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# Forest Floor Nutrient Properties in Single- and Mixed-species Stands of Western Hemlock and Western Redcedar

## Introduction

The influence of tree species on forest soils has been the subject of study for at least a century. Of particular interest have been western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western redcedar (*Thuja plicata* Donn ex D. Don) - two of the most common tree species in coastal and southern British Columbia, but each with a different nutrient amplitude. It has generally been found that acid, mycogeneous Mor humus forms develop in hemlock stands, while less acid and more zoogenous Mormoder, Moder, or even Mull humus forms develop in redcedar stands.

The objective of this study was to determine the influence of hemlock and redcedar, growing separately and together, on forest floor nutrient properties. The questions addressed were: (1) does each stand type have unique forest floor nutrient properties? and (2) can any forest floor nutrient property discriminate between stand types?

## Study Stands and Methods

Study stands were located in three areas: Capilano River (Capilano), University of British Columbia, Malcolm Knapp Research Forest east of Vancouver (Knapp), and Mission Tree Farm License No. 26 (Mission). Within each area, 9 stands were selected: 3 hemlock, 3 redcedar, and 3 mixtures of approximately equal proportion, by basal area. The study stands were naturally regenerated, unmanaged, closed-canopied, and even-aged (50 to 70 years at breast height), and represented the end of the stem exclusion stage of stand development. All stands were within the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant, and were located on fresh, nutrient-medium sites.

Within each stand a 30 x 30 m (0.09 ha) sample plot uniform in topography, vegetation, and soil was established. Forest floors were sampled at 12 random locations in each stand. The samples collected were amalgamated into 3 samples, so that each composite sample consisted of 4 randomly chosen samples from the initial 12 samples. All samples were air-dried to constant mass and ground on a Wiley mill to pass through a 2-mm sieve. Samples were analyzed for pH, mineralizable nitrogen (min-N), and concentrations (%) of nitrogen (N), carbon (C), calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), and sulfur (S).

Mean values of forest floor nutrient properties among the three stand types were compared with a one-way analysis of variance (ANOVA), utilizing a general linear regression model testing the stand type, location, and their interaction with nutrient properties:

[1] $$Y_i = b_0 + b_1 STAND + b_2 LOC + b_3\ STANDxLOC + \varepsilon i$$

where $Y_i$ is a nutrient property, $b_0$ is an overall mean, STAND is stand type, LOC is location, STANDxLOC is stand type by location interaction, and $\varepsilon i$ is model error.

Various discriminant function analyses were performed to determine those forest floor nutrient properties which significantly discriminate among stand types at $\alpha = 0.05$. These properties were then subjected to canonical discriminant analysis to determine the degree of discrimination among stand types.

# Results and Discussion

ANOVA by model [1] indicated that: (i) C, C:N ratio, and S were significantly related to stand type but not to location, (ii) min-N was significantly related to both stand type and location, (iii) a significant stand type x location interaction existed for pH, Ca, and K, and (iv) N, Mg, and P were not significantly related to stand type or location (Table 1).

Table 1. Means and standard errors (in parentheses) of forest floor nutrient properties of study stands, stratified according to stand type and location. For a given chemical property, values in the same row with the same superscript are not significantly different ($\alpha = 0.05$); no superscripts indicates no significant differences ($p \leq 0.05$).

| Chemical property | Stand type | | | Significant Stand x location interaction | Location | | |
|---|---|---|---|---|---|---|---|
| | Hw | Hw-Cw | Cw | | Capilano | Knapp | Mission |
| pH | 3.8 (0.1) | 4.2 (0.2) | 4.3 (0.2) | * | 3.9 (0.1) | 4.0 (0.1) | 4.2 (0.2) |
| C (%) | 49.8$^{a}$ (6.0) | 47.2$^{a,b}$ (6.7) | 44.1$^{b}$ (5.6) | | 49.5 (5.4) | 47.8 (5.8) | 45.0 (7.5) |
| N (%) | 0.750 (0.120) | 0.739 (0.099) | 0.682 (0.093) | | 0.724 (0.117) | 0.727 (0.102) | 0.712 (0.112) |
| C:N ratio | 67.2$^{a,b}$ (8.5) | 70.3$^{a}$ (12.7) | 60.3$^{b}$ (8.9) | | 69.8 (12.2) | 66.5 (10.3) | 63.7 (9.3) |
| Mineralizable N (ppm) | 54.79$^{b}$ (8.03) | 60.75$^{a,b}$ (9.20) | 70.60$^{a}$ (15.14) | | 54.12$^{b}$ (7.26) | 67.13$^{a}$ (13.97) | 64.10$^{a,b}$ (10.08) |
| Ca (%) | 0.232$^{b}$ (0.072) | 0.324$^{b}$ (0.080) | 0.571$^{a}$ (0.107) | * | 0.284 (0.082) | 0.312 (0.086) | 0.338 (0.082) |
| Mg (%) | 0.032 (0.016) | 0.027 (0.014) | 0.027 (0.007) | | 0.032 (0.016) | 0.025 (0.007) | 0.028 (0.014) |
| K (%) | 0.071 (0.021) | 0.076 (0.026) | 0.096 (0.019) | * | 0.073 (0.025) | 0.070 (0.021) | 0.092 (0.021) |
| P (%) | 0.020 (0.004) | 0.020 (0.003) | 0.019 (0.002) | | 0.019 (0.004) | 0.021 (0.003) | 0.020 (0.003) |
| S (%) | 0.192$^{a}$ (0.040) | 0.161$^{a,b}$ (0.039) | 0.148$^{b}$ (0.040) | | 0.175 (0.032) | 0.169 (0.045) | 0.165 (0.053) |

