Comparison of Winter Litterfall Between Two Different Forest Communities in Northern Vermont

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ABSTRACT

Winter litterfall is important in determining the energy balance of a snowpack beneath a forest canopy in addition to representing nutrient recycling. Forest composition and winter litterfall in two different forest communities in northern Vermont were characterized—a coniferous spruce–fir and a deciduous northern hardwood forest. The density of trees taller than 2 m in the coniferous plot was 2127 trees ha^{-1}, and total DBH was 360.6 m ha^{-1}. The density of trees taller than 2 m in the deciduous plot was 1137 trees ha^{-1}, and total DBH was 216.2 m ha^{-1}. Litterfall was collected in each site during the snow accumulation and ablation periods. The dry weight of the winter litterfall in the coniferous site (1809.9 kg ha^{-1}) was 3.8 times greater than the deciduous site (477.8 kg ha^{-1}) during the entire winter and 8.6 times greater (227.8 kg ha^{-1} compared to 26.1 kg ha^{-1}) during snowpack ablation. In both sites fine twigs (< 5 mm in diameter) were a major component of the litterfall, and in the coniferous site needles were also a high percent of the total. Litter accumulation varied over time because of weather events, and the litter composition and dry weight were unevenly distributed within the snowpack.

INTRODUCTION

Litterfall is often studied to better understand the dynamics of nutrient cycling and forest productivity, and is also important in determining the energy balance of a snowpack beneath a forest canopy. The presence of forest litter (Fig. 1) on and at shallow depths within the snowpack reduces the albedo of the snow (Melloh et al. in preparation), and can influence the rate of snowmelt (Hardy et al. 2000). There is very little literature that focuses exclusively on winter litterfall. Gosz et al. (1972) collected litterfall biweekly for an entire year in a northern hardwood forest in the Hubbard Brook Research Forest in New Hampshire. They reported that winter litterfall, including large branches and fallen trees, contributed 22.4% (1277.2 kg ha^{-1}) of total aboveground annual litterfall (5702 kg ha^{-1}). Al-Mufti et al. (1977) studied seasonal differences of litterfall at thirteen sites in the Sheffield region of England. They reported that tree litter in a hardwood forest remained high during the winter months, but fell off sharply in the early spring.

The purpose of this study was to compare litterfall collected in a predominantly coniferous and a predominantly deciduous forest during the snow accumulation and ablation season of 1998–1999. The two study sites are located at 550-m elevation within the W-9 sub-watershed of the Sleepers River Research Watershed (44^0 29′ 28″ N and 72^0 09′ 44″ W), near Danville, Vermont. This highland area of the Northern Vermont Piedmont region is known for long winters and heavy snowfalls that stay on the ground from early December until mid-April (Shanley et al. 1995).

METHODS

Forest Community Description

We sampled the two plots using plot-sampling methods described in Brower et al. (1990) and Daubenmire (1968). In each plot (22 m × 22 m, 0.05 hectares) we measured the diameter at breast height (DBH) (diameter measured at 1.5 m above ground) for each tree taller than 2 m (living and dead). We estimated percent canopy cover based on basal area (area of cross section of living trees

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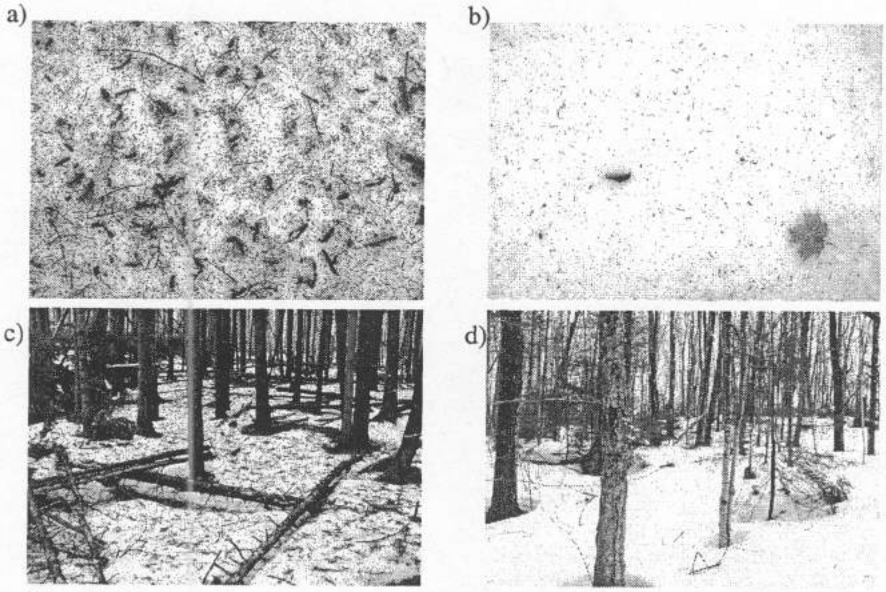

