Comparison of Bighorn Sheep Forage, Hair, and Feces Using Stable Isotopes

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Abstract: Stable isotopes have been used to document diet history in black bears (Mizukami et al. 2005), short term diet changes in horses (West et al. 2004), and to determine the diets of various African ungulates and bovids (Sponheimer et al. 2003a, Sponheimer et al. 2003b, Codron et al. 2007). We collected samples of forage, hair, and feces from bighorn sheep (*Ovis canadensis)* in 6 areas during summer and autumn in 2005 and 2006 in Utah, USA. We observed foraging locations of bighorn and collected fecal samples as well as plant species eaten by these animals. Similarly, we collected forage samples from nearby random locations for comparison with plants eaten by bighorns. We also collected hair from animals in one population. Mass spectrometry was used to analyze each of these samples for $\delta^{13}C$ and $\delta^{15}N$ isotope ratios. We are looking to see if the difference in ram and ewe diets is quantifiable using isotope rations and to determine diet differences between seasons. Our preliminary results indicate that there is a difference between ram and ewe diets. Analysis of stable isotopes can be a useful tool to identify plant species that are consumed by bighorns. This technique can be used by wildlife managers to reseed in bighorn habitat after fires or treatment.

Key Words: bighorn sheep, stable isotope analysis, forage selection

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Introduction

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) have been an integral part of the natural history of Utah. Their original range covered all but the southeastern and southernmost parts of Utah. Their depictions are common in native art and are mentioned in the annals of the earliest explorers of what is now Utah. These animals were mostly extirpated from the state by the 1960's (Rawley 1985) because of factors relating to interactions with settlers and their livestock and livestock management practices (Shields 1999). This includes direct competition for forage resources and diseases, especially lungworm from domestic sheep.

Current practices of bighorn sheep management in Utah include the reintroduction of animals from Montana and Colorado into local historic ranges. The primary purpose of these releases is for sheep conservation, but it also provides wildlife viewing and hunting experiences for people. Currently, Rock Mountain bighorn and California bighorn (*O. c. californiana*) have been used to reestablish populations of these animals in northern Utah. California bighorns have been released on Antelope Island and the Newfoundland Mountains (Jericho Whiting, personal communication 2007). All other areas in our study received

Rocky Mountain bighorn. In southern and southeastern Utah mostly desert bighorn have been translocated. California and Rocky Mountain bighorn sheep should not be considered separate subspecies (Wehausen and Ramey 2000); therefore, in this paper, we treat them as a single species (UDWR Statewide Management Plan for Bighorn Sheep 1999).

Bighorn sheep reintroductions are not uncommon and have been used throughout the western United States (Krausman 2000). Indeed, of 100 sheep reintroductions 70 of these were either successful or moderately successful (Singer et al. 2000). The Utah Division of Wildlife Resources has exerted much effort reintroducing bighorn sheep to their native ranges in Utah including Flaming Gorge and Cache Valley in the north, the Newfoundland Mountains west of the Great Salt Lake, Antelope Island, the Stansbury Mountains, and the Wasatch Mountains (American Fork Canyon, Rock Canyon, and Mt. Nebo).

The management plan for bighorns in Utah indicates that research is needed to increase lamb survival and to "initiate vegetative treatment projects to improve bighorn habitat lost to natural succession or human impacts" (UDWR Statewide Management Plan for Bighorn Sheep 1999). Before performing range improvements, such as reseeding of desired plant species, both for existing wildlife populations and prior to wildlife introductions it is critical to understand the diets of each animal to be released. Previously this required many man hours and time consuming practices such as direct observation of bite counts and captive rearing of wild ungulates (Dailey et al. 1984 and Goodson et al. 1991). Now, new technology involving mass spectrometry makes it possible to determine the chief components of an animal's diet simply by analyzing hair composition (West, et al. 2004, Schwertl et al. 2003). The ratio of $\delta^{12}C$ to $\delta^{13}C$ and $\delta^{14}N$ to $\delta^{15}N$ is standard in different plant species. When consumed, these ratios remain constant and are used in the growth of the animal, or in other words, there is a set differential offset between diet and hair, and because this value is set and does not fluctuate, the offset value can be used to indicate the forage signature (Todd Robinson 2008 personal communication). By determining the presence of these ratios, hair can indicate which plant species or types are consumed. By decreasing the amount of time and funds spent to determine plant use wildlife management agencies will be better able (both in time and money) to enact range improvements.

