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Estimates of biomass and fixed nitrogen of epiphytes from old-growth Douglas-fir

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Abstract

Epiphytes are sampled concurrently with measurements of surface area of trunk and branch systems of old-growth Douglas-fir (Pseudotsuga menziesii). *Crude predictions of epiphyte biomass in branch systems are corrected by more detailed sampling of a subset of branch systems. Nitrogen analyses enable conversion of epiphyte biomass to the total amount of nitrogen present in the epiphytes.*

Introduction

Epiphytic lichens and mosses are a conspicuous component of forest ecosystems in the Pacific Northwest. Because of their ability to concentrate materials from the environment and the ability of some of them to fix atmospheric nitrogen, their importance in nutrient cycling within the system may be greater than their contribution to total biomass would suggest.

In old-growth Douglas-fir forests, epiphyte biomass is expected to be in a steady state; epiphyte growth is balanced by litterfall, *in situ* decomposition, and consumption by herbivores. Annual turnover of epiphytic lichens varies from 5 to 25 percent (Edwards et al. 1960, Pike 1971).

Epiphyte-fixed nitrogen accounts, at least in part, for the nitrogen needed for the growth of these epiphytes, and may represent a significant input to the forest ecosystem. Nitrogen is added to water flowing over tree surfaces through decomposition of epiphytes and leakage from nitrogen-fixing epiphytes, and enters the soil from the epiphyte system via throughfall, stemflow, and litterfall.

Measurements of biomass are necessary to relate process studies of epiphytes to their contribution to forest mineral cycles on an ecosystem level. Estimating epiphyte biomass by felling and sampling selected trees is neither possible nor desirable in old-growth Douglas-fir forests (where trees may approach 100 m in height) because such felling is destructive, not only of the host tree, but also of the epiphytes one wishes to study.

This paper outlines the methods and gives preliminary results of techniques developed for sampling epiphytes on old-growth Douglas-fir in the H. J. Andrews Experimental Forest. The relatively nondestructive sampling is an extension of the procedure for estimating tree structure and biomass described by Denison et al. (1972).

Methods

The Study Tree

Epiphyte sampling by the methods described here has been carried out on a single old-growth Douglas-fir tree. This tree is located on a north-facing slope in watershed 10 of the H. J. Andrews Experimental Forest, 75 km east of Eugene, Oregon. The base of this 65 m tall tree is at an elevation of 500 m. The surrounding stand of old-growth Douglas-fir has an understory which includes western hemlock *(Tsuga heterophylla)* and vine maple *(Acer circinatum)*. Epiphytic lichens and bryophytes are present on the understory trees and shrubs as well as the overstory Douglas-fir.

Sampling of Epiphytes

For sampling, the tree was divided into trunk(s) and branch systems. The trunk is the main vertical axis of the tree; branch systems are sets of branches leaving the trunk at the same point and are made up of axes (>4 cm in diameter) and branchlets (<4 cm in diameter).

Techniques for rigging and climbing the tree are described by Denison et al. (1972). In brief, modified rock-climbing techniques coupled with a movable spar allow access to all parts of the trunk and branch systems.

Trunk Sampling

Epiphytes were sampled from each of two climbing paths on opposite sides of the trunk. Quadrats, 1 x 2.5 dm, were placed alternately to the right and left sides of each climbing path at 1 m intervals, and cover data for epiphytes were obtained. Epiphytes for biomass estimates were cleared from one of every four quadrats; sequential samples were taken from alternate sides of the climbing path. Ultimately, the four compass directions located at 45° from the climbing paths were sampled with equal frequency both for cover data and for biomass samples. Each 8 m high section of trunk yielded 16 sets of cover data (four from each compass direction) and four samples for biomass determinations (one from each compass direction).

Description of Branch Systems

From climbing positions on the trunk, descriptions were made of the various branch systems (length, basal diameter, number of axes, epiphyte cover, etc.). Denison et al. (1972) have discussed the processes of describing branch systems and calculating an importance value, v, related to total wood, foliage, and epiphyte biomass, for each branch system. Branch systems to be sampled in detail were selected with the sampling probability for any branch system being directly related to the v for that branch system.

The descriptive data for each branch system were also used to compute an importance value for epiphytes (EIV). EIV is a rough initial estimate of the total area (in square decimeters) covered by lichens and bryophytes on the axes within the branch system and is used to extrapolate the biomass of epiphytes on the sample branches to the entire tree. In the future, EIV (which relates to epiphyte biomass) will be used in sample branch selection when epiphytes are concerned, and not v (which relates to total wood, needle, and epiphyte biomass).

In computing EIV for a branch system, each axis was treated as a right cone truncated at a diameter of 4 cm. The product of the percentage cover by epiphytes and total surface area of the axes is an estimate of the total area covered by epiphytes within the branch system, exclusive of the epiphytes on the branchlets. EIV for an axis is computed by the formula:

$$\mathrm{EIV} = \frac{C\pi(r + 4)\sqrt{h^2 + (r - 4)^2}}{100}$$

where C is the percentage cover by epiphytes, r is the radius at the base of the axis, and h is the length of the axis. The bulk of epiphyte biomass for these branch systems is assumed to occur on the axes; if this is not the case, the biomass of epiphytes on the many small branch systems, which are made up entirely of branchlets, may be significantly underestimated.