Figure 1. Litter on a late lying snowpack in coniferous and deciduous plots, 8 April 2000.
a) coniferous litter, b) deciduous litter, c) coniferous plot, and d) deciduous plot.

at 1.5 m above ground), and recorded the total number of trees of each species per hectare, and the percent of dead trees per species. Percent canopy cover for each plot was also calculated using a convex spherical crown densiometer as described by Lemmon (1957). Readings were taken at each of eight sites within the plots, located radially from a central point, and varying from 9- to 12-m distances from the center. The average percent canopy cover for each plot was calculated from these eight calculations. The eight sites coincide with radiation instrumentation sites of Melloh et al. (in preparation). For the shrub layer (woody plants taller than 0.5 m and shorter than 2 m) we counted each separate stem below breast height and calculated the number of stems per hectare for each species as well as relative density based on percent of stems per species. Herbaceous and woody groundcover < 0.5 m were not recorded. Fallen trees and branches littering the forest floor were described along a 2-m-wide transect through the center of each plot on the north–south axis. Percent deadfall cover was estimated visually using a 2-m × 2-m square that was placed every 2 meters. Deadfall was recorded as either 0, or in one of five 20%-increment classes ranging from > 0 to 100% cover. The average height of the trees varied little, and was estimated by averaging the height of 5–7 trees per plot using a Suunto clinometer.

Litter Collection

Baskets were our primary method of litter collection for comparing the relative amounts and types of litterfall. We collected litter in 1.5-bushel baskets made of a plastic mesh design and with top openings measuring 0.37 m wide, 0.50 m long, and 0.28 m deep. Six full-season baskets were set out in each plot at approximately the time of the first snowfall and remained in place throughout the winter and early spring (17 November, 1998 through 23 April, 1999) (Fig. 2). The baskets became buried under the snowpack and collected both snow accumulation and ablation phase litter that accrued in the baskets as the snow melted. Six additional baskets were set out on 16 March and emptied four times between 16 March and 23 April, to quantify litter that fell during snow ablation only (Fig. 2). Six baskets represent a total sample area of 22.9 m^2 ha^{-1} of study plot. In a review of other litterfall studies that tested the accuracy of littertrap designs in estimating litterfall (Robinson, unpublished file report), we found that our collection design fit well within the range for both size and number of litter traps per site used in other studies.

Filter-cloth traps were used to determine whether or not litter was deposited evenly over time. Within each forest site, two 1-m by 1-m filter cloths (woven polyester filter fabric with a nominal

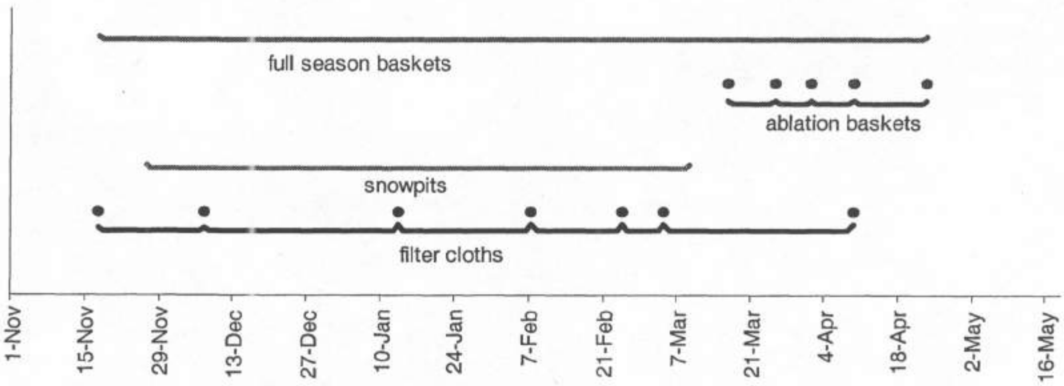

Figure 2. Time interval of litter collection by method during the winter and spring of 1998–1999.

particle retention rating of 50 microns) were laid on the surface of the snow and held in place by dowels that slipped through reinforced holes in each corner. These were set out on 17 November, 7 December, 13 January, 7 February, 24 February, and 4 March, each one being stacked on top of snow and litter that fell between the set-out dates (Fig. 2). The layers of snow and litter trapped between the dated filter cloths were harvested after the end of the snow accumulation period. We observed that newly placed filter cloths would flop in the wind until snow covered them and held them down. Because of this we excluded uncertain data intervals from the analyses.

