FECAL NITROGEN AS A DETERMINANT OF ANIMAL CONDITION IN BIGHORN SHEEP

Daryll Hebert, Ministry of Environment, Wildlife Branch, Williams Lake, B. C.

Joyce Hebert, 630 Atwood Place, Williams Lake, B. C.

Marlen Caskey, Ministry of Enviroment, Habitat Section, Nanaimo, B. C.

ABSTRACT

Fecal nitrogen (N) was used as an index of animal condition from 1977-1983 in a captive herd of California bighorn sheep (Ovis canadensis californiana). Comparisons were made with an earlier study (Hebert 1973) and with a free-ranging herd in the Cariboo region of British Columbia. Fecal N indicated a decline in animal and population condition from 1977 to 1982 and a slight recovery during 1982 and 1983. Spring values varied significantly each year while summer and winter values were the most constant. Fecal N was significantly related to other nutritional indices and to seasonal weight change.

INTRODUCTION

Most wildlife range studies (Blood 1961, Demarchi 1968, Harper 1969, Demarchi 1970, Scheffler 1972) have assumed that specific quantitative and qualitative changes in the range have been transmitted to a particular bighorn sheep (Ovis canadensis) herd or population. The magnitude or form of the transmission, in terms of animal response, has not been quantified sufficiently to produce sound range, habitat or animal population decisions.

Recently, research programs utilizing captive animals (Gates 1975, 1980, Mould and Robbins 1981, Westra and Hudson 1981) have attempted to analyze forage-animal relationships. Hebert (1973) utilized captive bighorn sheep to demonstrate nutritional relationships between forage quantity, quality and animal response. In association, Hebert (1978) examined the relationship between bighorn sheep nutrition and blood serum parameters.

However, field studies (Stelfox 1976, Pitt and Wikeem 1978, Hoefs and Cowan 1979, Bunnell 1980, Heimer 1980, Eccles 1981, Shank 1982) have been relatively unsuccessful in establishing significant relationships between range or habitat measurements and animal population qualitative or quantitative response. Relationships established by Hebert (1973) were further examined with a herd of California bighorn sheep in a 42 ha enclosure (Pitt and Wikeem 1978) at the Okanagan Game Farm, Penticton, prior to field testing with free ranging herds.

Specifically, fecal N techniques (Hebert 1973) were used to determine changes in animal conditon in the captive bighorn herd. Fecal N index methods have been developed to estimate "in vivo" digestibility (Corbett et al 1963, O'Donovan et al. 1967), feed intake (Lancaster 1949, 1954, Milford 1957, Hutchinson 1958, Fels et al. 1959) and feed N (Raymond 1948) in domestic animals. Holechek et al (1982) provide a comprehensive review of methods used to determine the quality of range ruminants diets. Similarly, feed-fecal N relationships, established for bighorn sheep (Hebert 1973) initiated the development of fecal N indices for other species (Gates 1975, incl. 1980, McFetridge 1977, Leslie and Starkey 1982, Janz 1983, Seip 1983). As a result, significant fecal N relationships have been established with plant protein (Hebert 1973, Leslie and Starkey 1982, Janz 1983), protein intake (Hebert 1973), dry matter digestibility (Hebert 1973, Leslie and Starkey 1982, Janz 1983), and body weight change (Gates 1980).

This study explores the reliability of fecal N indices to determine body condition, population condition, forage selectivity among age classes, spring green-up and the nutritional contribution from each season.

Preliminary data from studies in the experimental enclosure at Penticton (Pitt and Wikeem 1978, Eccles 1981, Wikeem in prog.) served as the basis for present data collection systems during 1980-1984.

STUDY AREA

During April, 1977, 20 California bighorn sheep were placed into a 42 ha enclosure adjacent to the Okanagan Game Farm (Fig. 1). The enclosure is on an east-southeast slope and is characteristic of the lower grassland zone dominated by big sagebrush (Artemisia tridentata) and bluebunch wheatgrass (Agropyron spicatum). The enclosure contains facilities that allow trapping and handling of the captive sheep.

Comparable data were obtained from Rocky Mountain bighorn (O. c. canadensis) sheep held in captivity in the East Kootenay during 1968-70 (Hebert 1973). In addition, samples were collected from the Vaseaux herd 15 miles south of Penticton and from the Junction sheep herd at the confluence of the Chilcotin and Fraser Rivers in the Cariboo. Both herds contain California bighorn sheep.

METHODS

Captive sheep were handled every 1-3 months from 1978-1984 in order to obtain fecal samples, body weight and chest girth. During trapping and handling, animals were weighed and measured without the use of immobilizing drugs. In addition, fecal samples were collected during each capture period and in the paddock in the months between capture periods, when possible, immediately after

FIGURE 1. The Okanagan Game Farm, Vaseaux Lake and Junction study areas in British Columbia.

sheep rose and defecated. Fecal samples were obtained at various intervals from the winter fed Vaseux Lake herd which was provided with alfalfa during the winter and from the free ranging Junction herd in the Cariboo.

Hebert (1973) analyzed fecal samples in conjunction with specific feeding experiments for a migratory and non-migratory group of captive sheep.

Nitrogen was analyzed with the macro-Kjeldahl technique at the University of B. C. and Washington State University and autoanalyzer at the Kelowna Soils Lab for the respective studies.

Statistical comparisons were based on standard seasonal periods: winter, December-February; spring, March-May; summer, June-August; fall September-November.

Independent means were compared using the "t" statistic. The relationship between nutritional variables was determined using the correlation coefficient statistic (r).

RESULTS

PLANT NITROGEN

In general, plant nitrogen (N) values for climax bluebunch wheatgrass grasslands cycle in a similar manner on an annual basis. Seasonal N values for grass mixtures from the East Kootenay and Okanagan grasslands were similar for much of the year (Fig. 2). Variation occurs mainly in the spring or during fall greenup. In 1978, spring values at the Okanagan Game Farm were approximately .75 percentage points higher. Fall greenup values at the Okanagan Game Farm were significantly higher (max. of 1.1 percentage points difference) than those in the East Kootenay but also varied significantly between years. Summers were generally wetter during the late 1970's and early 1980's than they were in the late 1960's.

FECAL NITROGEN

The variation in seasonal and annual plant N values is reflected in fecal N values for similar time periods (Fig. 3 - 6). Hebert (1973) developed a significant relationship between fecal crude protein (N x 6.25) and plant crude protein (N x 6.25) for migratory ($Y = -.9400 + 1.034\ x \pm 4.58$) and non-migratory ($Y = -6.987 + 1.797\ x \pm 2.19$) sheep populations. Leslie and Starkey (1982) and Janz (1983) developed similar relationships for blacktailed deer (O. h. columbianus) and Roosevelt elk (C. e. roosevelti).

In this study, fecal N values for free-ranging sheep in a paddock (1977) deviated significantly (Fig. 3) from those established for captive sheep fed hand cut forage (Hebert 1973). During May, they differed by 1.6 percentage points of N and in the fall, during greenup they differed by about .9 percentage points. However, the values for sheep fed hand cut forage did not appear to differ from those for captive sheep in 1981-1982 (Fig. 6), when they were close to their poorest condition. Similarly, comparison of fecal N values for 1977 through 1979 (Fig. 4) with those from 1980 through 1983 (Fig. 5) indicated a significant seasonal and annual decline during the initial period.

