# EFFECTS OF CONIFER RELEASE WITH VISION® (GLYPHOSATE) ON MOOSE FORAGE QUALITY

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ABSTRACT: During January and June, 1994, we collected twigs and leaves from 4 moose browse species growing in treated and control portions of 2 ongoing replicated block experiments in which Vision® had been applied aerially at 1.60 kg a.e./ha in 1990 (4 years before our sampling), and 1.07 kg a.e./ha in 1986 (8 years before sampling). Altogether, 350 samples of forage were analyzed for crude protein and associated parameters, e.g. cutin and lignin, to calculate digestible protein and digestible dry matter. Means (and ranges) follow: crude protein - twigs 8% (7-9), leaves 15% (12-19); digestible protein - twigs 3% (2-4), leaves 8% (4-13); digestible dry matter - twigs 60% (57-63), leaves 65% (62-70). Forage quality varied significantly among blocks and species, digestible protein varied between study areas in summer, but no significant differences were detected between treated and control plots either 4 or 8 years after treatment. Consistently higher values for digestible protein in summer forage from treated portions of the 8-year-old study may indicate differences that would show significance with more samples. But apart from that, the study suggests that any long-term effects of conifer release with Vision® are more likely to be quantitative than qualitative.

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Forest managers commonly control non-crop vegetation when regenerating (releasing) young conifer species (Smith 1986). In general this release is accomplished with aerial applications of herbicides. Various publics, however, continually question the effects of this forestry regeneration practice on wildlife (Lautenschlager 1991, 1993a), and hunters question potential effects on moose (Lautenschlager 1992).

Vision® (active ingredient glyphosate) is the herbicide most commonly used in Canadian forestry (Paquette and Bousquet 1991). Glyphosate is relatively non-toxic to both terrestrial and aquatic animals (Newton *et al.* 1984, Atkinson 1985, Sullivan 1985, 1990). The formulated product, Vision® in Canada (Roundup® in the United States) is considered practically non-toxic to mammals, but due to presence of a surfactant, it is listed as slightly to moderately toxic to aquatic invertebrates and fish (Hildebrand *et al.* 1980, Sullivan *et al.* 1981, Mitchell *et al.* 1987, Scrivener and Carruthers 1989). Although direct effects on moose (*Alces alces*) or other wildlife associated with conifer release using products containing glyphosate seem unlikely (Lautenschlager 1993a), indirect effects such as reduced food availability concern biologists, primarily because the hardwood "target" species constitute a major source of moose food throughout the year (Cumming 1987, Crawford *et al.* 1993).

Several recent studies (Kennedy and Jordan 1985, Hjeljord and Gronvold 1988, Cumming 1989, Newton *et al.* 1989, Lloyd 1989, 1990a,b, Connor 1992, Connor and McMillan 1990, Kelly 1993, Kelly and Cumming 1992,1994 ) have shown that conifer release with herbicides containing the active ingredient glyphosate reduce the short-term (0-4 years) availability of foods used by

moose. The only long-term work published to date found browse availability higher on sprayed areas 8 growing seasons after treatment (Newton *et al.* 1989), and moose tended to use treated areas more than controls 7-10 years after conifer release with Roundup® (Eschholz *et al.* 1992). Lautenschlager (1993a) using data from Newton *et al.* (1989) developed a model that suggests short-term browse reduction, which often follows conifer release with a herbicide, is likely offset by increased browse availability on treated areas several years post-treatment.

Hughes and Fahey (1991) conclude that browse which becomes available following clear-cutting has significantly more biomass and is more nutritious (higher levels of protein and soluble carbohydrates) than browse found in uncut stands. Lund-Heoie (1978), Smith *et al.* (1988), and Kimmins *et al.* (1989) report increased nutrient and water availability in soils after herbicide applications. Lautenschlager (1993b) argues that the same environmental resources that contribute to increased crop tree growth should also become available to the remaining, reemerging, and invading angiosperms (potential browse) in treated areas. Therefore, he suggests that browse in treated areas may be of superior nutritional quality, with increased digestibility and protein content. Balfour (1989) notes, however, that there is little quantitative information about how forestry herbicides may alter forage nutritional quality. If there are significant differences in forage quality between herbicide treated and untreated areas, models predicting the effects of conifer release on moose populations based solely on browse availability (Lautenschlager 1993a,b) will have limited value.

