

Implications of Selenium Levels in Washington Mountain Goats, Mule Deer, and Rocky Mountain Elk

Abstract

Samples of mountain goat forage, hair, blood, liver, and fecal pellets were analyzed for selenium content. Wild mountain goats had selenium levels which rated as deficient when compared to selenium levels desirable for livestock. Captive goats, which consumed diets supplemented with 0.1 ppm selenium, had normal to high blood selenium levels compared to livestock. Selenium levels in liver and hair samples were higher for mule deer and elk than for wild mountain goats but the selenium levels in the liver samples ranked as deficient relative to livestock. Selenium deficiency is a cause of white muscle disease and has also been linked to reduced production and neonate survival. Selenium supplementation of wild ungulates is proposed in selenium deficient areas to increase herd health and production.

Introduction

Selenium has long been recognized as an essential element in livestock nutrition (Young *et al.* 1961, Muth and Allaway 1963, Oldfield *et al.* 1963, Jenkins and Hidioglou 1972, Ammerman and Miller 1975, Andrews *et al.* 1976). Selenium deficiencies have been linked to white muscle disease (characterized by lesions of white striations and degeneration of muscle tissue), unthriftiness, weakness of newborn, reduced rate of weight gain, reduced production (because of increased infertility, stillbirths, and abortions), and a reduced immunosuppression system (Oldfield *et al.* 1963, Allaway and Hodgson 1964, Jenkins and Hidioglou 1972, Ammerman and Miller 1975, Andrews *et al.* 1976).

Recently researchers have identified the importance of adequate selenium to wildlife (Hebert and Cowan 1971, Fleming *et al.* 1977, Lewis *et al.* 1977, Stoszek *et al.* 1980, Ullrey *et al.* 1981, Robbins 1983). Most of this wildlife research has been concerned with the influence of selenium on the occurrence of white muscle disease (Hebert and Cowan 1971, Fleming *et al.* 1977, Ullrey *et al.* 1981, Foster *et al.* 1983) and capture myopathy (acidosis and death caused by stress during capture and handling) (Chalmers and Barrett 1977, Lewis *et al.* 1977). Stoszek *et al.* (1980) and Ullrey *et al.* (1981) hypothesized that selenium deficiency was linked to lower reproductive rates for pronghorns (*Antilocarpa americana*) and white-tailed deer (*Odocoileus virginianus*), respectively.

Since the distribution of selenium in soils and plants varies greatly throughout the United States (Muth and Allaway 1963, Muth 1970,

Ammerman and Miller 1975) it is likely that selenium concentrations also influence local wildlife populations. Selenium deficiency is recognized as a problem for livestock in the Northwest (Muth and Allaway 1963) and livestock growers now supplement their herds with selenium (P. South, personal communication). However, big game species that graze these same selenium deficient areas have not received the benefits of selenium supplementation.

Selenium deficiencies may be keeping big game herds from achieving their optimum productivity levels (Stoszek *et al.* 1980, Ullrey *et al.* 1981). Any influence of selenium deficiency on big game production would have been present for thousands of years. However, coupled with other limiting factors (e.g., reduction of winter ranges, human harassment, hunting mortality), selenium deficiency may be an additive factor which represses optimal herd growth.

Selenium concentrations in several big game species were studied as a part of wildlife studies required by the new Federal Energy Regulatory Commission license for the Lake Chelan hydroelectric project. The purpose of this study was to establish selenium concentration levels for mule deer (*Odocoileus hemionus*), mountain goats (*Oreamnos americanus*), and Rocky Mountain elk (*Cervus elaphus nelsoni*) and compare those levels with selenium levels found in livestock.

Methods

Mountain goat forage samples were collected along Lake Chelan in northcentral Washington for selenium analysis during the winters of

1982-83 and 1983-84. Feeding goats were backtracked and samples were taken from forage plants they had been eating. Samples of local forage species which have been identified in mountain goat food habits studies (Hjeljord 1973, Adams and Bailey 1983, Campbell and Johnson 1983, Fielder and McKay 1984) were also collected. The Washington State University (WSU) Washington Animal Disease Diagnostic Laboratory (WADDL) used the atomic absorption method to determine selenium content of the forage samples.

