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Selenium Levels and Productivity in Three Oregon Elk Herds

Abstract

Selenium (Se) is an essential dietary trace mineral and Se deficiency has been linked to decreased productivity in livestock and some species of wildlife. Productivity of elk *(Cervus elaphus)* in some areas of the Coast, Cascade, and Blue Mountains of Oregon is low or declining, yet the Se status of these herds is unknown. We compared liver Se levels and measures of elk productivity for 447 female elk collected from these 3 geographic regions of Oregon during controlled hunts held in December and January 1987-1993. Elk liver Se concentrations ranged 0.002 - 3.519 ppm, with 42 % of the elk liver samples considered deficient by standards determined for cattle (liver Se $\leq$ 0.120 ppm). Liver Se concentrations varied significantly between areas, and between some years within areas ($P \leq 0.01$). However, liver Se concentration was not related to age, body condition or conception dates of females $\geq$ 1 year of age, and mean herd Se concentration was not related to post season calf:cow ratios, ($P \geq 0.05$). Liver Se was not significant in predicting the probability of pregnancy or lactation in females 3-13 years of age ($P \geq 0.05$). Therefore, we conclude that liver Se levels were not related to the elk productivity parameters we measured. However, liver Se may not be the most appropriate measure of an animal's Se status, because it does not represent a measure of the bioactive form of Se. Instead, we recommend measuring levels of Se in blood.

Introduction

Selenium (Se) is a trace mineral considered by animal nutritionists to be an essential dietary element (Haigh and Hudson 1993, Robbins 1993). It occurs naturally in soils and vegetation worldwide, but its availability varies locally based on geologic history, climate, and land use practices. Se concentrations in $\geq$ 50% of the forage plants of Oregon is inadequate for livestock production ($\leq$ 0.1 ppm) (Haigh and Hudson 1993, National Research Council 1984, 1985).

In animals, Se functions primarily as a component of glutathione peroxidase, an enzyme that prevents oxidative damage to cell membranes and the resulting destruction of animal tissues. Se deficiency in livestock generally manifests itself through decreased productivity, causing reproductive problems in females (i.e. delayed conception, abortions, stillbirths, retained placentas, and mastitis) (Imhof, 1985), and decreased sperm production and motility in males (Hansen and Deguchi 1996). Se deficiency in livestock may also affect feeding efficiency and body condition (Imhof 1985), and may be related to general ill thrift or wasting syndrome in red deer (Knox et al. 1987). Se deficiency can cause myocardial dystrophy and/or white muscle disease in calves (Imhof 1985). Neonate calves with white muscle disease may be unable to nurse or follow their mother and are more susceptible to disease and predation.

Se levels considered less than adequate for livestock production have been measured in a number of game species found in the Pacific Northwest (Fielder 1986, Fleuk 1991, Hebert and Cowan 1991, Hein et al. 1994, Jessup 1990, Oliver et al. 1990, Robbins et al. 1985, Samson et al. 1989, Stoszek 1980), but whether these populations exhibited any symptoms of Se deficiency were not reported. Fielder (1986) theorized that Se deficiency may not exist in wildlife populations because animals may have adapted to patterns of local availability over time by developing alternate chemical pathways to compensate for Se deficient diets. However, Se supplementation of black-tailed deer *(O. h. columbianus)* living in a low Se environment in northern California elevated blood Se levels threefold and increased fawn:doe ratios by 51% (Fleuk 1994), demonstrating that low Se was a factor limiting deer productivity in this area.

Productivity of Oregon's elk is low or declining in some areas. Roosevelt elk (*C. e. roosevelti*) of the Coast Range generally bear calves in alternate years, as opposed to Rocky Mountain elk

(*C. e. nelsoni*) of the Cascade and Blue Mountains which typically bear calves annually (Trainer 1971). Elk from the south-central Cascades and northeast Oregon have both experienced declining calf:cow ratios in recent decades as low as 26 calves per 100 cows (D. Edwards pers. comm.), but the Se status of these herds has not been determined. Therefore, the purpose of our study was to measure liver Se levels in selected herds of Oregon's elk, and to examine the relationship between liver Se levels and factors associated with elk productivity.