An ongoing study of indirect effects of Vision® herbicide on moose browse availability, area use, and crop tree responses (Cumming 1989, Connor 1992, Kelly 1993, Kelly and Cumming 1992, Kelly and Cumming 1994) provided an opportunity to examine the effects of conifer release with glyphosate on nutritional qualities of browse plants 4 and 8 years after treatment. Cumming (1989) reported evidence of decreased browsing the first year following treatment, although high variability rendered differences insignificant. Kelly and Cumming (1994) found that moose winter browse availability and browsing decreased significantly in areas treated with 1.06 and 1.60 kg a.e./ha of glyphosate during the first 2 years following treatment. In addition to reduced forage availability, changes in plant nutrition may have contributed to reduced use of these areas by moose.

The objective of this study was to determine the effects of conifer release with Vision® on the nutritional quality (digestible protein and digestible dry matter) of 4 plant species commonly eaten by moose in early successsional forests (Cumming 1987, Crawford *et al.* 1993). Both winter twigs and summer leaves were analyzed.

## METHODS

### Study Areas

One study area was located near Raith, approximately 120 km northwest of Thunder Bay, Ontario, and another near Obonga Lake, 185 km north of Thunder Bay. Topography of both sites was rolling. At Raith, long-term daily temperatures ranged from -18°C in January to +16°C in July (Environment Canada 1992). Precipitation averaged 50 mm in January and 77 mm in July (Environment Canada 1992). Soils were mostly 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 along the lower edges of clear-cuts. This area grew black spruce (*Picea mariana* (Mill.) before it was harvested in a series of clear-cuts between 1982 and 1987. Residual dead and

dying white birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*) remained on parts of the cut areas. Most had been mechanically site prepared, and planted with black spruce or jack pine between 1980 and 1989. These clear-cuts had been scheduled for aerial (helicopter) treatment with Vision® because hardwood competition was growing higher than the planted conifers.

At the Obonga Lake study area, long-term daily mean temperatures were -21°C in January and +16 C in July (Environment Canada 1994). Precipitation averaged 34 mm in January and 97 mm in July. Soils ranged from small sphagnum bogs around a few potholes through glacial tills to high rock outcrops. Jack pine (*Pinus banksiana*, Lamb.) dominated this area, though black spruce, birch and aspen were also common. In 1980-1981, most of the wood from the area was harvested in a series of clear-cuts that left only scattered, tall hardwoods, mainly trembling aspen and white birch. In 1982 these cut areas were planted with jack pine; however, thick hardwood regeneration quickly overtopped the plantations and an aerial (fixed-wing) release was carried out in late August 1986. By 1994, treated plots were dominated by jack pine while control plots retained a higher deciduous component

Both these areas became the sites of experiments to find effects of glyphosate on moose browse (Kelly and Cumming 1992, Cumming 1989). In 1990, at the Raith study area, 7 clear-cuts ranging in size from 44-85 ha were chosen as replication blocks for a long term experiment concerning the effects of Vision® spraying on moose foods and moose behaviour (Kelly and Cumming 1992). Each block was divided into 4 treatment sub-blocks, 1 untreated for a control, and 3 sprayed from a helicopter with Vision® at differing rates, during August 30 to September 2, 1990 (Kelly and Cumming 1992). In 1986, an experiment was initiated at Obonga Lake on 6 clear-cuts (ranging from 15-41 ha), half treated and half controls. These blocks were equivalent to the treatment sub-blocks in the Raith study in terms of treatment/control comparisons.

**Sample collection**

At Raith we chose 4 winter-accessible replication blocks for the nutrition study. The portion of each block that had been sprayed at the heaviest application rate (1.60 kg a.e./ha) and its related control area, became our treatment sub-blocks. Within each sub-block we marked a transect line. To reduce variability, we chose plots with the following similar characteristics: slope (5-15% grade), aspect (south), and light intensity (no residual cover or conifer component). A plot was located at the closest patch of hardwood vegetation to a pre-determined point on the transect line. Plants within plots were chosen by throwing a meter stick backwards over the shoulder and choosing the closest stem of an appropriate species. From each plot, in winter, we collected a sample of trembling aspen and one of beaked hazel (*Corylus cornuta*). In summer only (because it would not extend above the snow in winter), we also sampled red raspberry (*Rubus idaeus*, L.). We sampled 5 plots in each control and treatment location. Thus, 80 samples were collected from the Raith study area in winter, and 120 in summer.

