Leaf Litter Quality in Adirondack Upland Streams: Managed vs. Preserve

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ABSTRACT

Leaf litter quality has an important nutritional role in headwater streams. Since upland streams are relatively small (1st order and 2nd order streams) with a dense forest canopy, primary productivity from stream macrophytes and microphytes is hindered (Fisher and Likens 1973). This creates a dependence on the adjacent riparian zone as a primary productivity input, making upland stream ecosystems detrital based and dependent on allochthonous organic matter (Fisher and Likens 1973, Cummins and Klug 1979). Differing riparian vegetation allocate varying nutritional value which in turn reflects the stream macro and microscopic fauna. Riparian vegetation composition can be influenced by disturbances such as logging or natural disasters. This study focused on the effects of logging on leaf litter composition.

To determine if logging had an effect on riparian leaf litter food quality indicators, four managed (logged) sites were compared to three Forest Preserve sites within the Adirondack Park. Food quality indicators, protein, ash free dry mass and hydrolysis resistant organic matter, were compared across sites. Managed sites had a slightly higher contribution by volume of all food quality indicators. Differences for individual indicators largely reflected changes in litter species composition.

Key Words: Adirondack Upland streams, leaf litter, land use .

INTRODUCTION

Upland stream ecosystems are detrital based and dependent on allochthonous organic matter (Fisher and Liken 1973, Cummins and Klug 1979). Once leaf litter enters the stream leeching begins causing an initial nutrient release from the leaves. Fungi (hyphomycetes) begin to colonize and decompose down leaf litter, which is then mechanically broken down by detritivores which are able to obtain nutrients from intermediates of fungal metabolism. Detritivores out populate collectors, scraper and predators populations in upland streams due to allochthonous food sources (Cummins and Klug 1979).

Leaf litter can be separated into organic and inorganic portions, with organisms obtaining nutrients from the organic fraction. The organic portions of the leaf include protein, lipid, fatty acids, carbohydrates and cell wall. These portions can provide important information about leaf litter quality (Cargill et al. 1985). Due to its poor ability to assimilate carbohydrates and protein, leaf litter tends to have a lower food quality than other stream food sources. Cummins and Klug (1979) also indicated that as litter is broken into smaller particle size, levels of lignin and refractile nitrogen impede the ability of an organism to breakdown and extract nutrients.

Each food quality indicator is important for various life processes. Protein influences growth rate. The greater ability the invertebrate has to assimilate protein the more energy available for growth. Since detritus is low in protein it can be a limiting factor to invertebrate growth (Bowen et al. 1995). Hydrolysis resistant organic matter is comprised of mostly lignin and cellulose. Lignin and cellulose can be limiting factors as to how well invertebrates or fungi can break down leaf litter. Lignin is a complex organic molecule that resistant to decomposition. Lignin itself is not easily broken down and lignin acts as buffer to enzymatic decay of other plant nutrients such as cellulose, carbohydrates and proteins (Aber et. al. 1985).

Adirondack upland streams are primarily 1st and 2nd order systems so their food webs are most likely influenced by the adjacent forest. The objective of this experiment was to determine the nutritional values for multiple tree species to help determine leaf litter quality available to stream ecosystems (Cargill et al 1985). This information allowed a comparison between leaf litter chemical food quality in logged (managed) versus reference sites (located in the NYS Forest Preserve for 85+ years).

METHODS

Sites and Collection

Leaf samples were collected from three Adirondack Preserve sites (Pettigrew, Ampersand, Dutton) and four Adirondack logged sites (North Stephenson, Mountain Brook, Big Brown and Deep Inlet; Figure 1). At each site, 10 litter baskets were placed at various intervals on either side of the stream. The baskets were then collected and separated out by species (Myers et al. 2007). Major leaf species studied include: *Acer saccharum, Fagus grandifolia*, *Fraxinus americana*, *Betula alleghaniensis*, *Betula papyrifera, Acer pensylvanicum*, *Acer rubrum and Populus tremuloides*, which represented tree species found across the 7 studied sites. Each leaf species was also given a specific abbreviation (Table 1). Leaf species collected represented potential food source for stream systems and an early stage of decomposition.

Table 1. Leaf species studied, their abbreviations and common names.