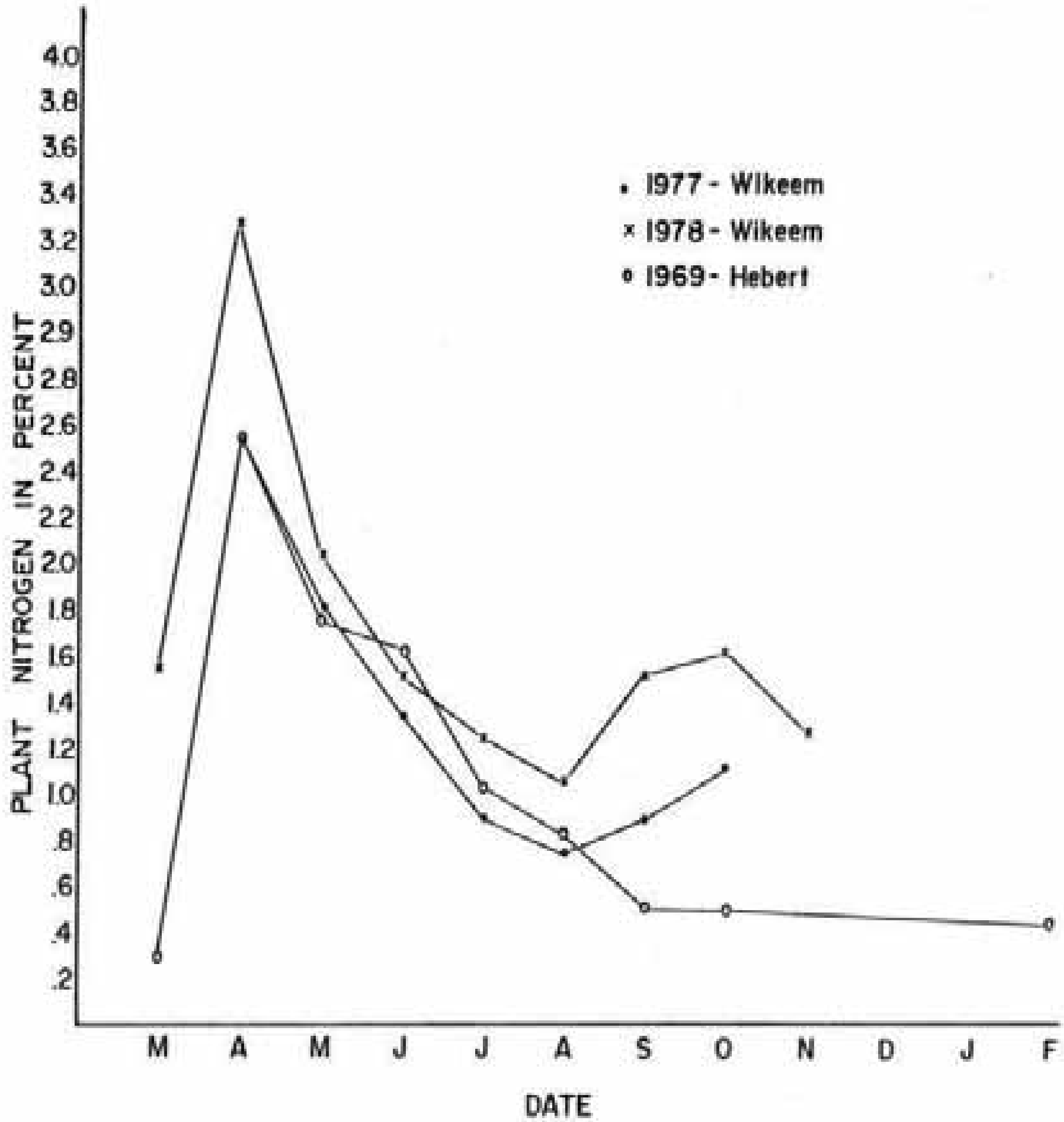

FIGURE 2. Monthly changes in plant nitrogen for the Okanagan and East Kootenay study areas.

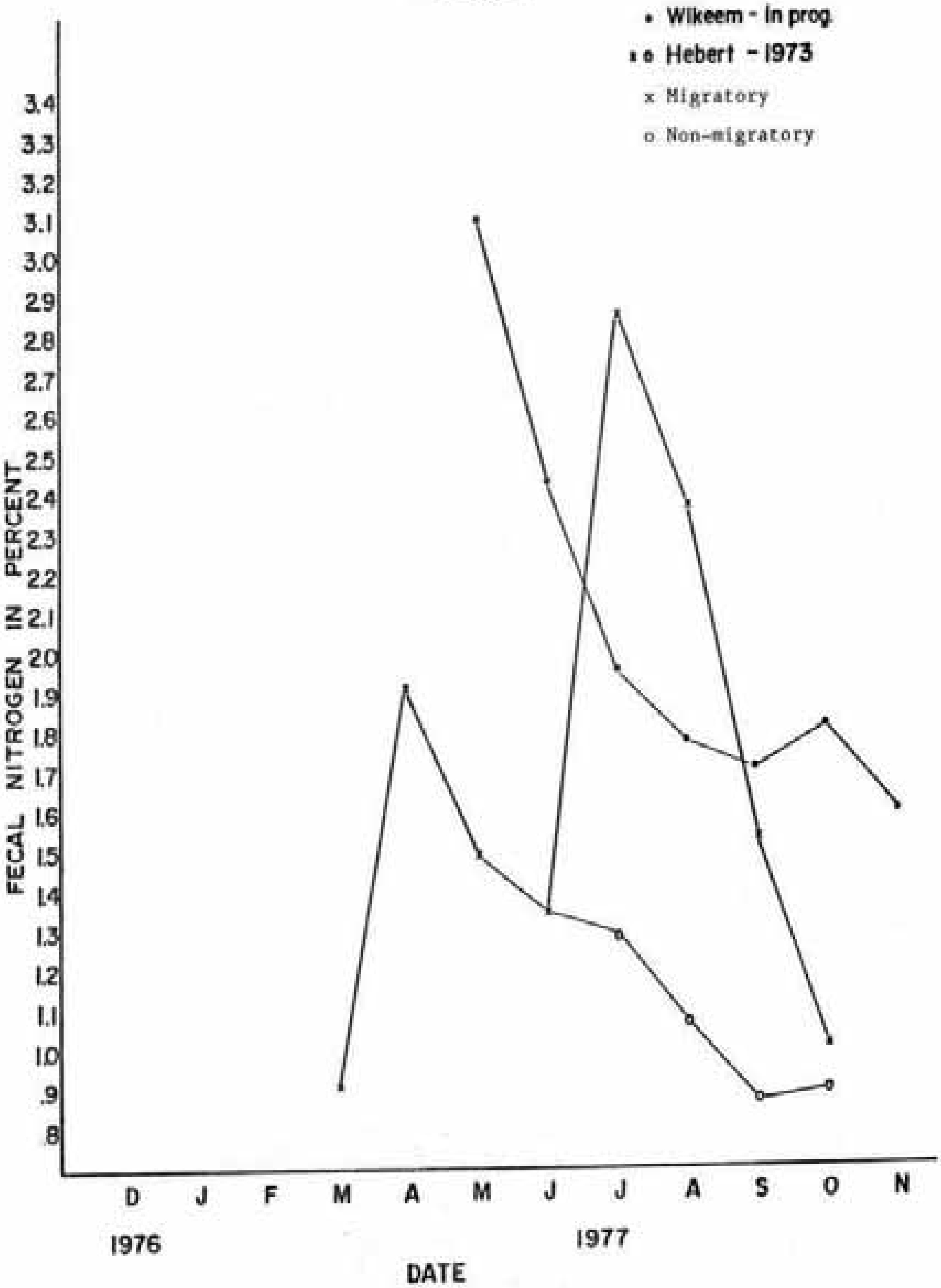

FIGURE 3. Monthly changes in fecal nitrogen for the Okanagan Game Farm (1977) and East Kootenay[†] captive herds.

