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Comparison of Rumen and Fecal Analysis to Estimate Moose Diets

Abstract

Large ungulate management and research projects often require estimates of diet composition, and indirect methods are often the only feasible alternatives. We compared diet estimates based on moose (*Alces alces gigas*) rumen and fecal samples taken from the same animal on the Copper River Delta, Alaska. Twenty-five animals were sampled, the majority of which were killed by hunters during September. Three procedures were used, a standard microhistological technique on both rumen and fecal samples and a macroscopic technique on rumen samples. The macroscopic analysis of rumen samples identified contents to species and specific plant parts. However, the results of macroscopic rumen analysis can be affected by seasonal changes in rumen particle size. Microhistological analysis of both rumen and fecal samples could not differentiate among willow species (*Salix* spp.), the dominant food item, nor could plant parts be distinguished. These are major shortcomings of this procedure. However, when willows were identified only to genus, diets estimated by the 3 procedures differed ($P < 0.001$) only for minor items (<5% of the diet), or items that were unidentifiable microhistologically (i.e., wood fragments, catkins). Quantifying rumen and fecal winter samples was difficult. Each procedure had shortcomings, and a combination of procedures may have to be used, particularly if study objectives require large sample sizes from a variety of individual animals. Knowledge of the strengths and weaknesses of diet estimation procedures allows investigators to assess methods in relation to project objectives and when evaluating the results of other studies.

Introduction

Estimates of diet composition for large ungulates are basic to many management programs and research efforts. A variety of methods are potentially available and information on the magnitude and direction of relative bias for each technique would be valuable in project planning and in assessing data on diet composition.

Moose occur in most regions of Alaska and inhabit a variety of habitat types that differ in forage species composition, abundance, and quality (LeResche *et al.* 1974). However, information on the diets of moose in Alaska is limited to the Kenai Peninsula (LeResche and Davis 1973, Cushwa and Coady 1976, Regelin *et al.* 1987a), Fairbanks and vicinity (Cushwa and Coady 1976), Denali National Park (Risenhoover 1989, Van Ballenberghe *et al.* 1989, Miquelle *et al.* 1992), and a small population in southeast Alaska (Doerr *et al.* 1980).

This information gap is probably due to a number of factors including lack of confidence in some techniques (Regelin *et al.* 1987b). Moose forage selection in Alaska has been inferred from browse surveys (Peek 1974) and indirectly estimated from rumen samples (Cushwa and Coady 1976, Doerr *et al.* 1980) or fecal samples (Regelin *et al.*

1987b). In addition, direct observation of tame-habituated animals (LeResche and Davis 1973, Regelin *et al.* 1987a, Risenhoover 1989) or a combination of techniques (Van Ballenberghe *et al.* 1989, MacCracken 1992) have been used.

The most accurate method of estimating the diets of moose is probably the bite-count technique, where results are expressed as mass of dry matter ingested. However, this method is extremely labor intensive and requires that tame or habituated animals be available. For most management and research projects, rumen and fecal analyses are the methods commonly used. The availability of rumen samples can be limited and skewed by seasonal mortality patterns, but fecal samples are potentially widely available.

The purpose of this study was to compare diet estimates derived from the analysis of paired rumen and fecal samples of moose on the Copper River Delta, Alaska.

Study Area and Methods

Rumen and fecal samples were collected from moose on the Copper River Delta (CRD) in south-central Alaska. The CRD is immediately east of Prince William Sound and encompasses about 3,200 km². MacCracken (1992) described the study area in detail, the habitat types important to moose, and other aspects of moose ecology on the CRD.

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Samples for this study came from the west CRD (WCRD) subpopulation during 1987-1989. Samples were collected by hunters and project personnel. Twenty-five paired rumen and fecal samples were examined in this study. Nineteen of the samples were collected during the hunting season. The remainder were collected in October (2), November (2), and 1 each in February and May.

Moose rumens were sampled by taking 4 subsamples from each quarter of the rumen-reticulum complex. A handful of material constituted a subsample and the subsamples were combined in a plastic bag, making an approximate 1-2 L sample. A 0.25-0.5 L fecal sample was taken directly from the rectum. Both rumen and fecal samples were oven-dried at 60°C for 48 h for storage.