Snowpit sampling was used to document whether or not the litter was distributed evenly throughout the snowpacks. Snow and litter were excavated from snowpits in both forest sites near the time of peak snow accumulation (9 March). The horizontal dimensions of the excavated samples were 0.4 by 0.31 m. There were five layers, each 10 cm deep, in the coniferous snowpit, and five layers, each 16 cm deep, in the deciduous snowpit.

All litter and associated snow samples were initially collected into white polyethylene bags and transported to a common site at the basin outlet. To ensure the litter would not be lost in the event that the polyethylene bags ruptured, the bags were placed inside of white filter-cloth bags. These were left in the field until the end of the ablation period and then transported to the laboratory. To separate litter from the melted snow, the samples were filtered through the filter-cloth bags. The filtered litter was placed into small, clear plastic bags, labeled, and stored in a refrigerated room at 2° C. In order to compare the quantity of litter gathered at different times and from different sites, each litter sample was oven-dried at 70° C for 48 hours and immediately weighed.

Litter samples were separated into six categories: 1) fines, defined as materials that fell through a 2-mm-mesh metal sieve; 2) > 2 mm, defined as items caught in a 2-mm-mesh sieve; 3) needles; 4) fine twigs defined as those with a diameter < 5 mm; 5) large twigs, defined as those with a diameter equal to or > 5 mm and < 1 cm; and 6) branches defined as those with a diameter equal to or > 1 cm. The > 2-mm category consisted of leaf parts, cone parts, lichens, catkins, bracts, and bark, and excluded needles, twigs, and branches. These categories are comparable to those cited in similar studies (McShane et al. 1983). The percent dry weight of each category was calculated for each litter sample, and the diameter and length of each twig were recorded in order to approximate the surface area of the twigs. We must emphasize that our sampling strategy allowed for the capture of small litter materials and cannot be directly compared with studies that included large litter materials. One large branch and a tree crown that fell onto our sampling devices were removed, and excluded from analyses.

Given the importance that the percent surface cover of litter may have on snowpack albedo (Hardy et al. 2000; Melloh et al. in preparation), and the importance of twigs as an indicator of weather events (Bray and Gorham 1964, Gosz et al. 1972), we decided to estimate twig area differences between the coniferous and deciduous sites. This was done by measuring twig dimensions as the twig would lie on the ground.

RESULTS

Forest Community Description

The coniferous plot is a spruce–fir plant community with red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*) the dominant canopy species. The density of trees taller than 2 m in the plot, both living and dead, was 2127 trees ha^{-1}, and total DBH was 360.6 m ha^{-1} (Table 1). Nineteen percent of the red spruce were standing dead, and the DBH of living trees was 91.5% of the total. The average of the eight densiometer readings in the plot provided an estimate of 89.4% canopy cover. The average tree height was 25 m and crown height was 8 m. There was no shrub–sapling layer between 0.5 m and 2 m in the coniferous plot, though there were many small balsam fir seedlings of less than 0.5-m height (Table 2). The forest floor was covered with dead branches and fallen dead trees. None of eleven 2-m squares laid along a 2-m-wide N–S transect through the center of the plot were without some deadfall, and almost half had over 30% cover. The dead branches and trees stood as high as 0.8 m above the ground, though the median height was 0.11 m. The median diameter of deadfall was 0.08 m.

The deciduous site is a northern hardwood forest community with sugar maple (*Acer saccharum*) and red maple (*Acer rubrum*) the most common species in the canopy. The density of trees taller than 2 m in the plot, both living and dead, was 1137 trees ha^{-1}, and total DBH was 216.2 m ha^{-1} (Table 1). Total DBH of living trees was 89.8% of the total DBH for the plot. The average hardwood tree height was 26 m, average spruce–fir crown height 5.5 m, and average spruce–fir tree height, 15.9 m. The average of the eight densiometer readings in the plot provided an estimate of 89.4% canopy cover. The two dominant species in the shrub–sapling layer were striped maple and sugar maple (Table 2). There was very little deadfall on the forest floor of the deciduous plot. Only two of eleven 2-m × 2-m squares laid along a 2-m-wide N–S transect down the center of the plot had any deadfall, and this was minimal (10% cover in each).