[†]Hebert, (1973)

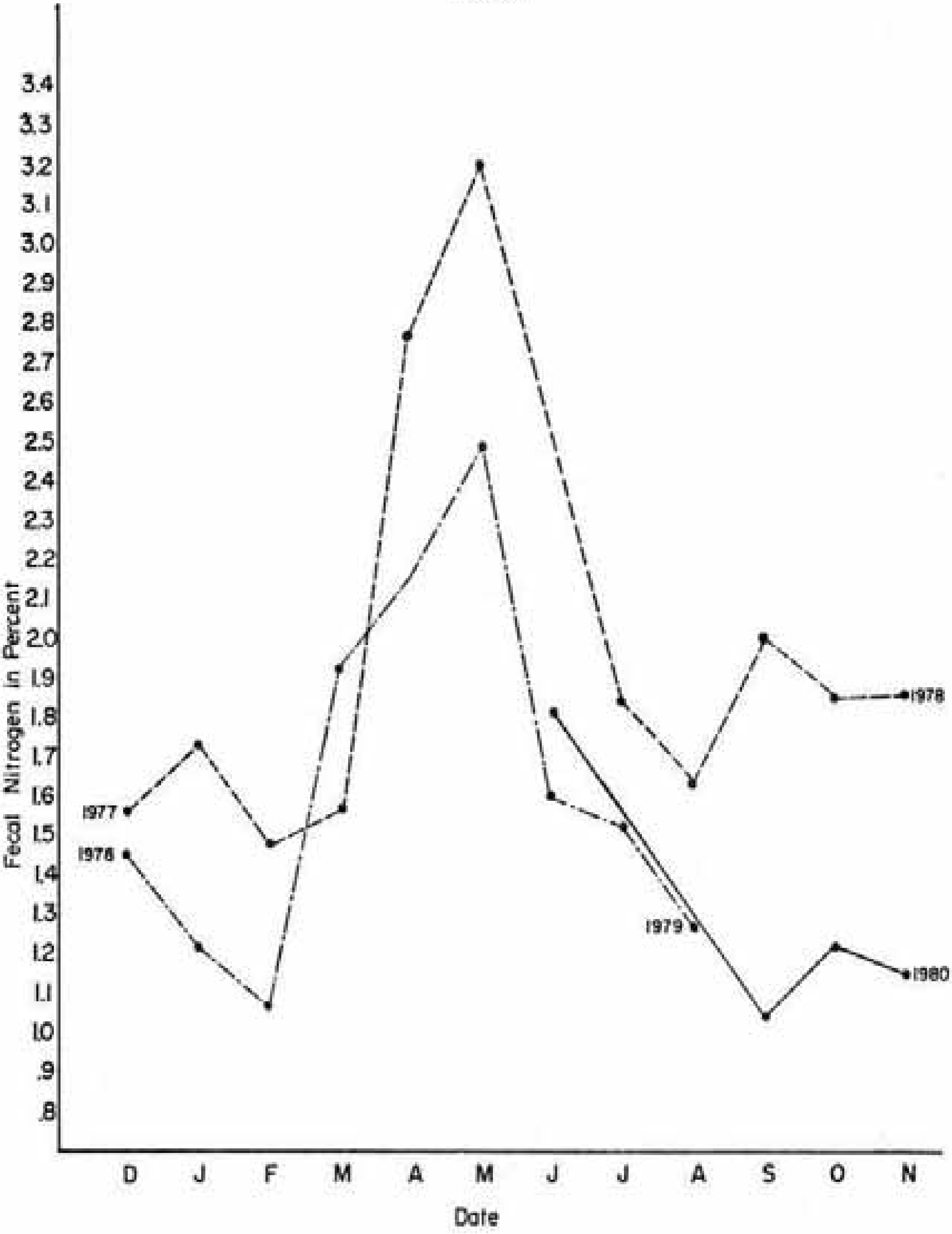

Figure 4. Monthly changes in fecal nitrogen for the Okanagan Game Farm captive herd from 1977 to 1980.

