose (*Alces alces*), and outbreaks of bovine tuberculosis and brucellosis in elk and white-tailed deer (Brown and Cooper, 2006; Cross et al., 2010; O'Brien et al., 2011; Peterson et al., 2006; Brook et al., 2013).

The purpose of this paper is to provide a comprehensive review of existing literature on the effects of baiting and feeding wildlife on species health; particularly in relation to disease transmission in large herbivores in Northern America. Our objectives were to: (1) define and characterize the aims of baiting and feeding of wildlife, (2) examine the mechanisms that facilitate disease transmission in relation to feeding and baiting, (3) present a set of case studies that have investigated the role of feeding and baiting on transmission of infectious diseases, (4) evaluate the implications of baiting and feeding wildlife for human and livestock health, and (5) assess the potential and efficacy of current management approaches available to reduce disease transmission risks associated with baiting and supplementary feeding of wildlife.

2. Baiting and feeding wildlife: definitions and objectives

Baiting of wildlife involves the purposeful placement of natural or artificial food resources in the environment to manipulate the behavior of wild species so as to attract and/or retain them in an area. Regulations regarding baiting wildlife vary significantly between regions and countries, ranging from being fully accepted to complete bans on their use. Additional attractants such as scent lures, calling devices, or decoys may be utilized for baiting purposes (Lothrop et al., 2012). Baiting is typically used for the purposes of (i) attracting wildlife to a specific location to enhance hunter harvest, trapping, or viewing opportunities (Litvaitis and Kane, 1994; Obbard et al., 2008); (ii) capturing wildlife for research purposes including animal relocation or population augmentation and restoration (Barrett et al., 2008); (iii) capture, vaccination, and/or treatment of animals for control of infectious diseases and vectors (Cross et al., 2007a,b; Fletcher et al., 1990).

Supplemental feeding can be broadly defined as the placement of natural or non-natural food into the environment with the goal of augmenting the regular natural food source of a given wild species. Feeding is conducted across a wide range of spatial scales including citizens occasionally distributing feed on their property (Robb et al., 2008a), as well as large scale provincial or state-funded programs. For example, several thousand elk are artificially fed each winter in the National Elk Refuge, Wyoming, USA (Smith, 2001). Supplemental feeding can also be unintentional, as wild species target garbage dumps (Lunn, 1986), livestock feeding troughs (Atwood et al., 2009), compost heaps (Gabrey et al., 1994), and standing or baled agricultural crops (Brook, 2010; Brook et al., 2013).

Supplemental feeding is the provision of food by humans with the intention to enhance some specific physical characteristics of individuals or to benefit population dynamics, e.g. increased antler growth, fecundity, and survival (Hansen, 1987; Ozoga and Verme, 1982). Winter feeding is as specific type of supplemental feeding to compensate for lower natural food availability for wildlife and higher energetic demands during winter conditions, primarily to prevent starvation mortalities and maintain body condition (Baker and Hobbs, 1985; Doenier et al., 1997). Intercept or diversionary feeding is the provision by humans of food at strategic places to modify animal distribution and movements so as to reduce environmental damage (Geisser and Reyer, 2004; van Beest et al., 2010; Ziegltrum, 2004), to divert wildlife away from major vehicle traffic corridors to reduce animal–vehicle collisions (Andreassen et al., 2005; Wood and Wolfe, 1988), or prevent disease transmission among wildlife and livestock (Brook, 2008).

3. Role of baiting and supplemental feeding in disease transmission

Large concentrations of wildlife activity centered around feeding or baiting sites have been widely implicated as a major mechanism influencing inter- and intra-specific transmission of infectious diseases (Hines et al., 2007; Miller et al., 2003; Thompson et al., 2008). If one or more individuals are carrying an infectious organism or prion, its transmission to uninfected individuals may be facilitated by higher rates of contact (i.e. direct transmission) between animals gathered at a single site (Miller et al., 1998). Indeed, fine-scale behaviors at baiting or feeding sites can enhance the levels of potentially infectious contact through actions such as sparring or muzzle contact (Garner, 2001). Direct transmission is especially problematic in social species, such as elk and deer, as contact occurs frequently and regularly within familial social groups (Marchinton and Hirth, 1984; Vander Wal et al., 2012). As animals congregate at a feeding site, contact rates can increase within familial groups but also among unrelated groups and individuals of other species (Blanchong et al., 2006). In addition, crowding of wildlife in confined spaces has also been shown to induce stress responses, which can reduce immune function and increase disease susceptibility (Forristal et al., 2012). Intra- and inter-specific aggressive interactions have also been observed at bait sites (Côté, 2001). Disease transmission can also occur when animals consume feed, water, and associated soil contaminated by the urine, blood, nasal secretions, saliva, or feces from infectious individuals (i.e. indirect transmission). Risks of infection increase when multiple individuals and species congregate in a confined area, such as bait sites or feeding stations (Garner, 2001; Thompson et al., 2008). The specific route and risk of disease transmission is, in part, dependent on the biology of the specific pathogen, which will be highlighted in subsequent sections.

4. Evidence for infectious disease transmission

4.1. Bovine tuberculosis

Bovine tuberculosis (bovine TB; *Mycobacterium bovis*) is a bacterial disease that occurs in wildlife and livestock throughout the world, predominantly in areas dominated by agriculture (Schmitt et al., 1997; Cosivi et al., 1998; Brook et al., 2013). In Canada, bovine TB was endemic in cattle until the mid-1960s and infected livestock are the most likely original source of infection to existing infected wildlife populations (Brook, 2009). There are two known Canadian endemic wildlife populations infected with bovine TB, free-ranging populations of wood bison (*Bison bison athabascae*) in and around Wood Buffalo National Park, Alberta, and elk and white-tailed deer in and around Riding Mountain National Park (RMNP), Manitoba (Nishi et al., 2006).