Litterfall Comparisons

The makeup of litterfall in the fine and > 2 mm categories was similar within the coniferous and deciduous plots. Fines (litterfall < 2 mm) consisted of seeds, small resin balls, broken wings from conifer and birch seeds, dirt, bark, and parts of leaves and needles. There were more fine cone parts and broken needles in the coniferous site, and more seeds, wings from seeds, and broken leaf parts in the deciduous site. Litterfall > 2 mm (Fig. 3 a–g) (excludes needles or twigs) was made up of cone scales, cone bracts, birch bracts, winged conifer and birch seeds, bark, lichen, resin from the balsam fir, unopened buds, and leaf parts and leaf stems. Entire leaves were not a significant part of the litterfall in either site. In the coniferous site, the dominant components > 2 mm consisted of cone parts and bark, as well as many resin balls from the balsam fir. In the deciduous site leaf parts and stems, seed-bearing bracts from the female cones of the white and yellow birch trees, and winged-birch seeds dominated this category. Cone spikes from the balsam fir trees (Fig. 3h) were included in the large twig category.

The bulk composition of litterfall differed between coniferous and deciduous plots and by season (Fig. 4). While fine twigs were the dominant component of both the coniferous and deciduous litter over the full season (37% and 33%, respectively), twigs increased in predominance in the coniferous during the ablation season (42%) while the dominant litter type shifted to the > 2-mm category in the deciduous plot (49%). Large twigs were an important component in both sites during the full season, but not during ablation. Needles were a consistently important component of litter in the coniferous plot in both full-season and ablation baskets (21.6% and 35.6%, respectively). Needles were relatively unimportant in the deciduous plot during the winter as a whole (6%), but made up a surprising percentage (20%) of the litter in the deciduous plot in the spring. Needles blew into the deciduous plot from surrounding areas and from the few coniferous trees within the predominantly deciduous plot.

The litter collected in full-season baskets indicates a rate of litterfall of 11.5 kg ha^{-1} day^{-1} dry weight in the coniferous site (Fig. 5a). This is 3.8 times greater than the 3.0 kg ha^{-1} day^{-1} collected in the deciduous. The ablation-season litterfall rates in the coniferous site (Fig. 5a) were 8.6 times the deciduous site (6.0 compared to 0.7 kg ha^{-1} day^{-1}). Litterfall rates varied moderately over the four time intervals of ablation, between 16 March and 23 April (Fig. 5b), and coniferous litterfall was greater than deciduous litterfall during each interval of time.

Table 1. Tree species in coniferous and deciduous plots.

	Trees ha^{-1} (living and dead)	Percent dead	DBH* m ha^{-1} (living and dead)	DBH* m ha^{-1} (living)	BA** m^2 ha^{-1} (living)	Percent cover (living)
Coniferous species						
Picea rubra	1198	19	170	144.9	18.1	35.8
Abies balsamea	888	2.3	183.2	180.7	31.6	62.8
Betula papyrifera	41	50	7.4	4.3	0.7	1.4
TOTAL	2127		360.6	329.9	50.4	100
Deciduous species						
Acer saccharum	434	0	84.1	84.1	15.7	40.7
Acer rubrum	165	0	45.2	45.2	10.4	26.9
A. saccharum or A. rubrum (dead)	62	9.4	8.7			
Betula allegheniensis	165	0	33.9	33.9	7.6	19.7
Acer pensylvanicum	145	0	11.6	11.6	0.7	1.8
Picea rubra	124	33.3	22.1	8.9	1.3	3.4
Fraximus americana	21	0	8.5	8.5	2.7	7.0
Fagus grandifolia	21	0	2.1	2.1	0.2	0.5
TOTAL	1137		216.2	194.2	38.6	100

* DBH: diameter at breast height

** BA: basal area

Table 2. Species in shrub/sapling layer (> 0.5 m and < 2 m).