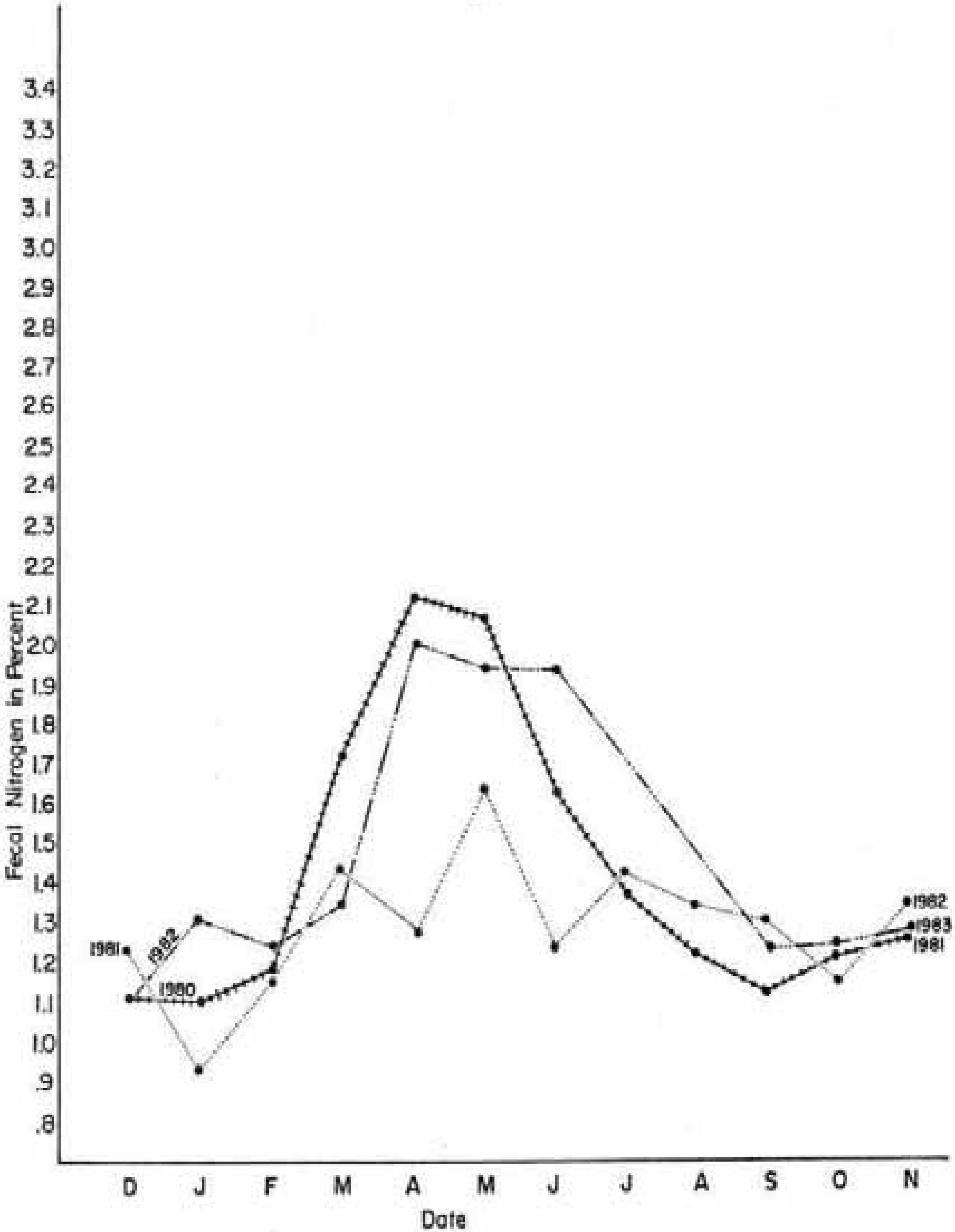

Figure 5. Monthly changes in fecal nitrogen for the Okanagan Game Farm captive herd from 1980 to 1983.

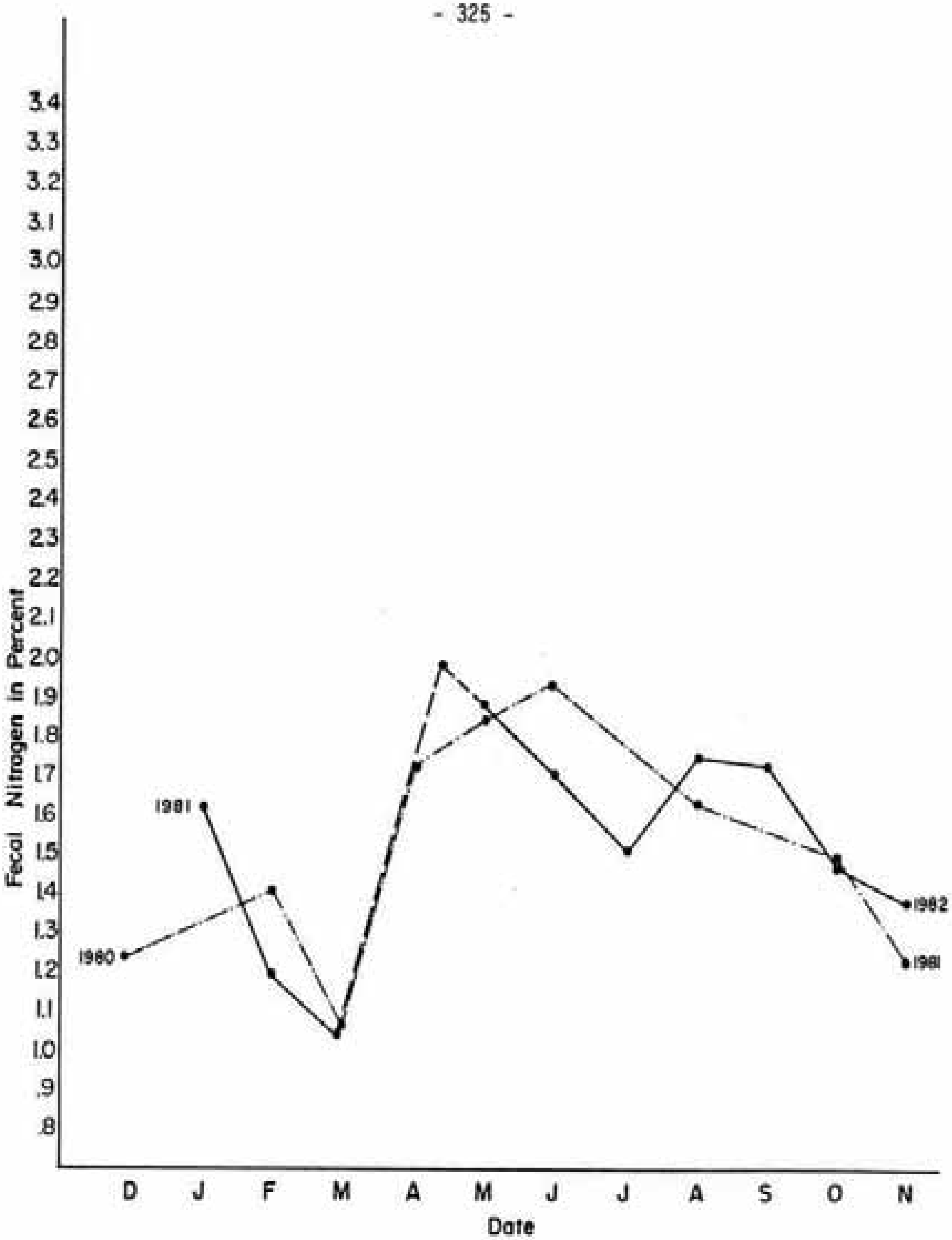

FIGURE 6. Monthly changes in fecal nitrogen for the Junction free ranging herd from 1980 to 1982.

A comparison of various figures indicated that spring and fall greenup periods occurred at similar times each year although the magnitude may differ.

Fecal N curves indicated possible significant differences between seasons and years. Average monthly precipitation was compared to monthly fecal N values using correlation coefficients for all years of the study when data were available. There were no significant relationships for annual or seasonal comparisons.

With captive animals it was possible to compare fecal N values from known animals to those collected randomly in the paddock (Table 1). This comparison was undertaken for 10 collection periods in 1981 and was not significant between methods at each collection period, except in August. One test was undertaken on March 22 to examine deterioration rates (N loss) for fecal samples left on the ground for periods of 2 weeks to 4 months. The March 22 average value was 1.53% N, and the same samples reanalyzed in July contained 1.43% N, a decline of approximately 6.5%.

Seasonal averages of fecal N were calculated in order to examine the seasonal contribution of N to the animal diet (Table 2). With the exception of the fall-winter change in 1980-81 and spring-summer values for 1982, all seasons contributed significantly different levels of N to the nutrition of the animal. Similarly, the fall-winter value for 1983 was just significantly different, indicating a degree of constancy at low levels of N intake for approximately half of each year. The spring-summer values for 1982 did not differ significantly because only March values (initial spring greenup values) represented the spring season. The addition of April and/or May values would increase the average and produce a significant difference.

In order to test the constancy within standard seasons (Table 3), comparisons were made between the beginning and end of each season. The winter season was the most constant while spring periods differed significantly in each of the three years. It appears that summer and fall may differ in some years because of differences in the magnitude of spring and fall greenup and summer dormancy.

Similarly, changes between seasons were significant in all years, with the exception of one fall-winter change and one summer-fall change (Table 4). The winter-spring change in 1983 was not significantly different because the March (1st spring month) collection occurred too early, prior to initiation of greenup. The winter-spring difference was significant, if one deviant point was omitted from the average.

Spring levels of fecal N differed most dramatically between years, winter levels differed the least (Table 5). The summer and fall periods may differ in some years due to above average precipitation in some summers or due to the magnitude of fall greenup in some falls.

During the four year study period, variation in spring greenup in March was examined weekly. Values of 1.35, 1.44 and 1.73 on March 2, 7 and 14, respectively, indicated that although there were minor changes in fecal N in early March, significant greenup did not occur for the animal until March 7-14.