Leaf Species	Abbreviation	Common Name
Acer saccharum	ACSA	Sugar Maple
Fraxinus americana	FRAM	White Ash
Fagus grandifolia	FAGR	American Beech
Betula alleghaniensis	BEAL	Yellow Birch
Betula papyrifera	BEPA	White Birch
Acer pensylvanicum	ACPE	Stripe Maple
Acer rubrum	ACRU	Red Maple
Populus tremuloides	POTR	Quaking Aspen

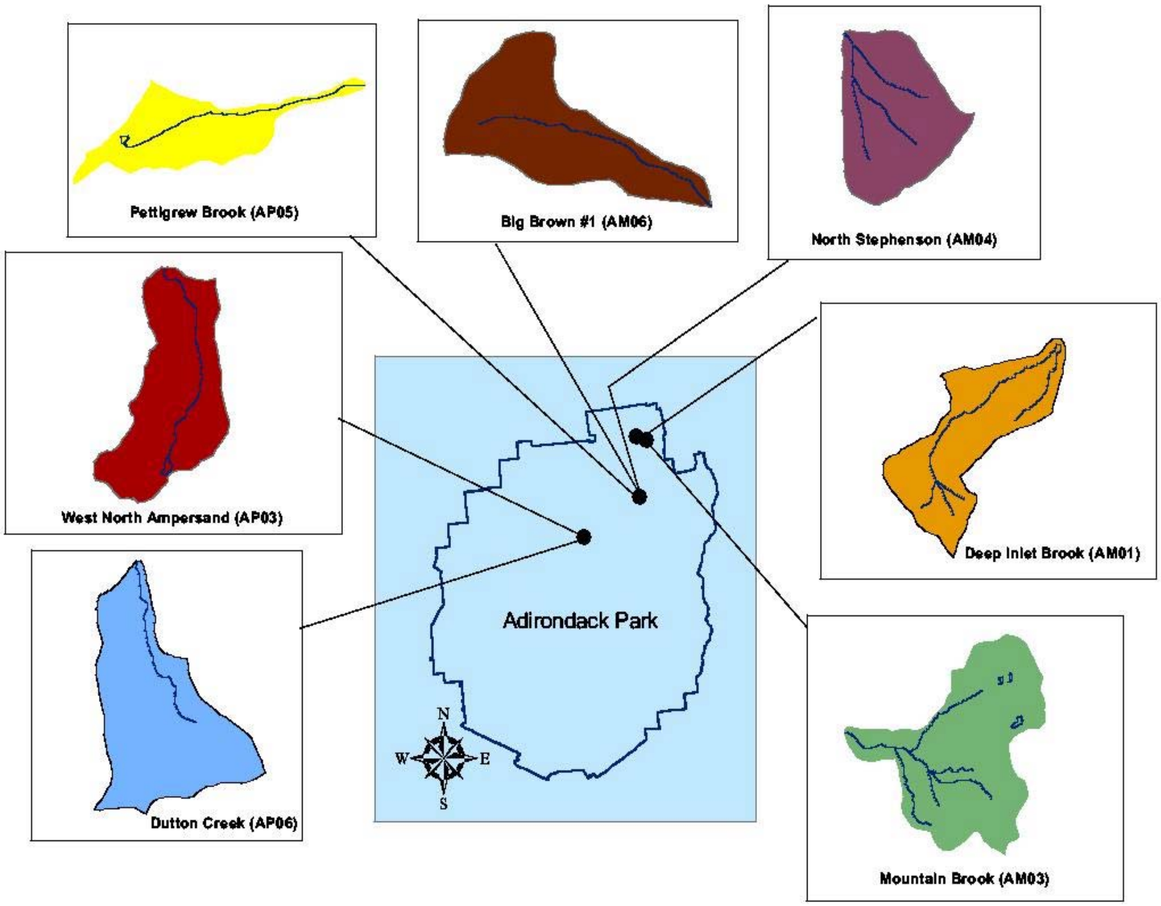

Figure 1. Site locations in Adirondack Park, NY.

Chemical Analysis

Ash-free Dry Mass

Ash-free dry mass was used to determined organic composition of each leaf species. Each species was separated into managed and preserved subsets. The samples for each watershed were then combined within the subset, managed or preserve, to determine an ash value for that particular species within the subset. Each species within a subset was tested three times to ensure precision and accuracy.

