T. M. Lord
Pedologist
Research Station
Canada Agriculture, Vancouver, B.C.
and
A. J. Luckhurst
Biologist
British Columbia Land Inventory (Ungulates)
Victoria, B.C.

Alpine Soils and Plant Communities of a Stone Sheep Habitat in Northeastern British Columbia

Abstract

An alpine habitat investigated in northern British Columbia contained a limited group of specific soil-plant associations that are critically important to the survival of a band of stone sheep. The occurrence of diverse alpine plant communities was correlated with geologic material, soil development, mesoclimate features and landforms. The habitat included low-yielding tundra communities on shallow, strongly acid soils and highly productive grasslands on basic, moderately deep to shallow soils. A hairy wildrye-bearded wheatgrass community, associated with base saturated Chernozem-like soils on steep, south-facing mountain slopes, comprised less than 20 percent of the winter range and only 4 percent of the total range, but supplied almost 60 percent of the total forage for wintering sheep. During the summer, when the sheep had a wide choice of vegetation, they made intensive use of the rough fescue-dryas community on basic soils.

Introduction

Alpine habitats, once remote, are becoming increasingly accessible to exploitation and damage by man. Integrated studies of soil, plant, animal, and climate interrelationships can provide essential information on these delicately balanced environments.

Many workers, including Nimlos and McConnell (1965) and Retzer (1964) in North America, and Costin (1968) in the Australasian region, have characterized the uniqueness of alpine ecosystems. Swan (1967) and others recognized a basic climatic relationship in which timberlines throughout the world closely approximate the 10°C mean isotherm for the warmest month. Cold soil temperatures, a short growing season, wind, frost action, and an unstable rooting medium contribute to environmental stress. Although alpine soils are often fertile and the surface horizons may contain up to ten times the amount of humified organic matter present in corresponding lowland grassland soils (Jenny, 1941), productivity levels are low. Van Ryswyk (1969) and Sneddon *et al.* (1972) have conducted detailed studies of alpine soils in British Columbia. Sneddon *et al.* classified five alpine soils from the Coast Mountains and Interior Plateau of British Columbia as Humo-Ferric Podzols and Alpine Dystric Brunisols according to the Canadian System of Soil Classification (C.S.S.C., 1970), and as Cryorthods and Cryumbrepts according to the 7th Approximation (USDA, 1960). Estimates of productivity of alpine tundra are few, but noteworthy is a study by Brink *et al.* (1972). Their estimates of net primary productivity of three alpine sites (one of which corresponds to the present study site) emphasize the low production of alpine tundra.

Study Area

From 1969 to 1971 Luckhurst (1973) studied a band of 50 to 60 stone sheep (*Ovis dalli stonei*), one of three races of the thin-horn group, and their habitat. The present study investigated alpine soils, plant communities, and mesoclimates and their relationship to native sheep use in a remote part of northeastern British Columbia. The study area is a ridge in the Rocky Mountain Foothills, designated as Nevis Mountain, about 30 km west of Milepost 175 on the Alaska Highway (Fig. 1). It is composed of steep mountain slopes which rise from the valley floor at about 1200 m to the summit at 2160 m.

The soil-forming colluvium of the slopes bears a close relationship to the underlying rock. The geological report by Pelletier and Stott (1963) shows that the sedimentary rocks of this portion of the foothills are dominated by two groups, Lower Cretaceous acid sandstone and shales, and Triassic limestone and calcareous siltstone.