Study Areas

We measured liver Se levels in elk from the Dean Creek elk viewing area in the mid-Oregon coast, the upper North Umpqua River basin in the south central Cascades, and the Starkey Experimental Forest and Range (Starkey) in the Blue Mountains of northeast Oregon (Figure 1). All areas were typical of most managed forest lands in Oregon, consisting of coniferous forests in various seral stages, interspersed with open foraging areas of grasslands, meadows, or recent timber harvests.

Elk from the Dean Creek area were non-migratory, year-round residents of coastal, low elevation, Douglas fir *(Pseudotsuga menziesii)* forests. Primary foraging areas were improved, wet meadows, natural marshes, and recent clearcuts. Wet meadows were improved by seeding winter active grasses and legumes, and by annual applications of fertilizer containing sulfur, boron, and

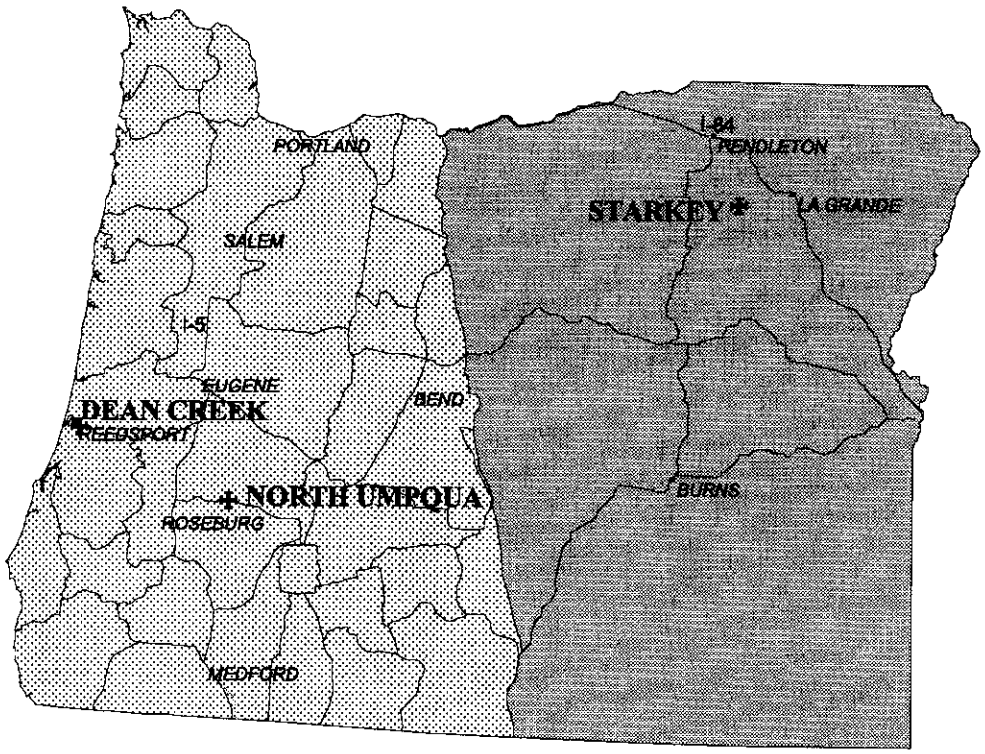

Figure 1. Liver Se collection areas in Oregon. (Reproduced in part from Robbins 1993)

nitrogen. Natural marshes and recent clearcuts contained a mix of coastal, native plant species.

Elk from the North Umpqua area were a mix of resident and migratory elk wintering at higher elevation, mixed coniferous, Douglas fir and white pine *(Pinus monticola)* forests above 915 meters. Primary winter forage areas were small natural meadows, recent clearcuts, and old-growth stands containing a mix of plant species native to the central Cascades. North Umpqua migratory elk summered on four national forests in a variety of habitats and foraged on a diverse array of plant species.

Elk from the Starkey area were confined to a 78-km^2 enclosure of Ponderosa pine *(Pinus ponderosa)* and grand fir *(Abies grandis)* forest. Primary foraging areas were open grasslands of native bluebunch wheatgrass *(Pseudoroegnaria spicata),* and Idaho fescue *(Festuca idahoensis)* and open coniferous stands in various seral stages. Although naturally migratory, Starkey elk were prevented from migrating by a 2.5-m high game-proof fence, baited onto a winter feed area, and fed locally grown alfalfa. A detailed description of Starkey is provided in Noyes et al. 1996 and Rowland et al. 1997.