In RMNP, TB was endemic in cattle, probably from the 1880s until the 1960s and TB cases in wildlife species were sporadically found in and around the park from the 1880s to the 1980s (Brook, 2009). In 1986 Manitoba cattle were declared TB-free, but the disease quickly re-emerged in the RMNP area in 1991 when seven beef cattle herds bordering the park tested positive (Brook, 2009). In 1992, a wild elk shot in the vicinity of an infected cattle farm tested positive for the disease (Lees et al., 2003), followed by a positive hunter-killed white-tailed deer in 2001 (Lees, 2004). Following concerns about wildlife being a reservoir of bovine TB, a 5-year management strategy and implementation plan was developed to attempt to eradicate bovine tuberculosis from the greater Riding Mountain ecosystem (Nishi et al., 2006). In the management plan it was recognized that hay bales were functioning as an attractant to elk and deer and likely facilitated disease transmission between and among wildlife and livestock due to high levels of interaction, especially during winter (Brook, 2010; Brook et al., 2013). Baiting and feeding of elk and deer has been hypothesized to be a key factor in transmission of TB in the region and efforts have been made to reduce the use of baits (Brook, 2008). However, empirical evidence does not exist to link TB specifically to wildlife baiting in this region.

Similar biological and socio-economic impacts of bovine TB occur elsewhere in the world, including the United States. In 1994 the disease was detected in northeastern Michigan, USA in a population of white-tailed deer, without infected livestock to serve as the existing reservoir (Schmitt et al., 1997). Increased monitoring and testing of wildlife and livestock revealed more TB-positive deer, elk, dairy cattle, beef cattle, and wild carnivores, though it seems likely that deer were the reservoir and other species were spill-over hosts (Bruning-Fann et al., 2001; Dorn and Mertig, 2005). Prior to the implementation of a localized ban of baiting and supplemental feeding in 1999, 72% of non-resident hunters and 87% of resident hunters reported using bait when hunting in northeast Michigan (Dorn and Mertig, 2005). Additionally, 74% of resident hunters, 59% of business owners, and 54% of the general public also reported feeding deer prior to the ban (Dorn and Mertig, 2005).

State veterinarians and wildlife biologists long attributed the occurrence of the disease in this area in significant part to baiting and feeding practices by hunters (Schmitt et al., 1997). Supplemental feeding practices may serve as a primary factor in bovine TB transmission between matriarchal deer groups (O'Brien et al., 2011). Human-caused aggregations draw TB-infected deer into close contact with infectious animals (Garner, 2001), and increase the opportunity for bovine TB to spread through aerosols or saliva on partially consumed feed (Palmer et al., 2001; Schmitt et al., 1997, 2002). Additionally, supplementation of deer diets allow a much greater density of deer to survive each winter, leading to extremely high densities that exceed any previously recorded, which most likely facilitate bovine TB transmission (Schmitt et al., 1997). Miller et al. (2003) conducted a retrospective study to test the hypothesis that supplemental feeding of white-tailed deer from 1995 to 1997 was positively associated with the prevalence of bovine TB in Michigan. Results showed a clear correlation and the authors subsequently suggested banning supplementary feeding in all areas affected by bovine TB. However, there have been only localized and temporary efforts thus far to control baiting in this endemic area. Bovine TB remains a critical problem to populations of deer in Michigan and is an important threat to livestock (O'Brien et al., 2011).

4.2. Bovine brucellosis

Brucellosis is a chronic bacterial disease caused by *Brucella abortus*, and is found in livestock and wildlife populations around the world (Godfroid and Käsbohrer, 2002). It primarily affects reproductive organs, causing abortion in female hosts, as well as swelling of limb joints. Transmission within and between wildlife and livestock typically occurs through contact with infected fetuses and placentas following abortion events (Cheville et al., 1998). In the Greater Yellowstone Ecosystem (GYE), brucellosis in elk and bison has been a major issue following the introduction of the disease from cattle to bison shortly before 1917 (Meagher and Meyer, 1994). Arguably the best known studies on the effect of supplemental feeding on disease transmission risk and spread were done on bovine brucellosis in the GYE.

Since 1910, resource managers have been providing supplemental feed annually to elk in the southern region of the GYE (Smith, 2001). Brucellosis seroprevalence in elk found on supplemental feeding grounds in winter varied from 10 to 35% (Cross et al., 2007a,b), while unfed elk populations around the GYE historically had brucellosis seroprevalence values of 2–4% (Aune et al., 2002; Etter and Drew, 2006), and brucellosis was not known to persist in elk populations outside the GYE (Cheville et al., 1998). By 2009, however, brucellosis was found to be expanding its range into new regions and elk populations as levels of seroprevalence in areas distant from feed grounds had increased to levels comparable to those measured close to feeding grounds (Cross et al., 2010). Thus, feed grounds clearly sustain and intensify the problems of brucellosis within elk populations, and potentially increase exposure of livestock in the surroundings of GYE (Cross et al., 2007a,b). Similar to the issues of bovine TB, steps to reduce or eliminate the feeding practices have not been implemented, despite the clear risks of feeding.

4.3. Chronic wasting disease

Chronic wasting disease (CWD) is a neurological disease belonging to the group of transmissible spongiform encephalopathies (TSEs). In contrast with other TSEs, such as bovine spongiform encephalopathy in cattle or scrapie in sheep, CWD is currently known to only infect free-ranging and domestic elk, mule deer, black-tailed deer, white-tailed deer, and moose (Edmunds, 2008). CWD has now been detected in wild and domestic cervids in 15 states in the USA, 2 Canadian provinces, and South Korea (Saunders et al., 2012). CWD is both infectious and contagious (Williams et al., 2002) but specific details on the pathways of transmission remain poorly understood (Miller et al., 2006).

