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ScienceDirect
Veterinary Parasitology 148 (2007) 350–355
veterinary parasitology
www.elsevier.com/locate/vetpar

Short communication

Effects of supplemental feeding on gastrointestinal parasite infection in elk (*Cervus elaphus*): Preliminary observations

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Received 6 March 2007; received in revised form 28 June 2007; accepted 2 July 2007

Abstract

The effects of management practices on the spread and impact of parasites and infectious diseases in wildlife and domestic animals are of increasing concern worldwide, particularly in cases where management of wild species can influence disease spill-over into domestic animals. In the Greater Yellowstone Ecosystem, USA, winter supplemental feeding of Rocky Mountain elk (*Cervus elaphus*) may enhance parasite and disease transmission by aggregating elk on feedgrounds. In this study, we tested the effect of supplemental feeding on gastrointestinal parasite infection in elk by comparing fecal egg/oocyst counts of fed and unfed elk. We collected fecal samples from fed and unfed elk at feedground and control sites from January to April 2006, and screened all samples for parasites. Six different parasite types were identified, and 48.7% of samples were infected with at least one parasite. Gastrointenstinal (GI) nematodes (Nematoda: Strongylida), *Trichuris* spp., and coccidia were the most common parasites observed. For all three of these parasites, fecal egg/oocyst counts increased from January to April. Supplementally fed elk had significantly higher GI nematode egg counts than unfed elk in January and February, but significantly lower counts in April. These patterns suggest that supplemental feeding may both increase exposure and decrease susceptibility of elk to GI nematodes, resulting in differences in temporal patterns of egg shedding between fed and unfed elk.

Keywords: *Cervus elaphus*; Elk; Gastrointestinal nematodes; Ungulates; Wildlife; Management; Supplemental feeding

1. Introduction

Host–parasite interactions are increasingly being considered in the management of both domestic and wildlife species (Bengis et al., 2002; Gortazar et al., 2006). Relative to domestic species and captive animals, however, we know very little about the impact of management on parasitism and infectious diseases in free-ranging wildlife. Nevertheless, accumulating evidence suggests that management practices can have important consequences for parasite transmission in wildlife, potentially magnifying disease spill-over from wildlife to domestic animals and/or humans (Bengis et al., 2002; Donnelly et al., 2006). As such, assessing the effects of management on host–parasite interactions in wildlife remains an important research frontier.

The Greater Yellowstone Ecosystem (GYE) encompasses about six million hectares, including Yellowstone National Park (YNP) and surrounding lands. The GYE represents one of the few areas of North America where wildlife populations have remained intact in the face of westward expansion (Smith, 2001); but outside YNP boundaries many wildlife species are intensively

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doi:10.1016/j.vetpar.2007.07.006

managed to reduce wildlife–human–livestock conflict. Some of the most widely recognized wildlife management actions occurring in the GYE are tightly linked to issues of parasite and disease spread. For example, American bison (*Bison bison*) undergo hazing and removal when they leave the boundaries of YNP to control potential brucellosis (*Brucella abortus*) transmission to cattle (Clark et al., 2005); and outside the park, Rocky Mountain elk (*Cervus elaphus*) are artificially supplemented throughout the winter to minimize their contact with cattle and impact on private haystacks (Smith, 2001).

Winter feeding of elk began in Jackson Hole, Wyoming, USA in 1910, and today, around 28,000 elk receive supplemental feed each year at the U.S. Fish & Wildlife Service National Elk Refuge and 22 state-operated feedgrounds. Past studies have documented positive effects of supplemental feeding on elk development (Smith et al., 1997), reproduction (Cook et al., 2002), survival (Smith and Anderson, 1998) and population growth (Smith and Robbins, 1994; Lubow and Smith, 2004); but feeding also causes unnaturally high concentrations of elk, which may promote transmission of diseases and parasites. For example, feeding has been linked to increases in the seroprevalence of *Brucella abortus*, the agent causing brucellosis, in elk (Bienen and Tabor, 2006; Cross et al., 2007). However, beyond brucellosis there is little quantitative data on how winter supplemental feeding might influence other parasites and infectious diseases. In this study, we examined the effects of supplemental feeding on gastrointestinal (GI) parasite load in elk around the southern GYE. To assess whether this management practice is correlated with an increase in GI parasitism, we compared temporal patterns of GI parasite infection in fed and unfed elk over a four-month period during the winter and early spring of 2006.