Methods

Liver sections and reproductive data from female elk ≥ 1 year of age were collected in controlled hunts administered by Oregon Department of Fish and Wildlife in December and January 1987-1993. Successful hunters were required to submit samples from harvested female elk, including a liver section, incisor tooth, kidneys with attached fat, udder, and reproductive tract. Liver sections were analyzed by the A.M. Craig Laboratory in the College of Veterinary Medicine, Oregon State University, Corvallis, Oregon for selenium concentrations (ppm) on a wet weight basis using the fluorometric method (Whetter and Ullrey 1978). Age in years, body condition (i.e. kidney fat index, KFI), pregnancy and lactation status, and estimated conception dates were determined as described by Trainer (1971). Annual post-season calf:cow ratios were estimated from helicopter surveys during January and February for Starkey (n = 228 - 434) and North Umpqua (n = 364 - 737) , but herd composition counts from Dean Creek included too few animals (n = 54 - 88) to provide reliable calf:cow ratio estimates.

We obtained data from 145 elk harvested at Dean Creek in 1990 and 1991, 124 elk harvested at North Umpqua in 1987 and 1989-1991, and 178 elk harvested at Starkey in 1989-1993. We used a log10 transformation of Se concentration and a reciprocal transformation of conception dates to improve normality of these variables. Samples for individual elk were pooled by area and year, and these groups of animals were compared using a 1-way ANOVA (BMDP Statistical Software 1991). We used the Fisher's LSD method of multiple comparisons (BMDP Statistical Software 1991) to identify which groups differed significantly. For each group, we used simple linear regression (BMDP Statistical Software 1991) to examine the relationships between liver Se and age, body condition, and estimated conception date of individual elk. We also regressed mean herd liver Se concentration (i.e. mean herd Se) and post-season calf ratios for the year following that in which the Se samples were collected. To determine whether liver Se was a significant variable in predicting the probability of pregnancy or lactation in female elk 3-13 years of age, we used logistic regression (BMDP Statistical Software 1991). In the pregnancy model, we used group, age, KFI, lactation status, and Se as covariates, and for the lactation model, we used group, age, KFI, pregnancy status, and Se as covariates. For all statistical tests we used P = 0.05 as our level of significance.

Results

Elk liver Se levels ranged from 0.002 to 3.519 ppm for all elk sampled (n = 447). Mean liver Se of female elk ≥ 1 year of age (i.e. mean herd Se) differed significantly between groups (F = 56.47, 446, 10df, P = 0.00) (Table 1), and was highest in elk from North Umpqua and lowest in elk from Starkey in all years in which data were collected simultaneously on any of the 3 areas. Within each area, mean herd Se varied by year, however the annual patterns of variation were not consistent between areas.

Elk age ranged from 1 to 23 years, but we found no relationship between liver Se concentrations and elk age in any group tested (n = 26 - 64, $r^2 \leq 0.02$, $P \geq 0.23$). Kidney fat indices of body condition ranged from 5 to 415, but KFI's were not related to liver Se in any group tested (n = 16 - 25, $r^2 \leq 0.08$, $P \geq 0.06$). Estimated conception

TABLE 1. Mean liver selenium levels in female elk ≥ 1 year of age (ppm).

Area	Year	N	Mean (SE)[1]	Range
Starkey	1989	36	0.107 (0.009)a	0.015 - 0.293
	1990	30	0.065 (0.008)d	0.002 - 0.160
	1991	41	0.101 (0.049)a	0.050 - 0.186
	1992	34	0.079 (0.007)a	0.018 - 0.195
	1993	37	0.144 (0.006)b	0.072 - 0.313
Dean	1990	71	0.291 (0.032)c	0.032 - 1.266
Creek	1991	74	0.181 (0.024)b	0.039 - 1.558
North	1987	28	1.777 (0.196)e	0.117 - 3.519
Umpqua	1989	27	0.944 (0.154)f	0.073 - 3.026
	1990	43	0.510 (0.068)g	0.055 - 2.172
	1991	26	0.253 (0.037)b,c	0.081 - 0.738

[1] like letters indicate similar means ($P \geq 0.05$)

dates ranged from September 7 to November 24, but we found no relationship between estimated conception dates and liver Se in any group tested (n = 7 - 37, $r^2 \leq 0.03$, $P \geq 0.19$). Annual post-season calf:cow ratios ranged from 24 to 57 calves per 100 cows , but calf:cow ratios were not related to mean herd Se (n = 9, r^2 =0.17, $P = 0.27$). Liver Se was not a significant predictor of pregnancy (n = 15 - 46, $P \geq 0.24$) or lactation status (n = 15 - 46, $P \geq 0.07$) in any group test.