Research on CWD epidemics in captive deer and elk demonstrate strong evidence of lateral transmission, either through direct contact with infectious individuals, indirectly through contaminated environments (Miller et al., 1998, 2000; Williams and Young, 1992) or via inhalation (i.e. aerosol transmission; Denkers et al., 2013). Field-based monitoring has shown that CWD prions can remain infectious in the environment for at least two years (Miller et al., 2006). Prions released into the environment, either through urinary excretions (Seeger et al., 2005), or infected carcasses (Brown, 1998) can remain infectious even after passage through the digestive tract of scavengers (VerCauteren et al., 2012). Inter-specific transmission of chronic wasting disease among elk, mule deer, and white-tailed deer is arguably the most urgent and serious concern for wildlife management in North America. The risk of transmission is high to multiple ungulate species that are widespread across the continent, survival in the environment is extensive, and the disease is spreading over large areas through the movement of multiple infected hosts through transfers of both domestic and free-ranging ungulates (Williams et al., 2002).

Contamination of areas frequently used by deer or elk contribute to CWD epidemics (Miller et al., 2006). Indeed, conditions that facilitate high animal densities have been shown to increase the rate of CWD transmission (Miller et al., 2000). Artificial feeding and baiting sites are likely exacerbating CWD transmission within and between species (Spraker et al., 1997; Williamson, 2000). The exponential increase of chronic wasting disease within the last two decades has led to active CWD surveillance in most Canadian provinces and US states (Saunders et al., 2012). However, efforts are now waning or ceasing in some jurisdictions such as Saskatchewan, the province in Canada with the highest prevalence of CWD. Banning of baiting and supplemental feeding is generally considered a first and necessary control strategy in an attempt to limit the transmission and spread of CWD (Lischka et al., 2010; Williamson, 2000), however actual implementation of complete baiting bans have been limited at best.

4.4. Psoroptic mange in elk

Samuel et al. (1991) found that psoroptic mange, or scabies, predisposed 20–30 adult elk to die each winter on the National Elk Refuge in Wyoming. The artificial feed provided on this range aids in winter survival of elk herds in this area (Smith, 2001) but elk carrying the *Psoroptes* mite may also act as a reservoir for infection of sympatric populations of bighorn sheep (*Ovis canadensis*, Smith, 2001). The transmission of such scab mites in elk has been found to greatly increase with overcrowded conditions (Mills, 1936) and so the link with feeding seems evident.

4.5. Skin papillomas and fibromas in ungulates

Skin tumors have a wide distribution in North American deer of all species and subspecies, including mule deer and white-tailed deer in Western Canada (Cosgrove and Fay, 1981). They are also reported, but infrequently, in moose, caribou, and pronghorn. At least some of these skin tumors are known to be caused by a papovavirus which is transmissible through tumor cell suspensions coming in contact with open skin wounds (Cosgrove and Fay, 1981). Fine scale behaviors at baiting or feeding sites could increase the levels of infectious contact through actions such as sparring or muzzle contact (Garner, 2001). The tumors are generally localized at the attachment point and do not invade deeper structures although large tumors located on the head could interfere with vision or eating (Cosgrove and Fay, 1981). At present there is no scientific evidence that baiting or supplemental feeding of wildlife augments the risk of skin tumors. However, crowding at feeding stations is known to increase aggressive behavior (e.g. fighting and biting) of individuals between and within species (Bartos et al., 1996; Ferretti, 2011), which may increase the risk of open skin wounds and as such the transmission of papovavirus.

5. Disease management options in the wake of baiting and supplemental feeding

Providing wildlife with additional forage seems intuitively a promising management tool to address various ecological-, and socio-economic concerns. In addition, the relative ease of placing high quality bait or forage in the environment and the near certainty that animals will feed on it makes it an attractive management and or conservation tool, which is clear from the rapidly increasing number of feeding programs throughout the world. In some cases, the decision to feed wildlife is successful in reaching its initial aim. For example, supplemental feeding of black bears can be a cost-effective strategy to reduce damage to commercially valuable conifer species (Ziegltrum, 2004, 2006) or to reduce animal–vehicle collisions (Andreassen et al., 2005). However, it is becoming increasingly clear that increased animal densities around bait or supplementary feeding sites and associated changes in behavior can lead to various problems that may undermine the initial purpose of feeding. The risk of disease transmission between and among species, and the facilitating role that bait sites or feeding stations play, is perhaps the most potent risk of all in terms of safeguarding biodiversity. Below we highlight some of the disease management options proposed in the scientific literature.

5.1. Preventive measures

An often recommended solution to reduce the risk of disease transmission and spread in wildlife communities is to completely ban baiting and feeding as a management tool (Thompson et al., 2008; Williamson, 2000). However, a legislative ban on baiting and supplemental feeding is not always feasible due to other ecological or socio-economic pressures, opposition of the public, or logistical challenges in the enforcement (Peterson et al., 2006; Rudolph et al., 2006). Preventive measures to reduce the risk of unintentional feeding are also advocated to control or limit disease transmission. A good example of such a precautionary action is the use of barrier fencing to store hay bales, as it may successfully reduce contact rates and bovine TB transmission between livestock and wildlife (Brook, 2010). Similarly, electric fencing has also been suggested to reduce the potential of CWD transmission between domestic and wild elk by reducing contact rates (Fischer et al., 2011). Reducing densities of large herbivore populations is also a common strategy as an attempt to limit the risk of disease transmission, which is especially critical when population densities are kept unnaturally high through supplemental feeding. Indeed, it may be that population reductions through a combination of harvest or culling activities and selective predation by wolves may suppress disease such as CWD and bovine TB emergence and prevalence in deer and elk populations (Nishi et al., 2006; Wild et al., 2011). However, selective hunting incentives and conservation of apex predators are management decisions regularly faced with opposition from the public and hunting agencies (Stronen et al., 2007; Van Deelen et al., 2010). Furthermore, direct empirical evidence that mitigation measures actually reduce disease prevalence is sparse. Management efforts directed at widespread improvement and augmentation of the natural forage base of large herbivore populations (through e.g. fire or changes in forest harvesting techniques) is likely the most efficient way to ensure that supplementary feeding or baiting efforts are redundant (Månsson et al., 2010; Nishi et al., 2006).