Hydrolysis Resistant Organic Matter

Leaf digestibility was determined using the Hydrolysis Resistant Organic Matter (HROM) assay. Leaf samples were ground and the weight of hydrolysis resistant organic matter per sample weight was determined (equation 1) (Georing 1990). This method is an indicator of cellulose and lignin composition (Buddington 1980).

$$HROM = \frac{(dried\ residual - combusted\ residual)}{original\ mass} \quad \text{Equation 1.}$$

Samples of each tree species was taken from each site if available.

% Nitrogen

Percent Nitrogen was determined by combustion at a high temperature in oxygen and measured through thermal conductivity detection (Association of Official Analytical Chemists). Samples were run with EDTA blanks and compared to standard apple leaves.

Crude Protein

Ground leaf samples of each species from each site were used to determine percent nitrogen through combustion. Data was then converted to crude protein (equation 2).

$$Crude\ protien = \%Nitrogen \times 6.25 \quad \text{Equation 2.}$$

After chemical analyses were completed an average food quality value was determined for each leaf species. Each average value was multiplied by the average biomass found at each site. Average biomass values were determined in a previous study (Myers et al. 2007).

Data Analysis

Data sets were analyzed using percent composition for each chemical variable to determine differences between logged and preserve sites as well as between individual sites and leaf litter species.

RESULTS

It was determined that White Ash (FRAM) had the highest ash free dry mass while White Birch (BEPA) had the least ash free dry mass of the leaf species studied (Table 2). White Birch had the highest % HROM while ACSA (Sugar Maple) had the lowest % HROM. Yellow Birch (BEAL) had the highest % nitrogen and crude protein while ACRU (Red Maple) had the lowest % nitrogen and crude protein.

Table 2. Summary of chemical analysis on leaf species. Tree species codes are found in Table 1.

Species	Ash Free Dry Mass	%HROM	% Nitrogen	Crude Protein
ACPE	0.9422	0.1559	0.5060	0.0316
ACRU	0.9237	0.1618	0.3067	0.0192
ACSA	0.9322	0.1496	0.4794	0.0300
BEAL	0.9297	0.1542	1.0326	0.0645
BEPA	0.9113	0.2438	0.6265	0.0392
CONIFER	n.d.	0.1790	0.5750	0.0359
FAGR	0.9223	0.1802	0.6830	0.0427
FRAM	0.9436	0.2062	0.9830	0.0515
POTR	0.9422	0.1635	0.8275	0.0517

Organic matter content varied between Managed and Preserve watersheds (Figure 2). Managed sites had more Sugar Maple (ACSA) contribution while preserve sites had more Yellow Birch (BEAL), which had a higher proportion of organic leaf matter than ACSA. Managed sites also had Quacking Aspen (POTR) as a contributor which out of all leaf species contained the most organic matter and had more organic matter than ACSA and ACPE. North Stephenson had the highest overall organic matter content while Dutton had the highest organic content for Preserve sites.