Discussion

The wide range of liver Se levels observed in Oregon's elk represents a range considered deficient (≤ 0.120 ppm) to toxic (≥ 1.250 ppm) for cattle (K. Walker, pers. comm.). Livestock in the extreme ends of the range we observed in Oregon's elk would be seriously ill or dead (Imhof, 1985). Twenty-five percent of the elk from North Umpqua had liver Se levels considered toxic for cattle. Although our data were not appropriate for identifying symptoms of Se poisoning (i.e. hoof lesions, stunted growth, skeletal deformities, blindness, and paralysis) (Robbins 1993), none of these symptoms have been reported in elk sampled by hunters.

Fourteen percent of North Umpqua elk, 39% of Dean Creek elk, and 66% of Starkey elk had liver Se levels considered deficient for cattle. Although liver Se varied by area and year, we found no significant relationships between liver Se and any of the productivity parameters we examined and we conclude that they are unrelated. Sample sizes were small and variation between individuals was high resulting in decreased power of some of our tests. However, our findings of significant differences in mean herd Se between areas and years is comparable to other surveys of elk Se levels in the Northwest (Hein et al. 1994, Jessup 1990). Our individual-based analysis of elk liver Se levels and the paired productivity parameters covers a wide range of values, and our consistent lack of any significant relationship further strengthens our conclusion. However, we cannot conclude from our analysis whether Se deficiency does or does not exist in Oregon's elk, nor make recommendations as to the levels at which liver Se becomes deficient or toxic in elk. Only through controlled studies can this be determined. Furthermore, liver samples may not provide the best estimate of Se status in elk. Liver Se concentrations calculated on a wet weight basis may not be as reliable as those calculated on a dry weight basis because of variations in liver water content (D. Hamar pers. comm.) Liver Se concentration does not represent a bioactive level of Se, but rather a stored or reserve amount, and Se stored in the liver may not be available for glutathione production which occurs in the blood only when adequate amounts of vitamin E are present (C. Robbins, pers. comm.). Both high and low liver Se levels can be associated with low blood Se levels, and liver Se levels may appear adequate when blood Se levels are not (C. Robbins pers. comm.). High dietary sulfur and/or heavy metals may also interfere with Se absorption and metabolism (Finch and Turner 1996, Oliver et al.1990), but measures of these chemicals were not obtained or held constant in our study involving free-ranging animals.

Management Implications

We believe that critical levels of liver Se affecting livestock production cannot be applied to elk. However, the significance of adequate dietary Se in optimizing livestock production, and the concerns over declining elk productivity in the Pacific Northwest, suggest a need to better understand the potential effects of Se on elk productivity. In future evaluations of Se status in elk, measures of blood Se levels and concurrent measures of vitamin E and glutathione peroxidase are needed to determine whether Se or vitamin E levels are affecting the production of glutathione peroxidase. Concentrations of sulfur and heavy metals in the

blood would also be useful in evaluating potential inhibitory effects of these chemicals on Se absorption when availability of dietary Se may be otherwise adequate. We recognize that obtaining an adequate number of blood samples from free-ranging elk is logistically difficult in the typical wildlife management context . Therefore, determining whether Se induced productivity problems exist in elk should be determined through highly controlled studies.

Literature Cited

BMDP Statistical Software. 1991. SOLO Statistical System. BMDP Statistical Software, Los Angeles, California, USA

Fielder, P.C. 1986. Implications of selenium levels in Washington mountain goats, mule deer, and Rocky Mountain elk. Northwest Science 60:15-20.

Finch, J.M. and R.J. Turner. 1996. Effects of selenium and vitamin E on the immune responses of domestic animals. Veterinary Science 60:97-106.

