This file report is an unedited, unpublished report submitted as partial fulfilment of NODA/NFP Project #4047, "Glyophosate effects on nutritional quality of moose browse".

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FINAL REPORT OF NODA PROJECT NUMBER 4047: GLYPHOSATE EFFECTS ON NUTRITIONAL QUALITY OF MOOSE BROWSE.

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PROGRAM COMPONENT ADDRESSED
Applied Research
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December 31, 1995.
STUDY LOCATION:
100 Km north-west of Thunder Bay, at Lakehead University, and at Tara Scientific Laboratories, Thunder Bay.

PRINCIPAL INVESTIGATOR/PROJECT TEAM
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Project Team: Leader - Colin Kelly, Graduate Student (winter), Shatal Thapa, Assistant - Undergraduate student (summer).
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Project Title
Glyphosate effects on nutritional quality of moose browse.

Objective

To determine the effects of the silvicultural use of glyphosate on the nutritional quality (digestibility and protein) of selected plants commonly eaten by moose (*Alces alces*) in early successsional forests. Results will allow forest managers to better assess the effects of conifer release with herbicides on moose habitat quality, and better integrate forest and wildlife management.

Problem Description

This project is part of a continuing investigation of moose/forestry interactions that has resulted in the following publications and theses: (Todesco et al. 1985; Cumming 1987; Todesco 1988; Cumming 1989; Mastenbrook and Cumming 1989; Mastenbrook 1990).

Intensified silviculture in the boreal forest requires that forest managers tend young conifer regeneration to control non-crop species. In general this tending has been accomplished with aerial applications of herbicides. However, many publics question the effects of this treatment on wildlife in general, and moose in particular.

Several studies (Kennedy and Jordan 1985; Connor and McMillan 1988; Hjeljord and Gronvold 1988; Cumming 1989; Lloyd 1989; Newton et al. 1989; Connor and McMillan 1990; Lloyd 1990; Lloyd 1990; Kelly and Cumming 1992) have quantified the short-term effects of conifer release with herbicides on moose browse availability and habitat use, and an ongoing study (Kelly and Cumming 1992) near Thunder Bay, Ontario, was designed to provide long-term information on these ecosystem components. Although (Lautenschlager 1993) speculates that the remaining, reemerging, and invading angiosperms (potential browse) on treated areas may be of superior nutritional quality, quantitative information on the effects of this treatment on the quality of forage in treated areas does not exist (Balfour 1989). Without this information, models predicting the effects of conifer release on moose browse availability (Lautenschlager 1991) have limited value. Therefore we propose to study changes in browse quality on established study areas where studies of browse availability and use following treatment have been, or are currently being studied. Results of the ongoing study have shown that for the two heaviest application rates moose browsing decreased significantly over two years compared with unsprayed areas, at least partly because availability of browse plants decreased significantly. This study will determine whether nutritional changes might have contributed to this change in moose browsing behaviour. We will also have some information on whether the reactions of moose to spraying change with population densities, but not on population changes brought about be the spraying. This information will provide both forest industry and natural resource managers with specific information which will help them plan multiple value forest management (i. e. integrated resource management).

Economic Rational

Although the value of wildlife cannot approach the values derived from wood products, any deviation from an optimum integration of wildlife management and timber/pulpwood management is bound to result in lost revenue in one industry or the other. Detailed knowledge of the interactions between forest requirements for moose and wood products are essential for an integrated management approach. More specifically, tending forest plantations will become substantially more expensive if, through lack of knowledge about impacts, the use of chemicals for tending crop trees should be forbidden. If the crop trees are not tended at all, the loss in terms of planted stock lost and growth curtailed is still undesirable.

Wood Products	CANADA ($ billion)	ONTARIO ($ billion)
Lumber	6.26[1]	0.67
Pulp	8.19	2.35
Wildlife - Direct Benefits		
-net economic value	1.00[2]	0.37
Indirect Benefits		
-actual expenditures	5.10	1.62
which generates:		
gross business production	10.70	3.85
gross domestic product (GDP)	6.50	2.23
taxes	2.50	0.36
personal income	3.70	1.38
jobs created	**160 000**	**62 000**

The total gross value of hunting moose in North America in 1982 was estimated at $463.9 million (Bisset 1987). In Ontario, license revenue alone came to over $2 million, direct expenditures for moose hunting $25 million (Bisset 1987) Table 2), indirect expenses amounting to about $55 million (Bisset 1987) Table 3), and expenditures for moose-related activities other than hunting about $87.5 million (3.5 times direct hunting expenditures as calculated by (Filion et al. 1983). In addition the value of meat from Ontario moose in 1981 amounted to about $10 million, and 7,362 hides were donated to native people who hand made items estimated to cost $30-100.

Production of moose to sustain, and perhaps increase, these economic values depends on food of sufficient quantity and quality. Yet silvicultural practices may be taking out of production each year many hectares of the best food available - that growing 5-20 years after burning or harvesting. More precise information about the extent of these losses will allow better predictions about the effects of conifer release on moose populations and, therefore, this specific economic resource (i.e. economic considerations of adjusting management practices in light of research results).

CONTRIBUTORS/COLLABORATORS

The project was carried out on a forest management agreement area of Canadian Pacific Forest Products Limited. The following were involved in the successful completion of this project:
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b) Ontario Forest Research Institute, Sault Ste. Marie - Dr. R. A. Lautenschlager, Research Scientist.

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[1] Data for 1984. Canada Year Book, 1988.

[2] Filion, F.L., A. Jacquemot, P. Boxall, R. Reid, P. Bouchard, E. DuWors and P.A. Gray, 1987. The importance of wildlife to Canadians: The economic significance of wildlife related activities. Env. Can, Can. Wildl. Serv. 40p.

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ABSTRACT

Digestible protein in 4 moose browse species aerially treated with the silvicultural herbicide, Vision® (glyphosate), was not significantly reduced 4 and 8 years after treatment. On the other hand, significant differences were found between study areas, seasons (winter vs summer) and among species. These results suggest that any nutritional changes due to applications of Vision® must be short-term; long-term effects of this chemical on moose browse are more likely to be quantitative than qualitative. The study also found that except for one instance of higher protein levels in willow, trembling aspen produced more digestible protein than willow, beaked hazel, or red raspberry.