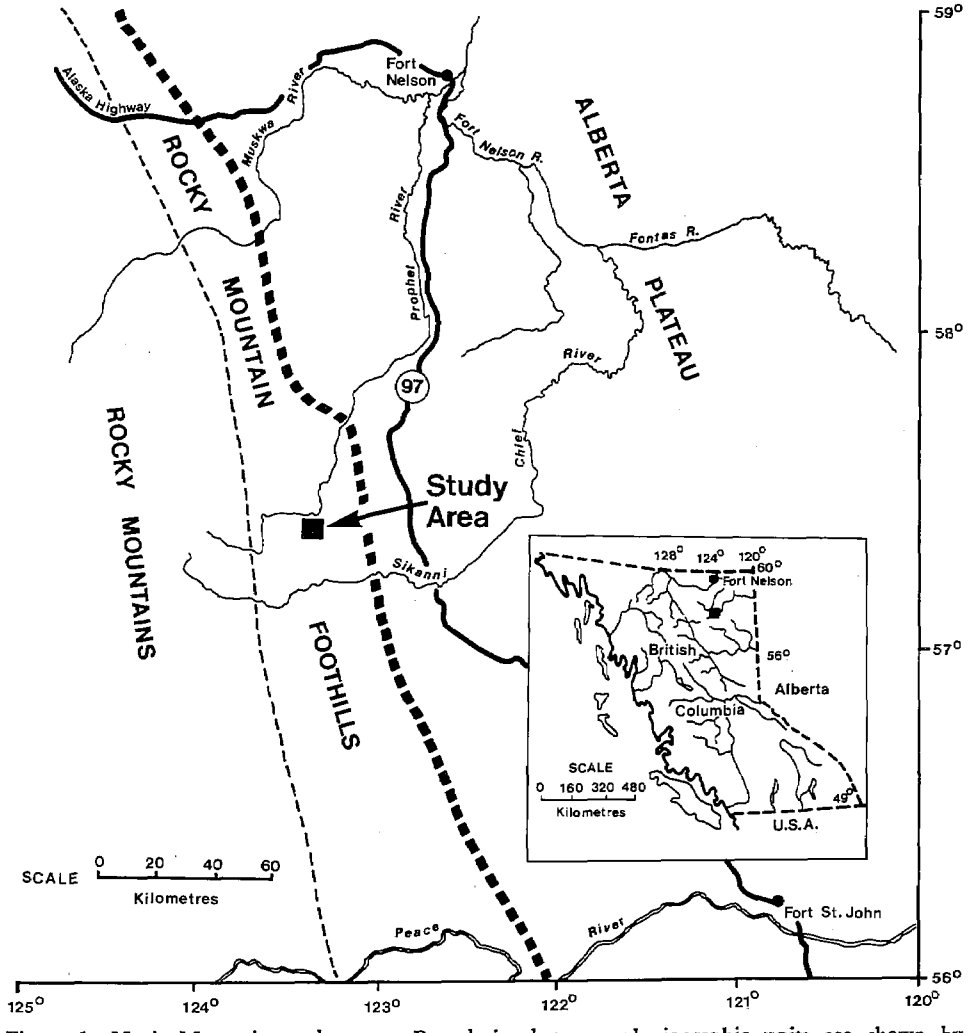

Figure 1. Nevis Mountain study area. Boundaries between physiographic units are shown by dashed lines.

The acid rocks have been largely eroded from the southern and western slopes of Nevis Mountain leaving basic materials exposed. Calcareous till and glacial drift from the west mantle the lower slopes and valley floor, but above treeline evidence of glaciation lies in widely scattered erratics.

The climate is continental with long, cold winters and brief, cool summers. During summer, moist Pacific air from the west frequently causes sudden, often violent, local storms. In winter a more stable air mass dominates the area, but cold spells may be broken by foehn winds (Chapman, 1952).

Two broad vegetation zones, alpine tundra and the northern foothills section of the boreal forest region, characterize the foothills (Rowe, 1959).

Methods and Procedure

The Nevis Creek area has not had a soil survey, but aerial photographs and large-scale planimetric maps were available for the study area.

Luckhurst (1973) described and classified the alpine vegetation on selected sites within each plant community, using the quantitative macroplot method of Poulton and Tisdale (1961) and paired 15 m transects. Percentage cover by species and their frequency were determined by the canopy coverage method of analysis (Daubenmire, 1959). To give a relative measure of use by the sheep, counts of numbers of pellet groups per square meter were made within the vegetation plots. Primary net productivity and forage use were determined from spring and fall clippings taken at 10 sites inside and outside large exclosures in the three most important communities used by wintering sheep. Common plant names are mainly those from "Northwest Range—Plant Symbols" (USDA, 1967), and plant nomenclature follows Hultén (1968) and Hitchcock *et al.* (1955, 1959, 1961, 1964).

In the present study, soils were investigated in six alpine grassland communities and in two forest communities studied by Luckhurst. Soils were described in prepared pits using standard terminology, and selected natural features were recorded, such as drainage, slope, aspect, elevation, and nature of the parent material. Soil samples were collected for selective analyses (Table 1). After the samples had been dried, crushed and sieved, determinations on the less than 2 mm fraction were as follows: soil texture by the pipette method of Toogood and Peters (1953); soil pH at 1:2 ratio of soil:calcium chloride suspension (0.1 M); organic matter (Peech *et al.*, 1947), total nitrogen (Bremner, 1965), easily soluble phosphorus (Bray, 1948), cation exchange capacity by the 1N neutral ammonium acetate method, exchangeable cations by atomic absorption spectrophotometry; and oxalate-extractable iron and aluminum (McKeague and Day, 1966). Soil classification was according to the Canada Soil Survey Committee (1970). Soil colors are given as dry or moist after the Munsell system.