Fleuk, W.T. 1991. Whole blood selenium levels and glutathione peroxidase activity in erythrocytes of black-tailed deer. Journal of Wildlife Management 55 :26-31.

_____. 1994. Effect of trace elements on population dynamics: selenium deficiency in free-ranging black-tailed deer. Ecology 75:807-812.

Haigh, J. C. And R. J. Hudson. 1993. Selenium and vitamin E. Pages 203-205 *In* R. W. Reinhardt (editor) Farming wapiti and red deer. Mosby-Year Book, Incorporated, Saint Louis, Missouri, USA.

Hansen, J.C. and Y. Deguchi. 1996. Selenium and fertility in animals and man-A review. Acta Veterinaria Scandaniavica 37:19-30.

Hebert, D.M., and I.M. Cowan. 1971. White muscle disease in mountain goats. Journal of Wildlife Management 35:752-756.

Hein, R.G., P.A. Talcott, J.L. Smith, and W.L. Meyers. 1994. Blood selenium values of selected wildlife populations in Washington. Northwest Science 68:185-188.

Imhof, N. 1985. Selenium deficiencies in livestock. Animal Nutrition and Health June/July:22-25.

Jessup, D.A. 1990. Monitoring health parameters in California's elk herds. Pages 92-97 *In* R.L. Callas, D.B Koch, and E.R. Loft (editors) Proceedings of the Western States and Provinces Elk Workshop. California Department of Fish and Game. Sacramento, California

Knox. D.P., H.W. Read, and J.G. Peters. 1987. An outbreak of selenium responsive unthriftiness in farmed red deer, *Cervus elaphus*. Veterinary Record. 120:91-92.

Received 9 March 1999
Accepted 14 January 2000

Acknowledgements

The authors would like to thank George Kiester, John Toman, and Terry Farrel for providing North Umpqua and Dean Creek data and area descriptions. We would also like to acknowledge Chuck Trainer and Richard Green for conducting elk reproductive exams. Charles Robbins and Mike Gratson provided reviews of earlier drafts of this manuscript.

National Research Council. 1984. Nutrient requirements of beef cattle. Sixth edition. National Academy Press, Washington D.C., USA.

_____. 1985. Nutrient requirements of sheep. Sixth edition. National Academy Press, Washington D.C., USA.

Noyes, J.H., B.K Johnson, L.D. Bryant, S.L. Findholt, and J.W. Thomas. 1996. Effects of bull age on conception dates and pregnancy rates of cow elk. Journal of Wildlife Management 60(3):508-517.

Oliver, M.N., G. Ros-McGauran, D.A. Jessup, B.B. Norman, and C.E. Franti. 1990. Selenium concentrations in blood of free-ranging mule deer in California. Transactions of the Western Section of the Wildlife Society 26: 80-86.

Robbins, C.T. 1993. Selenium. Pages 62-64 *In* T. J. Cuhna (editor) Wildlife feeding and nutrition, 2nd ed. Academic Press, Incorporated. San Diego, California, USA.

Robbins, C.T., S.M. Parrish, and B.L. Robbins. 1985. Selenium and glutathione peroxidase activity mountain goats. Canadian Journal of Zoology 63:1544-1547.

Rowland, M.M, L.D. Bryant, B.K. Johnson, J.H. Noyes, M.J. Wisdom, and J.W. Thomas. 1997. The Starkey Project: History, Facilities, and Data Collection Methods for Ungulate Research. USDA Forest Service General Technical Report PNW-GTR-396.

Samson, J., J.T. Jorgenson, and W.D. Wishart. 1989. Glutathione peroxidase activity and selenium levels in Rocky Mountain bighorn sheep and mountain goats. Canadian Journal of Zoology 67:2493-2496.

Stoszek, M.J., H. Willmes, and W.B. Kessler. 1980. Trace mineral metabolism of Idaho pronghorn antelope. Transactions of the Northwest Section of the Wildlife Society. Banff, Alberta, Canada.

Trainer, C.E. 1971. The relationship of physical condition and fertility of female Roosevelt elk (*Cervus canadensis roosevelti)* in Oregon. Masters Thesis, Oregon State University, Corvallis, Oregon, USA.

Whetter, P.A. and D.E. Ullrey. 1978. Improved fluorometric method for determining selenium. Journal of the Associated Official Analytical Chemists 61:927-930.