At Obonga Lake, we used all 6 of the original treatment (Vision® at 1.07 kg a.e./ha) and control blocks, again collecting 5 samples of each species (2 winter, 3 summer) from plots chosen in the same way. Thus, 60 were collected from the Obonga Lake study area in winter, 90 in summer. Aspen and red raspberry were collected here also, but since no hazel could be found, willow (*Salix spp.*) was collected in its place.

Winter samples were collected between January 28 and February 3, 1994, summer samples in mid-June. Except for trembling aspen, winter samples were taken from the

snow line (about 0.5m) to 1.5 meters above the snow. Aspen was sampled up to 3.5 m above snow line because moose commonly break stems to reach the tops. Summer samples were taken between 0.5 m and 1.5 m above the ground. In the winter, current annual growth (>1 cm) from the terminal twigs was clipped at the bud scar. During summer, leaves were hand-stripped from branches; commonly all current annual growth of terminal twigs or leaf mass was removed from the sampled plants. To obtain sufficient mass from some small plants, additional samples were taken from the nearest neighbour to the identified individual (of the same species). Plants too large for clipping or stripping (up to 3.5 m) were sampled randomly from within their crowns.

Because winter ambient temperatures were well below zero during the warmest parts of the days (-20 to -35°C), samples were simply cut and placed in a cooler for transport to the laboratory. In the summer, stripped leaves were immediately placed on dry ice. Samples remained frozen until arriving at the laboratory where they were freeze-dried prior to grinding in a barley mill to pass through a 1 mm screen.

### Nutrient Analysis

Forage digestions were by the standard detergent techniques outlined by Goering and Van Soest (1970), Mould and Robbins (1981), but with the refinements developed by Hanley *et al.* (1992). Crude protein (nitrogen x 6.25) was determined by the Kjeldahl method. Due to the low concentration of tannins in twigs (Hanley *et al.* 1992), bovine serum albumin (BSA) precipitation was not performed on winter forages. But because leaves are high in tannin content, the protein-precipitating capacity of forage tannins for summer leaves was determined using a BSA precipitation assay for proteins (Martin and Martin 1982, Robbins *et al.* 1987a, Hanley *et al.* 1992) to adjust for protein digestion in the presence of secondary compounds, as recommended by Robbins *et al.* (1987a) and Hanley *et al.* (1992). Cutin and lignin percentages were determined by sequential detergent analysis as follows: samples were extracted and rinsed using standard neutral detergent fiber (NDF) procedures, with an extra water rinse to clear acetone; the NDF was then extracted with acid detergent (Mould and Robbins 1981) and this fibre was used for lignin and cutin determinations. The acid detergent fibre was washed with 72% $H_2SO_4$ to remove cellulose. Ashing of the residue determined the cutin fraction including cutin (Goering and Van Soest 1970). Sodium sulfite was added to the NDF digestions of the collected summer forages to reduce overestimates of NDF digestibility, as suggested by Hanley *et al.* (1992). Using formulas presented by Robbins *et al.* (1987a,b), and Hanley *et al.* (1992), we calculated from the crude protein (CP) determinations provided by these analyses digestible protein (DP) and digestible dry matter (DDM) as follows:

**(1) Digestible Protein** (following Robbins *et al.* 1987a, Hanley *et al.* 1992)

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

where X = crude protein content (6.25 * total nitrogen, expressed as percent dry matter)

Y = Bovine Serum Albumin precipitation assay: proteins (mg/mg forage dry matter, as in 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.

**(2) 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 per-

centage 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.

††† sodium sulfite omitted for winter browse (little tannin content in stems), included for summer browse (high tannin content in leaves; Hanley *et al.* 1992).

Most laboratory techniques were considered standard practice by Tara Scientific Laboratories, but determination of the protein-precipitating capacity of forage tannins by the BSA precipitation assay for proteins was new. 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.

### Statistical Analysis

Normality was examined using the Macintosh program, Datadesk, which plots observed values against normal scores. Although the laboratory determinations were expressed as percentages of dry matter, most were acceptably close to normality. Normality of two data sets was improved by using square-root transformations, but differences for another two were exacerbated. Under these circumstances, we chose to present and analyze non-transformed data (following Brown, pers. comm.).