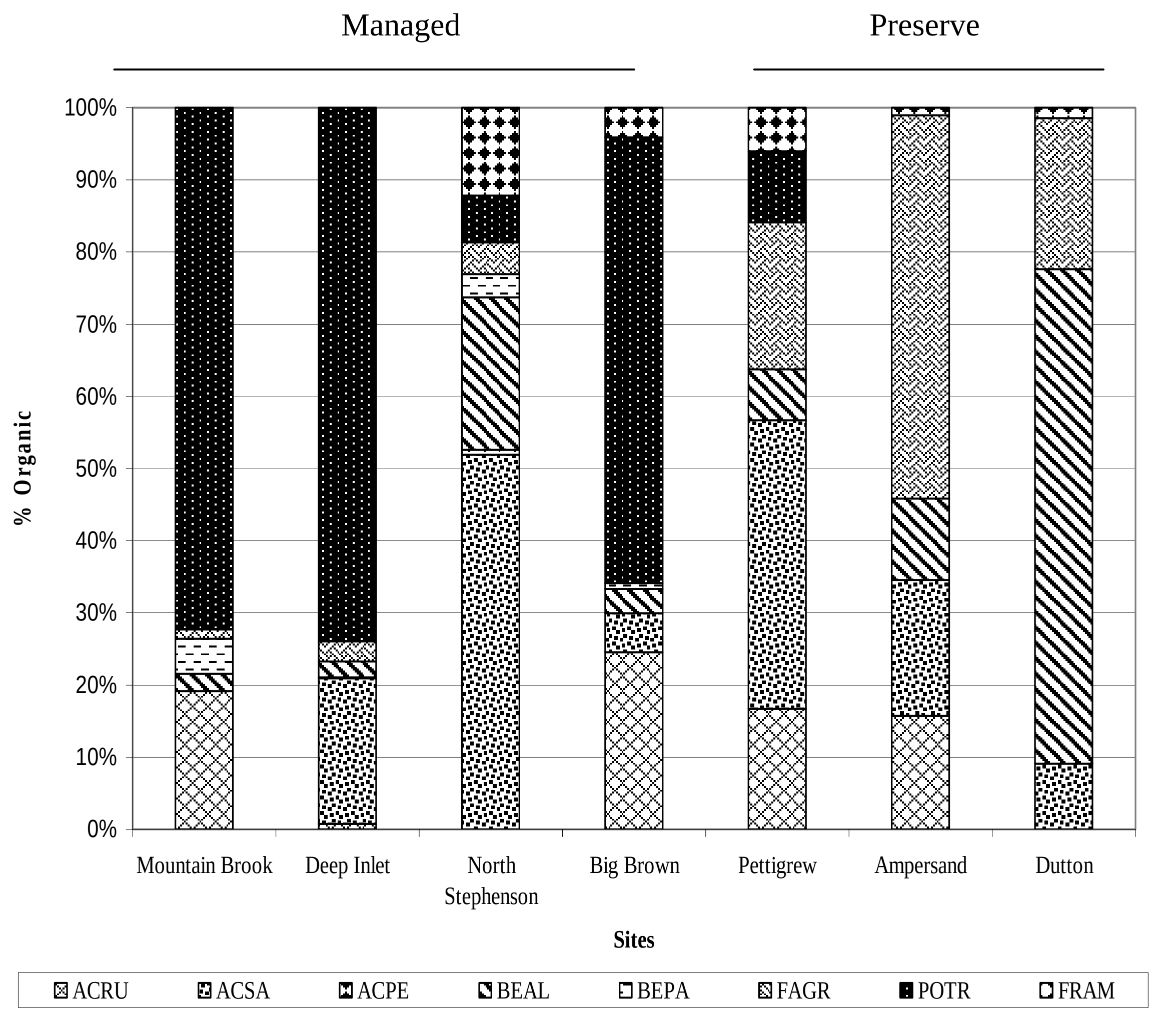

Figure 2. Percent organic matter contribution by volume for each leaf species across sites. Species codes are found in Table 1.

HROM contribution also varied between land-use types (Figure 3). Managed sites had contribution from ACSA which had the lowest HROM while preserve sites had contributions from conifer and FAGR which contained more HROM. BEAL also found in preserve sites had a lower value of HROM. North Stephenson, a managed site has the highest HROM content while Dutton has the highest HROM content for preserve sites.