Table 1. A comparison of known and random fecal nitrogen values by month and by season.

Year	Month/Season	Known	Mean n	Random	n	t	p	Signif.
81	January	1.09	(6)	1.10	(8)	.34	.74	x
	February	1.22	(10)	1.19	(7)	.347	.73	x
	March	1.89	(4)	1.73	(15)	1.64	.12	x
	April	2.08	(9)	2.13	(13)	.68	.50	x
	June	1.61	(11)	1.63	(11)	.32	.76	x
	August	1.10	(8)	1.23	(15)	3.19	.004	/
	Aug. 13 - Sept. 7	1.10	(8)	1.13	(11)	.65	.53	x
	Winter (Jan-Feb)	1.17	(27)	1.12	(25)	.84	.59	x
	Spring	2.02	(13)	1.92	(28)	1.29	.20	x
	Summer	1.39	(38)	1.40	(19)	.18	.86	x

Table 2. A comparison of average fecal nitrogen values to show seasonal differences within years.

Year	Season	Mean Season 1	Season 2	t	df	p	Signif.
80-81	f80-w81	1.09	1.14	1.67	(56)	.10	x
1981	w-s	1.12	1.99	-23.19	(90)	.000	/
1981	s-s	1.99	1.39	13.29	(87)	.000	/
1981	s-f	1.39	1.20	5.37	(78)	.000	/
81-82	f81-w82	1.20	1.09	3.28	(89)	.0016	/
1982	w-s	1.09	1.44	-8.67	(76)	.000	/
1982	s-s*	1.44	1.38	1.54	(69)	.12	x
1982	s-f	1.38	1.24	4.90	(74)	.000	/
82-83	f82-w83	1.24	1.15	2.34	(71)	.022	/
1983	w-s	1.15	1.87	-10.35	(67)	.000	/
1983	s-f	1.48	1.24	6.42	(53)	.000	/

*only March value for spring

Table 3. A comparison of fecal nitrogen values to determine within season changes.

Year	Month	Mean Month 1	Month 2	t	df	p	Signif.
80-81	Dec.80-Feb.81	1.11	1.19	-1.31	(22)	.202	x
1981	Mar-May	1.73	2.07	-7.51	(36)	.00000	/
1981	June-Aug	1.63	1.23	9.31	(24)	.00000	/
1981	Sept-Nov	1.13	1.25	-4.50	(38)	.00006	/
81-82	Dec.81-Feb.82	1.24	1.16	2.10	(26)	.046	/
1982	Mar-June[1]	1.44	1.25	2.97	(33)	.006	/
1982	June-Aug.	1.25	1.35	-2.01	(15)	.06	x
1982	Sept-Nov..	1.31	1.35	-1.05	(14)	.32	x
82-83	Dec.82-Feb.83	1.10	1.25	-1.77	(32)	.08	x
1983	March-May	1.35	1.96	-4.40	(13)	.0008	/
1983	May-Aug.[2]	1.96	1.48	6.37	(33)	.000	/
1983	Sept-Nov.	1.24	1.29	1.03	(16)	.32	x

1. Do not have May figures
2. Do not have June figures

Table 4. A comparison of average fecal nitrogen values to determne changes between the end of one season and the start of the next season.

Year	Month	Mean 1	2	t	df	p	Signif.
1981	Feb-Mar.14	1.19	1.73	-6.77	(20)	.000	/
1981	May-June	2.07	1.61	10.70	(31)	.000	/
1981	Aug-Sept	1.23	1.13	3.63	(24)	.0014	/
1981	Nov-Dec	1.26	1.24	.5092	(27)	.62	x
1982	Feb-Mar.7 & 22	1.16	1.44	-5.20	(36)	.000	/
Aug-Sept		1.35	1.31	.9683	(18)	.34	x
1982	Nov-Dec	1.35	1.10	3.35	(33)	.002	/
1983	Feb-Mar.2	1.25	1.35	-9.29	(10)	.38	x
1983	Feb-Mar	1.25	1.44*	2.43	(9)	.04	/
1983	Aug-Sept	1.48	1.24	4.13	(32)	.0002	/

*left off last point

Table 5. A comparison of average fecal nitrogen values to show seasonal comparisons between years.

Year	Season	Mean 1	Mean 2	t	df	p	Signif.
80-81	Fall	1.09	1.20	-5.03	(66)	.000	/
81-82	Fall	1.20	1.24	-1.57	(74)	.12	x
82-83	Fall	1.24	1.24	-.137	(61)	.90	x
81-82	Winter	1.17	1.09	.61	(62)	.55	x
82-83	Winter	1.09	1.15	-1.31	(86)	.20	x
81-82	Spring	1.99	1.44	13.03	(78)	.000	/
82-83	Spring	1.44	1.87	-6.41	(57)	.000	/
81-82	Summer	1.39	1.38	.1131	(78)	.92	x
82-83	Summer	1.38	1.48	-2.62	(62)	.010	/

Table 6. A comparison of fecal nitrogen values from sheep which were baited or winter fed (alfalfa) with those which were not (1981).

Season	Area: Vaseaux Lake	Area: OK Game Farm	t	df	p	Signif.
January	1.55	1.07	8.21	(14)	.000	/
February	2.22	1.19	9.5	(16)	.000	/
March	1.91	1.73	2.1	(18)	.05	/
April	2.32	2.13	2.58	(21)	.02	/
May	2.30	2.07	3.21	(32)	.000	/
	Feeder	Upper Slope				
January	1.55	1.28	4.74	(15)	.000	/
	Baited	Unbaited				
January	1.25[2]	1.08	6.78	(23)	.000	/
	1.77	1.08	6.75	(25)	.000	/

1. Winter fed
2. Partial baiting

Fecal N can be a valuable tool to assess a variety of feeding regimes. In 1981, the winter fed herd at Vaseaux Lake (about 16 km from the captive herd) was compared to that in the captive paddock (Table 6). In all months the Vaseaux herd was taking in significantly more N. Spring greenup allowed he captive herd to approach the winter fed herd in N nutrition. In January Vaseaux sheep feeding on upper slopes, away from the feeder, were significantly lower in N nutrition than those at the feeder but were higher than those in the captive herd. Similarly, two days of baiting of the captive herd produced significant differences between the unbaited animals monitored at the same time. Prolonged baiting (feeding) produced a dramatic increase in the N nutrition of the captive animals, similar to that of the winter fed herd at Vaseaux Lake. It appeared that fecal N was sufficiently sensitive to detect minor qualitative dietary changes (2 days of baiting).

Fecal N was used to determine diet quality changes between ewes and lambs feeding in the captive paddock (Table 7). In all months, during a four year period there was no significant difference between the fecal N levels of lambs and ewes. This suggests no apparent difference in dietary quality between these two groups.

Table 7. A comparison of known fecal nitrogen values for captive lambs and ewes at the Okanagan Game Farm.

Year	Month	Mean Ewe	Mean Lamb	t	df	p	Signif.
1980	November	1.23	1.22	.18	(15)	.86	x
1981	January	1.44	1.53	.31	(28)	.76	x
1981	March	1.85	2.01	.64	(2)	.58	x
1982	November	1.28	1.23	.63	(4)	.56	x
1983	February	1.44	1.39	.50	(10)	.62	x
1983	April	1.70	1.73	.56	(14)	.58	x
1983	November	1.27	1.41	1.81	(13)	.10	x

Using fecal N, it was possible to determine the initiation of greenup available to the animal in relation to the latitude and elevation at which the population occurs (Table 8). In general, initiation of greenup differed by 1.5 to 2 months with approximately 25° change in latitude and 1000 m change in elevation. Delays in spring greenup at higher latitudes and elevations may be compensated to some degree by reduced summer dormancy periods.

