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The effect of collector size on forest litter-fall collection and analysis

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Litter fall is commonly collected for a variety of ecological studies. This study was designed to test the effect of collector size on the precision of forest litter-fall estimates and on the time involved in laboratory sample sorting. Collectors varied in size from 0.010 to 0.933 m^2 and were physically nested, the smaller units within larger units. Ten of these collector combinations were randomly placed on a 1-ha plot in a Douglas-fir/western hemlock (*Pseudotsuga menziesii* (Mirb.) Franco/*Tsuga heterophylla* (Raf.) Sarg.) stand in H. J. Andrews Experimental Forest. Collections were made monthly and records were kept of the time required to sort the litter into needles, epiphytes, and miscellaneous categories. Based on a definition of precision as ±10% of the mean, 90% of the time, results indicate (*i*) that the cost of obtaining precise estimates of needle fall decreases with decreasing collector size to 0.010 m^2, (*ii*) that collectors of any size can be used to obtain estimates of total litter fall if the number of collectors required to obtain precise results is determined, and (*iii*) that precise estimates of epiphyte biomass require large numbers of samplers and are not cost effective.

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La cueillette de litière est une opération courante pour des études écologiques diverses. La présente étude fut entreprise dans le but de déterminer l'effet des dimensions des collecteurs sur la précision des estimations de litière et sur le temps consacré en laboratoire à la séparation des constituants. À cette fin, on a disposé une série de collecteurs (0,010 à 0,933 m^2) les uns dans les autres en batterie concentrique. Dix de ces batteries furent placées aléatoirement dans une placette de 1 ha sous couvert de *Pseudotsuga menziesii* (Mirb.) Franco et *Tsuga heterophylla* (Raf.) Sarg., dans la Forêt Expérimentale H. J. Andrews. Les cueillettes étaient mensuelles et on a noté le temps requis pour la séparation des constituants (aiguilles, épiphytes et autres catégories). Pour une précision définie comme étant ±10% de la moyenne à 90% du temps, les résultats montrent que: (*i*) le coût nécessaire à l'obtention d'estimations précises de la litière d'aiguilles décroît avec la diminution des dimensions des collecteurs jusqu'à 0,010 m^2; (*ii*) des collecteurs de toutes dimensions peuvent être utilisés pour des estimations de la litière totale si le nombre de collecteurs requis pour obtenir une précision donnée est prédéterminé; (*iii*) les estimations précises de biomasse d'épiphytes requièrent un grand nombre de collecteurs et sont coûteuses.

[Traduit par le journal]

Introduction

Litter fall is commonly collected for ecosystem-level research on nutrient cycling, biomass distribution, decomposition, and productivity. In many forest studies litter fall is collected monthly for at least a year and then dried, sorted into categories such as needles and (or) leaves, twigs, cones, etc., and weighed.

Sampling designs used for litter-fall collection vary, even in research on similar species. In the central Oregon Cascades, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) litter fall has been measured using simple random sampling and varying numbers of 0.26-m^2 traps (Grier and Logan 1977; Abee and Lavender 1972). In Alaska, litter fall from a Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stand was collected with 10 collectors, each 0.19 m^2 in size, arranged along a single transect (Hurd 1971). In Ireland, Sitka spruce litter fall was collected with two 1.0-m^2 samplers per 250-m^2 plot (Adams et al. 1980). A study in Australia used three different collector sizes ranging from 0.18 to 0.27 m^2 to sample litter fall from four coniferous species (Spain 1973). The sampling design of a study at Hubbard Brook Experimental Forest was based on the desired precision of litter-fall estimates. To obtain estimates with a standard error less than 10% of the mean, litter fall was collected in forty-five 0.224-m^2 traps placed randomly on a 12.23-ha plot (Gosz et al. 1972).