5.2. Vaccination

Baiting or supplemental feeding in itself can also be used as a wildlife disease management option, for example through the delivery of vaccines in bait or feed (Cross et al., 2007a,b). Typically the provisioning of vaccines in bait or feed is utilized for treatment of existing wildlife diseases representing a threat to public health (e.g. rabies, sylvatic plague, Lyme disease), livestock production (bovine TB, brucellosis, pseudorabies), or where they threaten the survival of endangered animal populations (Cross et al., 2007a,b). One of the most successful oral vaccination programs in wildlife has been the widespread dispersal of vaccine-laced baits to control rabies throughout southeastern Canada, the eastern United States, and parts of Europe (Artois et al., 2001; Rosatte et al., 2001). The success of rabies vaccination programs led to the development of numerous vaccines aimed at treating a wide variety of diseases affecting wildlife but these initiatives have resulted in varying levels of success. Several studies have attempted to deliver an oral vaccine through bait for pseudorabies to feral pigs (*Sus scrofa*) in Georgia (Fletcher et al., 1990; Kavanaugh and Linhart, 2000) and Texas (Campbell et al., 2006). While a substantial portion of local feral swine were successfully reached, high uptake rates by non-target species were also encountered, with the exact impacts on non-targets relatively unknown but potentially important.

Vaccines aimed to combat Lyme disease (Telford et al., 2011) and plague (Creekmore et al., 2002) have proven effective in laboratory and captive specimens, but have yet to be distributed in field trials. Moreover, vaccines for some infectious diseases currently threatening large herbivore populations in North America have not yet been developed. Research is currently focused on developing a CWD vaccine, but actual implementation in the wild is at least years away. Moreover, the effectiveness of vaccination is dependent on the quality and heterogeneity of the natural habitat in which the target species lives (Rees et al., 2013). Since 1985, the Wyoming Fish and Game Department has been delivering the brucellosis vaccine to elk calves on feed grounds (Davis and Elzer, 2002). In captive studies, this vaccine reduced abortion events from 93% to 71% during the first pregnancy, with the vaccine protecting 25% of the vaccinated group (Roffe et al., 2004). Over the longer term the reduced abortion rate, and thus transmission, may result in lower seroprevalence on the vaccinated feed grounds (Cross et al., 2007a,b), though vaccines are most likely not a panacea.

5.3. Low density and low quantity feeding

A potentially valuable approach to reduce disease transmission at feeding grounds is low density feeding (Creech et al., 2012). Low-density feeding involves distributing supplemental feed in small, discrete units over a much larger area than conventional concentrated feeding. This encourages individuals to disperse evenly across the feeding area, reducing animal densities at various feeding areas. As such, this approach attempts to address the problem at the source, as disease transmission and prevalence are generally assumed to increase with increasing animal densities. However, evidence of population density thresholds for disease in wildlife remains sparse (Lloyd-Smith et al., 2005). Using an experimental design on the elk feed grounds of Wyoming, Creech et al. (2012) showed that low density feeding led to a significant reduction in the number of elk–elk contacts as well as the number of elk–fetus contacts compared to normal (high density) feeding practises. Although this was the first test of the efficacy of low density feeding it has considerable potential to reduce, though unlikely eliminate brucellosis transmission among cow elk on Wyoming feed grounds.

Another approach to reduce contact rates or animal densities is to provide a limited amount of bait or feed in the environment. In Saskatchewan, Canada baiting of ungulates is permitted outside of protected areas as long as the volume of bait does not exceed 10 gallons, or in the case of bales, exceed 90 kg (Saskatchewan Ministry of Environment, 2012). Besides potentially reducing animal densities and contact rates at bait sites, limited bait quantities may also reduce the risk of ruminal acidosis (Timmons et al., 2010). However, evidence of efficacy is currently lacking as few studies have explored the effect of low quantity feeding on disease transmission rates. Results of Thompson et al. (2008) indicated that provisioning rationed or unlimited forage to white-tailed deer did not reduce contact rates and thus the potential risk for disease transmission.

6. Implications for human and livestock health

Diseases in wildlife pose serious and even potentially catastrophic risks to human and livestock health (Morens et al., 2004; Jones et al., 2008) and baiting and feeding may play an important role in facilitating the maintenance and spread of disease. The majority (72%) of emerging infectious disease globally originated from wildlife and the economic impact exceeded $120 billion from 1995 to 2008 (Jones et al., 2008). For example, the U.S. program aimed at eradicating brucellosis cost over $3.5 billion, yet the disease continues to be found in cattle due to wildlife reservoirs (Cheville et al., 1998; USDA-APHIS-VS, 2009). Similarly, the majority of emerging infectious diseases found in humans come from wildlife (Daszak et al., 2000). However, while the role of baiting and feeding are likely important, we are unaware of any studies that explicitly link supplemental feeding of wildlife to disease prevalence or outbreaks in humans or livestock.