Although the original Raith 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 denominators of the ANOVA's from Error terms to the 3-way interactions (BlocksXTreatmentsXSpecies). As suggested by Hazenburg (pers. comm.), we examined the data to find whether 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 ($P$ (regression) 0.001, $R^2$=39.1) between these variables for summer leaves. For this reason, summer data from each study area were analyzed for each parameter (DP, DDM) using MANOVA's. Because no consensus exists among statisticians concerning the best way to test MANOVA results, as it does for ANOVA's (Abacus Concepts 1989), the Macintosh program, SuperAnova, provides 4 tests formed from eigenvalues representing different statistical approaches to the multivariate problem - Wilk's Lambda, Roy's Greatest Root, Hotelling-Lawley Trace, and the Pillai Trace (Abacus Concepts 1989). Overall conditions between study areas were compared by t-tests and chi-square.

## RESULTS AND DISCUSSION

Nutrient values of winter twigs showed considerable variability (Table 1), but averaged (with ranges) as follows: CP 8% (7-9), DP 3% (2-4), DDM 60% (57-63). Quality varied significantly ($P$<0.05) among species, but not by block, treatment (sprayed/not sprayed), or study area (Table 2). Therefore, moose may have good reason to select among winter browse species, but they would have no nutritional reason for selecting one local

Table 1. Crude protein (CP), digestible protein (DP), and digestible dry matter (DDM) means for 4 moose browse species commonly found in northwestern Ontario.*

S.D. indicates standard deviation.

| | | | Raith Study Area | | | | | | Obonga Lake Study Area | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Treated | | Control | | Raith | | Treated | | Control | | Obonga |
| Season | Species | Test | Mean | S.D. | Mean | S.D. | Average | | Mean | S.D. | Mean | S.D. | Average |
| | | CP | 8.2 | (0.6) | 8.8 | (1.1) | 8.5 | | 8.1 | (0.3) | 8.2 | (0.3) | 8.2 |
| | Aspen | DP | 3.7 | (0.2) | 4.3 | (0.3) | 4.0 | Aspen | 3.6 | (0.2) | 3.8 | (0.2) | 3.7 |
| Winter | | DDM | 62.5 | (0.4 | 63.0 | (0.3) | 62.8 | | 61.3 | (0.6) | 61.1 | (0.9) | 61.2 |
| | | CP | 7.1 | (0.7) | 7.3 | (0.4) | 7.2 | | 7.0 | (0.6) | 6.8 | (0.3) | 6.9 |
| | Hazel | DP | 2.7 | (0.2) | 2.9 | (0.2) | 2.8 | Willow | 2.6 | (0.3) | 2.5 | (0.2) | 2.6 |
| | | DDM | 59.6 | (0.8) | 60.0 | (0.5) | 59.8 | | 58.4 | (0.7) | 57.2 | (0.6) | 57.8 |
| | | CP | 13.4 | (1.9) | 13.4 | (2.2) | 13.4 | | 16.7 | (1.3) | 16.0 | (1.9) | 16.4 |
| | Aspen | DP | 6.8 | (0.6) | 7.0 | (0.6) | 6.9 | Aspen | 10.6 | (0.7) | 9.9 | (1.0) | 10.3 |
| | | DDM | 67.4 | (0.6) | 68.7 | (0.6) | 68.1 | | 65.5 | (0.6) | 68.7 | (0.5) | 67.1 |
| Summer | | CP | 12.6 | (1.4) | 13.4 | (0.3) | 13.0 | | 19.4 | (2.0) | 17.0 | (0.6) | 18.2 |
| | Hazel | DP | 6.1 | (0.5) | 7.2 | (0.4) | 6.7 | Willow | 13.0 | (1.0) | 10.3 | (0.7) | 11.7 |
| | | DDM | 62.2 | (0.7) | 64.9 | (2.2) | 63.6 | | 70.0 | (1.0) | 66.1 | (1.1) | 68.1 |
| | | CP | 13.1 | (1.7) | 12.3 | (1.4) | 12.7 | | 18.7 | (1.7) | 15.1 | (1.3) | 16.9 |
| | Raspberry | DP | 4.9 | (0.6) | 4.0 | (0.6) | 4.5 | Rasb. | 10.6 | (0.7) | 7.0 | (0.6) | 8.8 |
| | | DDM | 63.1 | (0.8) | 62.7 | (0.6) | 62.9 | | 64.9 | (0.6) | 64.4 | (0.5) | 64.7 |

*means based on 4 (Raith) or 3 (Obonga Lake) replicates of 5 samples each.