Two short-term weather stations were installed in 1969 by the Climatology Section of the Canada Land Inventory (B.C.), one in the valley at 1235 m elevation and the other on a gentle slope of the south face of the mountain at 1675 m. Instrumentation included hygrothermographs, maximum and minimum thermometers, rain gauges, anemometers, six-month continuous air temperature and precipitation recorders, snow depth recording stakes, and soil thermistors.

A reproduction of an enlarged aerial photograph (Fig. 2) shows the relative posi-

TABLE 1. Selected chemical and physical properties of 5 soils.

Horizon	Depth (cm)	pH (CaC12)	Organic Matter (%)	Total N (%)	C:N	Base Satn. (%)	CEC	Exchangeable cations (meq/100g) Ca	Mg	K	Na	Available P (ppm)	Oxalate extractable Fe (%)	Al (%)	Sand (%)	Silt (%)	Clay (%)	Fine Clay (%)	Texture
Black Chernozem-like (Site 1)																			
Ah	0-20	6.4	27.11	1.38	14	96.78	61.75	55.99	3.31	0.44	0.02	101.7	—	—	36.6	41.5	21.9	11.8	loam
CBk	74+	7.5	1.65	0.09	11	100+	8.90	20.86	0.33	0.05	0.02	55.6	—	—	44.2	41.6	14.2	7.8	loam
Lithic Humisol (Site 2)																			
H	0-20	6.8	39.83	1.65	14	100+	88.15	83.59	6.87	0.61	0.08	48.3	—	—	24.1	49.0	26.9	14.07	silt loam
Lithic Orthic Dystric Brunisol (Site 3)																			
Ahe	0-5	3.5	20.65	0.84	14	18.26	33.35	4.87	1.02	0.16	0.04	41.1	0.22	0.27	41.9	37.0	21.1	9.43	loam
Bm	5-15	3.6	2.74	0.14	11	5.57	13.64	0.61	0.09	0.04	0.02	34.9	0.62	0.24	53.0	30.7	16.3	7.80	sandy loam
C	15-20	3.7	2.79	0.12	11	4.37	13.50	0.51	0.02	0.04	0.02	104.0	0.89	0.24	60.8	23.9	15.3	8.20	sandy loam
Chernozem-like (Site 4)																			
Ah	0-20	6.2	25.08	1.13	13	97.52	55.63	51.29	2.56	0.37	0.03	120.6	—	—	48.9	32.6	18.5	11.5	loam
Bm	20-25	6.3	9.03	0.42	12	98.14	31.73	30.08	0.97	0.07	0.02	102.4	—	—	57.7	27.2	15.1	9.0	sandy loam
BC	25-46	6.8	5.30	0.30	10	100+	23.90	24.99	0.37	0.08	0.03	487.5	—	—	17.4	63.9	18.7	8.9	silt loam
Orthic Humo-Ferric Podzol (Site 5)																			
Ae	0-5	3.1	1.06	0.05	10	8.17	6.98	0.37	0.13	0.06	0.01	20.6	0.06	0.06	44.6	49.1	6.3	2.1	silt loam
Bf	5-15	4.1	1.79	0.08	11	31.50	12.74	3.17	0.80	0.09	0.01	427.2	1.00	0.22	39.9	41.1	19.0	9.1	silt loam
BCk	30-62	7.5	1.27	0.06	11	100+	5.51	20.49	0.71	0.04	0.01	8.2	0.40	0.04	55.7	31.6	12.7	5.5	sandy loam

tions of the plant communities and locates the two weather stations. One alpine community, the moss-lichen willow (*Salix* spp.) unit, on a slope across the valley from Nevis Mountain, is not shown in Figure 2.

Figure 2. Nevis Mountain study area showing selected plant-soil landscape units. Alpine grasslands: hairy wildrye-rough fescue and hairy wildrye-bearded wheatgrass communities—Eutric Brunisols and Chernozem-like soils (A); dryas-rough fescue community—Eutric Brunisols (B); rough fescue-dryas community—Humisols (C); reedgrass-sweetgrass community—Dystric Brunisols (D); moss campion-reedgrass community—Dystric Brunisols (E). Forest: poplar community—Chernozem-like soils (F) and white spruce community—Humo-Ferric Podzol (G). ■ Weather station.