Forest type	Species	Shrub/sapling ha^{-1} (> 0.5 m and < 2 m)	Relative density (percent)*
Coniferous	None		
Deciduous	*Acer pensylvanicum*	1484.3	51.0
	Acer saccharum	1260.3	43.3
	Picea rubra	62.0	2.1
	Abies balsamea	62.0	2.1
	Fagus grandifolia	41.3	1.4
	Total	2909.9	100.0

*Number of stems ha^{-1} of a species divided by total number of stems ha^{-1} of all species

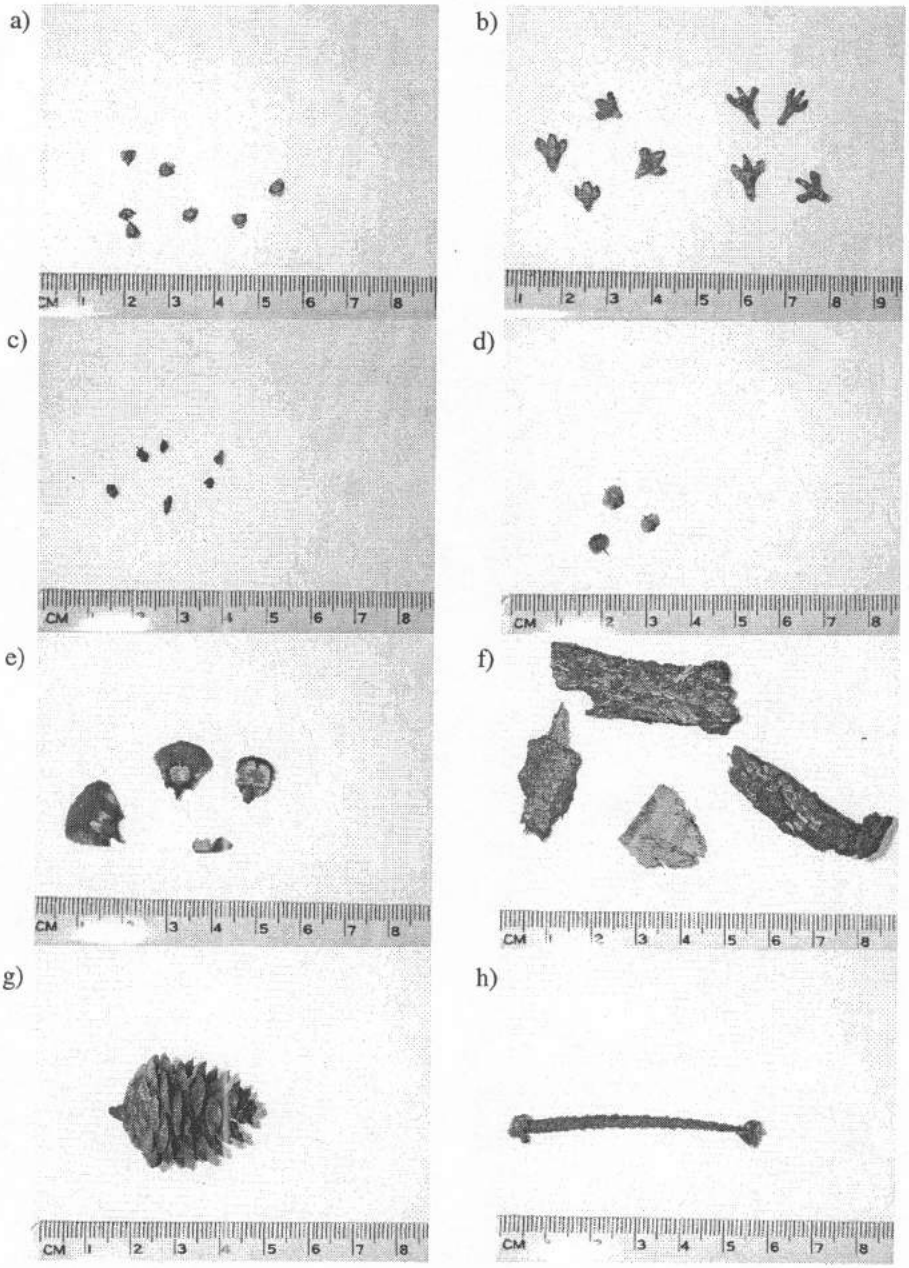

Figure 3. Examples of litter components.

a) birch seeds, b) white (left) and yellow (right) birch bracts, c) balsam fir resin balls, d) balsam fir cone bracts, e) balsam fir cone scales with bracts (left), red spruce scale with winged seeds (right), red spruce winged seed (below), f) pieces of bark, g) red spruce cone, and h) balsam fir cone spike.

The dry weight of litter collected in filter cloths also supports higher litter rates in the coniferous plot and higher rates of litterfall early in the winter (Fig. 6). The total area of twigs per day (Fig. 7) in the coniferous site was 4.9, 26.7, and 7.8 times that of the deciduous site in the full-season baskets, ablation-season baskets, and on filter cloths, respectively. The layered samples from the snowpit excavation showed large vertical variability of dry weight of litter within the snowpack at a time near maximum accumulation (Fig. 8) on 9 March. The composition of litter also varied from layer to layer.