Methods

We observed bighorn sheep foraging various locations across the Great Basin, including the Newfoundland Mountains, Stansbury Mountains, Antelope Island, American Fork Canyon, Rock Canyon (Provo), and Mt. Nebo. We located sheep that had been equipped with radio collars before and during the 2005-2006 using radio telemetry and observed for at least 20 minutes while grazing using spotting scopes and binoculars. A detailed map of the foraged area was made by hand showing plants and locations the sheep foraged. After sheep had left the site, either later the same day or the next day researchers returned and using the map made previously, we would locate exactly where sheep had foraged, based on evidence of bites on plants. When a use site was found, a 1 m. plot was centered around the bite site and all plant species within the plot were cut to ground level and separated by species, bagged, and weighed. We also recorded percent cover, percent use, and dominant phenotype for each plant species found in the plots. Five such use plots were collected

for each day of sampling. For each use site a random site was also sampled following the same protocol. If a plant species that was consumed was found in the random site it was collected and processed in the same manner as in the use site. If the species was not found in the random site then the nearest plant was found and at least 20g was collected. After collection each plant sample was dried in an oven in 60°C for 24 hours and then reweighed (Flinders and Hansen 1972). Furthermore, we entered all information that was collected into a database based on location and date and whether the group of sheep was composed of rams, ewes and lambs, or a mix. Additionally, we collected fecal samples from foraging locations. These samples were dated and labeled based on the use group (ewe, ram, lamb).

These plants and feces are now being ground using a 0.425 mm mill, to produce a fine homologous sample. Like species from each sample day were ground together, keeping plants from use sites separate from those in random sites. From these ground samples a 600-700µg sub sample will be collected for stable isotope analysis in a mass spectrometer. To date the focus has been on processing samples from Antelope Island.

We also collected hair samples from sheep on Antelope Island to determine if the stable isotope ratios of different plant species of known use collected from Antelope Island appear in the hair after stable isotope analysis. Hairs were labeled according to the sex of the animal and the date it was extracted. We cut hairs in 1 mm segments starting at the proximal end (Spoonheimer et al. 2003). To obtain a sufficiently large sample (350-550µg) more than one hair from each individual will be used. Hair samples will then be run on a continuous flow mass spectrometer to determine isotope ratios.

Values gained from the mass spectrometer were used to determine each plant species fraction in the diet based on the fecal values based on the equation $[(\delta^{13}C_{feces/hair} +1000) /(\delta^{13}C_{forage} +1000)–1] /1000$ = diet fractionation. This provides an estimate of the short term diet. The results from the hair analysis will provide a better look at the long term and seasonal diets.

Results

The correlations gathered from stable isotope analysis of bighorn sheep hair and forage from Antelope Island will be paired with a nutritional analysis of the Antelope Island forage. This information will detail which plant species are preferred by the sheep and which provide the best nutrition. These findings will then provide the state with the focal species that should be used to reseed areas of ewe and lamb use. The same analysis on other forages in the other bighorn locations will provide the same information for each of the different locations sampled by researchers.

As can be seen in Figure 1, C3 and C4 plants are easily identified by their different isotope signatures. Then in Figure 2 the diet fractionation of different plant species in ram and ewe diets is expressed. Values that are positive or near zero are relatively abundant in the diet, whereas negative values make up small proportions of the diet. These results are preliminary and not yet refined or compared with the other sheep populations along the Wasatch Front and Great Salt Lake Desert of Utah. Four more populations of bighorn sheep will be compared with the same techniques and will result in a description of the differences in diet over short distances.