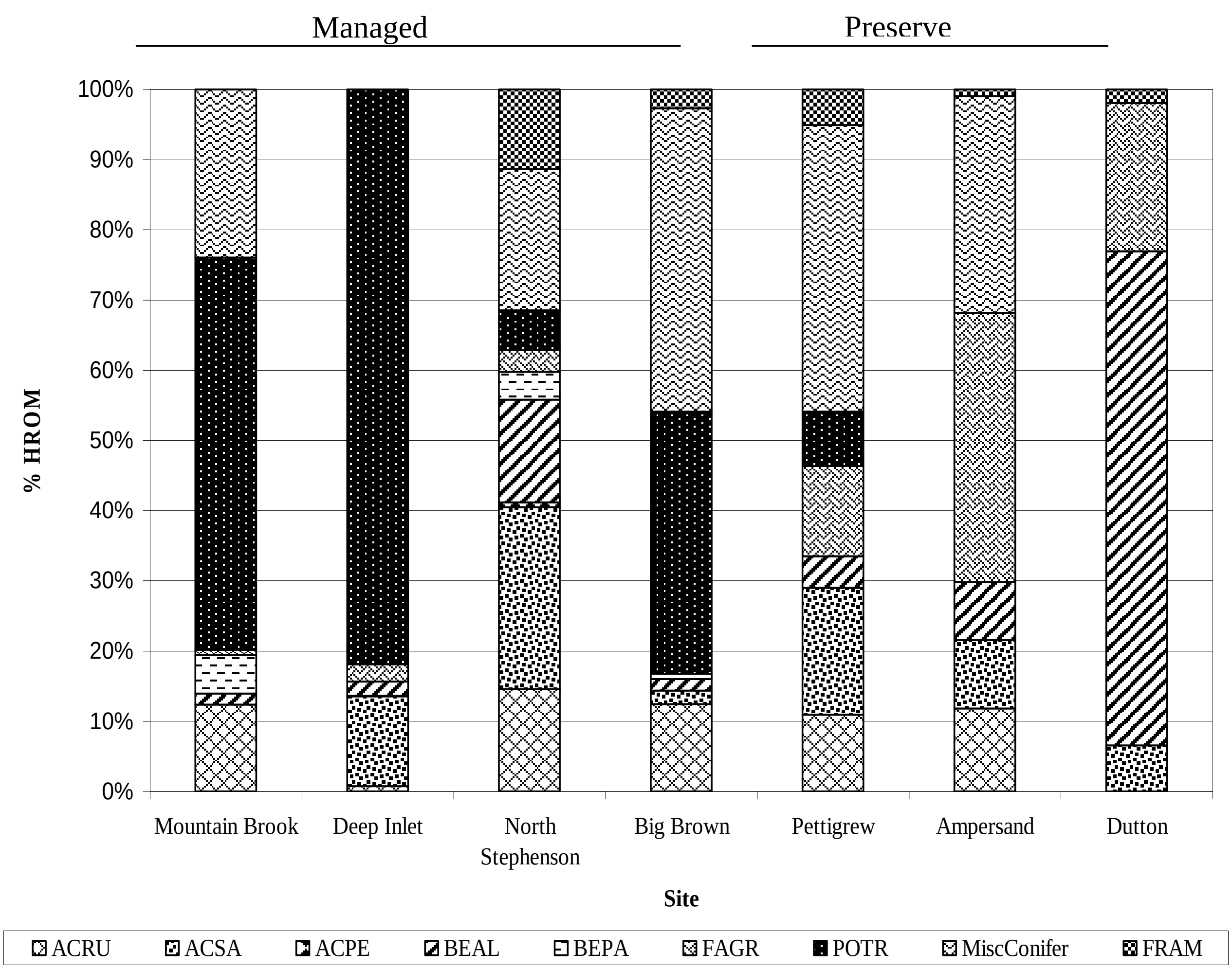

Figure 3. Percent HROM composition by volume of leaf species across sites. Tree species codes are found in Table 1.

Nitrogen contribution also varied between managed and Preserve watersheds (Figure 4). North Stephenson has the highest nitrogen content while Dutton has the highest nitrogen content of the preserve sites. Managed sites had major nitrogen contribution from POTR while preserve sites had major nitrogen from BEAL, a species with high nitrogen.