Table 2 characterizes the six landscape units of the alpine grassland and two forest units investigated in the study area.

Results and Discussion

Table 2 shows the geologic materials, landform components, mesoclimate features, and relative use by sheep of each unit or subunit. Average dry-matter yields are given for three communities and pellet group counts are shown for most communities. About 50 percent of the total alpine study area consists of rock outcrop or scree.

Unit A

The irregular, very steep (30 to 60+%) slopes extend from treeline, at about 1500 m elevation, to near the crest at about 1900 m, on the south flank of Nevis Mountain.

Subunit A 1. Slopes exceed 40 percent and aspects range from southwest to southeast on this extensive grassland subunit (Fig. 2).

Vegetation. The major community of the south-facing alpine slopes is the hairy wildrye (*Elymus innovatus*)-rough fescue (*Festuca scabrella*) grassland. In addition to these dominant species, characteristic forbs and shrubs include white dryas (*Dryas integrifolia*), arctic lupine (*Lupinus arcticus*), alpine bistort (*Polygonum viviparum*), cinquefoil (*Potentilla fruticosa*), glaucous willow (*Salix glauca*), bog birch (*Betula glandulosa*), and bearberry (*Arctostaphylos uva-ursi*).

Soils. The Eutric Brunisol Great Group of soils is dominant. A pedon of this soil, described near the mountain weather station (1675 m) on a 55 percent, south-facing slope, had the following characteristics described by horizons:

Ahe—5 cm of very dark grayish brown (10 YR 3/2m) loam; moderate, fine granular structure; friable consistence; medium acid reaction and a clear boundary.
Bm 1—13 cm of dark brown (10 YR 3/2m) loam; weak, subangular blocky structure; friable consistence; medium acid reaction and a gradual boundary.
Bm 2—28 cm of dark yellowish brown (10 YR 4/4m) loam; weak medium subangular blocky structure; friable consistence; slightly acid reaction and a diffuse boundary.
BC—45 cm of very dark grayish brown (10 YR 3/2m) loam; weak, fine subangular blocky structure; friable consistence and neutral reaction.

The soils are developed from colluvium derived from weathered basic rock formations. Small variations in slope, aspect, or parent material appear to favor the development of Chernozemic Ah horizons on closely associated soils within the subunit.

Mesoclimate. The mountain weather station, located within the wildrye-rough fescue community, recorded about 30 cm of precipitation for the five-month May to September periods of 1970-71. This amount was about two-thirds of the total precipitation for the year and was comparable to that recorded for the same period at the valley station. In 1970, the mean temperature of the valley station was –2.5°C. Because of instrument malfunction, the 1970 mean temperature for the upper station was not recorded. Soil thermistors were placed at a 50 cm depth in a loam soil at the mountain station and at the same depth in gravelly loamy sand at the valley station. At the end of May 1970 the soil temperature was –1.4°C at the mountain station and +5.3°C at the valley station. Soil temperatures through June, July, and August averaged +3.1°C at the upper station and +10.6°C at the lower station. Luckhurst (1973) gives a comprehensive summary of climate data from long-term stations at Fort Nelson and Fort St. John and supplements these data with personal observations over the 1969 to 1971 period.

TABLE 2. Some characteristics of the landscape units.

Unit	Plant Community	Dominant Soils	Geologic Materials	Elevation Range m	Slope Range %	Aspect	Mesoclimate W=winter S=summer	Pellet Group Counts per sq m	Sheep Use Period		Sheep Use Frequency
				Alpine Grassland							
A	(A1) Wildrye-rough fescue	Eutric Brunisol	Colluvium from weathered limestone, calcareous sandstone and shale	1500-1700	40-60	S,SE,SW	*Pptn.: May-Sept. = 30 cm Temp.: air July = +9.7°C soil—End of May = −1.4°C —Jun.-Aug. av. = +3.1°C	0.71	Winter	(A1)	moderate
	(A2) Wildrye-bearded wheatgrass	Black Chernozem-like		1500-1600	50-60	S		4.35		(A2)	very high
							W —largely snow-free or with light discontinuous snow cover		Spring	(A1)	moderate
										(A2)	very high
							S —comparatively warm, especially on steep slopes abundant soil moisture		Summer	(A1)	low
										(A2)	nil
B	Dryas-rough fescue	Eutric Brunisol		1700-1750	25-35	SW	W —windswept, light discontinuous snow cover, soils deep freezing	0.60	Winter		moderate
							S —windswept, cool, abundant soil moisture		Summer		low
C	Rough fescue-dryas	Humisol (Lithic)		1750-1850	> 60	SW	W —moderate, almost continuous snow cover	1.09	Winter		low
							S —comparatively warm, abundant basic seepage water		Summer		high