STUDY AREAS AND TREATMENTS

The original research areas on which this study was carried out consisted of 7 paired control and treatment blocks located near Raith, Ontario, approximately 120 km northwest, Ontario (Kelly and Cumming 1992) from which 4 were used once more, and 3 treatment-control pairs of blocks near Obonga Lake, approximately 185 km north of Thunder Bay.

The Raith Study Area

The Raith blocks supported black spruce (*Picea mariana* (Mill.) before they were harvested between 1982 and 1987. Soils on these upland sites were generally dry, shallow glacial tills over granite bedrock (the Canadian Shield), although sphagnum (Sphagnum spp.)/feathermoss (Hylocomium spendens, Pleurozium schreberi, Ptilium crista-castrensis) bogs were common in the lower areas at the edges of clear-cuts. Kelly (1993) classified these soils, by the Forest Ecosystem Classification for Northwestern Ontario (Sims et. al. 1989) and Baldwin et. al. (1990), as 40% very shallow mineral soils (soil types SS1, SS2 and SS4), 25% shallow to moderately deep mineral (SS5, SS6 and SS7), 25% deep mineral soils (S1, S2, S3 and S9), and 10% organic (S12S and S12F). Topography was rolling. Temperature was cold; mean daily temperatures for January and July were -18.5°C and +16.1°C, respectively. Precipitation averaged 50.5mm in January and 77.5mm in July (Environment Canada 1992). These blocks were mechanically site prepared, and planted with black spruce or jack pine between 1980 and 1989, and released with a single helicopter application of Vision® between August 30 and September 2, 1990, at 3 application levels (Kelly and Cumming 1992) . For the present study, twigs and leaves were collected from blocks with the heaviest application rate (1.60 kg a.e./ha) and their controls.

The Obonga Lake Study Area

The Obonga Lake blocks, located on a jack pine (*Pinus banksiana*, Lamb.) sandflat cut in 1980-1981, were planted with jack pine during the following spring. Scattered tall hardwoods, mainly trembling aspen (*Populus tremuloides*, Michx.) and white birch (*Betula papyrifera*, Marsh.) remained after harvesting. Thick hardwood regeneration quickly overtopped the plantation and an aerial release with Vision® at 1.07 kg a.e./ha was completed on half the blocks in late August 1986. By 1994, treated plots were dominated by jack pine while control plots retained more deciduous cover.

METHODOLOGY

Field Methods

During October, 1993, plots from the previous study at Raith with were restaked to enable their location in presence of winter snows. After preliminary development of methodology, 140 (5 paired samples - treated and control - of 2 browse species in 7 areas) winter twig samples (annual growth clipped from twigs between snowline and 1.5 m above the snow) were collected during January 28 - February 3, 1994, from blocks where browse quantities were significantly reduced by glyphosate applications 3.5 and 7.5 growing seasons before the sampling (Kelly and Cumming 1992) (Cumming 1989) . All 210 summer samples were collected as detailed in the agreement between June 13 - 30, 1994. Summer samples were placed in dry ice containers for transportation to a freezer in the lab. Freeze drying was carried out as other duties permitted and was completed by September 6, 1994. Samples were taken to the commercial laboratory where analysis was completed.

Four important moose food species (Cumming 1987) representing different plant forms (tree - trembling aspen [*Populus tremuloides*], shrub - beaked hazel [*Corylus cornuta*], willow (*Saliz spp.*), and shrub/herb - wild red raspberry [*Rubus idaeus*]) were chosen for analyses (Note: willow had to be substituted for beaked hazel at the 7.5-year-old plots because no hazel was available). Sample areas were standardized as follows: slope - 5-15%, aspect - south, light intensity - no residual cover. Plants selected from within plots were chosen at random.

Sampling methods were designed to simulate moose browsing behaviour. Thus, samples of current year's growth of terminal twigs (140 samples) were clipped with shears from aspen and hazel in January. However, in spring and summer moose frequently strip leaves from the twigs. Therefore, summer samples were collected by hand-stripping leaves, and terminals if they separate in the hand, from the tree and shrub species plus raspberries in June, 1994.

Obonga Lake Soil Survey

Since original Obonga Lake soil descriptions preceded modern soil classifications, a new survey was undertaken using methods similar to those of Kelly (1993). However, due to time and economic constraints, fewer plots were examined in more detail than in the near total coverage achieved by Kelly (1993). Soils were classified from 3 soil pits <50cm deep for each block, located at the highest, lowest, and one between-point, totaling 18 locations. Soils were classified according to (Vanson and Meyer 1995), a system requiring more detailed descriptions than those of Sims, et al. (1989), used by Kelly (1993) . Coloured photographs of representative pits assisted classification.

Laboratory Methods

Ultimately two parameters were sought: digestible protein (DP) and digestible dry matter (DDM). Digestions were by the standard techniques outlined by (Goering and Soest 1970) and (Mould and Robbins 1981). As recommended by (Hanley et al. 1992), sodium sulfite was added to the neutral detergent fiber (NDF) digestions of the collected forages.

Crude protein was determined using the traditional Kjeldahl method; for conversion to total nitrogen the value was multiplied by 6.25. The protein-precipitating capacity of forage tannins, determined by the bovine serum albumin (BSA) precipitation assay for proteins (Martin and Martin 1982; Robbins, et al. 1987 a; Hanley et al. 1992) was determined to adjust digestible protein values for the inhibiting presence of secondary compounds. Due to the low concentration of tannins in browse stems BSA precipitation were not performed on these forages; however, since leaves are high in tannin content their values must be adjusted (Robbins et. al. 1987 a, Hanley at. al. 1992).

Cutin and Lignin percentages were determined from sequential detergent analysis. Samples were extracted and rinsed using standard NDF procedures, with an extra water rinse to clear acetone. The NDF was then extracted with acid detergent (Mould and Robbins 1981). The boiling time for acid detergent was increased to two hours to increase protein extraction and minimize artifact lignin (Robbins et. al. 1987 b). This fibre was then used for lignin and cutin determinations. The ADF was washed with 72% H_2SO_4 to remove cellulose. Ashing of the residue determined the crude lignin fraction including cutin (Goering and Van Soest 1970).