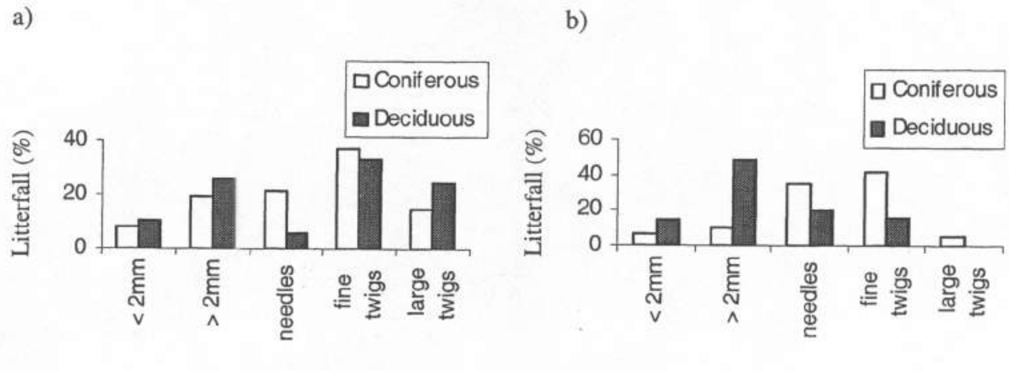

Figure 4. Percent litterfall by category collected in baskets.
a) full season, and b) ablation.

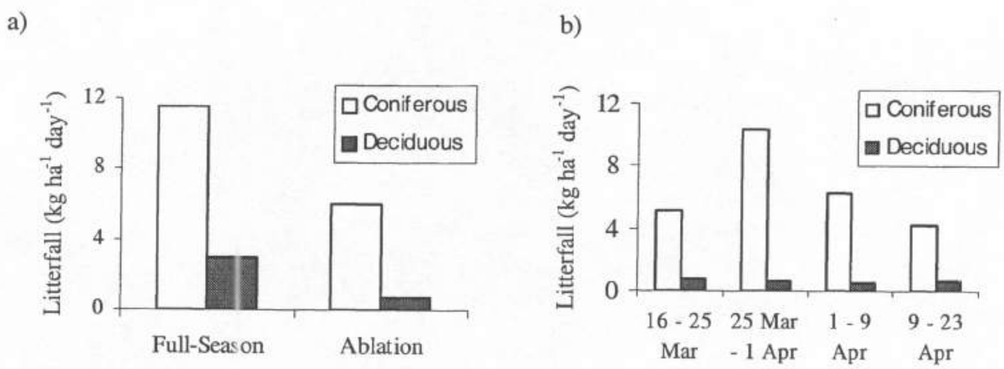

Figure 5. Dry weight of litterfall per day that fell in baskets for
a) the full season and ablation, and b) intervals during ablation.

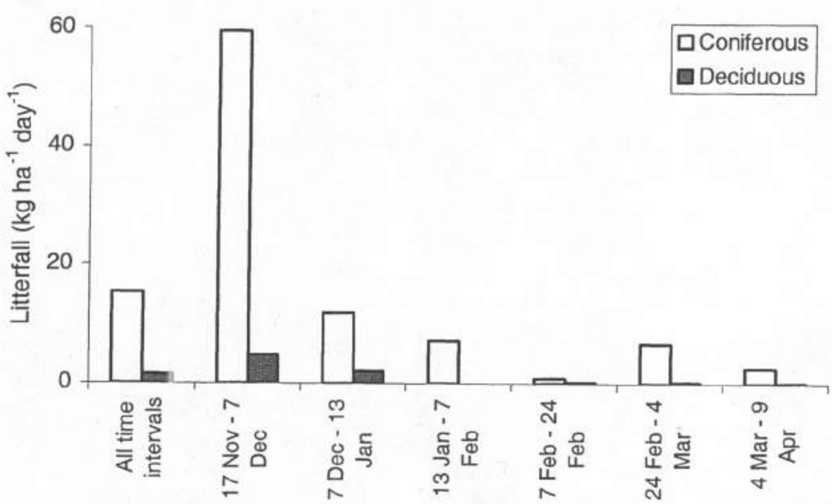

Figure 6. Litter rates over time intervals that fell on filter cloths. Rates for the 13 January to 7 February interval in the deciduous plot were excluded due to poor capture.