2. Materials and methods

Winter feeding of elk typically occurs from late November through April and supplementation is in the form of hay and alfalfa pellets. We sampled fed and unfed elk for GI parasites between January and April 2006. Sampling occurred opportunistically at eight feedground sites and two control sites with herds of unfed elk (Fig. 1). The feedground sites are all located in northwestern Wyoming, USA along the southernmost extent of the GYE along the Wind River and Wyoming mountain ranges. The two control sites are also located within the GYE. Both feedground and control sites are similar in habitat type, comprised of wide valleys dominated by sagebrush (*Artemisia* spp.), and montane areas dominated by lodgepole pine (*Pinus contorta*). Over the 4-month sampling period, climatic conditions across feedground and control sites were also similar, with minimum and maximum temperatures at unfed sites falling within the range observed across fed sites. To assess temporal changes in gastrointestinal parasite loads between fed and unfed elk, we collected fecal samples on a monthly basis. Each month, ten to twenty fresh fecal pellet groups were collected from the ground at control and feedground sites. At a subset of sites, rectal samples were also collected from captured elk when available. All sites could not be sampled every month, however at least one feedground and one control site were sampled in each month. Fecal samples were shipped cold to the University of Montana, Missoula, MT within 24 h of collection and stored at 4 °C until processing.

To quantify GI parasite eggs/oocysts in elk fecal samples, we used a modified double centrifugation technique (Foreyt, 2001), a well-established method for determining FEC with a high (∼100%) sensitivity at low egg concentrations (Egwang and Slocombe, 1981). For each sample, 1.0 g of feces was homogenized and double-spun in a centrifuge, first in water and then in a sugar flotation solution (specific gravity 1.27). A single coverslip was placed on each test tube during the final centrifugation step, and then mounted on a glass slide for parasite enumeration. Parasites were identified and counted using the 40× objective of a compound microscope. Immature stages of six parasite types were identified from elk feces including four groups of nematodes (*Trichuris* spp., *Capillaria* spp., *Strongyloides* spp., and other GI nematodes [Nematoda: Strongylida]); one cestode (*Moniezia* spp.,); one protozoan (coccidia [Apicomplexa: Eimeriidae]). Fecal egg count (FEC) was estimated as the number of eggs/oocysts observed per gram of feces for each parasite type, and prevalence was calculated as the percentage of samples infected with each parasite. We compared FEC between fed and unfed elk and across months using two-way analysis of variance (ANOVA) and Fisher's protected least significant difference (PLSD) post hoc tests. Because all sites were not consistently sampled every month we did not use a repeated measures procedure for this analysis. All fecal egg counts were $\log_{10}(x + 1)$ transformed to normalize the data prior to analysis. For all tests, significance was accepted at $p \leq 0.05$.

3. Results

Out of 298 fecal samples examined, 145 (48.7%) were infected with at least one GI parasite. GI