These variables yielded values for digestible protein and digestible dry matter when placed into the formulas below.

Digestible Protein (From Robbins et. al. 1987 a, Hanley et. al. 1992)

$DP = -3.87 + 0.9283X - 11.82Y^{\dagger}$

where

X = crude protein content
= 6.25 * total Nitrogen (expressed as a percent of dry matter)
total Nitrogen is determined from Kjeldahl procedure

Y = Bovine Serum Albumin precipitation assay: proteins (mg/mg forage dry matter) (Martin and Martin 1982)

†no correction is needed for tannins when analyzing zero or low tannin forage (grasses/agricultural legumes/browse stems); 11.82Y = 0.

Digestible Dry Matter (From Robbins et. al. 1987 b, Hanley et. al. 1992)

$DDM = [(0.9231e^{-0.0451A} - 0.03B)(NDF)] + [(-16.03 + 1.02\ NDS) - 2.8P^{\dagger\dagger}]$

(cell wall digestion) (cell solubles digestion)

where

A = (lignin + cutin) content as a percentage of NDF (from Goering and Van Soest 1970 and Robbins et. al 1987 b)

B = biogenic silica content of monocots (assume = 0)

NDF = neutral detergent fibre (%) (from Goering and Van Soest 1970)*

NDS = neutral detergent solubles (%) (= 100 - NDF%)

P = reduction in protein digestion (%) (the 11.82Y term in DP above) (Hanley et. al. 1992)

†† because no correction for tannins is necessary for browse stems, the reduction in protein digestion due to tannins is negligible; 2.8P = 0.

*with sodium sulfite for summer browse (leaves have high tannin content) without sodium sulfite for winter browse (little tannin content in stems) (Hanley et. al. 1992).

Statistical Analysis

Normality was determined using the graphical tools of the Macintosh program, DataDesk. Although the data are presented as percentages, these percentages represent laboratory determinations rather than calculations from field counts. Thus most were acceptably close to normality. Two data sets were improved by using square-root transformations, but another two were made worse. Under these circumstances, we chose to present and analyze non-transformed data (following Brown, pers. comm.).

Although the experiment was designed for analysis by ANOVA, an operational change during spraying left only a single treatment in each block. Thus, Residuals in the ANOVA's became measures of sampling variation rather than aspects of the experimental design. For this reason, we changed the denominator from the ANOVA from Error terms to the 3-way interaction (BlocksXTreatmentsXSpecies - using the program SuperAnova). A further problem arose when, another consultant (T. Hazenburg pers. comm.), suggested that the 2 variables, digestible protein and digestible dry matter, might be related. We found no correlations among data from winter twigs, but a significant correlation ($\underline{P}$ (regression) ≤ 0.001, R^2=39.1) between these variables for summer leaves. For this reason summer, data were analyzed using MANOVA's. Because no consensus exists among statisticians concerning the best way to test MANOVA results (as it does for ANOVA's), SuperAnova provides 4 tests formed from eigenvalues representing different statistical approaches to the multivariate problem. These include Wilk's Lambda, Roy's Greatest Root, Hotelling-Lawley Trace, and the Pillai Trace.

Validation of Results

Most laboratory techniques were standard for Tara Scientific Laboratories, but the determination of protein-precipitating capacity of forage tannins by the bovine serum albumin (BSA) precipitation assay for proteins was not. Therefore, 12 samples were selected randomly from the collected material and forwarded to Dr. Bruce Davitt, Wildlife Habitat Laboratory, Department of Natural Resource Sciences, Washington State University, Pullman, WA, 99164-6410, for further analysis. Results of these samples from the two laboratories were then compared.

RESULTS

Crude protein

Crude protein of winter browsed varied around 8% for winter aspen browse in both the Raith and Obonga Lake study areas (Appendix Tables 1, 2) with no significant differences between them (t=1.155, p=0.25). Willow and beaked hazel contained about 7% crude protein. In summer aspen leaves ranged from 9.2 to 24.8 %, beaked hazel from 8.1- 19.1% and willow 13.4-- 27.3 % . Raspberry ranged from 8.2 - 17.4 at Raith and 12..2 - 22.7 at Obonga Lake. For comparison, Hjleljord, 1982 #700 found crude protein in twigs of 4 Norwegian browse species ranging from 5.4-10.1%. and Risenhoover, 1989 #702 found crude protein values of 5.9-9.5 in winter twigs of 8 Alaskan trees and shrubs. Therefore, the crude protein values in our winter samples fell well within previously determined ranges. Schwartz, 1987 #701 fed moose pelletized foods ranging from 8-20%; Hanley, 1992 #704 reported crude protein values ranging from 11.4 -18.7 for leaves, suggesting that summer crude protein values were reasonable also.

Typically, differences between treated and control areas were small and often reversed in direction (Fig. 1). These crude protein differences generally determined relative levels of digestible protein.

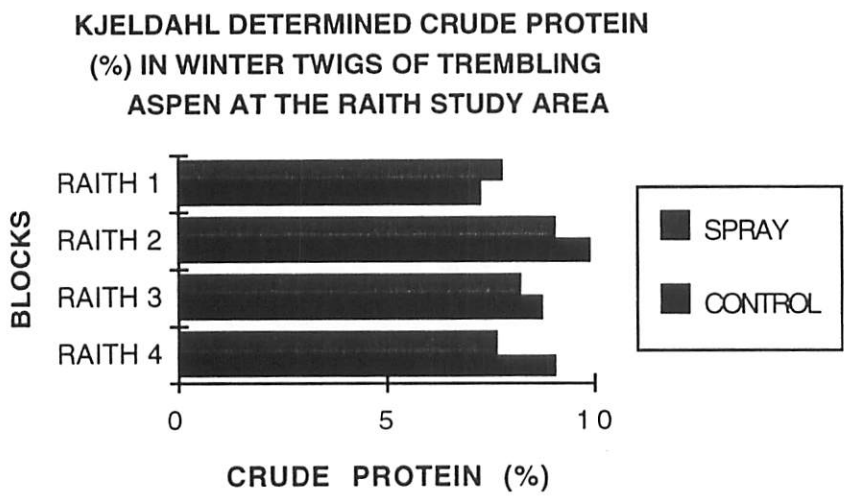


Fig. 1. Crude protein in winter twigs of trembling aspen at Raith study area.