The rumen samples were analyzed using 2 procedures. First, a macroscopic examination (rumen-macro) of the contents was conducted (Zach *et al.* 1982). The dried rumen samples were soaked in water for ≥ 48 h then washed through a series of sieves. Material that accumulated in a sieve with a 4-mm opening was air dried then spread onto a white enamel tray that was marked with a grid system delineating 100 cells that were 8 cm² each. Thirty of the 100 cells were selected at random and the contents identified to species-part with the aid of a dissecting microscope (10 x power). The identified material was dried at 60°C for 48 h then weighed to the nearest 0.01 g. A percent dry weight for each species-part was calculated for each sample. The identified material was then added to the contents remaining on the tray, and the remainder of the rumen sample that had passed through the 4-mm mesh sieve and collected in a 2-mm mesh sieve.

The recombined rumen samples were then analyzed microhistologically (rumen-micro). The samples were ground in a Wiley mill to pass through a 1-mm mesh screen. A portion of the ground material for each sample was made into 5 microscope slides and 20 fields/slide examined for identifiable plant fragments. A valid field had at least 2 identifiable plant fragments and an identifiable plant fragment had at least 2 unique characteristics. Plant fragments were identified to the lowest taxonomic level possible, most often genus, and frequently species. Each slide was a subsample and the counts of identifiable plant fragments/100 fields were quantified as percent relative density, a close

approximation to percent dry weight (Sparks and Malechek 1968). The fecal samples were also analyzed microhistologically following the same procedures.

This analysis assumed that moose diets did not change significantly between the meal(s) represented by the feces and the rumen. Schwartz *et al.* (1988) reported total mean retention times of liquid ingesta by moose of 38 and 54 h for high and low quality diets, respectively. Hubbert (1987) reported a high correlation between passage rates of liquid and particulate ingesta in moose. Hanley *et al.* (1985) conducted a similar analysis with Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) and stated that constant forage selection a week prior to sampling was assumed. Significant changes in the diets of moose on the WCRD occurred during April-May, July, and November (MacCracken 1992). Based on these facts, the assumption of constant diet composition was likely met for a majority of samples analyzed in this study.

The samples were not independent which violated a major assumption of most statistical tests. However, our objective was to assess the variation among diet estimation techniques which was most accurately determined with dependent samples.

Two questions were addressed. The first was whether there were any significant differences in diet composition estimated by the 3 procedures. This was examined with a 2-way MANOVA, blocking on individual animals. Due to the preponderance of estimates $\geq 80\%$ and $\leq 5\%$ in the data matrix, percentages were converted to ranks prior to analysis (Conover and Iman 1981, K. Steinhorst, pers. commun., 1991). The canonical structure of the MANOVA model was examined to determine which diet items were responsible for any differences (SAS Inst., Inc. 1988).

The second question considered the degree of association among the procedures. This was assessed by plotting the data for comparisons between the rumen-macro analysis and the rumen-micro and fecal analyses. We assumed that rumen-macro estimates were closest to the true diet, since most material could be positively identified and differential digestion of plant species would be minimal. Four forage categories were evaluated in this analysis: willows, other browse, total forbs, and total graminoids. A least squares regression line was estimated and plotted for each comparison.

Results and Discussion

The twigs and leaves of Barclay willow (*S. barclayi*) were the most abundant items identified by the rumen-macro procedure (35% and 42%, respectively). Willow twigs that could not be identified to species were the next most abundant item (23%), followed by Sitka alder (*Alnus sinuata*) leaves (9%), sweetgale (*Myrica gale*) twigs (8%), wood fragments (5%) and sweetgale leaves and willow catkins (3% and 2%, respectively).

Rumen-micro and fecal procedures could not distinguish among species of willow or specific plant parts. Thus, statistical comparisons among the 3 procedures were made by lumping willows and not differentiating plant parts.