As Gosz et al. (1972) recognized, the precision of litter-fall estimates depends partly on the size and number of collectors used for litter-fall sampling. Although rarely addressed in the literature on litter-fall estimation, the cost of sampling also depends partially on the size and number of collectors used. Generally, the cost of a sampling program increases with the size and number of collectors. Minimizing the cost of sampling while maintaining estimates with a high level of precision is a desirable objective for any sampling effort and is particularly important for long-term research programs.

We are currently developing methods appropriate for detecting subtle, slowly paced changes in forest eco-

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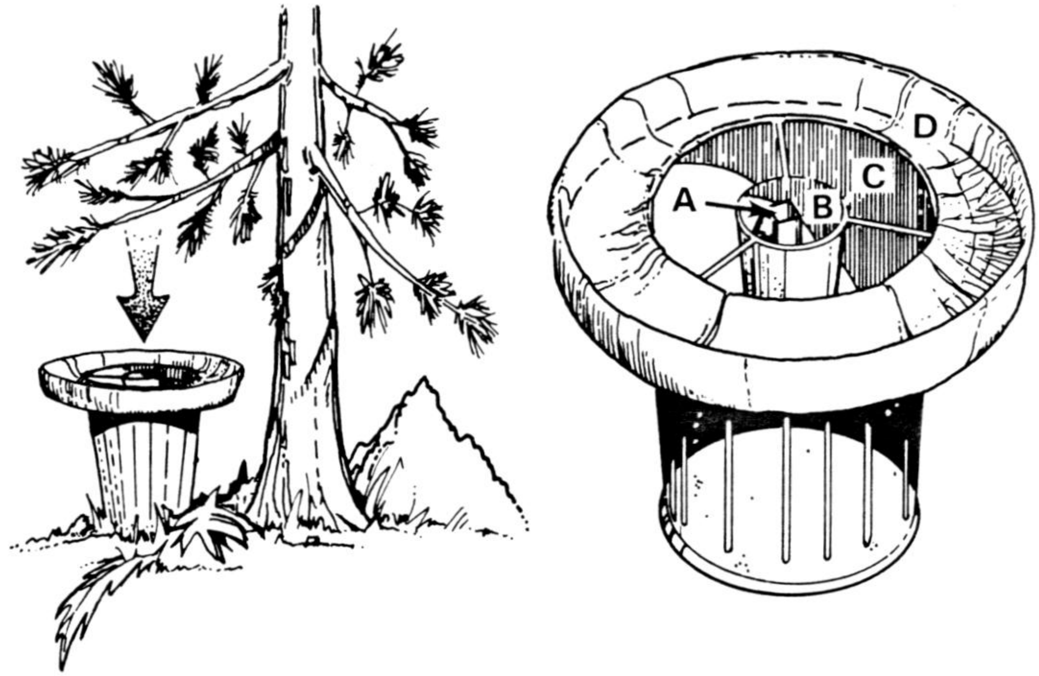

FIG. 1. Sampler design. The four discrete collection areas are $A = 0.010\ m^2$ (freezer container); $B = 0.035\ m^2$; $C = 0.159\ m^2$; and $D = 0.729\ m^2$. Three composite collector areas were also compared: $A+B = 0.045\ m^2$ (bucket); $A+B+C = 0.204\ m^2$ (trash can); and $A+B+C+D = 0.933\ m^2$ (swimming pool).

systems. As one step in this process, we collected litter fall in variously sized traps and accounted for the time necessary to process the samples. The objectives of this study were to determine, for a particular forest stand, (*i*) the optimal size and number of collectors needed to obtain precise estimates of litter fall, (*ii*) the cost of acquiring these estimates, and (*iii*) the most cost-effective collector size for litter-fall estimates.