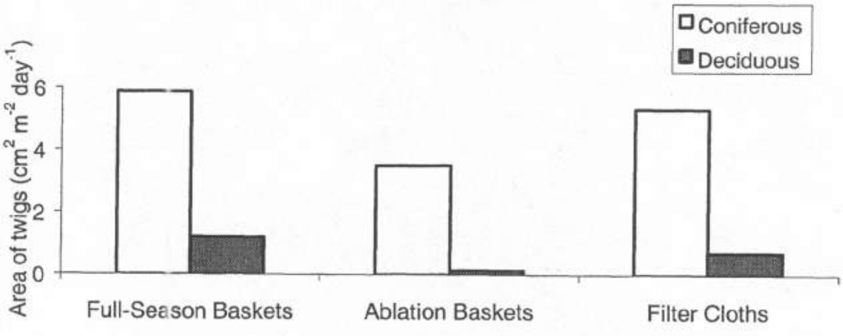

Figure 7. Surface area of twigs that fell in collection baskets and on filter cloths.

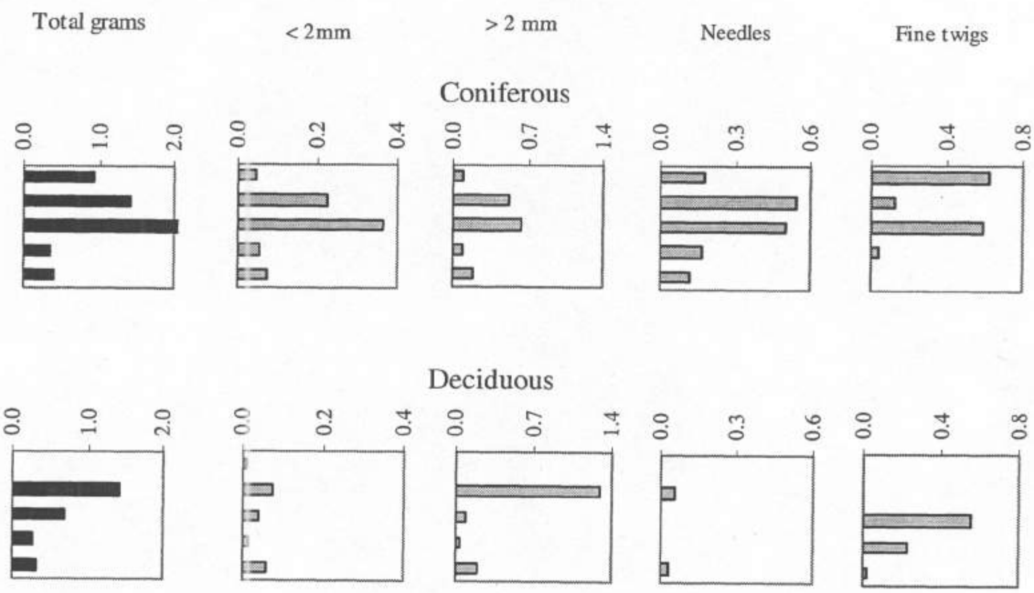

Figure 8. Litter distribution by category within the five snowpack layers at one location in each forest plot.

DISCUSSION

Comparison of the Two Forest Communities

There were 990 more trees per hectare in the coniferous plot than in the deciduous plot, and the trees there also had a greater total DBH (Table 2). The minor difference in percent cover calculated using a convex spherical crown densiometer (89.4% for the coniferous plot and 83.5% for the deciduous plot) did not adequately reflect the relative transmittance of solar radiation in the two plots of 10% in the coniferous and 43% in the deciduous (Melloh et al. in preparation). There was more species richness in the canopy layer in the deciduous plot than in the coniferous plot (seven species compared to three), and there was a substantial shrub–sapling layer in the deciduous plot that was totally lacking in the coniferous plot. Finally, there was much more deadfall in the coniferous plot than the deciduous plot.