7. Conclusion

An important aim of feeding large herbivores is to enhance body condition, which, in theory, could enable individuals to better combat diseases. In practice, however, crowding of individuals and species at baiting and feeding stations has strong potential to increase the risk of both direct and indirect disease transmission and spread. Evidence for this is found for bovine TB in white-tailed deer in Michigan and for brucellosis in elk in the Greater Yellowstone Ecosystem. Nevertheless, most scientific studies on the role of baiting and feeding on disease occurrence and transmission do not compare prevalence between fed and unfed individuals or populations, which then become mere observations of disease prevalence at feeding grounds. This makes it impossible to conclude that feeding and baiting of large herbivores has a persistent, negative effect on disease transmission. Although the link between feeding and disease makes intuitive sense, the empirical evidence remains inconclusive. Moreover, various conditions appear to affect the risk of disease transmission such as the actual densities at baiting and feeding stations and the quality and heterogeneity of the surrounding natural habitat. The decision to implement feeding or baiting as a wildlife management tool should at least consider the strong potential for disease transmission and spread. If feeding or baiting is indeed implemented we recommend a pro-active approach to limit disease transmission through a combination of preventive actions such as low density feeding, vaccination if possible, and continuous monitoring of disease prevalence. However, given the on-going challenges of addressing wildlife disease issues and the role of baiting, it seems unlikely that diseases will be successfully eradicated or even managed while widespread baiting and feeding is permitted.

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References

Andreassen, H.P., Gundersen, H., Storaas, T., 2005. The effect of scent-marking, forest clearing, and supplemental feeding on moose–train collisions. J. Wildl. Manage. 69, 1125–1132.

Artois, M., Delahay, R., Guberti, V., Cheeseman, C., 2001. Control of infectious diseases of wildlife in Europe. Vet. J. 162, 141–152.

Atwood, T.C., Deliberto, T.J., Smith, H.J., Stevenson, J.S., Vercauteren, K.C., 2009. Spatial ecology of raccoons related to cattle and bovine tuberculosis in Northeastern Michigan. J. Wildl. Manage. 73, 647–654.

Aune, K., Alt, K., Lemke, T., 2002. Managing wildlife habitat to control brucellosis in the Montana portion of the greater Yellowstone area. In: Brucellosis in Elk and Bison in the Greater Yellowstone Area. Wyoming Game and Fish Department, Cheyenne, WY, USA, pp. 109–119.