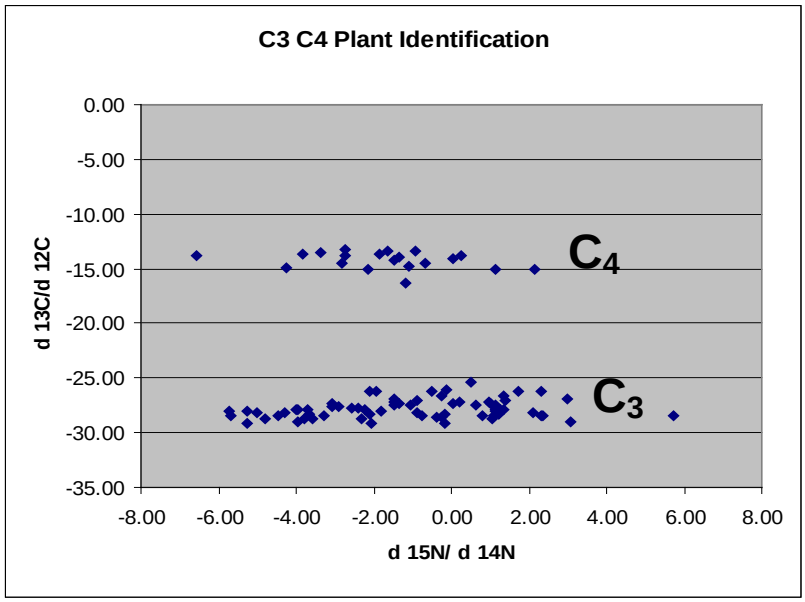

Figure 1. A comparison of C3 and C4 plants types found in the diet of bighorn sheep on Antelope Island, Utah from 2005 to 2006.

	Ram	Ewe
Eriogonum divergens	1.66	-0.13
Carex spp.	1.64	-1.28
Artemesia ludoviciana	1.21	0.09
Lactuca serriola	0.58	No use
Helianthus annuus	-0.02	-1.23
Compositae spp.	-0.15	No use
Epilobium brachycaulum	-0.16	-15.05
Bromus tectorum	-1.74	-13.67
Erodium cicutarium	-13.94	-0.54
Aristida purpurea	-14.08	0.51

Figure 2. Fractionation values of different plant species in the feces of rams and ewes from Antelope Island, Utah. Values that are positive or near zero denote a higher proportion in the diet.

Discussion

Rams and ewes separate into separate groups, except during breeding season. During segregation rams stay in bachelor herds and will move around looking for the best feed (Bleich et al. 1997). Ewes, however, tend to stay near escape terrain (cliffs and steep slopes), where they and their lambs can more effectively avoid and/or escape from predators. These areas offer the best opportunity for safety, but do not allow access to the best available forage. While bighorn sheep have a highly variable diet, one that is difficult to quantify by species (Krausman and Bowyer 2003) stable isotope analysis will cheaply register plant types consumed. Any reseeding projects can focus on the local plant species best suited for ewes and lambs and be located near escape terrain. Since the survival of young and their recruitment, or their addition to the breeding population, is of vital importance to the sustainability and growth of bighorn sheep herds, increasing the vigor of lambs without removing them from escape terrain will allow the bighorn sheep herds in the Great Basin to grow.

By knowing the best plants to revegetate range with, based on use and known nutrient content, management agencies will be able to determine which species to reseed based on a nutritional and foraging preference basis. Currently the methods used to determine forage use in wild ungulates is to observe foraging behavior. This is time consuming and costly. Using hair samples (even from harvested animals or carcasses) could simplify and cut the costs associated with determining forage use. This method can then be replicated with other wildlife species to help in other revegetation projects, or during reseeding after wildfires.

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