Digestible protein

Digestible protein in winter samples of trembling aspen from Raith ranged from 2.5 to 3.22% on control areas, 2.07 to 3.39 on sprayed areas (Table 1). At the Obonga Lake study area, digestible protein ranged from 3.52 to 4.02 on control areas and 3.33 to 3.87 on sprayed areas. For comparison, Thus, very small differences were observed between control and treated areas, but Obonga Lake percentages appeared generally higher than those at Raith. Digestible protein in aspen tended to be higher than in either beaked hazel or willow.

Table 1. Digestible protein (%) in 4 moose browse species commonly found in northwestern Ontario (means - bold, standard deviations - plain).

		Winter		Summer		
		Aspen	Hazel	Aspen	Hazel	Raspberry
Raith	Treated	**3.74**	**2.69**	**6.80**	**6.07**	**4.94**
	(N=4)	1.05	0.95	2.49	0.46	2.06
	Control	**3.87**	**2.93**	**6.98**	**7.18**	**4.04**
	(N=4)	2.22	0.96	2.63	0.40	1.78
			Willow		Willow	
Obonga Lake	Treated	**3.64**	**2.60**	**10.63**	**12.96**	**10.60**
	(N=3)	0.90	0.99	2.90	3.84	2.76
	Control	**3.77**	**2.46**	**9.90**	**10.27**	**7.01**
	(N=3)	0.76	0.73	3.38	2.78	2.23

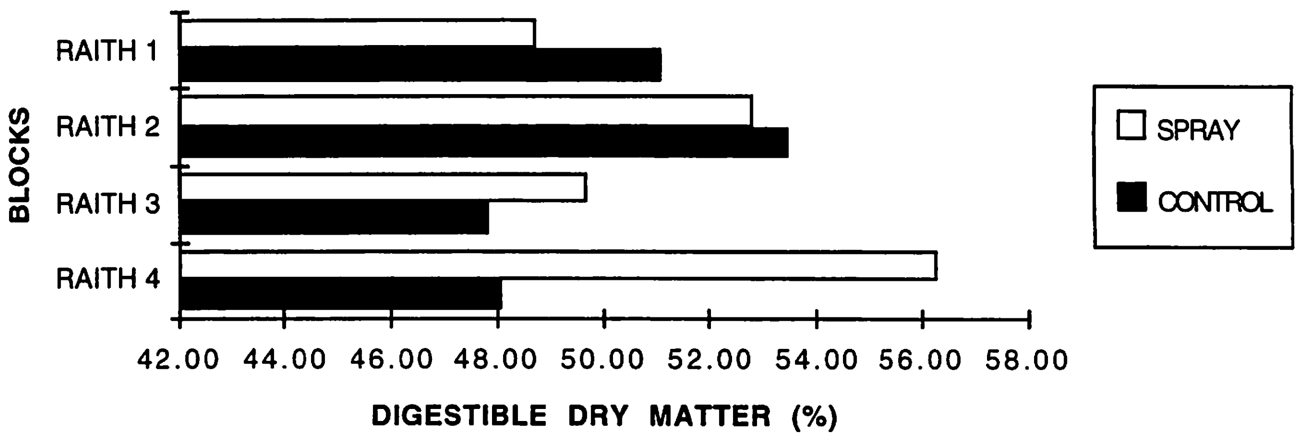
Summer values for digestible protein percentages showed greater ranges at Raith (control 3.39-8.54, treatment 4.92-9.95) and Obonga Lake (control 7.55-12-59, treatment 9.23-12-73) (Appendix Table 2). Differences in nutritional quality between Raith and Obonga Lake study areas were even more evident in these summer data.

For comparison, Hanley, 1992 #704 found digestible protein values ranging from 2.4 for twigs through 5.0-16.0 for leaves.

Digestible Dry Matter

Digestible dry matter percentages during winter tended to differ in ways similar to but differing lest than those of digestible protein (Fig. 2).

Fig. 2. EXAMPLE OF DIGESTIBLE DRY MATTER (%) IN WINTER TWIGS: TREMBLING ASPEN AT THE RAITH STUDY AREA



Winter percentages of digestible dry matter in trembling aspen on control areas at Raith ranged from 61.27 to 63.98 while on sprayed areas they ranged from 62.32 to 67.90, slightly higher but with much overlap (Table 4). At Obonga Lake, digestible dry matter in aspen ranged from 61.27 to 63.98 in winter on treated areas, 62.32 to 67.90 on controls. Thus digestible dry matter results at Raith differed little from those at Obonga Lake, but aspen continued to show slightly higher values than other species (details in Appendix Table 4).

Digestible dry matter in summer showed much narrower ranges at Raith (control 66.69-70.04, treatment 66.14-70.26) and Obonga Lake (control 67.64-69.92, treatment 64.35-67.22) but differences between study areas were not as obvious.

For comparison, Hjleljord, 1982 #700 found dry matter (not digestible) ranging from 49.3 - 62.2 in Norwegian browse. Schwartz, 1987 #701 found dry matter digestibility ranging from 54.9 - 53.8 in his pelleted food. Robbins, 1987 #703 reported dry matter digestibility ranging from 49.9-72.2 in leaves, grasses and flowers. Hanley, 1992 #704 found digestible dry matter ranging from 47.7-71.5 in leaves and 36.8 for a single sample of twigs.

Statistical analyses

Analysis of winter moose browse 4 and 8 years after treatment showed significant differences between species (trembling aspen, and beaked hazel or willow) in digestible protein and digestible dry matter, with aspen having about 1.3-1.5 times more digestible protein, and about 1.05-1.07 times higher digestible dry matter (Table 3). Summer digestible protein and digestible dry matter differed significantly among blocks and species at Raith (Table 3). In the supplementary MANOVA tables for summer data from Raith (4 years after treatment), 3 of the 4 tests indicated probabilities of 0.0001 for differences among blocks and among species, but all 4 showed $p = 0.1070$ for treatments. None of the interactions tables showed significant probability values. Thus, these tables confirmed that treatments do not differ significantly.