Baker, D.L., Thompson Hobbs, N., 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. J. Wildl. Manage. 49, 934–942.
Barrett, M.A., Morano, S., Delgiudice, G.D., Fieberg, J., 2008. Translating bait preference to capture success of Northern white-tailed deer. J. Wildl. Manage. 72, 555–560.
Bartos, L., Vankova, D., Siler, J., Losos, S., 1996. Fallow deer tactic to compete over food with red deer. Aggress. Behav. 22, 375–385.
Blanchong, J.A., Scribner, K.T., Epperson, B.K., Winterstein, S.R., 2006. Changes in artificial feeding regulations impact white-tailed deer fine-scale spatial genetic structure. J. Wildl. Manage. 70, 1037–1043.
Brook, R.K., 2008. Elk–agriculture conflicts in the Greater Riding Mountain ecosystem: building bridges between the natural and social sciences to promote sustainability. University of Manitoba, Canada (PhD-thesis).
Brook, R.K., 2009. Historical review of elk interactions with agriculture around Riding Mountain National Park, Manitoba, Canada. Hum. Wildl. Confl. 3, 72–87.
Brook, R.K., 2010. Incorporating farmer observations in efforts to manage bovine tuberculosis using barrier fencing at the wildlife–livestock interface. Prev. Vet. Med. 94, 301–305.
Brook, R.K., Vander Wal, E., van Beest, F.M., McLachlan, S.M., 2013. Evaluating use of cattle winter feeding areas by elk and white-tailed deer: implications for managing bovine tuberculosis transmission risk from the ground up. Prev. Vet. Med. 108, 137–147.
Brown, P., 1998. BSE: the final resting place. Lancet 351, 1146–1147.
Brown, R.D., Cooper, S.M., 2006. The nutritional, ecological, and ethical arguments against baiting and feeding white-tailed deer. Wildl. Soc. Bull. 34, 519–524.
Bruning-Fann, C., Schmitt, S., Fitzgerald, S., Fierke, J., Friedrich, P., Kaneene, J., Clarke, K., Butler, K., Payeur, J., Whipple, D., Cooley, T., Miller, J., Muzo, D., 2001. Bovine tuberculosis in free-ranging carnivores from Michigan. J. Wildl. Dis. 37, 58–64.
Campbell, T.A., Lapidge, S.J., Long, D.B., 2006. Using baits to deliver pharmaceuticals to feral swine in Southern Texas. Wildl. Soc. Bull. 34, 1184–1189.
Cheville, N., McCullough, D.R., Paulson, L.R. (Eds.), 1998. Brucellosis in the Greater Yellowstone Area. National Research Council, Washington, DC.
Corcoran, M.J., Wetherbee, B.M., Shivji, M.S., Potenski, M.D., Chapman, D.D., Harvey, G.M., 2013. Supplemental feeding for ecotourism reverses diel activity and alters movement patterns and spatial distribution of the southern stingray, *Dasyatis americana*. PLoS ONE 8, e59235.
Cosgrove, G.E., Fay, L.D., 1981. Viral tumors. In: Infectious Diseases of Wild Mammals. Iowa State University Press, Ames, IA, USA, pp. 424–428.
Cosivi, O., Grange, J.M., Daborn, C.J., Raviglione, M.C., Fujikura, T., Cousins, D., Robinson, R.A., Huchzermeyer, H., de Kantor, I., Meslin, F.X., 1998. Zoonotic tuberculosis due to *Mycobacterium bovis* in developing countries. Emerg. Infect. Dis. 4, 59–70.
Côté, S.D., 2001. Determining social rank in ungulates: a comparison of aggressive interactions recorded at a bait site and under natural conditions. Ethology 106, 945–955.
Creech, T.G., Cross, P.C., Scurlock, B.M., Maichak, E.J., Rogerson, J.D., Henningsen, J.C., Creel, S., 2012. Effects of low-density feeding on elk–fetus contact rates on Wyoming feedgrounds. J. Wildl. Manage. 76, 877–886.
Creekmore, T., Rocke, T., Hurley, J., 2002. A baiting system for delivery of an oral plague vaccine to black-tailed prairie dogs. J. Wildl. Dis. 38, 32–39.
Cross, M.L., Buddle, B.M., Aldwell, F.E., 2007a. The potential of oral vaccines for disease control in wildlife species. Vet. J. 174, 472–480.
Cross, P.C., Edwards, W.H., Scurlock, B.M., Maichak, E.J., Rogerson, J.D., 2007b. Effects of management and climate on elk brucellosis in the greater yellowstone ecosystem. Ecol. Appl. 17, 957–964.
Cross, P.C., Heisey, D.M., Scurlock, B.M., Edwards, W.H., Ebinger, M.R., Brennan, A., 2010. Mapping brucellosis increases relative to elk density using hierarchical Bayesian models. PLoS ONE 5, 9.
Daszak, P., Cunningham, A., Hyatt, A., 2000. Wildlife ecology – emerging infectious diseases of wildlife – threats to biodiversity and human health. Science 287, 443–449.
Davis, D.S., Elzer, P.H., 2002. Brucella vaccines in wildlife. Vet. Microbiol. 90, 533–544.
Denkers, N.D., Hayes-Klug, J., Anderson, K.R., Seelig, D.M., Haley, N.J., Dahmes, S.J., Osborn, D.A., Miller, K.V., Warren, R.J., Mathiason, C.K., Hoover, E.A., 2013. Aerosol transmission of chronic wasting disease in white-tailed deer. J. Virol. 87, 1890–1892.
Doenier, P.B., DelGiudice, G.D., Riggs, M.R., 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildl. Soc. Bull. 25, 235–243.