Selenium values were determined for mountain goats from fecal pellets, hair, blood, and liver samples. Fecal pellets were collected along Lake Chelan during winter forage collections, from goats immediately after they were trapped in Olympic National Park (ONP), and from goats in captivity at WSU and at the Woodland Park Zoo (WPZ) in Seattle.

Hair samples were taken from the hind-quarters of mountain goats captured in ONP, goats in captivity at WSU and WPZ, and from goats harvested by hunters in the Cascade Mountains of Washington and mule deer and elk harvested in central Washington. Liver samples were also collected from the goats, mule deer, and elk harvested by hunters. The deer, mountain goat, and elk hair and liver samples were obtained on an "as available" basis. All of the deer sampled were harvested in Chelan County and the elk were harvested in Chelan and Kit-titas counties. Blood samples were obtained from mountain goats captured in ONP and from captives at WSU and WPZ.

All of the samples (forage, fecal pellet, hair, liver, and blood) were sealed in plastic bags, kept as cool as possible until they could be frozen, and were kept frozen until analyzed. The samples were analyzed at WSU-WADDL by the atomic absorption method using a Perkin-Elmer 360 atomic absorption spectrometer with a MHS-10 mercury hydride system. Charles Robbins (WSU) also had 11 of those same blood samples from the ONP goats analyzed at Oregon State University by the fluorometric method (Whetter and Ullrey 1978), as part of his research and graciously shared those data.

Captive mountain goats at WSU were maintained on a selenium supplemented alfalfa-grain pellet (approximately 0.10 ppm Se), and received varying doses of selenium injections as part of

a research project. The goats at WPZ utilize an apple-carrot-yam mixture which is supplemented with selenium (0.10 ppm), alfalfa hay (grown in eastern Washington), and Purina horse chow.

Results

All of the forage plants used by mountain goats along Lake Chelan during winter had either low or undetectable levels of selenium (Table 1). Hebert and Cowan (1971) found that mountain goat forages in southeast British Columbia were also low in selenium. A high proportion of the winter diet of the Lake Chelan goat herd is comprised of grasses and conifers (Fielder and McKay 1984) which included all with the highest selenium concentrations (Table 1).

TABLE 1. Selenium content (ppm) of mountain goat forage plants along Lake Chelan, Washington.

Forage plant	Shore	
	South	North
Bluebunch wheatgrass (<i>Agropyron spicatum</i>)	0	.02
Fescue spp. (<i>Festuca</i> spp.)	0	—
Bluegrass spp. (<i>Poa</i> spp.)	0	—
Needlegrass spp. (<i>Stipa</i> spp.)	.01	—
Paintbrush spp. (<i>Castilleja</i> spp.)	—	0
Fumariaceae	0	—
Lewisia (<i>Lewisia columbiana</i>)	0	—
Penstemon spp. (<i>Penstemon</i> spp.)	0	0
Eriogonum spp. (<i>Eriogonum</i> spp.)	0	—
Unknown green forb	0	—
Unknown forb	—	0
Serviceberry (<i>Amelanchier alnifolia</i>)	0	—
Kinnikinnick (<i>Arctostaphylos uva-ursi</i>)	0	—
Red-osier dogwood (<i>Cornus stolonifera</i>)	TR	—
Oregon boxwood (<i>Pachystima myrinites</i>)	0	—
Antelope bitterbrush (<i>Purshia tridentata</i>)	—	0
Ponderosa pine (<i>Pinus ponderosa</i>)	TR	.03
Douglas fir (<i>Pseudotsuga menziesii</i>)	.02	.02
Sword Fern (<i>Polystichum munitum</i>)	0	0

TR = trace, — = no sample tested, 0 = none detected (detection of selenium concentrations less than .005 ppm was unreliable).