Similarly, fecal N can be used to compare range nutrition and population condition (Fig. 5 and 6, Table 9). The Junction sheep population was significantly (Table 9) but only slightly higher (Fig. 5 and 6) than annual and seasonal N values for the Okanagan Game Farm sheep. The Junction herd is non-migratory, but with a significant fall greenup period it maintained a higher N intake (Fig. 6) than the Okanagan Game Farm herd which was at its lowest nutritional point (highest adult and lamb mortality). The Okanagan Game Farm herd recovered in 1983 (Fig. 5) and approached the level of N nutrition achieved by the Junction herd. Seasonally, the Junction herd did not differ significantly between years (Table 10) with the exception of the fall period (due to exceptional fall greenup of 1982). Spring was almost significantly different between years but the calculation was based on a reduced sample size. Winter and summer values were most constant, similar to the trend at the Okanagan Game Farm (Table 5).

Table 8. Green-up initiation and peak, and fall regrowth initiation compared to latitude and elevation.

Location	Latitude*	Elevation (Type of Range)	Initiation of Green-up**	Peak Green-up**	Initiation of Fall Regrowth
Okanagan[1] B.C.	49°23' (Approx.)	480-730M (Year Round)	mid-March	mid-May	Aug./Sept.
Junction[1] B.C.	51°46'	700-1000M(Year Round)	March/April	April	Aug./Sept.
East Koot.[2] B.C.	49°20'	820-1220M (Winter Range)	March/April	April	None (1969)
	50°	1525-1980M (Summer Range)	May/June	June/July	None
Ya-Ha-Tinda[2] Alta.	51°42'	1740-2320M (Winter Range)	April/May	(July?)	None
Ram Mtn[2] Alta.	51°57'	1082-2173M (Year Round)	mid-April	early to mid June	August
Smoky River[3] Alta.	53°55'-54°	914-2134M (Year Round)	(May?)	end June	None
Maroon Mtn.[3] B.C.	54°42'	(Approx)600-2066M (Year Round)	March ***	June/July	Aug./Sept

* Latitudes are estimates only
** Dates are taken from fecal N curves
*** Coastal influence

1. California bighorn sheep
2. Rocky Mountain bighorn sheep
3. Rocky Mountain goats (*Oreamnos americanus*).

Table 9. A comparison of seasonal fecal nitrogen values between the Junction sheep range and the Okanagan Game Farm.

Year	Date/Season	Junction	OK Game Farm	t	df	p	Signif.
1982	Winter	1.42	1.09	3.97	(57)	.000	/
1982	Spring	1.90	1.39	6.72	(33)	.000	/
1982	Summer	1.68	1.38	6.71	(68)	.000	/
1982	Fall	1.55	1.24	7.65	(63)	.000	/
1983	Winter	1.34	1.12	4.23	(48)	.000	/
1983	Spring	1.57	1.87	3.31	(66)	.000	/
1983	Summer	1.79	1.48	5.12	(48)	.000	/
1983	Fall	1.35	1.24	2.77	(52)	.000	/
1984	Winter	1.05	1.11	1.38	(66)	.1692	x

Table 10. A comparison of seasonal fecal nitrogen values between years for the Junction sheep herd.

Year	Season	Mean 1	Mean 2	t	df	p
82-83	Winter	1.42	1.45	-.253	(16)	.80
82-83	Spring	1.90	1.58	1.95	(41)	.06
82-83	Summer	1.68	1.77	-1.50	(54)	.14
82-83	Fall	1.55	1.35	3.94	(54)	.0004

FECAL N - WEIGHT CHANGE

Weight change is a cumulative expression of the bioenergetic balance of an animal. The relationship between fecal N and weight change was explored with captive sheep at maintenance and submaintenance diets (Hebert 1973) and at the Okanagan Game Farm 1977-1982 (Table 11). Although several workers have established relationships between fecal N and digestibility (Coop and Hill 1962, Lambourne and Reardon 1963, Hebert 1973, Holechek et al 1982), few workers have established fecal N - weight change relationships (Hebert 1973, Gates 1980).

In general, weight change was significantly related to fecal N under a variety of conditions (Table 11), yet the relationship was confounded by two variables. In the spring, fecal N rose rapidly while weight change continued to decline (Gates 1980) for 1 - 2 months, especially when the animals were in poor winter condition. This was shown during the period 1977-79 and during 1981 when the correlation was established with and without spring values. Similarly, the relationship established by Hebert (1973) was not significant due to the affect of spring values. When only summer values were used, the relationship improved. The lack of significance for the summer period was attributed to the lower sample size and the fact that digestion trials were not carried out during winter (October - March). In association, the relationship for the migratory group was better than that for the non-migratory group. Low weight change experienced by the non-migratory group (low quality and constancy of diet) may be within the variance of the equipment used and may provide a second confounding factor. The relationship between fecal protein and protein intake per day was highly significant (Table 11). This will allow weight change to be related to absolute protein intake on an instantaneous or cumulative basis (Hebert and hebert in prog.). The relationship between fecal N and weight change was significant for the Okanagan Game Farm sheep when spring values were not included. During 1981 and 1982, the relationship was significant even when spring values were included, probably due to the minor change in spring greenup values.

If weight change is the result of a cumulative expression of bioenergetic balance, the relationship between N and weight change should improve with the specificity of measurement (Table 12). This in fact occurs, if r values are compared for fecal N and weight change and for protein retained (basic N balance) and weight change. The improvement is less obvious when the energy intake (Avg .716), digestible energy (Avg .733) - weight change relationship is compared (Table 12).

DISCUSSION

Since its inception (Raymond 1948), fecal N has seen increasing use (Hebert 1973, Gates 1975, 1980) as an indicator of animal nutrition and condition. Most early studies with wildlife species developed annual curves based on monthly changes (Gates 1975, McFetridge 1977). Later studies (Gates 1980, Leslie and Starkey 1982, Janz 1983) related fecal N values to other measures of nutrition (digestibility) and growth (body weight). However, with the exception of Hebert (1973) and Gates (1980) all relationships were established with free ranging populations, where few variables were controlled.

Table 11. The relationship between fecal nitrogen (protein) and body weight change and crude protein intake for captive sheep (Hebert 1973) and sheep at the Okanagan Game Farm.

CORRELATION	YEAR/SEASON	r Value	n	p
Fecal Protein/Weight	1969	non-migratory .9193	8	<.005
		migratory .0185	8	---
Fecal Protein/ Wt. Change	1969	non-migratory .3612	8	---
		migratory .553	8	>.05
Fecal Protein/ Wt. Change	Spring/69	non-migratory .0340	3	---
		migratory .9535	3	>.05
Fecal Protein/ Wt. Change	Summer/69	non-migratory .48	5	---
		migratory .86	5	<.05
Fecal Protein/ Protein Intake Gm/Day	1969	non-migratory .9031	8	<.005
		migratory .9427	8	<.005
Fecal Protein/ Wt. Change	1977-79[a]	.933	5	<.01
		.24[1]	7	---
Fecal Protein/ Wt. Change	1977-79[b]	.89	5	<.01
		.25[2]	7	---
Fecal Protein/ Wt. Change	1981	.70[3]	8	<.05
		.82[4]	6	<.05
Fecal Protein/ Wt. Change	1982	.9383	3	>.05
Fecal Protein/ Wt. Change	1981-82	.7686	8	<.01

a. All sheep except lambs
b. Eight selected ewes

1. April & June added
2. April & June added
3. Jan-Oct period (Feb. fecal N and March wt.)
4. Removed Spring (Mar & Apr) values

Table 12. Correlation coefficients comparing weight change to various nutritional parameters (Hebert 1973).

r = correlation coefficient

1. % Fecal Protein vs Weight Change in kg.