Dorn, M.L., Mertig, A.G., 2005. Bovine tuberculosis in Michigan: stakeholder attitudes and implications for eradication efforts. Wildl. Soc. Bull. 33, 539–552.
Edmunds, D.R., 2008. Epidemiology of Chronic Wasting Disease in White-Tailed Deer in the Endemic Area of Wyoming (MSc). University of Wyoming, Laramie, WY.
Etter, R.P., Drew, M.L., 2006. Brucellosis in elk of eastern Idaho. J. Wildl. Dis. 42, 271–278.
Ferretti, F., 2011. Interspecific aggression between fallow and roe deer. Ethol. Ecol. Evol. 23, 179–186.
Fischer, J.W., Phillips, G.E., Baasch, D.M., Lavelle, M.J., Vercauteren, K.C., 2011. Modifying elk (*Cervus elaphus*) behavior with electric fencing at established fence-lines to reduce disease transmission potential. Wildl. Soc. Bull. 35, 9–14.
Fletcher, W., Creekmore, T., Smith, M., Nettles, V., 1990. A field trial to determine the feasibility of delivering oral vaccines to wild swine. J. Wildl. Dis. 26, 502–510.
Forristal, V.E., Creel, S., Taper, M.L., Scurlock, B.M., Cross, P.C., 2012. Effects of supplemental feeding and aggregation on fecal glucocorticoid metabolite concentrations in elk. J. Wildl. Manag. 76, 694–702.
Gabrey, S., Belant, J., Dolbeer, R., Bernhardt, G., 1994. Bird and rodent abundance at yard-waste compost facilities in northern Ohio. Wildl. Soc. Bull. 22, 288–295.
Garner, M.S., 2001. Movement Patterns and Behavior at Winter-Feeding and Fall Baiting Stations in a Population of White-Tailed Deer Infected with Bovine Tuberculosis in the Northeastern Lower Peninsula of Michigan (PhD). Michigan State University, East Lansing, USA.
Geisser, H., Reyer, H.U., 2004. Efficacy of hunting, feeding, and fencing to reduce crop damage by wild boars. J. Wildl. Manag. 68, 939–946.
Godfroid, J., Käsbohrer, A., 2002. Brucellosis in the European Union and Norway at the turn of the twenty-first century. Vet. Microbiol. 90, 135–145.
Hansen, A.J., 1987. Regulation of bald eagle reproductive rates in Southeast Alaska. Ecology 68, 1387–1392.
Hines, A.M., Ezenwa, V.O., Cross, P., Rogerson, J.D., 2007. Effects of supplemental feeding on gastrointestinal parasite infection in elk (*Cervus elaphus*): preliminary observations. Vet. Parasitol. 148, 350–355.
Jones, K.E., Patel, N.G., Levy, M.A., Storeygard, A., Balk, D., Gittleman, J.L., Daszak, P., 2008. Global trends in emerging infectious diseases. Nature 451, 990–993.
Kavanaugh, D., Linhart, S., 2000. A modified bait for oral delivery of biological agents to raccoons and feral swine. J. Wildl. Dis. 36, 86–91.
Lees, V.W., 2004. Learning from outbreaks of bovine tuberculosis near Riding Mountain National Park: applications to a foreign animal disease outbreak. Can. Vet. J. 45, 28–34.
Lees, V.W., Copeland, S., Rousseau, P., 2003. Bovine tuberculosis in elk (*Cervus elaphus manitobensis*) near Riding Mountain National Park, Manitoba, from 1992 to 2002. Can. Vet. J. 44, 830–831.
Lischka, S.A., Shelton, P., Buhnerkempe, J., 2010. Support for chronic wasting disease management among residents of the infected area in Illinois. Hum. Dimens. Wildl. 15, 229–232.
Litvaitis, J.A., Kane, D.M., 1994. Relationship of hunting technique and hunter selectivity to composition of black bear harvest. Wildl. Soc. Bull. 22, 604–606.
Lloyd-Smith, J.O., Cross, P.C., Briggs, C.J., Daugherty, M., Getz, W.M., Latto, J., Sanchez, M.S., Smith, A.B., Swei, A., 2005. Should we expect population thresholds for wildlife disease. Trends Ecol. Evol. 20, 511–519.
Lothrop, H.D., Wheeler, S.S., Fang, Y., Reisen, W.K., 2012. Use of scented sugar bait stations to track mosquito-borne arbovirus transmission in California. J. Med. Entomol. 49, 1466–1472.
Lunn, N.J., 1986. Observations of nonaggressive behavior between polar bear family groups. Can. J. Zool. 64, 2035–2037.
Månsson, J., Bergstrom, R., Pehrson, A., Skoglund, M., Skarpe, C., 2010. Felled scots pine (*Pinus sylvestris*) as supplemental forage for moose (*Alces alces*): browse availability and utilization. Scand. J. For. Res. 25, 21–31.
Marchinton, R.L., Hirth, D.H., 1984. Behavior. In: White-tailed Deer: Ecology and Management. Stackpole, Harrisburg, PA, USA, pp. 129–168.
Meagher, M., Meyer, M.E., 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. Conserv. Biol. 8, 645–653.
Miller, M., Wild, M., Williams, E., 1998. Epidemiology of chronic wasting disease in captive Rocky Mountain elk. J. Wildl. Dis. 34, 532–538.
Miller, M., Williams, E., McCarty, C., Spraker, T., Kreeger, T., Larsen, C., Thorne, E., 2000. Epizootiology of chronic wasting disease in free-ranging cervids in Colorado and Wyoming. J. Wildl. Dis. 36, 676–690.
Miller, M.W., Hobbs, N.T., Tavener, S.J., 2006. Dynamics of prion disease transmission in mule deer. Ecol. Appl. 16, 2208–2214.