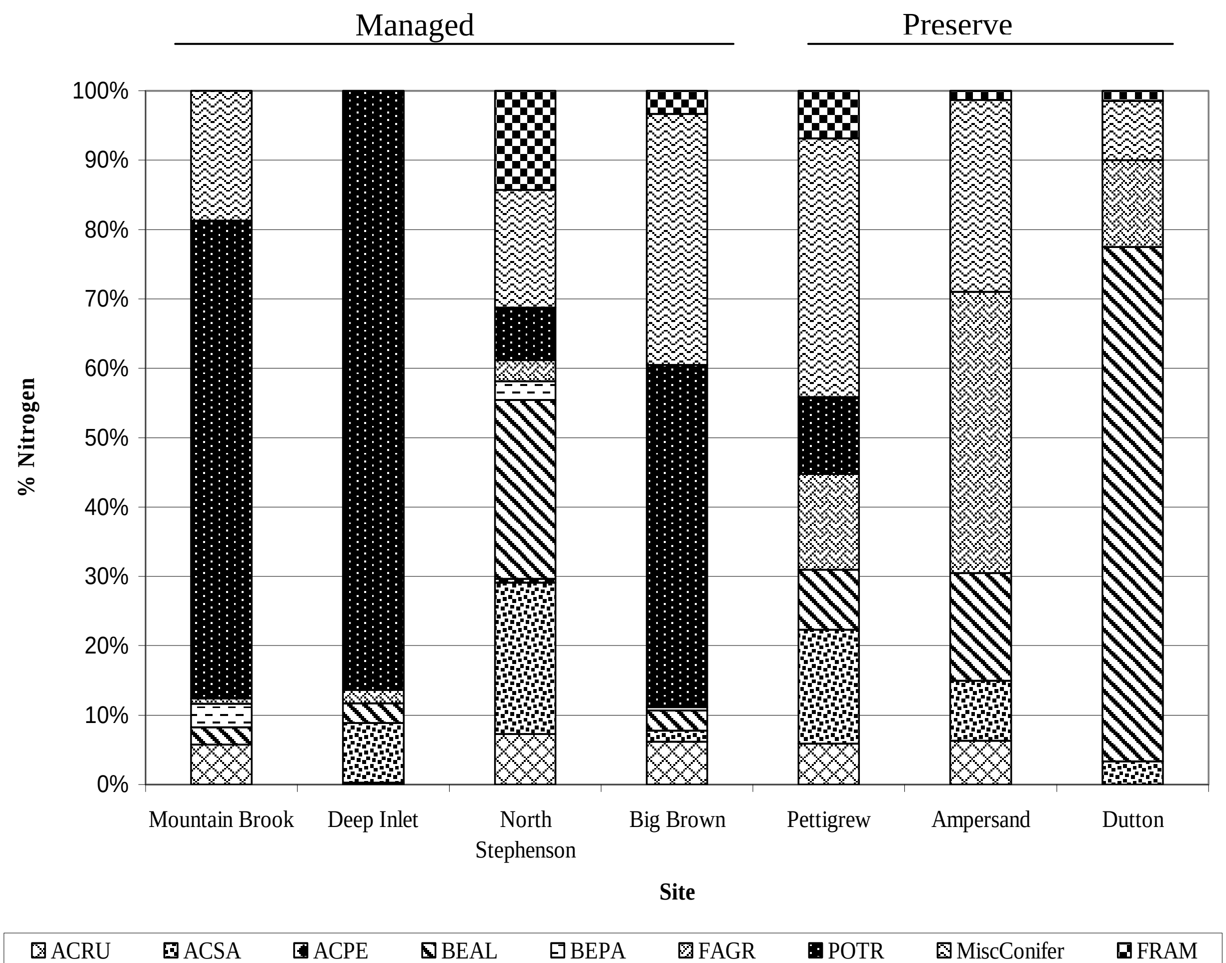

Figure 4. % Nitrogen contribution by volume from leaf species across study sites. Tree species codes are found in Table 1.

Overall managed sites had higher protein content than preserve sites (Figure 5). Managed sites have POTR as a major contributor while preserve sites have BEAL which has significantly more protein than ACSA. North Stephenson had the highest protein content while Dutton has the highest protein content of the preserve sites.