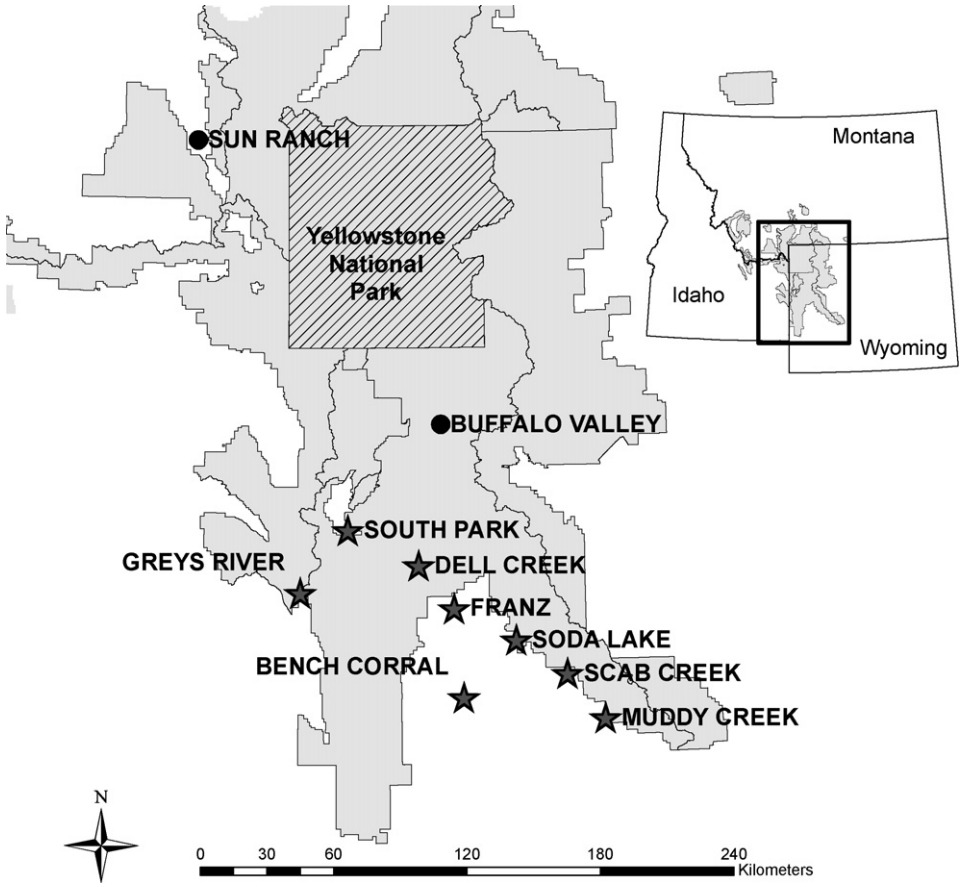

Fig. 1. Map of the study region with National Park and Forest Service land noted in gray. Stars indicate sites where elk receive supplemental feed and circles represent sites with unfed elk.

nematodes were the most prevalent parasite type with 26.5% of samples infected, followed by *Trichuris* (17.8%), coccidia (16.8%), *Capillaria* (9.1%), *Strongyloides* (0.67%) and *Moniezia* (0.34%). Analyses testing the effect of month and feeding status on parasite FEC were conducted for the three most prevalent parasite types: GI nematodes, *Trichuris* and coccidia. Overall, we examined 193 samples from fed elk and 105 samples from unfed elk. Mean monthly parasite counts for the two groups are reported in Table 1.

The month of sample collection had a significant effect on GI nematode FEC (ANOVA: $F_{3,290} = 4.68$, $p = 0.003$; Fig. 2A); with counts generally increasing from January to April (Fisher's PLSD: January versus March: $p = 0.006$; January versus April: $p = 0.001$; February versus March: $p = 0.007$; February versus April: $p = 0.001$). Although feeding status (fed versus unfed) had no independent effect on GI nematode FEC ($F_{1,290} = 0.30$, $p = 0.58$; Fig. 2A), there was a significant interaction between feeding status and month ($F_{3,290} = 3.22$, $p = 0.02$; Fig. 2A). In post hoc analyses testing for within-month effects, fed elk had marginally higher GI nematode egg counts than unfed elk in January, and significantly higher counts in February (January: $F_{1,46} = 3.81$, $p = 0.06$; February, $F_{1,172} = 6.59$, $p = 0.01$; Fig. 2A). In March, there was no significant difference between the two groups ($F_{1,54} = 1.38$, $p = 0.25$; Fig. 2A), and in April the pattern was reversed, with fed elk showing significantly lower GI nematode egg counts than unfed elk ($F_{1,18} = 6.26$, $p = 0.02$; Fig. 2A).