Table 3. Probability values from ANOVAS of winter moose browse analyses and MANOVA's of summer leaf analyses.

	Winter		Summer	
Nutrient	Digestible protein	Digestible dry matter	Digestible protein	Digestible dry matter
	Raith Study Area		Raith Study Area	
Blocks	0.0975	0.9842	0.0102*	0.0062**
Treatments	0.1235	0.4731	0.7792	0.0581
Species	0.0073**	0.0122*	0.0066**	0.0003***
	Obonga Lake Study Area		Obonga Lake Study Area	
Blocks	0.4465	0.3541	0.3967	0.2637
Treatments	0.9879	0.346	0.0466*	0.4858
Species	0.023*	0.0302*	0.1144	0.0129*

Note: Type III MANOVA Table values (Effect:TREATMENT) for Wilks' Lambda, Roy's Greatest Root,
Hotelling-Lawley Trace, and Pillai Trace all showed p=0.107 for Raith summer leaves and 0.190 for Obonga Lake summer leaves, indicating non-significance.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

At Obonga Lake digestible dry matter in summer also differed among species . However, in addition, digestible protein of summer leaves differed between treatments, the only significant difference between treatments in the study. In MANOVA tables for Obonga Lake summer data, 3 of the 4 tests confirmed that neither differences among blocks nor among species were significant. However, all 4 tests also showed probabilities of 0.19 for treatments. Again interactions were not significant. Re-calculation after a square-root transformation of the data did not change these results. Therefore, the apparent significant difference between treatments in digestible protein of summer samples from Obonga Lake, when examining individual ANOVA's, must have been due to the relationship between digestible protein and digestible dry matter, and real differences between treatments may not exist.

Obonga Lake Soil Surveys

Soil surveys at Obonga Lake showed that most soils were moderate- deep glacial deposits consisting of fine-course sands with some silt and many stones, boulders (Appendix Table 5). In some places digging to 1 m depth was impossible without a crowbar because of the stones and boulders; therefore, we standardized on 50 cm for maximum soil pit depths for analysis purposes. Although the land was relatively flat, some higher points showed small areas of flat igneous bed rock. The deepest depressions contained standing water in the form of small lakes; here the sands were courser, boulders absent, and 1 plot revealed peat.

A comparison between soils on treatment and control areas at Obonga Lake suggested generally deeper soils on the treated areas (Table 4), but, the difference was not significant (κ^2=1.55, d.f.=2, p>0.5). All 3 bedrock sites were located on the control areas.

Table 4. Comparison of soil depths between treatment areas at Obonga Lake study area.

Average Total Soil	Treatment		
Block	Cnt	Tr	Grand total
B1	37	50	87
B2	21	42	63
B3	30	43	73
Grand total	88	135	223

Thus although soils on both study areas consisted of glacial tills over granite bedrock, the Obonga Lake soils were generally deeper (Table 5; κ^2=21.4, p < 0.005).

Table 5. Depths of soils (cm) at Raith and Obonga Lake.

Depth (cm)	Raith %	Obonga Lake %	
0-20	40	22	62
21+	50	78	128
40	10	0	10

Validation

The values for protein-precipitating capacity of forage tannins, determined by the bovine serum albumin (BSA) precipitation assay for proteins, reported by Tara Scientific Laboratory were generally higher than those in the sub-sample (12 samples) analyzed at Washington State University. Ignoring 2 negative values in the latter, which brought the means to).184 and 0.144, the differences in a paired t-test were still significant (P =0.03); however, the Wildlife Habitat Laboratory personnel are constantly attempting to improve methods, and it was not clear that the methods were identical. Furthermore, as Hanley (pers. comm.) pointed out, both values are in a reasonable range and the difference would result in only 2.4 units of DDM . If this difference were a critical issue, both labs could be asked to do replicate analyses of the same samples to determine precision. A blind tests of a known standard would be required to determine accuracy. But given the complexity of the analysis, requiring multiple subsamples at different dilutions to establish a curve from which the slope can be determined (Hanely, pers. comm.), with associated costs, such testing would seem impractical and unnecessary.

Table 6. Comparison between tannin determinations from Tara Scientific Laboratories and Washington State University Wildlife Habitat Laboratory.

Sample no.	Tara Sc.	Wash. State.
145	0.174	0.147
146	0.084	-0.045
151	0.287	0.121
160	0.225	0.107
163	0.19	0.122
166	0.311	0.153
175	0.062	0.045
180	0.102	0.054
182	0.307	0.206
185	0.298	0.253
196	0.135	0.235
192	0.032	-0.012
Means	0.184	
	Mean as is	0.116
	Mean less negs	0.144
Mean X-Y	0.065	
Paired t-value	2.63	
P	0.0273	

A comparison of the mean values obtained from this study compared with Hanley et al. (1992) shows BSA and crude protein values very similar. NDF values for the current study were somewhat lower for twig samples and slightly higher for leaf samples, but the differences were not great. Lignin and cutin values differed more widely. Furthermore, the lignin and cutin values from this study were very similar for twigs and leaves, though one might expect otherwise. For entry in the equation the cutin and lignin values must be presented as percentages of neutral detergent fibre. The column with these values shows even greater differences between studies for twigs, but less difference for leaves, and a larger difference between twigs and leaves in this study. When the calculations were completed, values for digestible protein were similar, as were those for digestible dry matter in leaves. The single value for twigs reported by Hanely et al. (1992) remained substantially different. Still, once more, all these values seem in the same general orders, and, as Hanley (pers. comm.) pointed out, the species and areas differ, and results can vary widely even within the same species in the same area. In summary, the values in general seem reasonable, and should be accepted.

Table 7. Comparisons of mean values from this study with those in Hanley et al. (1992).