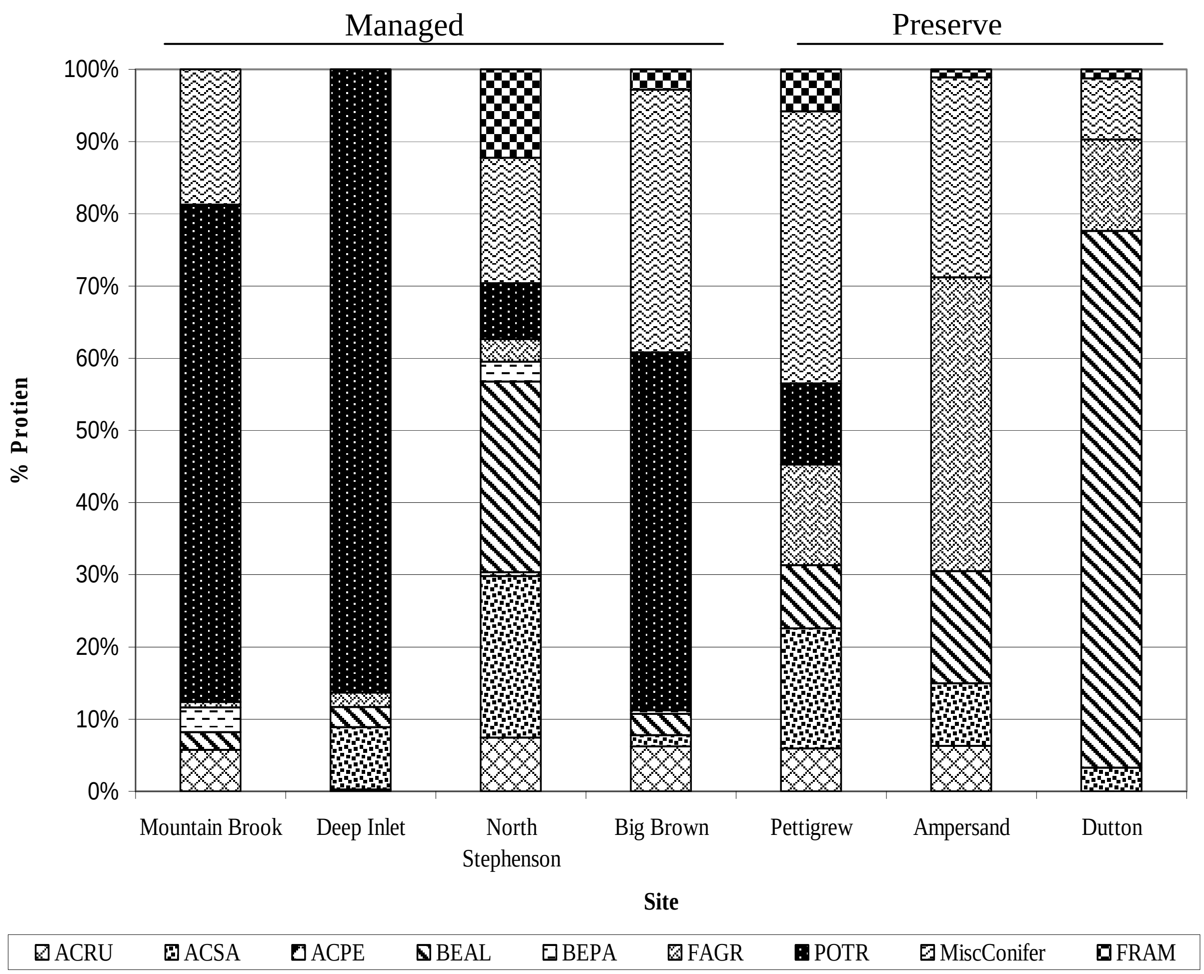

Figure 5. % Crude protein contribution by volume of leaf species across sites. Tree species codes are found in Table 1.

Managed sites had a higher overall proportion of organic matter, nitrogen, protein and HROM (Figure 6). Organic matter content showed the greatest increase in managed sites, most likely due to the shifts in litter composition in those sites to taxa that contain high organic matter content.