Materials and methods

Site description

The study area was located in H. J. Andrews Experimental Forest, which is on the west slope of the Cascade Mountains, about 81 km (50 miles) east of Eugene, OR. The litter fall collectors were placed on a 1-ha plot encompassing a portion of a research stand (southwest corner of reference stand 2). The area is on a pediment surface and about half of the plot was steeply sloped with a gradient of about 35% and a west-northwest aspect. The remainder was part of a fan terrace from a draw on the hillside. Soils are deep and well drained and the site is mesic (Hawk et al. 1978). The plant community is classified as *Tsuga heterophylla/Rhododendron macrophyllum – Berberis nervosa*. Tree canopy is closed and consists of a mixture of dominant Douglas-fir and codominant western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Understory conifers are predominantly shade-tolerant western hemlock and a few western red cedar (*Thuja plicata* Donn.). The shrub layer is sparse; dominant species include Pacific yew (*Taxus brevifolia* Nutt.), vine maple (*Acer circinatum* Pursh.), western rhododendron (*Rhododendron macrophyllum* G. Don), Oregon grape (*Berberis nervosa* Pursh.), and red huckleberry (*Vaccinium parvifolium* Smith). Herbaceous cover is moderate. Oregon beaked moss (*Eurhynchium oreganum* (Sull.) Jaeg. & Sauerb.) provides extensive ground cover (Hawk et al. 1978).

Litter-fall collection and analysis

Collectors used in this study were physically nested as a single unit to minimize the effects of collector location on litter-fall sampling (Fig. 1). The smallest collector was a square freezer container with an area of $0.010\ m^2$. It was clipped inside a circular polyethylene bucket that had an area of $0.045\ m^2$. The collecting area between the freezer container and bucket rims was $0.035\ m^2$. The bucket was suspended inside a circular trash can using electrical tie clamps. The total area of the trash can was $0.204\ m^2$; the open ring between trash-can and bucket rims had an area of $0.159\ m^2$. A child's swimming pool surrounded the trash can. The collection area between the pool rim and the trash can was $0.729\ m^2$. The surface area of the pool, and therefore the entire combined collector, was $0.933\ m^2$. Thus seven litter-fall collectors of different sizes were compared in this study: four discrete collection areas and three composite collecting areas formed by the bucket, trash can, and pool. Since the focus of this research was on the collection of small litter components, collector shape was not a factor, although it is possible that shape as well as size affects litter-fall estimates. The rims of each collector were level with the rim of the swimming pool. With the trash can acting as the support base

TABLE 1. Annual litter fall (kilograms per hectare per year) (± 1 SD) from seven different-sized collectors in a Douglas-fir/western hemlock stand (July 1980 to July 1981)

Sampler size[a]	Conifer needles	Epiphytes	Miscellaneous[b]	Total litter
0.010	1917±332.7	115±280.6	1121±2088.8	3153±2422.5
0.035	1909±312.7	59±55.2	969±730.5	2936±783.0
0.045	1937±312.0	71±63.9	1003±966.0	2984±1075.8
0.159	1931±319.5	47±55.4	1115±698.4	3099±897.6
0.204	1931±306.5	52±42.5	1090±580.0	3074±770.4
0.729	1822±326.9	45±25.3	756±311.0	2623±617.0
0.933	1846±315.4	46±20.0	829±336.4	2722±613.2

[a]Units are in square metres.
[b]Includes bark, twigs, cones, bud scales, and unidentifiable material.

for the entire sampler unit, the trap surface was approximately 1 m above ground level. Ten of these collector combinations were randomly placed within the 1-ha plot. Collectors located on a slope were placed so that the collecting surface was level.

Accumulated litter fall was collected every 4 weeks. Samples were oven-dried at 50°C for 72 h and then sorted. Needles, epiphytes, and miscellaneous debris (twigs, bark, cones, bracts) in each of the four discrete collectors were weighed and total litter-fall weight per month was determined by adding these components. For the three composite collecting areas, litter-fall weights were estimated by adding the weights of litter fall from the appropriate distinct collectors. Careful records were kept of the time required to sort litter fall from each of the collectors.