Control	n=8	r=0.361	Not significant
Experimental	n=8	r=0.553	Not significant

2. % Crude Protein in feed vs Weight Change.

Control	n=8	r=0.541	p=>.05
Experimental	n=8	r=0.677	p=<.05

3. Crude Protein Intake in gm/day vs Weight Change.

Control	n=8	r=.596	p=>.05
Experimental	n=8	r=.646	p=<.05

4. Monthly Crude Protein vs Weight Change.

Control	n=6	r=.703	p=>.05
Experimental	n=6	r=.719	p->.05

5. Digestible Protein in gram/day vs Weight Change

Control	n=8	r=0.612	p=>.05
Experimental	n=8	r=0.640	p=<.05

6. Digestible Protein per kg body weight vs Weight Change.

Control	n=8	r=0.552	p=>.05
Experimental	n=8	r=0.658	p=>.05

7. Protein Retained in gm/day vs Weight Change.

Control	n=7	r=0.924	p=<.01
Experimental	n=7	r=0.736	p=<.05

8. Energy Intake vs Weight Change.

Control	n=8	r=0.678	p=<.05
Experimental	n=8	r=0.754	p=<.05

9. Digestible Energy vs Weight Change/Control

Control	n=8	r=0.785	p=<.05
Experimental	n=8	r=0.681	p=<.05

This study was undertaken to examine the fecal N - nutritional relationships established by Hebert (1973) under controlled conditions, to determine if they applied to semi-controlled (paddock) and free ranging populations. Firstly, it determined that a minimum of 6-15 fresh samples collected from random individuals in the paddock were identical to those collected from known individuals. Preliminary tests suggested minimal changes (6.5%) between fresh and four month old samples. However, more testing is required to determine deterioration rates due to time, site, weather and season. Generally, the random samples were indicative of the nutritional status of the paddock herd. However, in order to accurately assess a wide variety of free ranging populations, more testing of sample size and distribution should be undertaken. At present, a captive, semi-captive, winter fed free ranging and non-migratory free ranging herd have been examined. Gates (1975) has preliminary information on a free-ranging migratory sheep population on the east slopes of the Rockies but little information on free-ranging migratory populations is available for B. C.

During the paddock study, changes in stocking rate were used to produce light to heavy grazing pressure on the range. During this procedure, forbs and browse were reduced in availability or eliminated. Thus, the data show a general decline in forage quality (N) from 1977 to 1982 and a slight recovery in 1983. Similarly, seasonal comparisons of body condition using fecal N were examined during this long term decline. Collection of this type of data will allow examination of fecal N relationships with food habit changes from 1977 to 1982 (Hebert and Hebert in prog.) and the resultant effect on weight change, growth and mortality. Most importantly, fecal N can be converted to crude protein intake (Hebert 1973) by month and/or season in order to examine and/or predict seasonal weight change (Hebert and Hebert in prog.), productivity (Jorgenson and Wishart 1982), winter mortality, maintenance and the effect of grazing by domestic cattle, as well as controlled fire.

The procedure is sufficiently sensitive to identify diet quality changes due to baiting, winter feeding and elevational changes due to chinooks (Gates 1975). Geist and Petocz (1977) hypothesize that young animals (lambs) should consume a higher quality diet than adults due to differences in metabolic rate. The data in this study indicated that there was no significant difference between quality of diets for lambs and ewes. Seip (1983) also suggests that there is no significant difference between the quality of ewe and ram diets for Stone sheep (O. dalli stonei).

During the study (1977-1983), the average body weight of adults declined. Similarly, each generation of lambs grew at a slower rate than the previous generation (age specific weights of each generation decline). Data analysis did not always allow the seasonal and annual changes to be isolated from the longer term decline in overall body condition.

Body weight change has been related to fecal N values in several instances (Hebert 1973, Gates 1980, this study) and indicates that fecal N is capable of estimating the annual condition of an animal. Mould and Robbins (1981) concluded, while using single and simple mixed dietary species trials, that inhibitors (phenols) may reduce digestibility of N and fecal N values may in fact predict arbitrarily high N intakes. Since fecal N is related to body weight change in both bighorn sheep and elk (Gates 1980), this problem appears minimal with multispecies diets, even with browsing species.

Although fecal N and body weight change were significantly related, this relationship is often confounded in the spring when N values increase rapidly while weight change may continue to decline for 1-2 months. Thus, the sample size and sample distribution be season are extremely important variables to consider during the study design. For example, Hebert (1973) conducted the majority of his digestion trials during the spring and early summer when fecal N and weight change correlated the least. Digestion trials were not conducted in late fall and winter due to climatic conditions (freezing urine and water). All r values should improve considerably with a shift in seasonal sampling distribution.

Gates (1980) established a significant relationship between fecal N and young growing elk (calves) (r^2 = 0.89) and yearling bulls (r^2 = 0.89) undergoing a high degree of weight change between seasons. In contrast, Hebert (1973) did not establish a significant relationship for non-migratory sheep given a maintenance diet low weight change for 3 of 4 seasons). The relationship was further confounded by the lag effect between spring fecal N values and weight change. Similarly, the relationship between fecal N and weight change for the migratory group improved over that for the non-migratory group because weight changes were larger. However, it is also confounded by the spring lag effect and a second less pronounced spring lag effect during the change to and from alpine forage. The relationship for the migratory group was greatly improved (r = .86) when only summer and fall values were considered.

Conversion of fecal N to cumulative protein intake (Table 11) will allow evaluation of the N contribution from each season. It is possible that the total annual N intake may be the same between years, however, survival or productivity may differ due to the timing contribution of spring and fall greenup.

Upon establishment of suitable sampling regimes, fecal N could be used as a long term population condition indicator. It could be used to assess differences in population density and total grazing pressure through time. It is possible that it could replace the more traditional plot and clipping procedures which suffer from human variability, sampling design and cost. Similarly, it can be used to assess the nutritional status of pre and post bighorn sheep dieoffs. Most importantly, it can be combined with a variety of fecal techniques (fecal fragments, fecal larval levels, fecal cortisol) that assess the status of the individual or the population.

The data in this paper suggest that it is now possible to assess the nutritional status of most bighorn sheep herds in south central B. C. and Alberta.