D	Reedgrass-sweetgrass	Dystric Brunisol (Lithic)	Acidic colluvium and weathered siltstone	1800-1900	20-35	E	W	—cool exposure, continuous moderate to heavy snow cover	0.33	Winter	low
							S	—late warming, cool abundant seepage, saturated conditions		Summer	moderate low
E	Moss campion-reedgrass	Dystric Brunisol (Lithic)	Acidic sandstone	1900-2035	0-10	—	W	—cold, continuous late snow cover	0.33	Winter	low
							S	—cold, saturated with cold seepage waters, ice lenses in subsoil		Summer	low-moderate
	Moss-lichen —dwarf willow	Gleysols and organics (Cryic, Lithic)	Colluvium (weakly calcareous)	1370-1675	25-45	N,NE	W	—cold, continuous late snow cover	—	Winter	nil
							S	—cold, saturated, discontinuous permafrost		Summer	nil
					Forest						
F	Poplar	Chernozem-like	Calcareous sandstone	1250-1500	60-80	S	W	—moderate to heavy snow (accumulated drifting snow)	0.01	Winter	low (occasional use near tree-line)
							S	—comparatively warm, moist		Summer	nil
G	White Spruce	Humo-Ferric Podzol, Dystric Brunisol	Glacial till	< 1500	10-25	all	W	—moderate, heavy snow	—	Winter	nil
							S	—cool, moist, subsoil frozen till mid-summer		Summer	nil-low (travel routes)

* 1970 data from weather station in Subunit A1.

Dry matter Yields. Clippings from four sites in the hairy wildrye-rough fescue grassland gave modest yields that averaged 1236 kg/ha in 1970. Grasses made up 70 percent and forbs 30 percent, by weight.

Sheep Use. The subunit makes up most of the wintering area for sheep. The animals are mainly dependent on the hairy wildrye-rough fescue and the associated bearded wheatgrass (*Agropyron subsecundum*) communities for winter survival. Pellet group counts averaged 0.71 per square meter.

Subunit A 2. Slopes average 50 to 60 percent and aspects are due south on these small discontinuous subunits below 1600 m elevation. They form part of the extensive grassland (Fig. 2) that has developed on basic soil materials.

Vegetation. Grasses, predominantly hairy wildrye and bearded wheatgrass, are the basic components of the subunit, but other grasses and forbs include bluegrass (*Poa* spp.), loco-weed (*Oxytropis* spp.), sweetvetch (*Hedysarum alpinum*), yarrow (*Achillea millefolium*), and fireweed (*Epilobium angustifolium*).

Soils. The hairy wildrye-bearded wheatgrass community is usually associated with Black Chernozem-like soils developed on calcareous colluvium. A well drained pedon on a 63 percent south-facing slope at an elevation of 1520 m was analyzed (Table 1, Site 1) and described as follows:

Ah—20 cm of black (10 YR 2/1d) loam; fine granular structure; friable consistence; slightly acid reaction and a clear boundary.

Bm—12 cm of dark brown (7.5 YR 3/2d) loam; medium subangular blocky structure; firm consistence; neutral reaction and a gradual boundary.

BCk—42 cm of dark grayish brown (10 YR 4/2d) loam; medium angular blocky structure; firm consistence; mildly alkaline reaction and a diffuse boundary.

CBk—74+ cm dark grayish brown (10 YR 4/2d) gravelly loam; medium angular blocky structure and moderately alkaline reaction.

This soil has the morphology of a Chernozem, and the top 20 cm meets the thickness and color requirements of a Chernozemic A horizon (C.S.S.C., 1970). However, it would be excluded from the Chernozemic Order on the basis of a mean annual soil temperature of less than 0°C.

Mesoclimate. This mesoclimate, discussed under Subunit A1, appears to be a major factor favoring the development of highly productive communities on Chernozem-like soils and Eutric Brunisols.