area over another, nor (for or against) treatment with Vision®. Timmermann (1991) reviewed 33 papers reporting CP and analyses of dry matter for trembling aspen from across North America. CP percentages in winter forage ranged from 5.6 - 11.8%, averaging 7.9%; thus, our mean value of 8.3% for winter aspen (Table 1) fell slightly above the reported average, but well within the overall range. Other authors reported similar results: Hjeljord *et al.* (1982) found 5.4-10.1% CP in twigs of 4 Norwegian browse species, Risenhoover (1989) 5.9-9.5% in twigs of 8 Alaskan trees and shrubs. Thus our CP val-

Table 2. Probability values for comparisons of digestible protein and digestible dry matter in winter twigs (ANOVA's) and summer leaves (MANOVA's) for 4 species of hardwoods commonly eaten by moose in northwestern Ontario.

| | | Raith Study Area | | | Obonga Lake Area | | |
|---|---|---|---|---|---|---|---|
| Season | Nutrient | Blocks | Treatments | Species | Blocks | Treatments | Species |
| Winter | DP | 0.098 | 0.124 | 0.007 | 0.447 | 0.988 | 0.023 |
| | DDM | 0.984 | 0.473 | 0.012 | 0.354 | 0.346 | 0.030 |
| Summer | DP | 0.010 | 0.779* | 0.007 | 0.397 | 0.047* | 0.114 |
| | DDM | 0.006 | 0.058 | 0.000 | 0.264 | 0.486 | 0.013 |

*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.

ues were similar to those previously reported. The data on DDM do not present as clear a picture. Timmermann (1991) reported dry matter digestibility (DMD) values for aspen values ranging from 27.1 - 44.3% and averaging 36. 2 in winter. Table 1 shows DDM values for winter twigs of aspen averaging much higher 62.0% ( 61.1 - 63.0); however, it is not clear that the values reported by Timmermann (1991) were analyzed with the same methods as those in this study.

In summer leaves, our values averaged (with ranges) for CP 15% (12-19), DP 8% (4-13), and DDM 65% (62-70). For these summer values, DP differed significantly among species and blocks (Tables 1, 2) in several comparisons, generally restricted to the Raith area, but showed only a single significant difference between treatments - for DP at Obonga Lake (Table 2). This comparison showed the only significant difference between treatments in the study, and even in this case, the 4 supplementary MANOVA analyses indicated insignificant treatment effects ($P$ =0.190, Table 2). Yet all treated areas at Obonga Lake provided higher DP percentages than controls suggesting that a larger sample might have shown significantly more digestible protein in summer vegetation treated by Vision® than in samples from controls. The nearly significant difference in DDM between treated and control areas at Raith ($P$=0.06) resulted from higher DDM values for raspberry; those for aspen and hazel were the reverse, perhaps influenced by the highly significant difference among species (Table 2). Thus, any generalization concerning DDM values would be difficult.

Timmermann (1991) reported crude protein in summer aspen ranging from 10.4 - 36.8 and averaging 17.6%, Summer values for aspen in this study averaged 14.9% (10.22-18.16), slightly lower than the mean reported elsewhere, but well within the range. We conclude that the general nutritional level of forages examined in this study was similar to those reported elsewhere. Summer DMD values ranged from 29.6-72.7% with a mean of 50.3. Table 1 shows values ranging from 65.5 - 68.7%, well within the reported range, but with a mean of 67.6% somewhat higher than the reported mean. Again it is not clear that methods were similar. Other studies showed somewhat lower ranges for dry matter: Hjeljord *et al.* (1982) found dry matter (not digestible) in Norwegian browse ranging from 49.3 - 62.2%; Schwartz *et al.* (1987) found dry matter digestibility in pelleted food ranging from 54.9 - 53.8% ; and Robbins *et al.* (1987b) reported dry matter digestibility in leaves, grasses and flowers ranging from 49.9-72.2% .

Three topics require further discussion: nutrient variation between sites (possible soil differences), nutrient variation among species, and validation of results. Obonga Lake values for DP were significantly higher (unpaired t = -4.524, $P$ =0.001) than those at Raith. DDM values with 2 exceptions were also higher at Obonga Lake. To find if soil conditions contributed to these differences, we classified a small systematic sample of sites according to Vanson and Meyer (1995), a system similar to but more detailed than that of Baldwin *et al.* (1990) used by Kelly (1993) at Raith . We dug pits to 50 cm depth on the highest, lowest, and one between-point of each treatment block, totaling 18 locations. Most soils at Obonga Lake were moderately deep to deep glacial deposits consisting of fine to coarse sands with some silt, many stones and boulders; these soils were not unlike many soils at Raith (Kelly 1993). However, half of the Raith sites were either shallow or composed of deep peat, both conditions likely to provide less suitable conditions for plant growth. As a consequence, significantly more soils at Obonga Lake were classified as 21-40 cm ($\chi^2$=21.4, $P$ <0.005), the depth most conducive to growth. Crawford (1993) found that forage with the highest DDM consistently came from plots

with deep soils, thus the more favourable soil depths could have contributed to the higher nutrient levels found at Obonga Lake.