There is significant variation in selenium values of blood ($P < 0.01$), hair ($P < 0.01$), liver ($P < 0.01$), and fecal pellet ($0.01 < P < 0.05$) samples from the groups of mountain goats in Washington which we sampled (Table 2). Eleven

TABLE 2. Selenium concentrations (ppm) in several sample types from Washington mountain goats, Mule deer, and Rocky Mountain elk.

Sample group ¹	Sample size	Range	Mean	Standard deviation
Hair				
Washington St. Univ. goats	4	.12-.188	.148	.028
Woodland Park Zoo goats	7	.01-.047	.020	.013
Olympic National Park goats	22	.00-.087	.020	.023
Washington hunter kill goats	6	.04-.094	.070	.021
Washington hunter kill deer	10	.01-.314	.150	.080
Washington hunter kill elk	8	.05-.240	.110	.062
Blood				
Washington St. Univ. goats	3	.05-.21	.142	.086
Woodland Park Zoo goats	7	.20-.25	.222	.020
Olympic National Park goats	20	.01-.11	.035	.025
Olympic National Park goats ²	11	.01-.15	.057	.056
Pellets				
Washington St. Univ. goats	4	.09-.21	.159	.057
Woodland Park Zoo goats	6	.02-.04	.029	.010
Olympic National Park goats	16	.00-.04	.009	.008
Lake Chelan goats	12	.01-.05	.020	.010
Liver				
Washington hunter kill goats	10	.01-.07	.022	.020
Washington hunter kill deer	10	.05-.20	.121	.057
Washington hunter kill elk	9	.02-.21	.070	.066

¹All samples analyzed by atomic absorption method unless indicated.

²Samples analyzed by fluorometric method. These 11 samples were also among the 20 blood samples from ONP goats which were sampled by the atomic absorption method.

blood samples from ONP goats were analyzed by both the atomic absorption and fluorometric methods. The fluorometric method yielded selenium values for these samples which were slightly higher than those yielded by the atomic absorption method ($0.01 < P < 0.05$). Selenium concentrations in hair and liver samples from hunter harvested goats did not differ significantly from similar samples from deer and elk ($P > 0.05$). However, deer and elk hair and liver selenium levels ranged to as much as three times the concentration levels as samples from goats harvested by hunters (Table 2). The goats at WSU and WPZ had higher blood and fecal pellet selenium levels ($P < 0.01$) than did wild mountain goats.

Selenium concentrations in blood, liver, and hair samples from mountain goats, mule deer, and elk were compared to similar samples from domestic sheep, cattle, and hogs (Table 3). Selenium levels in the samples from goats at WSU (whose feed is supplemented with selenium)

rate as normal or high compared to domestic livestock. Selenium levels in liver samples from elk and deer harvested by hunters rank as deficient compared to sheep and hogs. Wild mountain goats (those captured in ONP and those harvested by hunters) are deficient in selenium, compared to livestock (Table 3).

Discussion

Most mountain goat habitat in North America occurs in mountainous areas of volcanic origin with relatively new soils where selenium levels in forage would be expected to be relatively low. Mountain goat diets in Washington, like those in southeast British Columbia (Hebert and Cowan 1971), are low in selenium. Selenium levels were highest in conifers (Table 1), which comprise a major portion of the winter diet of mountain goats in Washington (Campbell and Johnson 1983, Fielder and McKay 1984). However, the

TABLE 3. A comparison of selenium levels in big game and livestock.