ACKNOWLEDGEMENTS

This study is part of a larger research program (University of B. C., Simon Fraser University, B. C. Fish and Wildlife Branch) conducted at the Okanagan Game Farm. During 1977, 1978 and part of 1979, fecal samples were collected by Eccles (1981) and Wikeem (in prog.) for use in their studies as well as in this study. In addition, collection of initial body measurements (1977-79) was aided by members of the research program. Members of the Okanagan Game Farm (Harold and Howard Lacey, Cathy Ure), the Oliver Fish and

Game club (particularly Greg and Chris Norton and the Goltz brothers) and my family (Joyce, Todd, Tricia) aided at each capture period, or when needed. The study was made possible through the cooperation of Ed Lacey, Game Farm manager. The North American Sheep Foundation (Guide-Outfitters Assoc. of B. C.) and the B. C. Fish and Wildlife Branch provided funding to undertake the research. Analytical support from the Kelowna soils lab was greatly appreciated. Mrs. S. Schlitt typed the manuscript and Mrs. B. Coulter drafted the figures.

LITERATURE CITED

Blood, D. A. 1961. An ecological study of California bighorn sheep (Ovis canadensis californiana Douglas) in Southern British Columbia. M. Sc. Thesis, Univ. of B. C., Vancouver. 127pp.

Bunnell, F. L. 1980. Weight estimation of Dall's sheep and mountain goats. Wildl. Soc. Bull. 8(4):291-297.

Coop, I. E. and M. K. Hill. 1962. The energy requirements of sheep for maintenance and gain. II. Grazing Sheep. J. Agric. Sci. 58:187-199.

Corbett J. L., Langlands, J. P. and G. W. Reid. 1963. Effects of season of growth and digestibility of herbage on intake by grazing dairy cows. Anim. Produc. 5:119-129.

Demarchi, D. A. 1970. Effects of grazing on the botanical and chemical composition of range vegetation in the low Chilcotin River Region, British Columbia. M. Sc. Thesis. Univ. of Idaho, Moscow. 41pp.

Demarchi, R. A. 1968. Chemical composition of bighorn winter forages. J. of Range Mgmt. 21(6):385-388.

Eccles, T. R. 1981. Aspects of social organization and diurnal activity patterns of California bighorn sheep (Ovis canadensis californiana Douglas 1829). M. Sc. Thesis. Univ. of British Columbia. 108pp.

Fels, H. E., R. J. Moir, and R. C. Rossiter. 1959. Herbage intake of grazing sheep in South Western Australia. Aust. J. Agr. Res. 10(2):237-247.

Gates, C. C. 1975. Aspects of the environment - lungworm (Nematoda; metastrongloidea) - bighorn sheep (Ovis c. canadensis) system. M. Sc. Thesis. Univ. of Alberta, Edmonton. 55pp.

Gates, C. C. 1980. Patterns of behaviour and performance of wapiti (Cervus elaphus nelsoni) in the boreal mixed wood forest. Ph. D. Thesis. Univ. of Alberta, Edmonton. 240pp.

Geist, V. and R. g. Petocz. 1977. Bighorn sheep in winter: do rams maximize reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.

Harper, F. E. 1969. Effects of certain climatic factors on the productivity and availability of forages on the Ashnola bighorn winter ranges. M. Sc. Thesis. Univ. of B. C. Vancouver, B. C. 112pp.

Hebert, D. M. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph. D. Thesis. Univ. of British Columbia, Vancouver. 357pp.

Hebert, D. M. 1978. Blood chemistry as an indicator of nutritional condition in bighorn sheep. Pp. 365-37. In Proc. 1978 Northern Wild Sheep and Goat Conf. B. C. Fish and Wildlife Branch, Victoria.

Hebert, D. M. and Joyce Hebert, in prog. The relationship between fecal N, food habit changes and cumulative nitrogen intake for bighorn sheep.

Heimer, W. E. 1980. Can population quality be related to population density through nutrition? In Proc. of the biennial symposium of the Northern Wild Sheep and Goat council. Idaho Dept. of Fish & Game, Salmon, Idaho. p. 288-309.

Hoefs, M. and I. McTaggart Cowan. 1979. Ecological investigation of a population of Dall sheep (Ovis dalli dalli Nelson) Syesis. 12(1):1-81.

Holechuek, J. L., M. Vara and R. d. Pieper. 1982. Methods for determining the nutritive quality of range ruminants diets: A eview. J. of Anim. Sci. 54(2):363-376.

Hutchinson, K. J. 1958. Factors governing fecal nitrogen wastage in sheep. Aust. J. of Agric. Res. 9(4):508-520.

Janz, D. W. 1983. Seasonal composition and quality of Roosevelt elk diets on Vancouver Island. M. Sc. Thesis. Univ. of British Columbia. Vancouver. 68pp.

Jorgenson, J. T. and W. Wishart. 1982. Ram mountain bighorn study. Dept. Energy and Nat. Res., Fish and Wildlife Div. Prog. Report. 41pp.

Lambourne, L. J. and T. F. Reardon. 1963. The use of chromium oxide and fecal nitrogen concentration to estimate the pasture intake of merino wethers. Austral. J. Agr. Res. 14:257.

Lancaster, R. J. 1949. Estimation of digestibility of grazed pasture from feces nitrogen. Nature 163:330-331.

Lancaster, R. J. 1954. Measurement of feed intake by grazing cattle and sheep. V. Estimation of the feed to feces ratio from the nitrogen content of the feces of pasture fed cattle. New Zealand J. Sci. and Tech. A. 36(1):15-20. 331-341pp.

Leslie, D. M. and Starkey, E. E. 1982. Cervid-Habitat Interactions in Olympic National Park, Oregon Co-operative Park Studies Unit, Report 82-2. 109pp.

McFetridge, R. J. 1977. Strategy of resource use by mountain goats in Alberta. M. Sc. Univ. of Alberta, Edmonton. 148pp.

Milford, R. 1957. The value of fecal nitrogen and fecal crude fibre in estimating intake of four subtropical grass species. Austral. J. Agr. Res. 8(4):359-370.

Mould, E. D. and C. T. Robbins. 1981. Nitrogen metabolism in elk. J. Wildl. Manage. 45:323-334.

O'Donovan, P. B., R. F. Barnes, M. P. Plumlee, G. O. Mott, and L. V. Plackett. 1967. "Ad libitum" intake and digestibility of selected reed canary grass (Phalaris arundinacea L.) clones, as measured by the fecal index method. J. of An. Sci. 26(5):1144-1152.

Pitt, M. D. and B. M. Wikeem, 1978. Diet preference of California Bighorn sheep on native rangeland in South Central British Columbia. In Proc. 1978 Northern Wild Sheep and Goat Conf., B. C. Fish and Wildlife Branch, Victoria.

Raymond, W. F. 1948. Evaluation of herbage for grazing. Nature 161:937-938.

Scheffler, E. G. 1972. An appraisal of ungulate habitats in the Ashnola resource management unit. M. Sc. Thesis. Univ. of British Columbia, Vancouver. 197pp.

Seip, D. R. 1983. Foraging ecology and nutrition of Stone sheep. Ph. D. Thesis. Univ. of British Columbia, Vancouver. 182pp.

Shank, C. C. 1982. Age-sex differences in the diets of wintering Rocky Mountain bighorn sheep. Ecol. 63(3):627-633.

Stelfox, J. G. 1976. Range ecology of Rocky Mountain bighorn sheep. Can. Wildl. Service Rept. Series No. 39. 50pp.

Westra, R. and R. J. Hudson. 1981. Digestive function of Wapiti calves. J. Wildl. Manage. 45(1):148-155.

Wikeem, B. M. (In Prog.). Forage selection by California bighorn sheep and the effects of selective grazing on an Artemisia-Agropyron community in southern British Columbia. Ph. D. Thesis. Univ. of British Columbia, Vancouver.