There were significant differences ($F = 4.1$, $P = 0.0001$) in diet estimates among the 3 procedures (Table 1). However, these differences occurred only for items that were a minor portion of the diet (i.e., *Epilobium* spp., *Populus trichocarpa*), or plant parts that were unidentifiable microhistologically (i.e., wood fragments, catkins). Estimates

of other items in the diets were not different ($P > 0.05$) among the 3 procedures. There were also significant differences among animals ($F = 1.25$, $P = 0.02$), but again, these were attributed to estimates of relatively minor items (i.e., *Epilobium* spp., *Equisetum* spp., and *Carex* spp.).

Results of the regression analyses were variable. For willows, fecal estimates were closest to rumen-macro estimates (Figure 1). This relationship was also true for forbs (Figure 2). However, for the other browse and graminoid categories, the two rumen estimates produced the closest results (Figures 3 and 4). This inconsistency has no apparent explanation. We would have predicted that estimates from fecal samples would have consistently deviated the most from the rumen-macro estimates due to differential digestion of plants, variable passages rates, and greater amounts of unidentifiable material in feces (Gill *et al.* 1983).

TABLE 1. Mean (SE) percent of items identified in paired rumen and fecal samples of moose on the west Copper River Delta, Alaska.

Item	Rumen ^a		Fecal
	Macro	Micro	
<i>Alnus sinuata</i>	3(1)	1(0.4)	2(1)
<i>Myrica gale</i>	3(2)	2(0.3)	3(1)
<i>Populus trichocarpa</i>	1(1)	1(0.2)	1(0.1)
<i>Salix</i> spp.	83(4)	86(4)	90(2)
Total browse	90(4)	90(4)	96(1)
<i>Epilobium</i> spp.	1(1)	*	*
<i>Equisetum</i> spp.	1(0.3)	2(1)	1(0.4)
Total forb	3(1)	3(1)	2(0.1)
<i>Calamagrostis</i> spp.	*	1(1)	*
<i>Carex</i> spp.	2(2)	1(1)	*
<i>Eriophorum</i> spp.		1(1)	1(0.4)
Unidentified graminoid	1(0.3)	1(0.1)	*
Total graminoid	3(2)	3(2)	2(1)
Lichen	1(1)	*	
Catkin	2(2)		
Wood fragment	5(2)		

^aRumen samples were analyzed macroscopically and microhistologically. Fecal samples were analyzed microhistologically.

* < 1%.

SALIX SPP.

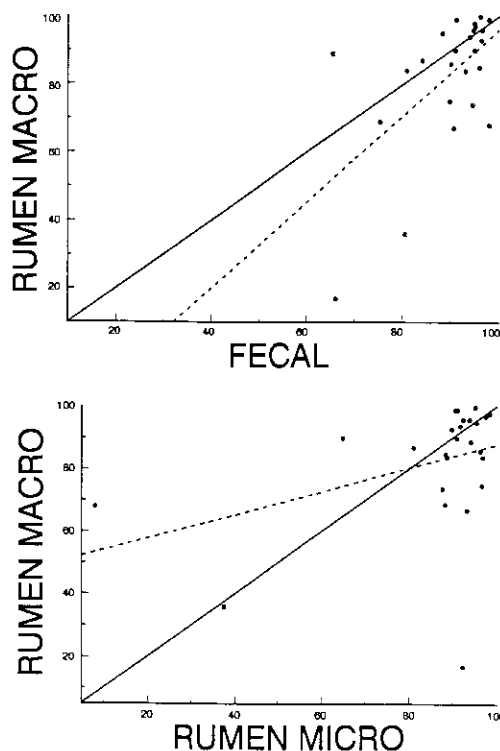


Figure 1. Plots of percent willows (*Salix* spp.) in moose rumen and fecal samples. The solid line is the 1:1 relationship. The dashed line is the least squares regression.