Patterns of coccidia infection were similar to those observed for GI nematodes. Month of collection was significantly associated with coccidia oocyst count (ANOVA: $F_{3,290} = 7.96$, $p < 0.0001$; Fig. 2B), and count increased from January to April (Fisher's PLSD: January versus April: $p = 0.0006$; February versus March: $p = 0.003$; February versus April: $p < 0.0001$; March versus April: $p = 0.011$). While feeding status was not independently associated with coccidia oocyst count ($F_{1,290} = 0.65$, $p = 0.42$; Fig. 2B), the interaction between feeding status and month was significant ($F_{3,290} = 3.64$, $p = 0.01$; Fig. 2B). Although monthly

Table 1
Arithmetic mean ± standard error (range) of untransformed gastrointestinal parasite egg/oocyst counts in fed and unfed elk

	January		February		March		April	
	Fed (n = 36)	Unfed (n = 12)	Fed (n = 100)	Unfed (n = 74)	Fed (n = 47)	Unfed (n = 9)	Fed (n = 10)	Unfed (n = 10)
GI nematodes	0.42 ± 0.14 (0–4)	0	1.06 ± 0.30 (0–19)	0.26 ± 0.09 (0–5)	4.13 ± 1.54 (0–57)	0.22 ± 0.15 (0–1)	0.80 ± 0.39 (0–4)	2.60 ± 0.62 (0–6)
Coccidia	2.11 ± 1.29 (0–45)	0	0.30 ± 0.12 (0–7)	3.53 ± 3.20 (0–237)	10.0 ± 5.72 (0–236)	0.67 ± 0.44 (0–4)	1.60 ± 0.91 (0–7)	17.2 ± 7.90 (0–65)
Trichuris	0.47 ± 0.19 (0–5)	1.00 ± 0.56 (0–6)	1.34 ± 0.84 (0–81)	0.12 ± 0.05 (0–3)	1.96 ± 0.92 (0–37)	2.00 ± 1.48 (0–13)	0.60 ± 0.27 (0–2)	5.50 ± 3.51 (0–35)

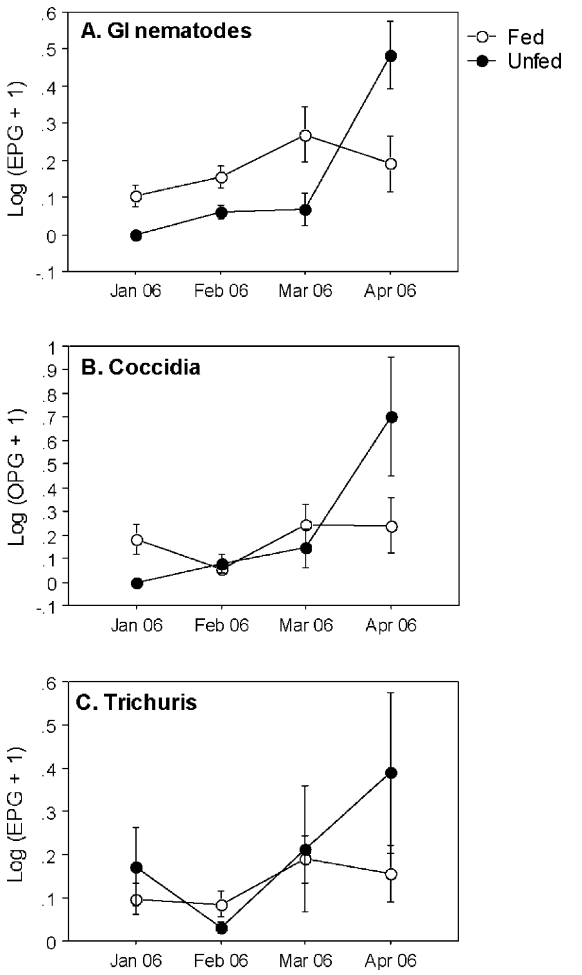

Fig. 2. Log-transformed fecal egg/oocysts counts [log(EPG/OPG + 1)] for fed (open circles) and unfed (closed circles) elk from January through April 2006. (A) GI nematodes, (B) coccidia and (C) *Trichuris*. Error bars represent one standard error.

comparisons were not significant ($p > 0.10$), coccidia counts were higher in the fed group in January and March, and lower in April (Fig. 2B).