For each collector size, the number of collectors needed to obtain an estimate of mean monthly litter-fall, needle-fall, or epiphyte biomass with a specified precision was calculated according to the equation $N_{ij} = (t^2)(S_{ij}^2)/d^2$ (Cochran 1977). In this equation, N_{ij} represents an approximation of the number of collectors needed to estimate the mean from collector size, i, during sampling period, j (month). The term t^2 is the critical value of the t statistic squared for a specific α level (we chose 0.10) and sample size (in this study, $n = 10$). S_{ij}^2 refers to the sample variance of the estimate for collector size, i, and collection period, j. Finally, d^2 indicates the limit within which we would like the estimate of litter-fall, needle-fall, or epiphyte biomass to be. We chose to place this limit within $\pm 10\%$ of the mean, 90% of the time. Throughout this paper precision will be defined as $\pm 10\%$ of the mean, 90% of the time. Approximations of sample sizes are based on a single application of the formula for N_{ij}.

The function used to obtain the cost of an estimate of mean needle fall or epiphyte amount with a predetermined precision was $C_{ij} = (\bar{c}_{ij})(N_{ij})$. In this equation $\bar{c}_{ij}$ is the mean cost, in hours, associated with sorting the litter from collector size, i, during sampling period, j. The term C_{ij} is the total cost of obtaining an estimate from collector size, i, during sampling period, j.

Results

Litter fall

Estimates of annual needle fall were very similar for all collector sizes (Table 1). The greatest difference, 115 $kg \cdot ha^{-1} \cdot year^{-1}$, was between the needle-fall estimate from the bucket ($A = 0.045$ m^2) and the needle-fall estimate from the pool ring ($A = 0.729$ m^2). Coefficients of variation (CV) for all collector sizes were less than 18%. No consistent trend in standard deviation with increasing collector size was observed.

The seven collectors did not provide similar annual estimates of total litter, epiphytes, and miscellaneous debris. In general, the estimates from the smallest collector ($A = 0.010$ m^2) were higher than those of other collectors. For example, the annual estimate of epiphyte biomass from the smallest collector was nearly 3 times greater than estimates from the two larger collectors. The standard deviations of the estimates for the two nonneedle categories and total litter also tended to decrease with increasing collector size. For example, the coefficient of variation for the estimate of litter fall collected from the smallest collector was 77%; for the largest sampler this value decreased to 22%.

Despite nearly a 100-fold range in area, no consistent relationship could be detected between collector size and the number of collectors required to estimate monthly litter fall or needle fall precisely (Figs. 2 and 3). Within this size range the numbers of collectors required were similar and did not decrease with increasing collector size. However, the bucket, with an area of 0.045 m^2, required the fewest number of collectors to estimate monthly litter fall and needle fall precisely.

In general, more collectors were needed to estimate mean monthly litter fall precisely than were required to obtain the same precision for mean monthly needle-fall estimates: 31−58 collectors were needed for litter fall compared with 20−34 for needle fall. It is most likely that in estimating litter fall precisely, larger numbers of collectors are required because litter fall is more heterogeneous than needle fall, and variability among collectors is therefore greater, regardless of size.

The lack of homogeneity in epiphyte distribution is reflected by the number of samplers required to obtain

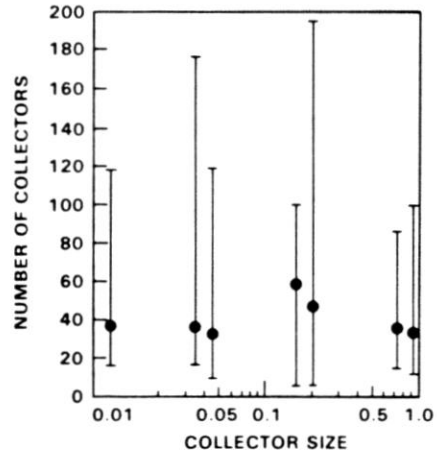

FIG. 2. Median (N = 12) number versus size (square metres) of collectors required to estimate monthly litter fall within ±10% of the mean 90% of the time (bars respresent range).