	BSA	Crude protein	NDF	Lignin, Cutin	Lig &Cut%NDF	DP%	DDM%
				TWIGS			
Hanley et al.(1992)	**0.1**	**7.7**	**60.3**	**19.8**	**32.8**	**2.2**	**34.0**
(1 sample only)							
Raith	0.0	7.8	50.6	11.9	23.7	3.3	50.9
Obonga Lake	0.0	7.5	53.2	12.6	26.3	3.1	47.5
				LEAVES			
Hanley et al.(1992)	**0.2**	**15.6**	**28.7**	**7.0**	**23.6**	**8.4**	**59.7**
Raith	0.2	13.0	32.2	10.6	32.5	6.0	53.9
Obonga Lake	0.2	17.2	30.8	12.0	38.6	10.2	55.0

*Calculated values

Publication

These results have been summarized for publication in a scientific paper (Cumming et al. in press) and an OMNR Research Note (Submitted). They were presented in the form of a Poster at seminars in Dryden (October, 1994) and Timmins (March, 1995). The posters led to many interesting discussions with viewers. Especially, detailed were discussions with foresters, biologists, high school students and experienced hunters.

DISCUSSION

Results of this study do not support earlier suggestions that glyphosate treatment might alter nutritional quality of remaining browse plants, at least 4, 8 years after treatment. Any differences that might occur would appear to be most likely short term, i.e. 1-3 years after spraying. Unless subsequent studies refute these initial findings, this means that nutritional differences do not need to be considered when assessing effects of silvicultural glyphosate treatments on moose browse. Published studies showing decreased quantities of moose browse up to 4 years after treatment can be taken as representing the true impact of glyphosate on moose food supplies. Predictions such as those provided by these studies and by models (RAE) should be reasonably reliable without further modification for food quality.

The sum of evidence to date suggests that silvicultural glyphosate spraying substantially reduces quantities of winter food available to moose on the sprayed areas. Furthermore, moose eat fewer browse plants and ingest less plant biomass on these treated areas, probably because optimal foraging dictates that they move to places where food plants are more dense and hence nutritional supplies more easily obtained with less energy output.

SIGNIFICANCE OF GLYPHOSATE SPRAYING FOR FOREST MANAGEMENT

The actual impact of spraying on moose, then, will vary depending on spray area patterns and timing. If most cut-overs in an area are sprayed within a short period of time, numbers of moose on that area will be most likely be greatly reduced for some years. Although the spraying may, or may not, affect the over-all moose population, depending on the proportion of their winter range that is affected, availability of moose to local hunters will most likely change dramatically. Some favoured moose hunting areas could be completely eliminated as places worth hunting for many years. On the other hand, a schedule of spraying on a rotation basis with individual treated areas well spaced could actually prolong the value of an area for winter moose browse long after it would normally have grown out of reach.

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Appendix Table 1. Crude protein values for winter twigs and summer leaves at the Raith study area. Bold numbers are means of 5 determinations. Plain numbers are standard deviations.

	Winter twigs		Summer leaves		
	Trembling aspen	**Beaked hazel**	**Trembling aspen**	**Beaked hazel**	**Raspberry**
Sprayed					
Raith 1	**7.78**	**7.82**	**13.74**	**12.94**	**14.98**
	0.75	0.66	0.43931765	1.66973052	0.93914855
Raith 2	**9.06**	**7.46**	**15.9**	**14.32**	**13.42**
	1.77	0.80	2.10831686	1.66943104	3.2889208
Raith 3	**8.24**	**6.40**	**11.54**	**11.98**	**10.94**
	0.56	1.11	1.8447222	0.94180677	1.28179562
Raith 4	**7.70**	**6.58**	**12.5**	**11.18**	**13.1**
	0.78	0.93	1.2922848	2.27530218	1.69263109
Control					
Raith 1	**7.28**	**7.18**	**14.92**	**13.52**	**14.32**
	0.79	1.39	2.60518713	0.49699095	2.81549285
Raith 2	**9.94**	**7.60**	**14.24**	**13.14**	**12.08**
	1.17	1.08	1.23612297	2.07557221	0.75630682
Raith 3	**8.78**	**7.64**	**14.3**	**13.72**	**11.62**
	0.84	0.78	1.72191754	4.10998783	1.33865604
Raith 4	**9.10**	**6.88**	**10.22**	**13.04**	**11.08**
	1.30	0.94	0.57183914	0.53197744	1.92535711

Appendix Table 2. Crude protein values for winter twigs and summer leaves at the Obonga Lake study area. Bold numbers are means of 5 determinations. Plain numbers are standard deviations.

	Winter twigs		Summer leaves		
	Trembling aspen	Willow	Trembling aspen	Willow	Raspberry
Sprayed					
Obonga Lake	**8.34**	**7.56**	**18.16**	**19.68**	**19.16**
	1.05	1.23	2.343715	2.310194797	1.836572895
Obonga Lake	**8.16**	**6.90**	**15.48**	**21.24**	**16.92**
	1.21	0.45	3.74793276	5.054997527	1.60530371
Obonga Lake	**7.76**	**6.46**	**16.54**	**17.22**	**20.14**
	0.74	3.71	1.62726765	1.640731544	2.093561559
Control					
Obonga Lake	**8.24**	**6.54**	**14.12**	**17.44**	**15.48**
	0.88	1.23	1.85660981	1.176010204	1.930543965
Obonga Lake	**8.50**	**6.84**	**15.86**	**16.28**	**13.7**
	1.10	0.38	1.76153342	2.418057071	1.769180601
Obonga Lake	**7.96**	**7.08**	**17.98**	**17.34**	**16.2**
	0.40	0.54	4.15415455	3.478936619	2.468805379

Appendix Table 3. Mean values for digestible protein in moose browse at Raith and Obonga Lake study areas.