Dry Matter Yields. The hairy wildrye-bearded wheatgrass subunit was sampled at three sites. Yields averaged 1789 kg/ha in 1970, with one site yielding over a metric ton of dry matter per hectare. Grasses made up more than 80 percent by weight.

Sheep Use. The annual growth is almost completely removed from the bearded wheatgrass subunits by grazing sheep in winter. Counts of pellet groups (4.5 per sq m) and field observations show that this plant community receives the heaviest use by sheep.

Unit B

The exposed west-facing ridges of the mountain lie above and have less precipitous slopes than those of the A unit. Colluvium derived from weathered basic rocks forms the parent materials of soils that support the main community, dryas-rough fescue.

Vegetation. The dryas-rough fescue community is characterized by a relative abundance of forbs and a sparse cover of grasses. Rough fescue and sheep fescue

(*Festuca ovina*) are the dominant grasses. Forbs include dryas, arctic lupine, alpine bistort, saxifrage (*Saxifraga tricuspidata*), and moss campion (*Silene acaulis*).

Soils. Eutric Brunisols predominate in this unit as in the hairy wildrye-rough fescue grasslands. However, the Lithic subgroup is more prominent here. These shallow Brunisols have horizon sequences and morphology similar to those of the deeper soil subgroup, but bedrock occurs within 10 to 50 cm of the mineral surface. In addition, all soils examined in the unit had relatively thick organic (H) surface layers and an absence of lime carbonate in the subsoils.

Mesoclimate. The exposed dryas-rough fescue community on west-facing ridges is subject to almost continuous winds. Under the sparse snow cover the soils freeze early in the fall and remain frozen until early summer.

Dry Matter Yields. Yields averaged 420 kg/ha in 1970 (excluding the low-growing dryas). Forbs, mostly lupine, made up 70 percent by weight, and grasses, mostly rough fescue, made up only 30 percent by weight of dry matter.

Sheep Use. In spite of the sparse grass cover and predominance of unpalatable dryas, the vegetation is lightly to moderately grazed by sheep. Wind sweeps much of the vegetation free of snow, and it is during the winter that the unit receives the most use. Pellet group counts averaged 0.6 per square meter.

Unit C

The extremely steep (60+%) slopes of this unit have a southwest exposure above 1750 m elevation. The community has developed on basic colluvial materials that include many rock fragments and large boulders.

Vegetation. The rough fescue-dryas community contains most of the major plants, such as rough fescue, dryas, and lupine, found in the lower elevation dryas-rough fescue unit. It lacks saxifrage but includes other species such as panicle bluebell (*Mertensia paniculata*) and anemone (*Anemone parviflora*).

Soils. Soils with thick, dark-colored surface horizons are associated with the rough fescue-dryas community. Basic seepage waters flowing downslope maintain near-saturated soil conditions through the growing period and contribute to the accumulation of organic matter. A soil pedon examined on a 55 percent west-facing slope had an H horizon 20 cm thick, consisting of black (10 YR 2/1d) well-decomposed organic matter (Table 1, Site 2). The underlying mineral horizon consisted of calcareous loamy sand and angular rock fragments stained with black organic coatings. The soil was classified as Lithic Humisol. On drier sites within the plant community Regosolic Chernozem-like soils occur.

Mesoclimate. Snow cover is almost continuous in winter. High insolation combined with a continuous supply of nutrient-rich seepage waters in summer contributes to the development of a rich flora.

Dry Matter Yields. Although figures on yields are not available, field observations indicate yields in excess of the 400 kg/ha produced on the dryas-rough fescue unit.

Sheep Use. The rough fescue-dryas community receives moderate to heavy use by sheep in summer, but its use is limited by snow cover in winter. Pellet group counts (1.09 per sq m) indicate that, next to the hairy wildrye-rough fescue community, this unit received the heaviest use by sheep.

Unit D

The moderately steep slopes of this unit lie generally above 1500 m elevation on the east side of Nevis Mountain. Acidic colluvium and weathered siltstones and shales comprise the soil-forming materials.

Vegetation. The reedgrass (*Calamagrostis lapponica*)-sweetgrass (*Hierochloë alpina*) community is dominated by these grasses, and by rough fescue. The grass-like spike woodrush (*Luzula spicata*) is a common forb in the community and two blueberries (*Vaccinium vitis-idaea* and *V. uliginosum*) occur on better drained sites. Black crowberry (*Empetrum nigrum*), mountain juniper (*Juniperus communis*), and cassiope (*Cassiope tetragona*) occur on protected sites. Mosses and lichens comprise the main ground surface cover.