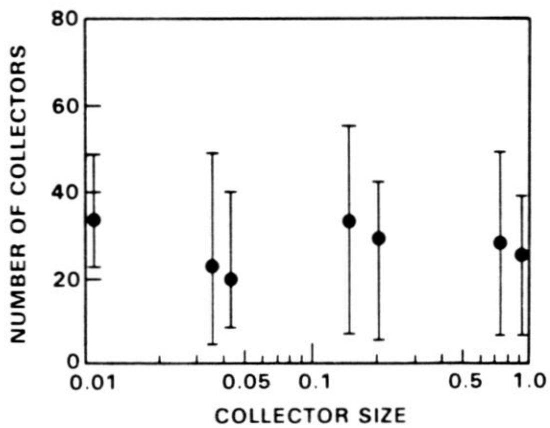

FIG. 3. Median (N = 12) number versus size (square metres) of collectors required to estimate monthly needle fall within ±10% of the mean 90% of the time (bars represent range).

precise monthly epiphyte estimates. The median number of collectors required decreased as collector size increased (Fig. 4). Regardless of size, however, it would be necessary to use large numbers of collectors to obtain precise monthly epiphyte estimates: 100–200 times the number needed for needle-fall estimates of the same precision.

Sorting-time analysis

As expected, the cost of sorting litter increased consistently with the size of the collector (Table 2). Compared with the smallest collection area, the largest required 38 times more effort to process. Sorting-time estimates for the three composite collector areas could not be calculated because sorting rate varied with col-

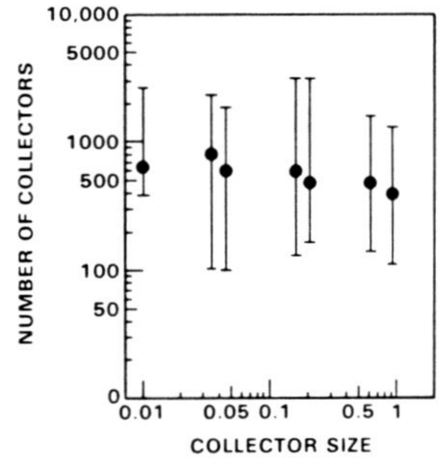

FIG. 4. Median (N = 12) number versus size of collectors required to estimate monthly epiphyte biomass within ±10% of the mean 90% of the time (bars represent range).

TABLE 2. Mean (n = 10) time required, per collector, to sort and weigh annual litter accumulation from each of four collector sizes (±1 SD)

Collector size (m^2)	Sorting time (h)	Coefficient of variation (%)
0.010	0.96±0.10	10.3
0.035	1.86±0.13	7.0
0.159	9.60±1.46	15.2
0.729	35.89±6.2	17.4

lector size. As a result, only the actual sorting times recorded for each of the discrete collection areas were used for analysis. Two factors probably contribute to the inconsistent relationship between collector size and sorting rate. First, keeping track of exact sorting times is difficult. For example, if a sample from the largest collector took 125 min to process, a measurement error of ±5 min is only a small percentage of the total sorting time. If, however, a sample from the freezer container took only 3 min to sort, a timing error of ±1 min is a substantial portion of the sorting time. Therefore the relative precision of the sorting-time measurements was variable. Time measurements for the smaller samples were probably more prone to error. Second, sorting litter was a tedious job and technician sorting rate may have varied in relation to collector size.

Discussion

Annual litter-fall and needle-fall estimates in this study were close to those reported by other investigators for similar forest communities. For example, litter fall from nine Douglas-fir stands (>40 years in age)