RAITH WINTER

Average DP%		SPECIES		
TREAT	BLOCK	Corylus cornuta	Populus tremul	Grand total
control	RAITH 1	2.80	2.89	2.84
	RAITH 2	3.19	5.36	4.27
	RAITH 3	3.22	2.65	2.93
	RAITH 4	2.52	4.58	3.55
control Average		2.93	3.87	3.40
spray	RAITH 1	3.39	3.35	3.37
	RAITH 2	3.06	4.54	3.80
	RAITH 3	2.07	3.78	2.93
	RAITH 4	2.24	3.28	2.76
spray Average		2.69	3.74	3.21
Grand total		2.81	3.80	3.31

RAITH SUMMER

Average DP%		Species			
Treatment	Block	Corylus cornuta	Populus tremul	Rubus spp.	Grand total
control	Raith 1	7.27	8.54	6.84	7.55
	Raith 2	7.28	8.29	4.02	6.53
	Raith 3	7.04	7.72	2.77	5.84
	Raith 4	7.13	3.39	2.43	4.31
control Average		7.18	6.98	4.01	6.06
spray	Raith 1	5.81	6.38	7.22	6.47
	Raith 2	8.07	9.95	5.89	7.97
	Raith 3	5.58	4.92	1.83	4.11
	Raith 4	4.81	5.94	4.81	5.18
spray Average		6.07	6.80	4.94	5.94
Grand total		6.62	6.89	4.48	6.00

OBONGA WINTER

Average DP%		SPECIES		
TREAT	BLOCK	Populus tremul	Willow spp.	Grand total
control	OBONGA 1	3.78	2.20	2.99
	OBONGA 2	4.02	2.48	3.25
	OBONGA 3	3.52	2.70	3.11
control Average		3.77	2.46	3.12
spray	OBONGA 1	3.87	3.15	3.51
	OBONGA 2	3.70	2.54	3.12
	OBONGA 3	3.33	2.13	2.73
spray Average		3.64	2.60	3.12
Grand total		3.70	2.53	3.12

OBONGA SUMMER

Average DP%		SPECIES			
TREATMENT	BLOCK	Populus tremul	Rubus spp.	Willow spp.	Grand total
CONTROL	OBONGA 1	7.55	7.16	11.18	8.63
	OBONGA 2	9.57	5.37	9.26	8.06
	OBONGA 3	12.59	8.52	10.38	10.50
CONTROL Average		9.90	7.01	10.27	9.06
SPRAY	OBONGA 1	12.73	12.12	13.78	12.88
	OBONGA 2	9.23	8.04	14.61	10.63
	OBONGA 3	9.93	11.63	10.48	10.68
SPRAY Average		10.63	10.60	12.96	11.40
Grand total		10.27	8.81	11.61	10.23

Appendix Table 4. Digestible dry matter means (%) for Raith and Obonga Lake study areas.

RAITH WINTER

Average DDM%		SPECIES		
TREAT	BLOCK	Corylus cornut	Populus tremul	Grand total
control	RAITH 1	49.50	52.76	51.13
	RAITH 2	51.56	55.43	53.50
	RAITH 3	51.37	44.33	47.85
	RAITH 4	47.70	48.54	48.12
control Average		50.03	50.27	50.15
spray	RAITH 1	47.81	49.75	48.78
	RAITH 2	51.82	53.83	52.83
	RAITH 3	45.07	54.38	49.73
	RAITH 4	51.11	61.55	56.33
spray Average		48.95	54.88	51.92
Grand total		49.49	52.57	51.03

RAITH SUMMER

Average DDM%		Species			
Treatment	Block	Corylus cornut	Populus tremul	Rubus spp.	Grand total
control	Raith 1	49.22	62.33	56.46	56.00
	Raith 2	52.40	61.64	48.09	54.04
	Raith 3	43.42	57.43	47.49	49.45
	Raith 4	53.94	58.46	61.03	57.81
control Average		49.74	59.96	53.27	54.33
spray	Raith 1	56.79	54.48	60.01	57.09
	Raith 2	53.76	61.61	56.77	57.38
	Raith 3	53.11	58.17	50.86	54.04
	Raith 4	42.56	69.79	47.34	53.23
spray Average		51.56	61.01	53.74	55.44
Grand total		50.65	60.49	53.51	54.88

OBONGA WINTER

Average DDM%		SPECIES		
TREAT	BLOCK	Populus tremul	Willow spp.	Grand total
control	OBONGA 1	49.56	40.86	45.21
	OBONGA 2	50.88	47.56	49.22
	OBONGA 3	44.45	45.16	44.81
control Average		48.30	44.53	46.41
spray	OBONGA 1	49.65	43.40	46.52
	OBONGA 2	50.59	43.60	47.10
	OBONGA 3	55.31	54.71	55.01
spray Average		51.85	47.24	49.54
Grand total		50.08	45.88	47.98

OBONGA SUMMER

Average DDM%		SPECIES			
TREATMENT	BLOCK	Populus tremul	Rubus spp.	Willow spp.	Grand total
CONTROL	OBONGA 1	57.74	50.67	56.17	54.86
	OBONGA 2	56.68	50.58	52.83	53.36
	OBONGA 3	57.72	52.14	51.80	53.89
CONTROL Average		57.38	51.13	53.60	54.04
SPRAY	OBONGA 1	44.32	61.22	58.44	54.66
	OBONGA 2	63.14	52.65	61.66	59.15
	OBONGA 3	55.44	60.33	58.50	58.09
SPRAY Average		54.30	58.07	59.54	57.30
Grand total		55.84	54.60	56.57	55.67

Table 5. Results of soil surveys at Obonga Lake study area, 1995.