For *Trichuris*, we found a similar effect of month on FEC (ANOVA: $F_{3,290} = 5.14$, $p = 0.002$; Fig. 2C), with an increase from January to April (Fisher's PLSD: January versus April: $p = 0.03$; February versus March: $p = 0.003$; February versus April: $p = 0.002$). However, there was no effect of either feeding status ($F_{1,290} = 2.05$, $p = 0.15$; Fig. 2C), or the interaction between month and feeding status ($F_{3,290} = 1.15$, $p = 0.39$; Fig. 2C) on *Trichuris* FEC.

4. Discussion

In this study, we examined the effects of winter supplemental feeding on GI parasite infection in elk in

the Greater Yellowstone Ecosystem, USA. Nearly half of all samples showed evidence of infection by at least one type of parasite; and for the three most prevalent parasites, GI nematodes, *Trichuris* spp. and coccidia, month was a significant predictor of fecal egg/oocyst count, with FECs increasing from winter to early spring. Declines in FEC in fall and winter with a subsequent spring rise are well-documented phenomena in temperate ruminant systems driven by a combination of changing climatic conditions and host immunity (Armour, 1980). These same factors likely explain the temporal patterns of egg shedding we observed in elk.

In addition to a month effect, we also saw an interaction between month and feeding status. From January to March, fed elk had consistently higher GI nematode (and to some extent coccidia) counts than unfed elk. On the feedgrounds, elk occur in artificially high concentrations (Smith et al., 1997; Smith, 1998), and this may facilitate parasite transmission by increasing contact rates between susceptible hosts and parasite infective stages (Altizer et al., 2003). Indeed, increased aggregation on feedgrounds is a key hypothesis that has been put forth to explain high brucellosis prevalence among feedground elk (Bienen and Tabor, 2006; Cross et al., 2007), and it may also account for higher GI parasite counts among fed elk in the winter.

Despite the possible effect of aggregation on host–parasite contact rates on feedgrounds, we saw an interesting reversal in relative GI nematode egg counts between fed and unfed elk beginning in the early spring. In April, fed elk had significantly lower FEC than unfed elk, and this could be due to improved nutrition on feedgrounds. Studies of domestic animals provide compelling evidence of a strong relationship between nutrition and GI parasite infection in ruminants, where animals with higher levels of protein and/or energy are better able to control establishment of new parasites and reduce fecundity of existing parasites, both of which would result in reduced FECs (Coop and Kyriazakis, 2001). Similar links have also been made for a variety of wild ungulate species (Ezenwa, 2004). Several studies have documented steep nutritional and condition declines among free-ranging elk in the winter as a result of prolonged winter undernutrition and catabolism of endogenous protein (DelGiudice et al., 1991, 2000). Elk winter supplemental feeding has been associated with increases in individual body condition, over-winter survival and calf:cow ratios (Smith and Anderson, 1998), all suggesting improved nutrition. Thus, it is likely that winter feeding could also result in enhanced resilience and resistance to parasites among fed elk in the spring.

Our results suggest that during the winter fed elk may be more exposed to parasites on feedgrounds explaining their higher FECs early in the season. On the other hand, in the spring, fed elk may be less susceptible to GI parasites as a consequence of improved winter nutrition, resulting in lower FECs compared to unfed elk during this period. Although our results are preliminary and based on a limited sample of elk populations, they highlight the complex effects management practices can have on host–parasite interactions. A larger study including multiple fed and unfed elk populations will be needed to confirm the patterns we report here and investigate the possible mechanisms underlying these effects. Nevertheless, our current findings emphasize the need for additional research focused on understanding the impacts of management strategies on a wide range of parasites and infectious diseases.

Acknowledgements

This project was supported by the Division of Biological Sciences, University of Montana; a Montana NSF EPSCoR Undergraduate Research Fellowship to A. Hines; and the U.S. Geological Survey. We thank J. Rogerson, J. Grigg, B. Scurlock and E. Maichak for assistance collecting fecal samples; and A. Pederson and W. Turner for helpful comments.

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