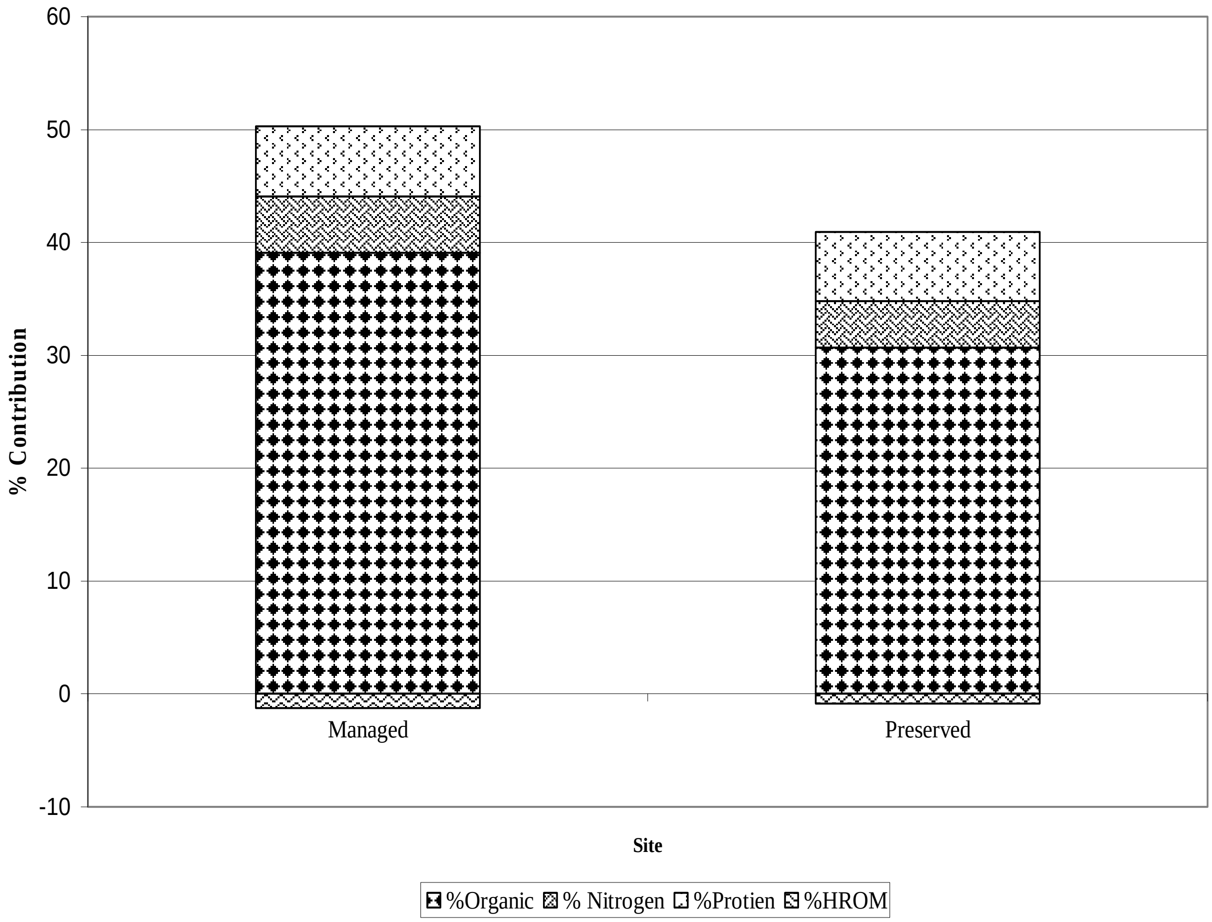

Figure 6. Overall food quality indicators in managed vs. preserve study sites.

DISCUSSION

In general managed sites had more organic input than Forest Preserve sites. This may be attributed to difference in litter species composition. Managed sites have a large input of organic matter from Quaking Aspen (POTR) which out of all leaf species had the highest proportion of organic matter in this study. Preserve sites did have a large proportion of contribution from Yellow Birch (BEAL) but, Yellow Birch has less organic matter than Quaking Aspen. So, due to the prevalence of Quaking Aspen, managed sites had a higher organic matter input.

Managed sites also had more HROM input than Preserve sites most likely due to higher contribution from species with higher HROM. In this case it might be the total input or biomass that enters the stream that affects HROM. In preserve sites HROM proportions came from conifer and American Beech (FAGR) which have higher HROM proportions while in managed sites a large input of HROM comes from Quaking Aspen which has a smaller HROM contribution than conifer and American Beech, but the high volume input of Quaking Aspen may be large enough to create a large HROM pool in managed sites.

Managed sites had higher nitrogen and crude protein contribution. Again, it is observed that preserve streams had an input from leaf species that contain high nitrogen content such as Yellow Birch. Managed sites had a large contribution from Quaking Aspen which had less nitrogen and crude protein content than Yellow Birch. The high volume inputs of Quaking Aspen to managed sites might be large enough to increase nitrogen contribution to these sites .

Since managed sites had higher contribution by volume of food quality indicators, in general litter in managed sites showed a higher food quality than the un-logged Preserve. It was observed that Sugar Maple (ASCA), conifer and Quaking Aspen are major contributors to managed sites while Yellow Birch, American Beech and conifer are major contributors to preserve sites. So, our observed differences may be attributed to the composition of tree species across managed and preserve sites altering the riparian contribution to stream litter.

Higher food quality may allow for a more complex food web to be present in managed ecosystems compared to Preserve ecosystems. Higher food quality may also reflect shifts in leaf litter species composition. Difference in composition could be a function of the relative age of the forests with managed forests are in an earlier stage of succession.

Further study of food quality and nutrient cycling within the watersheds are needed to better understand how leaf litter quality is affected by land management. One study that should be considered would be to compare the leeching rates of various litter species. Another option might be to consider the role of temperature and pH in nutrient cycling during decomposition.

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