A Review of Fuelbed Properties of Duff in Black Spruce Forests of Interior Alaska

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Introduction

Black spruce forest soils are commonly composed of accumulations of moss, mostly the feathermosses *Pleurozium schreberi* (red-stem moss) and *Hylocomium splendens* (stair-step moss, splendid feathermoss). For fire management purposes a typical soil profile from a black spruce forest in Interior Alaska consists of four organic layers: Live Moss, Dead Moss, Upper Duff, and Lower Duff.

The live moss (LM) layer is composed of green moss and is seldom more than 3 cm deep. The structure of the dead moss (DM) layer resembles the live moss layer except it is brown and slightly more compact. The upper duff (UD) layer is light brown, often with white fungal material, and much more compact and decomposed. The lower duff (LD) layer is most often black, very dense, and sits on the inorganic mineral soil.

In this paper I review the available literature for fuelbed properties of duff: bulk density, depth, surface area to volume ratio, packing ratio, and fuel load. Figures 1 and 2 show typical "duff plugs" or soil profiles extracted from the forest floor.

Figure 1.

Figure 2.

Alaska Fire Service Fuel Moisture Database

Over one hundred samples were collected from the Nenana Ridge prescribed fire (n=118) during 2008-2010 (Alaska Fire Service, fuel moisture database). Several additional samples were collected from the 2009 Blind Luck Fire southwest of Manley Hot Springs.

Layer	Bulk Density (g/cm^3)	Thickness (cm)	Thickness (in)	n
Live Moss	0.0182	2.85	1.12	45
Dead Moss	0.0263	6.44	2.53	44
Upper Duff	0.0533	6.90	2.72	29

Equivalent fuel loads are:

Layer	Fuel Load kg/m^2	Fuel Load t/ac
Live Moss	0.52	2.32
Dead Moss	1.69	7.55
Upper Duff	3.67	16.39

Wilmore (2001)

Wilmore (2001) provides a very large dataset from Fort Wainwright, Alaska.

Layer	Bulk Density (g/cm^3)	SE	n
Live Moss	0.014	0.0002	667
Dead Moss	0.023	0.0002	664
Upper Duff	0.044	0.0005	633
Lower Duff	0.111	0.0030	195

Lawson et al. (1997)

Lawson et al. (1997) collected soil information from the Tetlin National Wildlife Refuge near Tok, Alaska. Their samples were stratified by absolute depth in 5 cm increments rather than by soil layer. Their dataset is important because it contains ash content values.

Layer	Depth (cm)	Bulk Density (g/cm^3)	Ash Content %
Upper feathermoss	0-5	0.0464	17.0
Lower feathermoss	15-20	0.0389	19.5
Lichen-feathermoss	0-5	0.0563	25.9
White spruce duff	0-5	0.122	35.9
Upper sphagnum	0-5	0.0218	12.4
Lower sphagnum	5 to 25	0.119	56.5

O'Donnell et al. (2009)

O'Donnell et al. (2009) sampled duff physical and thermal properties in somewhat poorly and poorly drained black spruce stands at Bonanza Creek (west of Fairbanks), Delta Junction, and Washington Creek (north of Fairbanks). They stratified their samples into live feathermoss, fibrous duff, and amorphous duff. They also provide data for sphagnum moss. In addition to bulk density they provide figures for thermal conductivity and porosity which is the volume of voids divided by the sample volume. One minus the porosity is an estimate of the fuel layer packing ratio or the volume occupied by fuel divided by the sample volume.

Layer	Bulk Density (g/cm^3)	Porosity	Packing Ratio
Feathermoss			
Live moss	0.0200	98.9	0.0110
Fibrous	0.0600	96.5	0.0350
Amorphous	0.1200	88.3	0.1170
Sphagnum			
Live moss	0.0400	98.2	0.0180
Fibrous	0.0600	97.4	0.0260
Amorphous	0.1700	88.1	0.1190

Neff et al. (2005)

Neff et al. (2005) measured physical and chemical properties of burned and unburned duff near Jarvis Creek, Delta Junction.

Layer	Bulk Density (g/cm^3)	Thickness (cm)	Thickness (in)
Live Moss	0.02	2.40	0.94
Dead Moss	0.05	2.00	0.79
Fibric	0.17	3.00	1.18
Mesic	0.18	2.60	1.02
Humic	0.30	3.00	1.18

Equivalent fuel loads are:

Layer	Fuel Load kg/m^2	Fuel Load t/ac
Live Moss	0.48	2.14
Dead Moss	1.00	4.46
Fibric	5.10	22.75
Mesic	4.68	20.88
Humic	9.00	40.15

Surface Area to Volume Ratio

The ratio of surface area to volume (SAV) is a key factor used in fire behavior prediction models. SAV is directly related to the rate of moisture exchange with the atmosphere and also rate of heat penetration into the fuel particle. Fuels with high SAV trend quickly with atmospheric moisture and rapidly ascend to ignition temperature given a pilot flame. While the SAV of feathermosses is commonly believed to be higher than that of one-hour fuels (~1,200 to 2,200 m^2/m^3), I can find few empirical measurements in the literature except for 4,300 m^2/m^3 cited in Norum (1982) who cites Mutch and Gastineau (1976).

Stylized Model

Given the information reviewed above, these are suggested values fire behavior analysis.

Layer	Bulk Density (g/cm^3)	Thickness (cm)	SAV	Packing Ratio (m^2 /m3)	Fuel Load (kg/m^2)
Live Moss	0.018	2.5	4,300	0.0110	0.45
Dead Moss	0.024	5.0	4,000	0.0200	1.20
Upper Duff	0.050	6.5	2,000	0.0350	3.25

Layer	Bulk Density (g/cm^3)	Thickness (cm)	SAV	Packing Ratio (m^2 /m3)	Fuel Load (kg/m^2)
Live Moss	0.018	1.0	4,300	0.0110	2.01
Dead Moss	0.024	2.0	4,000	0.0200	5.35
Upper Duff	0.050	2.6	2,000	0.0350	14.50

References

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