## Does each stand type have unique forest floor nutrient properties?

The forest floors in the hemlock stands had significantly higher C and S concentrations than those in the redcedar stands. Although not significant, Mg and N concentrations appeared slightly higher in the hemlock stand type than in the mixed or redcedar types. The forest floors in the redcedar stands had significantly higher min-N concentrations than the forest floors within the hemlock stands (Table 1). The significant stand type by location interactions found for pH, Ca, and K precluded multiple range testing of these forest floor properties between stand types. However, plots of these interactions revealed that the redcedar stand forest floors had higher pH and Ca concentrations than the hemlock stands, while no trend was observed for K concentrations. The forest floors of the mixed stands had nutrient properties intermediate between the hemlock and redcedar, except in C:N ratio which was significantly greater than in the redcedar stand type.

Concentrations of forest floor min-N increased with increasing presence of redcedar, although min-N was also significantly related to location (Table 1). When measured by anaerobic incubation, min-N represents N liberated from microbes. This is consistent with the increase in both pH and min-N with increasing influence of redcedar, as the higher pH of redcedar forest floors has been associated with increased microbial populations, decreased fungal biomass, and increased rates of decomposition in the forest floor, relative to hemlock. These findings support the proposition that both species of trees have different influences on the microbial populations, fauna, and properties of the underlying forest floor and soil, and that these influences affect min-N concentrations. However, the significant differences in pH, min-N, and K among locations suggest that the influence of the tree species on N availability is site-specific. Mean forest floor C:N ratios significantly decreased with progression from the mixture to the hemlock to the redcedar stands. This trend is neither strengthened nor weakened by the findings of other studies and suggeststhat for hemlock and redcedar stands, C:N ratios are site-specific. Despite the interaction effect, Ca increased with increasing presence of redcedar.

### Does any forest floor nutrient property discriminate between stand types?

Significant differences between stand types were detected in 4 (C, C:N, min-N, S) of the 10 forest floor nutrient properties assayed, while 2 additional properties (pH, Ca) showed strong (but statistically insignificant) trends with respect to stand type. No significant differences in N, Mg, and P concentrations were associated with stand type. The canonical discriminant analysis identified three properties: pH, C:N, and Ca. Ordination of the data based on these properties showed a gradual progression of samples from the left to the right region of ordination, i.e., from hemlock to mixtures to redcedar stands (Figure 1). Cross-validation resulted in a low predicted overall misclassification error rate ($p < 0.111$), indicating good discrimination among stand types by the 3 forest floor nutrient properties selected. The hemlock and redcedar stand type means are well separated with the mixed stands intermediate. This indicates that the forest floors in hemlock and redcedar stands have distinct nutrient properties, while the mixed stands are intermediate.

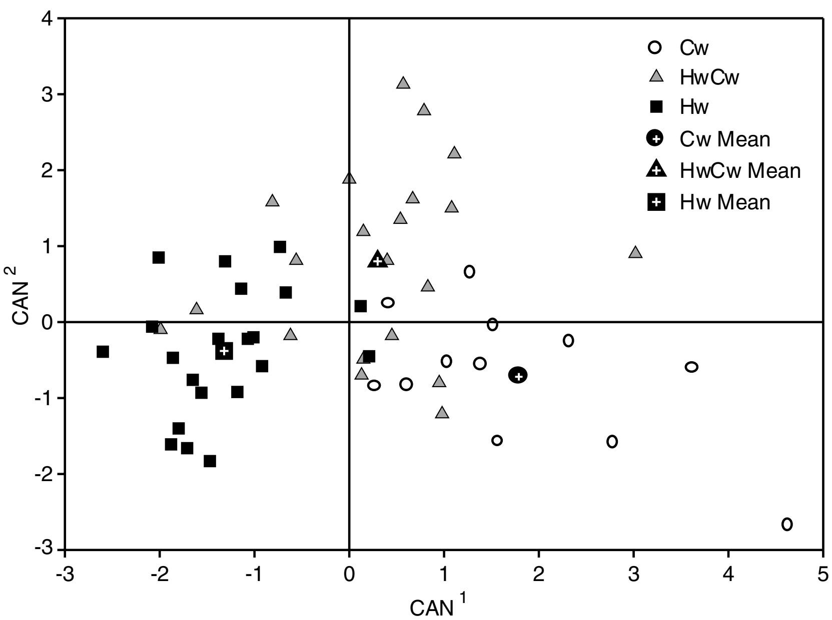


Figure 1. Ordination of 27 forest floor samples and means for each stand type as functions of the first two canonical variables, based on forest floor nutrient properties significantly discriminating among stand types (pH, C:N, Ca, and Mg) (*p* <0.10). Abbreviations for stand types are: Hw – western hemlock, Cw - western redcedar, HwCw – western hemlock-western redcedar.

## Conclusions

The forest floors under hemlock and redcedar stands had distinct nutrient properties, while hemlock-redcedar stands type had intermediate forest floor nutrient properties. Forest floor nutrient status generally improved with increasing presence of redcedar. Forest floor pH, C:N ratio, and Ca concentration effectively discriminate between stands of hemlock, redcedar, and their mixtures.

## Reference

Collins, D.B., M.C. Feller, K. Klinka, and L. de Montigny. 2001. Forest floor nutrient properties in single- and mixed-species, second growth stands of western hemlock and western redcedar. [submitted ms]

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