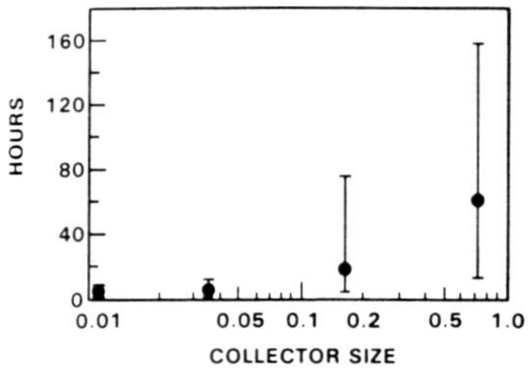

FIG. 5. Median (N = 12) number of hours required to estimate monthly needle fall within ±10% of the mean 90% of the time from four different collector sizes (square metres) (bars represent range).

in western Washington ranged from 2140 to 5130 kg·ha^{-1}·year^{-1} and average needle fall was between 1550 and 2690 kg·ha^{-1}·year^{-1}. In five mature Douglas-fir stands in H. J. Andrews Experimental Forest, the 2-year average for litter fall ranged from 3770 to 4265 kg·ha^{-1}·year^{-1} and for needle fall, from 1260 to 2065 kg·ha^{-1}·year^{-1} (Grier and Logan 1977). Between 1979 and 1981, 24 collectors (A = 0.045 m^2), located on the same plot as which this study was conducted, provided estimates ranging from 2780 to 3430 kg·ha^{-1}·year^{-1} for litter fall and 1910 to 2360 kg·ha^{-1}·year^{-1} for needle fall (M. C. McShane, unpublished data).

Estimating total litter fall for a particular forest stand does not require sorting the litter into components. Therefore, reducing costs associated with sorting is not a factor in studies with litter-fall estimation as an objective. Collectors of any size can be used if the number of collectors required to obtain precise results is determined. Using a larger number of available or easily constructed collectors may be more economical than constructing fewer collectors of a more appropriate size. However, because coefficients of variation for annual litter-fall estimates tend to decrease as collector size increases, it may be desirable to use a larger collector size to reduce estimates of annual variance if the collection is to span a period of years.

Cost is an integral part of estimating needle fall because needles must be separated from the litter. It is therefore logical to choose the collector size which gives the most precise data for the least amount of effort. For a given forest stand this choice involves determining (i) the number of each available collector size required to obtain precise monthly estimates and (ii) the cost of sorting the litter fall from that number of collectors. The results of this study suggest that for a Douglas-fir/western hemlock stand, using the appropriate number of either of the two smaller collectors (A = 0.010 or 0.045 m^2) will give precise estimates of monthly needle fall in less than 12% of the sorting time needed to obtain equally precise estimates from the largest collector (Fig. 5). In addition to being costly, using a larger sampler may not reduce the variance of annual estimates since the coefficients of variation for annual needle-fall estimates were similar for the collectors tested.

Estimating epiphyte biomass also requires sorting and again, the collector size chosen should be the one which gives the most precise data for the least cost. Very large numbers of collectors are needed to estimate monthly epiphyte fall precisely (Fig. 4); 625 of the smallest collector (A = 0.010 m^2) and 390 of the largest collector (A = 0.933 m^2). It would take about 1875 h to sort the litter from 625 small collectors and 23 000 h from 390 large collectors. If epiphytes were sorted into mosses, chlorophycophylous lichens, and cyanophycophylous lichens, some categories may prove considerably less variable than the composite. The cost of sorting may be offset by the fewer numbers of collections needed to estimate a particular epiphyte category precisely. However, a study with the sole objective of estimating epiphyte biomass in a particular forest stand should investigate alternative means of sampling.

Conclusions

In this study, four collectors were used to provide information on both cost and precision of litter-fall, needle-fall, and epiphyte estimates. Within the range of collector sizes studied, our results indicate that for a closed-canopy mature Douglas-fir/western hemlock stand, the cost of obtaining precise estimates of needle fall decreases with decreasing collector size to 0.010 m^2. Depending upon research objectives and other costs, collectors of any size (between 0.010 and 0.933 m^2) can be used to estimate litter fall if the number of collectors required to obtain precise results is calculated. Epiphyte estimation requires large numbers of collectors, and alternative methods of sampling would likely be more cost effective.

Acknowledgments

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