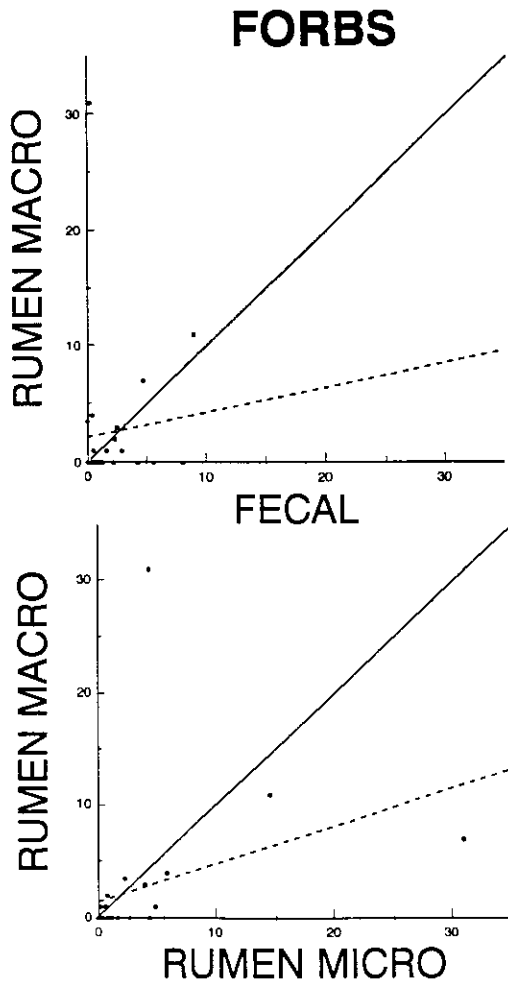


Figure 2. Plots of percent forbs in moose rumen and fecal samples. The solid line is the 1:1 relationship. The dashed line is the least squares regression.

Overall, agreement among the 3 procedures was greatest for graminoids, followed by willows, other browse, then forbs. These results were as expected based on the known biases of each procedure (Westoby *et al.* 1978, Vavra and Holecheck 1980, Hanley *et al.* 1985).

Despite close agreement for major diet components, each procedure had shortcomings. Rumen and fecal-micro procedures could not identify willows to species and could not identify specific plant parts. These traits are a major limitation of this procedure when applied to moose samples since willows are the primary diet item in many areas, numerous species of willow are often available, and moose preferentially forage on some species

(Risenhoover 1987). However, fecal analysis in combination with direct observations of foraging moose (Van Ballenberghe *et al.* 1989), examination of feeding sites, and browse surveys (Peck 1974, MacCracken 1992) may reasonably estimate the relative importance of willows and seasonal trends in use as well as preferences for species and plant parts.

The rumen-macro procedure can be affected by choice of sieve size in the preparation of samples. Nygren and Hoffman (1990) reported that the average rumen particle size in moose changed with forage digestibility and rumen retention time from approximately 2 mm in winter samples to ≥ 4 mm in summer samples. Additionally, we observed numerous fragments of horsetail (*Equisetum* spp.) passing through the 4-mm mesh sieve, suggesting that particle size also varies among plant species and may be related to cell wall structure and fracture characteristics. These results suggest that the analysis of rumen samples should use a 2-mm mesh sieve.

Winter diets of moose were difficult to estimate with either rumen or fecal samples. The February rumen sample examined in this study was dominated by relatively large fragments of wood devoid of identifying characteristics. This was typical of moose rumen contents in winter and was probably the source of some of the problems reported by Regelin *et al.* (1987b:263), i.e., "trashy" samples with lots of unidentifiable material. In addition, we relaxed the criteria defining an identifiable fragment and a valid field to 1 characteristic/fragment, and 1 fragment/field for the microhistological analysis of winter rumen and fecal samples.

Our results support Peck's (1974) conclusion that a variety of procedures may be needed to estimate moose diets. For studies having objectives that require replicated sampling from a large number of animals, fecal analysis is probably the only method that can meet those goals (Hanley *et al.* 1985). The biases associated with fecal analysis have been thoroughly examined (Holecheck 1982, Gill *et al.* 1983, Holecheck and Valdez 1985, Vavra and Holecheck 1980, Hinnant and Kothmann 1988) and can be partially overcome by incorporation of the results of other methods. We found relatively good agreement between fecal and rumen analyses, and Van Ballenberghe *et al.* (1989) reported similar results for fecal analysis and bite-count methods during summer. These conclusions suggest that investigators can confidently use fecal analysis to estimate trends in