Miller, R., Kaneene, J., Fitzgerald, S., Schmitt, S., 2003. Evaluation of the influence of supplemental feeding of white-tailed deer (*Odocoileus virginianus*) on the prevalence of bovine tuberculosis in the Michigan wild deer population. J. Wildl. Dis. 39, 84–95.
Mills, H.B., 1936. Observations on Yellowstone elk. J. Mammal. 17, 250–253.
Morens, D.M., Folkers, G.K., Fauci, A.S., 2004. The challenge of emerging and reemerging infectious diseases. Nature 430, 242–249.
Nishi, J.S., Shury, T., Elkin, B.T., 2006. Wildlife reservoirs for bovine tuberculosis (*Mycobacterium bovis*) in Canada: strategies for management and research. Vet. Microbiol. 112, 325–338.
O'Brien, D.J., Schmitt, S.M., Fitzgerald, S.D., Berry, D.E., 2011. Management of bovine tuberculosis in Michigan wildlife: current status and near term prospects. Vet. Microbiol. 151, 179–187.
Obbard, M.E., Pond, B.A., Schenk, A., Ron Black, Hall, M.N., Jackson, B., 2008. Suspended baits: can they help hunters distinguish male from female American black bears? Ursus 19, 33–42.
Ozoga, J.J., Verme, L.J., 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. J. Wildl. Manag. 46, 281–301.
Palmer, M.V., Whipple, D.L., Waters, W.R., 2001. Experimental deer-to-deer transmission of *Mycobacterium bovis*. Am. J. Vet. Res. 62, 692–696.
Peterson, M.N., Mertig, A.G., Liu, J., 2006. Effects of zoonotic disease attributes on public attitudes towards wildlife management. J. Wildl. Manage. 70, 1746–1753.
Putman, R.J., Staines, B.W., 2004. Supplementary winter feeding of wild red deer *Cervus elaphus* in Europe and North America: justifications, feeding practice and effectiveness. Mammal Rev. 34, 285–306.
Rees, E.E., Pond, B.A., Tinline, R.R., Bélanger, D., 2013. Modelling the effect of landscape heterogeneity on the efficacy of vaccination for wildlife infectious disease control. J. Appl. Ecol. 50, 881–891.
Robb, G.N., McDonald, R.A., Chamberlain, D.E., Bearhop, S.A., 2008a. Food for thought: supplementary feeding as a driver of ecological change in avian populations. Front. Ecol. Environ. 6, 476–484.
Robb, G.N., McDonald, R.A., Chamberlain, D.E., Reynolds, S.J., Harrison, T.J.E., Bearhop, S.B., 2008b. Winter feeding of birds increases productivity in the subsequent breeding season. Biol. Lett. 4, 220–223.
Roffe, T.J., Jones, L.C., Coffin, K., Drew, M.L., Sweeney, S.J., Hagius, S.D., Elzer, P.H., Davis, D., 2004. Efficacy of single calfhood vaccination of elk with *Brucella abortus* strain 19. J. Wildl. Manage. 68, 830–836.
Rosatte, R., Donovan, D., Allan, M., Howes, L.A., Silver, A., Bennett, K., MacInnes, C., Davies, C., Wandeler, A., Radford, B., 2001. Emergency response to raccoon rabies introduction into Ontario. J. Wildl. Dis. 37, 265–279.
Rudolph, B.A., Riley, S.J., Hickling, G.J., Frawley, B.J., Garner, M.S., Winterstein, S.R., 2006. Regulating hunter baiting for white-tailed deer in Michigan: biological and social considerations. Wildl. Soc. Bull. 34, 314–321.
Sahlsten, J., Bunnefeld, N., Mansson, J., Ericsson, G., Bergstrom, R., Dettki, H., 2010. Can supplementary feeding be used to redistribute moose *Alces alces*? Wildl. Biol. 16, 85–92.
Samuel, W., Welch, D., Smith, B.L., 1991. Ectoparasites from elk (*Cervus-elaphus-nelsoni*) from Wyoming. J. Wildl. Dis. 27, 446–451.
Saskatchewan Ministry of Environment, 2012. 2012 Saskatchewan Hunters' and Trappers' Guide.
Saunders, S.E., Bartelt-Hunt, S.L., Bartz, J.C., 2012. Occurrence, transmission, and zoonotic potential of chronic wasting disease. Emerg. Infect. Dis. 18, 369–376.
Schmitt, S., Fitzgerald, S., Cooley, T., Bruning-Fann, C., Sullivan, L., Berry, D., Carlson, T., Minnis, R., Payeur, J., Sikarskie, J., 1997. Bovine tuberculosis in free-ranging white-tailed deer from Michigan. J. Wildl. Dis. 33, 749–758.
Schmitt, S.M., O'Brian, D.J., Bruning-Fann, C.S., Fitzgerald, S.D., 2002. Bovine tuberculosis in Michigan wildlife and livestock. Ann. N. Y. Acad. Sci. 969, 262–268.
Seeger, H., Heikenwalder, M., Zeller, N., Kranich, J., Schwarz, P., Gaspert, A., Seifert, B., Miele, G., Aguzzi, A., 2005. Coincident scrapie infection and nephritis lead to urinary prion excretion. Science 310, 324–326.
Smith, B.L., 2001. Winter feeding of elk in western North America. J. Wildl. Manage. 65, 173–190.
Spraker, T., Miller, M., Williams, E., Getzy, D., Adrian, W., Schoonveld, G., Spowart, R., O'Rourke, K., Miller, J., Merz, P., 1997. Spongiform encephalopathy in free-ranging mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*) in northcentral Colorado. J. Wildl. Dis. 33, 1–6.
Stronen, A.V., Brook, R.K., Paquet, P.C., McLachlan, S., 2007. Farmer attitudes toward wolves: implications for the role of predators in managing disease. Biol. Conserv. 135, 1–10.
Telford III, S.R., Cunningham, J.A., Waltari, E., Hu, L., 2011. Nest box-deployed bait for delivering oral vaccines to white-footed mice. Ticks Tick-Borne Dis. 2, 151–155.
Thompson, A.K., Samuel, M.D., Deelen, T.R.V., 2008. Alternative feeding strategies and potential disease transmission in Wisconsin white-tailed deer. J. Wildl. Manage. 72, 416–421.
Timmons, G.R., Hewitt, D.G., Deyoung, C.A., Fulbright, T.E., Draeger, D.A., 2010. Does supplemental feed increase selective foraging in a browsing ungulate? J. Wildl. Manage. 74, 995–1002.
United States Department of Agriculture, 2009. Animal and Plant Health Inspection Service, Veterinary Services (USDA-APHIS-VS). A concept paper for a new direction for the bovine brucellosis program. Fed. Regist. 74 (191), 51115–51116.
van Beest, F.M., Gundersen, H., Mathisen, K.M., Milner, J.M., Skarpe, C., 2010. Long-term browsing impact around diversionary feeding stations for moose in Southern Norway. For. Ecol. Manage. 259, 1900–1911.
Van Deelen, T.R., Dhuey, B.J., Jacques, C.N., McCaffery, K.R., Rolley, R.E., Warnke, K., 2010. Effects of earn-a-buck and special antlerless-only seasons on Wisconsin's deer harvests. J. Wildl. Manage. 74, 1693–1700.
Vander Wal, E., Paquet, P.C., Andrés, J.A., 2012. Influence of landscape and social interactions on transmission of disease in a social cervid. Mol. Ecol. 21, 1271–1282.
VerCauteren, K.C., Pilon, J.L., Nash, P.B., Phillips, G.E., Fischer, J.W., 2012. Prion remains infectious after passage through digestive system of American crows (*Corvus brachyrhynchos*). PLoS ONE 7, e45774.
Weidman, T., Litvaitis, J.A., 2011. Can supplemental food increase winter survival of a threatened cottontail rabbit? Biol. Conserv. 144, 2054–2058.
Wild, M.A., Hobbs, N.T., Graham, M.S., Miller, M.W., 2011. The role of predation in disease control: a comparison of selective and nonselective removal on prion disease dynamics in deer. J. Wildl. Dis. 47, 78–93.
Williams, E., Young, S., 1992. Spongiform encephalopathies in Cervidae. Rev. Sci. Tech. 11, 551–567.
Williams, E.S., Miller, M.W., Kreeger, T.J., Kahn, R.H., Thorne, E.T., 2002. Chronic wasting disease of deer and elk: a review with recommendations for management. J. Wildl. Manage. 66, 551–563.
Williamson, S., 2000. Feeding Wildlife. . .Just Say NO!. Wildlife Management Institute, Washington, DC, USA.
Wood, P., Wolfe, M.L., 1988. Intercept feeding as a means of reducing deer–vehicle collisions. Wildl. Soc. Bull. 16, 376–380.
Ziegltrum, G.J., 2004. Efficacy of black bear supplemental feeding to reduce conifer damage in western Washington. J. Wildl. Manage. 68, 470–474.
Ziegltrum, G.J., 2006. Cost-effectiveness of the black bear supplemental feeding program in western Washington. Wildl. Soc. Bull. 34, 375–379.