Soils. Lithic and Degraded Dystric Brunisols, derived from acidic sedimentary rocks, have extremely acid horizons (pH 3.5) and brown silty textured Bm horizons. These soils are associated with shallow Regosols developed on black weathered shale. The Dystric Brunisols of the reedgrass-sweetgrass community have a morphology similar to the pedon described under Unit E.

Mesoclimate. Snow cover is more continuous and longer lasting than on southern and western exposures. Field investigations in August revealed that some soils on cold, high elevation slopes had frozen layers within 50 cm of the surface.

Dry Matter Yields. Figures on yields are not available, but observations indicate that they would fall between those recorded on the hairy wildrye-rough fescue and dryas-rough fescue communities.

Sheep Use. Although this large unit is used extensively by sheep in summer, the low pellet group counts (0.33 per sq m) indicate low use per unit area. Snow cover limits use in winter.

Unit E

This unit occupies a limited area on the narrow undulating ridge of the mountain top. The soil mantle is shallow over acidic sedimentary rock.

Vegetation. The impoverished moss campion-reedgrass community consists of moss campion, reedgrass, spike woodrush, and Jacob's ladder (*Polemonium acutiflorum*). These species were the only vascular plants having a canopy coverage exceeding 1 percent. Lichens and mosses comprise more than 50 percent of the ground surface components.

Soils. A pedon of a typical Lithic Orthic Dystric Brunisol of the moss campion-reedgrass plant community, on a 5 percent slope of the mountain ridge, was analyzed (Table 1, Site 3) and had the following horizon characteristics:

Ahe—5 cm of very dark brown (10 YR 2/2d) loam; medium granular structure; friable consistence; extremely acid reaction and a clear boundary.

Bm—10 cm of brown (10 YR 4/3d) loam; weak, medium subangular blocky structure; friable consistence; extremely acid reaction and a gradual boundary.

C—5 cm of brown to yellowish brown (10 YR 5/3.5d) sandy loam; weak blocky pseudostructure; extremely acid reaction and an abrupt boundary.

R—20+ cm of yellowish brown weathered sandstone.

Mesoclimate. Climatic conditions are characterized by early freezing temperatures, strong drying winds, and accumulated drift snow which on parts of the unit persists into June.

Dry Matter Yields. Although no figures are available it was apparent from field observations that this was the least productive unit, with yields considerably below those of the dryas-rough fescue unit.

Sheep Use. This unit is used lightly by sheep in summer and only very lightly in winter. Observations indicate that sheep travel over, and rest in these areas but graze sparingly. Pellet group counts averaged 0.33 per square meter.

The cold, partly frozen, moss-lichen-dwarf willow community on northerly aspects of the valley is not used by sheep (Table 2).

Although most of the boreal forest communities below treeline form a minor part of the sheep habitat, two of the units are broadly defined and briefly described in the present study. The two communities, the poplar (*Populus* spp.) and the white spruce (*Picea glauca*), are identified in Figure 2 and characterized in Table 2.

Unit F

The poplar community, which meets the alpine grassland at treeline, is the principal forest on the extremely steep south exposures of Nevis Mountain. Surface geologic materials are derived mainly from weathered calcareous sandstone.

Vegetation. Trees in the poplar unit are almost exclusively trembling aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*). The average stand height is 4 m, the diameter (breast height) 4.75 cm, and the average age 27.4 years. The forest floor is dominated by a heavy cover of hairy wildrye, but forbs are well represented.

Soils. Relatively deep soils with dark-colored Chernozemic surface horizons occur in the poplar forest. A soil pedon described on an 84 percent southwest-facing slope near treeline was analyzed (Table 1, Site 4) and had the following horizon features:

Ah—20 cm of black (10 YR 2/1d) sandy loam; moderate, fine granular structure; friable consistence; slightly acid reaction and a clear boundary.
Bm—5 cm of dark brown (7.5 YR 3/2d) gravelly sandy loam; weak, medium subangular blocky structure; friable consistence; slightly acid reaction and a gradual boundary.
BC—21 cm of dark grayish brown (10 YR 4/2d) gravelly sandy loam; weak, medium subangular blocky structure; very friable consistence; neutral reaction and a gradual boundary.
BCk—22 cm of dark grayish brown (10 YR 4/2d) cobbly, gravelly sandy loam; weak subangular blocky structure; very friable; mildly alkaline reaction and an abrupt boundary.
R—68+ cm limestone.