Treatment	Block	Plot no.	Site position	Total Soil Depth	H depth	H colour	A depth	A colour	B depth	B Colour
Tr	B1	2	Top	50+		black		brown		
Tr	B1	1	Middle	50	2	brown	25	faint yellow		
Tr	B1	3	Bottom	50	28	black	33			
Tr	B2	2	Top	50	12	black	4	grey		
Tr	B2	3	Middle	25+	11		9			
Tr	B2	1	Bottom	50	5		14			
Tr	B3	1	Top	40abs	10	black	11	dark brown		
Tr	B3	2	Middle	40 abs	2.5		12			
Tr	B3	3	Bottom	50	5	black	2	black		
Cnt	B1	3	Top	10abs			5			
Cnt	B1	2	Middle		10	light brown	10	light brown		
Cnt	B1	1	Bottom	50	6	black	16	dark brown		
Cnt	B2	1	Top	1abs						
Cnt	B2	2	Middle	12.5	8	black	10	brown	2.5	mottled
Cnt	B2	3	Bottom	50	10	Black	8	Dark grey		
Cnt	B3	3	Top	25 abs	8	black	6	dark brown		
Cnt	B3	2	Middle	50	10		10			
Cnt	B3	1	Bottom	14	10		10			

C depth	Colour	Texture	Stone size cm	Stone shape	Stone density	Bedrock outcrops	Rooting depth	Rooting abund:	Mottling	Drainage Class
			30-40	angular	40%					well
25	brown	loamy sand	20-30	round	90%					mod well
10	brown	silty loam	20	round	30					imperfect
35	brown	silt and clay	50-200	angular	60					imperfect
5			50	angular	75		25	abundant		Imperfect
30	a little yellow	course sand	25-Aug	round	75					imperfect
20	brown	very fine sand					35	medium		well
35		very fine sand	20	round	10		35	abundant		well
water		course sand						abundant		poor
bedrock										
8	light brown	very find sand								
25	medium brown	medium sand						abundant (sphagnum)		moderately wel
bedrock										
bedrock									grey 50%	very fine sand
50	Dark grey	very fine sand					18	abundant	brown 20%	poor
10	brown	silt and clay	8	round	few					restricted
40			8	round	few	water at 50 cn	27	not abundant		
35		fine sand	8	round	few near surfa	water at 30 cn	24	abundant	brown 50%	poor

FEC Moisture Regime	FEC Soil Type	FEC Vegetation Type
	S1	
	S3	
	S4	
	S1	V28
	S2	V29
	S20	V32
	SS5	V25
	S1	V25
	S12S	V34
	SS2	
	S2	
II	S7	
	SS2	V32
	SS7	V11
	S9	V19
	SS5	V25
	S4	V31
	S12S	V34

Appendix Table 5. Results of soil surveys at Obonga Lake study area, 1995.

Treatment	Block	Plot no.	Site position		Total Soil	H depth	H colour	A depth	A colour	B depth	B Colour
Tr	B1	2	Top		50		black		med brown		
Tr	B1	1	Middle		50	2	brown	25	faint yellow		
Tr	B1	3	Bottom		50	28	black	33			
Tr	B2	2	Top		50	12	black	4	grey		
Tr	B2	3	Middle	+	25	11		9			
Tr	B2	1	Bottom		50	5		14			
Tr	B3	1	Top	ab:	40	10	black	11	dark brown		
Tr	B3	2	Middle	abs	40	2.5		12			
Tr	B3	3	Bottom		50	5	black	2	black		
Cnt	B1	3	Top	ab:	10			5			
Cnt	B1	2	Middle		50	10	light brown	10	light brown		
Cnt	B1	1	Bottom		50	6	black	16	dark brown		
Cnt	B2	1	Top	ab:	1						
Cnt	B2	2	Middle		12.5	8	black	10	brown	2.5	mottled
Cnt	B2	3	Bottom		50	10	Black	8	Dark grey		
Cnt	B3	3	Top	abs	25	8	black	6	dark brown		
Cnt	B3	2	Middle		50	10		10			
Cnt	B3	1	Bottom		14	10		10			

Appendix Table 5. Results of soil surveys at Obonga Lake study area, 1995.

Treatment	Block	Plot no.	Site position	C depth	Colour	Texture	Stone size cm	Stone shape	Stone density	Bedrock outcrops
Tr	B1	2	Top				30-40	angular	40%	
Tr	B1	1	Middle	25	brown	loamy sand	20-30	round	90%	
Tr	B1	3	Bottom	10	brown	silty loam	20	round	30	
Tr	B2	2	Top	35	brown	silt and clay	50-200	angular	60	
Tr	B2	3	Middle	5			50	angular	75	
Tr	B2	1	Bottom	30	a little yellow	course sand	25-Aug	round	75	
Tr	B3	1	Top	20	brown	very fine sand				
Tr	B3	2	Middle	35		very fine sand	20	round	10	
Tr	B3	3	Bottom	water		course sand				
Cnt	B1	3	Top	bedrock						
Cnt	B1	2	Middle	8	light brown	very find sand				
Cnt	B1	1	Bottom	25	medium brown	medium sand				
Cnt	B2	1	Top	bedrock						
Cnt	B2	2	Middle	bedrock						
Cnt	B2	3	Bottom	50	Dark grey	very fine sand				
Cnt	B3	3	Top	10	brown	silt and clay	8	round	few	
Cnt	B3	2	Middle	40			8	round	few	water at 50 cn
Cnt	B3	1	Bottom	35		fine sand	8	round	few near surfac	water at 30 cn

Appendix Table 5. Results of soil surveys at Obonga Lake study area, 1995.

Treatment	Block	Plot no.	Site position	Rooting depth	Rooting abund	Mottling	Drainage Class	FEC Moisture Regime	FEC Soil Type	FEC Vegetatior Type
Tr	B1		2 Top				well		S1	
Tr	B1		1 Middle				mod well	dry	S3	
Tr	B1		3 Bottom				imperfect		S4	
Tr	B2		2 Top				imperfect		S1	V28
Tr	B2		3 Middle	25	abundant		Imperfect		S2	V29
Tr	B2		1 Bottom				imperfect		S20	V32
Tr	B3		1 Top	35	medium				SS5	V25
Tr	B3		2 Middle	35	abundant		well		S1	V25
Tr	B3		3 Bottom		abundant		poor		S12S	V34
Cnt	B1		3 Top						SS2	
Cnt	B1		2 Middle						S2	
Cnt	B1		1 Bottom		abundant (sphagnum)		moderately well		S7	
Cnt	B2		1 Top						SS2	V32
Cnt	B2		2 Middle			grey 50%	very fine sand		SS7	V11
Cnt	B2		3 Bottom	18	abundant	brown 20%	poor		S9	V19
Cnt	B3		3 Top				restricted		SS5	V25
Cnt	B3		2 Middle	27	not abundant				S4	V31
Cnt	B3		1 Bottom	24	abundant	brown 50%	poor		S12S	V34