Litterfall Composition

The morphology and reproduction of the dominant plants in these sites helped determine the type of litterfall. Female catkins in both paper birch and yellow birch mature in the fall. Paper birch drops most of its seed-bearing bracts at maturity, but yellow birch retains some of its bracts, which continue to fall through the winter. Birch seeds are small, flat nutlets with paper-thin wings extending from their sides (Fig. 3a). These are produced in large numbers and are dispersed over a broad area by the wind. Both birch bracts and seeds were abundant in the deciduous site litter (> 2 mm), and were also found in the coniferous site. The smaller seeds and pieces of wings were found in the fines category. Balsam fir and red spruce also distribute their seeds in the fall, but by different methods. Balsam fir cones break apart on the tree at maturity, dropping winged-seeds, cone scales, and bracts, leaving a naked cone spike on the tree (6–7 cm long) (Fig. 3h). These spikes were found in the litter and were counted as large twigs (with a diameter equal to or > 5 mm and < 1 cm). Red spruce cones remain on the tree after maturity, opening and distributing their seeds before falling during the first winter after maturity. They are, however, torn apart both in the trees and on the ground by red squirrels that favor their seeds. Few entire red spruce cones were collected in this study, but cone scales and seeds were.

Many 1- to 4-cm-long fine twigs were found in the litterfall in both sites, though the numbers were greater in the coniferous site. These could be the results of red squirrels foraging in the conifers in the early spring breaking off the tips of spruce and fir branches, as well as winter icing and wind events that break tips of conifer branches. Conifer tips were separately counted as tips and twigs, because the needles fell off of these branch tips during the drying process. Deciduous leaf litter was not abundant in this study since the litter traps were set out in mid-November, which is after peak leaf fall in this area (September to mid-October).

Comparison of Litterfall to Other Studies

Gosz et al. (1972) found that branch fall (defined as twigs < 10 cm in diameter) was a good indicator of weather events. The differences in litterfall rates between time periods in this study can be partially explained by weather. The filter cloth samples that collected during a late November storm accounted for 55.7% of all twigs in the coniferous site in the filter cloths and 72.2% of all twigs in the deciduous site (Fig. 6). The weather event included ice buildup on November 26th followed by windy days through the end of November. This layer of twigs was at the very base of the snowpack and was not represented in the snowpit excavations. In a multiple-year study, Bray and Gorham (1964) reported that annual leaf and needle litterfall was more consistent from year to year than was stem fall. In our study, the sampling method with the fewest twigs (the ablation baskets) had the more consistent daily litterfall across time intervals.

Gosz et al. (1972) reported that 75% of total annual branch fall occurred during the winter months in a northern hardwood forest, and Al-Mufti et al. (1977) found that tree litter in a hardwood forest in England remained high during the winter months, but fell off sharply in the early spring. Similarly, the results of our study indicate that litter fall rates were higher during the snow accumulation than the ablation period. More twigs may fall in the winter when they are brittle and easily broken by winter storms than in early spring storms. In our study the total number of twigs (m^{-2} day^{-1}) was greater in the full-season baskets than in the ablation baskets, which only collected during snowmelt (Fig. 4). There was also a higher percent of larger woody items in the full-season baskets. In the coniferous site twigs > 5-mm diameter accounted for 14.5% of the total in the full-season baskets, and only 5.7% in the ablation baskets (Fig. 7). In the deciduous site twigs > 5-mm diameter accounted for 24.6% of the total in the full-season baskets, and 0% in the ablation baskets.

CONCLUSION

The difference in both quantity and type of litterfall, in a spruce–fir (*Picea rubens–Abies balsamea*) community compared to a sugar maple–beech–yellow birch (*Acer saccharum–Fagus grandifolia–Betula allegheniensis*) community, was revealed. Litter collected in full-season baskets at a rate of 11.5 kg ha^{-1} day^{-1} dry weight in the coniferous site, 3.8 times higher than the 3.0 kg ha^{-1} day^{-1} rate in the deciduous site. Litter collected in ablation-season baskets at a rate of 6.0 kg ha^{-1} day^{-1} dry weight in the coniferous site, 8.6 times higher than the 0.7 kg ha^{-1} day^{-1} rate in the deciduous site. In both sites fine twigs (< 5 mm in diameter) were the main component of litterfall when averaged over the entire winter season (37% coniferous and 33% of deciduous litterfall). During ablation, fine twigs remained predominant in the coniferous site (42%) but were less important in the deciduous site where the 2-mm category (including seeds, bracts, bark, and resin balls) became predominant (49%).

The quantity of litter entering the nutrient cycle seasonally, or lowering snow albedo temporally in the winter and spring, is likely to be strongly influenced by storms. Litter did not fall at a steady rate during this study showing peaks and lulls, most markedly reflected in the filter cloth and snowpit layers. Weather appears to explain many of these differences. Over half of the total litter fell on the filter cloths in both sites during a time period that included a major early winter ice and wind storm. The rate of litterfall was much more consistent during ablation, when no major storms occurred.

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