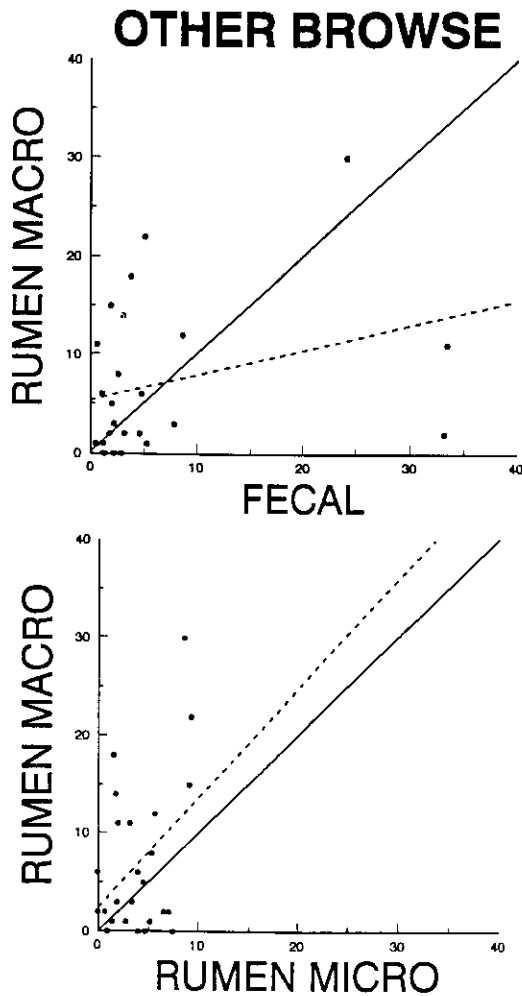


Figure 3. Plots of percent browse, excluding willows (*Salix* spp.), in moose rumen samples and fecal samples. The solid line is the 1:1 relationship. The dashed line is the least squares regression.

willow consumption and the relative importance of willows in the diet, realizing that winter diets and details on species and plant part selection during any season will have to be assessed using other methods.

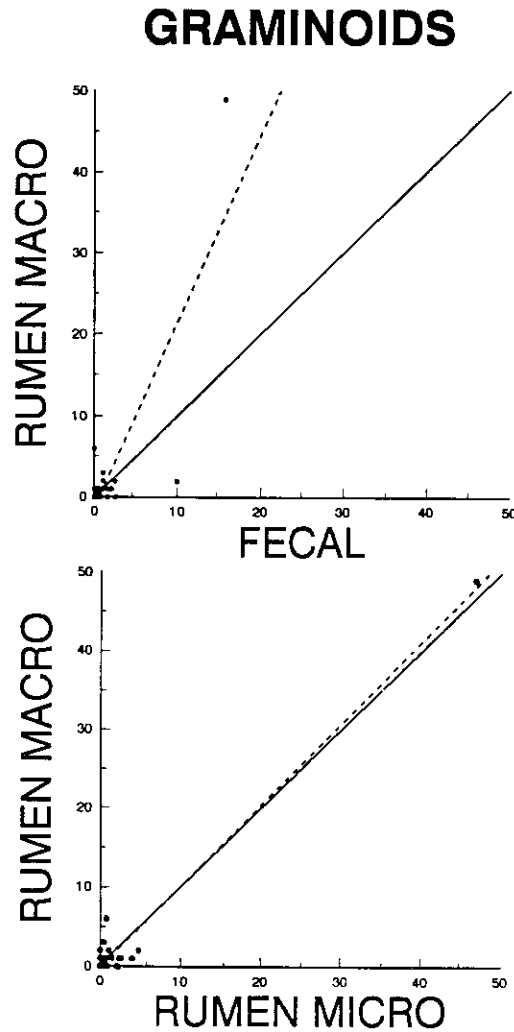


Figure 4. Plots of percent of graminoids in moose rumen and fecal samples. The solid line is the 1:1 relationship. The dashed line is the least squares regression.

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