Some soils developed under a heavy poplar canopy showed evidence of leaching in the A horizon.

Mesoclimate. The mesoclimate near treeline is considered comparable to that of the hairy wildrye-rough fescue community (Subunit A1).

Unit G

The white spruce unit occupies moderately to steeply sloping areas below treeline. Geologic materials include glacial till, colluvium and weathered rock.

Vegetation. This unit, representing the mature boreal forest, is dominated by white spruce in stands which are 150 to 200 years old. Subalpine fir (*Abies lasiocarpa*) is a common associate, especially at higher elevations. The forest understory contains willows, bog birch, mosses, and lichens.

Soils. Soil development is mainly Podzolic or Brunisolic. A pedon of an Orthic Humo-Ferric Podzol, at an elevation of 1280 m on a 17 percent east-facing slope, was analyzed (Table 1, Site 5) and described as follows:

L-F—5 cm of needles, wood fragments, and living mosses.
Ae—5 cm of light gray (10 YR 7/1d) loam; fine granular structure; friable consistence; extremely acid reaction and an abrupt boundary.
Bf—10 cm of yellowish brown (10 YR 5/4d) loam; weak, medium subangular blocky structure; firm consistence; extremely acid reaction and a clear boundary.
BC—15 cm of grayish brown (10 YR 5/2d) loam; moderate, medium subangular blocky structure; firm consistence; slightly acid reaction and a gradual boundary.
BCk—32 cm of dark grayish brown (10 YR 4/2d) loam; strong angular pseudostructure; very firm consistence and mildly alkaline reaction.

Cold northern exposures support a semi-open, white spruce forest with denser shrub layers and a thick mat of mosses and lichens on the forest floor. Gleysols and Organic soils, which are in part permanently frozen, are associated with this forest subunit.

Other forest communities recognized in the study are: lodgepole pine (*Pinus contorta* subsp. *latifolia*)-willow, and bog birch-lodgepole pine as seral communities on burns, and the bog birch-subalpine fir community occurring in protected draws. Soil development associated with these communities is either Podzolic or Brunisolic. Several shrub communities were also recognized, two of which were grass-forb communities of the valley floodplain. They occur on Regosolic soils developed on recent alluvium and outwash.

Conclusions

Stone sheep habitat on Nevis Mountain is dependent on a diverse alpine environment. Certain relationships in the complex interaction of plants, geologic materials, soils, and mesoclimates are of critical importance to the sheep.

High-yielding vegetation, dominated by hairy wildrye and bearded wheatgrass, is confined to grassland soils developed from basic geologic materials on steep south and west exposures. Insolation (radiation received per unit area), temperature, and soil moisture on these sites appear to favor the development of fertile Chernozemic soils. Yields may exceed one metric ton of dry matter per hectare on the hairy wildrye-bearded wheatgrass community. This unit, which accounts for less than 20 percent of the winter range and only 4 percent of the total range, but supplies almost 60 percent of the winter forage, is considered to be the most critical component of the sheep range. Pellet group counts, dry matter utilization, and field observation confirmed that the high-yielding grasslands had the heaviest use by the sheep.

The significance of plant communities supported by soils developed on basic parent materials is further emphasized by the heavy use the sheep made of the rough fescue-dryas community during the summer. Although the sheep had a wide choice of communities occurring on strongly acid soils on the summer range, pellet group counts indicated that use in the rough fescue-dryas community rated second only to the hairy wildrye-bearded wheatgrass community on the restricted winter range.

Chernozemic soils have developed under alpine conditions where annual temperatures are near 0°C. By definition (C.S.S.C., 1970) these borderline soils may be excluded from the Chernozemic Order under the Canadian System of Soil Classification, and classified as Alpine Eutric Brunisols. Under the U.S. System (USDA, 1960) they would be Typic Cryoborolls or Pergelic Cryoborolls.

The present study identified some cardinal relationships and interactions among native sheep, vegetation, soils, and mesoclimates in a delicately balanced, alpine environment. The results of this study are applicable to similar ecosystems that are

known to occur throughout the northern foothills. In addition, the observations presented here complement those relating to other native sheep and their habitats, notably California bighorn sheep (*Ovis canadensis californiana*) in southern British Columbia, and Dall sheep (*Ovis dalli dalli*) in more northern regions.

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