Animals/source	Average selenium levels or ranges (ppm) ¹		
	Blood	Liver	Hair
Big game			
Mule deer (hunters)		.12(.05-.20)	.15(.01-.31)
Rocky Mountain elk (hunters)		.07(.02-.21)	.06(.05-.24)
Mountain goats (hunters)		.02(.01-.07)	.05(.04-.09)
Mountain goats (WSL)	.14(.05-.21)		.15(.12-.19)
Mountain goats (WPZ)	.22(.20-.25)		.02(.01-.05)
Mountain goats (ONP)	.04(.01-.15)		.02(.00-.09)
Sheep			
Andrews <i>et al.</i> 1976	def. .010	def. .020	def. .050
Thompson <i>et al.</i> 1976	def. (.021-.067)		
Thompson <i>et al.</i> 1976	high (.133-.249)		
Jenkins and Hidiroglou 1972		def. (.08-.19)	
Burton <i>et al.</i> 1962		low .345 ± .12	
Burton <i>et al.</i> 1962		norm. .906 ± .06	
Jenkins and Hidiroglou 1972		norm. (.92-2.54)	
Cattle			
P. South, pers. comm.	def. <.05		
Thompson <i>et al.</i> 1976	low (.009-.072)		
P. South, pers. comm.	marg. (.05-.09)		
P. South, pers. comm.	norm. >0.1		
Perry <i>et al.</i> 1976			high .390(.214-.564)
Hogs			
Thompson <i>et al.</i> 1976	high (.093-.193)		
Jenkins and Hidiroglou 1972		def. (.19-.31)	
Jenkins and Hidiroglou 1972		norm. 1.82	

¹def. = deficient, marg. = marginal, norm. = normal.

selenium levels in conifers browsed by goats along Lake Chelan are well below the levels needed for protection against white muscle disease. White muscle disease in domestic livestock is rare where selenium concentrations in forage is greater than 0.1 ppm, occurs erratically at 0.1-0.05 ppm, and is common where selenium concentrations in forage are less than 0.05 ppm (Muth and Allaway 1963, Allaway and Hodgson 1964). Although these concentration levels are linked with the occurrence of white muscle disease, they may also suggest warning levels for other selenium related problems which inhibit herd health (e.g., unthriftiness, weakness of newborn, reduced rate of weight gain, reduced production, and a reduced immunosuppression system).

Robbins and Parish (personal communication) report that captive goats exhibit a more rapid growth in captivity than do goats in the wild, suggestive of nutritional difficulties of wild

mountain goats. This suggests that goats, on diets that are adequately supplemented, experience greater growth rates than unsupplemented goats as well as maintain higher selenium levels. The mountainous habitat occupied by mountain goats, usually characterized by relatively new, selenium deficient soils, may be a reason why goats harvested by hunters had lower hair and liver selenium levels which did not range as high as those of deer and elk (Tables 2 and 3). Deer and elk usually occupy lower elevations with older soils which are generally richer in selenium (Muth and Allaway 1963, National Research Council 1976).

Selenium deficiency in mountain goats (Hebert and Cowan 1971, this study) may be a factor contributing to low mountain goat productivity. Low selenium levels may be suppressing mountain goat production, just as it suppresses livestock production (Oldfield *et al.* 1963, Jenkins

and Hidioglou 1972, Ammerman and Miller 1975, Andrews *et al.* 1976) by causing increased infertility, still births, and abortions and/or reducing neonate survival by causing weakness of newborn, slow weight gain, or a reduced immunosuppression system. Although estimates of mountain goat production vary among areas (from 86 to 22 kids per 100 adult females (Rideout 1978)) production rates are generally lower for mountain goats than for deer and elk. Doe:fawn and cow:calf ratios for deer and elk in central Washington and other selenium deficient regions are low compared to western regions with adequate selenium levels (e.g., Colorado, Utah, Montana, Wyoming). Stoszek *et al.* (1980) analyzed tissues from livestock and Idaho and Montana pronghorns and suggest a relationship between selenium deficiency in pronghorns and the decline of eastern Idaho pronghorn herds. Based upon analysis of white tailed deer muscle tissues, Ullrey *et al.* (1981) believe that deer in regions with low plant selenium concentrations may have a lower reproductive efficiency and a high post-natal mortality rate. Low production rates of mountain goat herds may also be, in part, a result of selenium linked reproduction and neonate survival limitations.

More research is needed to test this hypothesis including either (1) selenium analysis of

big game samples from herds in several regions and correlation of selenium data with production data for those herds, or (2) monitoring of changes in productivity and newborn survival in big game herds, for which records of production are available, which have been supplemented with selenium (mineral or protein blocks). Selenium supplementation has been found to be desirable and effective by the livestock industry (Jenkins and Hidioglou 1972, Wharger *et al.* 1978). Big game herds may also benefit from supplementation.

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