Vivås (1987) supported the suggestion of Hjeljord (1980) that the thin cell walls of young plants are more digestible than the thicker cell walls of older plants. This idea suggests that the higher values for aspen collected in this study during winter could relate to the greater height at which some of those twigs were collected (up to 3.5m). Hjeljord's (1992) idea, that shaded plants produce forage with higher nutrient levels, might also help to explain our results. The generally taller vegetation on the older clearcuts at Obonga Lake commonly shaded the lower branches and plants (which were sampled), unlike at Raith where the younger plants were less likely to shade the sampled branches. This difference, along with the apparent soil differences, may explain the consistently higher, compared with Raith, nutrient values for all species during summer at Obonga Lake (Table 1).

An unexpected result of this study was the significant variation in DP among the species examined. Aspen showed consistently higher values than hazel and willow in both winter and summer, and generally higher summer values than raspberry. Only willow summer values at Obonga Lake exceeded those of aspen. Elevated nutrient values for aspen have not been reported elsewhere, and they could be affected by the higher levels of browse collection as discussed above, but if real, they might explain the extensive use of aspen and willow during both winter and summer across moose range.

Our results, however, fail to explain why hazel is often ranked highly (Cumming 1987), nor why so much raspberry may be consumed by moose during summer (Crawford *et al.* 1993).

The values for protein-precipitating capacity of forage tannins, determined by the BSA precipitation assay for proteins, as reported for the sub-sample by our contracting laboratory, were generally higher than those in the sub-sample (12 samples) analyzed at Washington State University (Table 3). Ignoring the 2 negative values in the latter that brought the means to 0.184 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 their methods were identical with ours. Furthermore, as Hanley (pers. comm.) commented, both values are within a reasonable range and the difference would result in a change of only 2.4 units of DDM .

Table 3. Comparison between a random sub-set of tannin determinations from this study and the same samples examined at Washington State University Wildlife Habitat Laboratory.

| Sample no. | This Study | 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 reported | 0.116 |
| | Mean less negatives | 0.144 |
| Mean X-Y | 0.065 | |
| Paired t-value | 2.63 | |
| P | 0.0273 | |

Since this study constitutes one of the first attempts to follow the method refinements developed by Hanley *et al.* (1992), our results should compare with theirs (Table 4). Our NDF values 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. In addition these values for twigs and leaves were similar to each other in our study, although one would expect major differences as reported by Hanley *et al.* (1992). Cutin and lignin values must be presented as percentages of NDF before they are entered into equation (2) to determine DDM (Hanley *et al.* 1992). These percentage values (Table 4) showed even greater differences between the 2 studies for both twigs and leaves, with our values for twigs resembling theirs for leaves, and our values for leaves closer to theirs for twigs. Still, when calculations were completed, values for DP from both studies were similar, as were those for DDM in leaves. The single value for twigs reported by Hanley *et al.* (1992), however, remained substantially different from those we calculated. 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, our values accord well with most of those reported by Hanley *et al.* (1992), but vary in some respects. The figures may indicate actual differences in both cases, or they may contribute to interpretation errors.

## CONCLUSION

These results provide little evidence of changes in forage quality associated with conifer release 4-8 years after treatment with glyphosate. One instance may have occurred. Morgan and McCormack (1973) found crude protein levels in simazine treated balsam fir twice those of controls 2 years post-treatment. Lautenschlager (1993b) suggested that increased availability of soil nutrients following conifer release with herbicides would benefit not only crop trees but also remaining, re-emerging and invading angiosperms. However, if these benefits are common, our results suggest that they must be short-lived, or restricted to better quality sites. In view of minimal nutritional differences observed between treated and control areas in this study, it seems that any long-term consequences of Vision® treatments that might concern moose biologists and managers must be quantitative rather than qualitative, i.e., that biomass availability of appropriate forage species, through time (Lautenschlager 1993a, b), is an appropriate way to predict the effects on moose of conifer release with herbicides.

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Table 4. 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) (1 sample only) | 0.1 | 7.7 | 60.3 | 19.8 | 32.8 | 2.2 | 34.0 |
| 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

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