Since EIV is based partly on subjective estimates of length of axes and percentage cover by epiphytes, the relationship between EIV and epiphyte biomass may be expected to vary from worker to worker and from sampling period to sampling period, and for this reason will be treated separately for each tree. However, it should be possible to correct importance values so that correlations may be obtained that will hold across a set of trees.

Sampling Branch Systems

The basic sampling unit for epiphytes on axes in the branch systems is a "cylindrat," which is analagous to a quadrat but runs completely around the axis so that two edges are fused. Our 1 dm cylindrats include the entire surface for a distance of 1 dm along an axis. Thus the surface area of the cylindrat varies, depending on the diameter of the axis in the region sampled.

Cylindrats were spaced along an axis with a distance of 4 dm from the center of one cylindrat to the center of the next. The distance from the trunk to the first cylindrat sampled along a main axis was varied from 0 to 1, 2, and 3 dm so as to avoid errors which would be introduced by horizontal zonation on the axis near its origin from the trunk. Estimates of epiphyte cover were made, and then the epiphytes were stripped from the cylindrat and bagged. Axis diameter at the center of each cylindrat was measured to enable calculation of surface area of the axes.

Branchlets ($<$4 cm diameter at the base) were numbered consecutively in a clockwise direction within a branch system. Every fourth branchlet was cut, bagged in the canopy, and returned to the laboratory for further analysis.

Sorting and Weighing

Epiphyte materials from quadrats, cylindrats, and branchlets, were sorted by species and freed of needles, bark, and other debris. Samples were ovendried (100° C) and weighed.

Computations

Epiphyte Biomass on Trunks

The biomass figures from quadrats of known area (2.5 dm^2) can be related to the trunk as a whole once trunk surface area is calculated. Since epiphytes show a marked vertical zonation, these computations were made for short sections of trunk. It was convenient to treat the trunk as a series of truncated cones, each 4 m high; this gave two quadrats with biomass data taken from opposite sides of each 4 m high cone. Measurements of trunk diameter were made at 5 m intervals; diameters at 4 m height increments were interpolated. In the future, we plan to adjust our sampling scheme so that epiphyte biomass may be calculated on 5 m sections.

Epiphyte Biomass on Branch Systems

Epiphyte biomass on axes of the branch systems was calculated in a manner similar to that employed on the trunks. Each axis is made up of a stack of truncated cones 4 dm in length; these cones start and end in the center of the cylindrats from which epiphytes were removed. Since we know the diameters at the center of the cylindrats, we can calculate the surface area of the cones. The average weight per unit area for each species of epiphyte in the two cylindrats associated with each of these cones was used to estimate epiphyte biomass, by species, for the truncated cone. Each cylindrat was treated as the surface of a cylinder with diameter equal to the diameter at the center of the cylindrat for the purpose of calculating epiphyte biomass per dm^2.

Average total weight of epiphytes per branchlet, multiplied by the number of branchlets, gives an estimate of the total weight of epiphytes on branchlets within the branch system. Total epiphyte weight for a branch system is the sum of the weights on axes and on branchlets.

Nitrogen Analyses

Samples analyzed for nitrogen content were collected in watershed 10 in August and October 1971. Samples were air dried, and nitrogen analyses were performed by Dennis Lavender of the Forestry Sciences Laboratory, Oregon State University, using the Kjeldahl method. Air drying samples analyzed for nitrogen content avoids losses of nitrogen that may occur with ovendrying. In order to enable expression of the nitrogen contents on an ovendry–weight basis, air dried samples of epiphytes were ovendried at 100° C to determine weight loss on drying.

Results

The results presented here are preliminary results from the first tree sampled in watershed 10 of the H. J. Andrews Experimental Forest. The estimates are crude. They are presented to give an idea of how the methodology is being applied and the order of magnitude of results that are being obtained. These preliminary results are being used in improving and refining the sampling strategy.

Biomass of Epiphytes on the Trunk

Total epiphyte biomass on the trunks of tree 1 is estimated to be 4.5 kg (table 1). Nearly 90 percent of this is bryophytes, and nearly 50 percent is found within 8 m of the ground. Lichens contribute the bulk of the epiphyte biomass on the trunk from about 50 to 60 m from the ground. Epiphyte biomass per unit area for the trunk as a whole is 0.31 g/dm^2, and is much higher than this figure only within 8 m of the ground and at the top of the second trunk, where large patches of *Lobaria oregana* (Tuck.) Müll. Arg. were encountered.

Biomass of Epiphytes on the Branch Systems

The frequency distribution of branch systems by EIV is presented in figure 1.

Epiphyte biomass on axes of the five branch systems sampled in detail ranged from 0 to 198 g (table 2); that on the branchlets ranged from 1 to 48 g (table 3). The five branch systems show a relationship between EIV and epiphyte biomass (fig. 2). Values from the least-squares regression line were used to convert the number of branch systems in an EIV class to an estimate of the total epiphyte biomass represented by that class (fig. 3).

The low importance value classes (EIV < 10), although representing many branch systems, make only a small contribution to the epiphyte totals for the tree. About one-half of the epiphyte biomass is contributed by branch systems with EIV above 35. In this connection, the preliminary nature of these results must again be emphasized as no branch system with an EIV higher than 32 was selected for detailed sampling.

Epiphyte Biomass for the Whole Tree

Total epiphyte biomass for the tree sampled is estimated to be 18.3 kg; 13.8 kg, or about 75 percent of the total, is on the branch systems (table 4). Assuming that the distribution of epiphyte biomass by species on the five branch systems studied is the same as the distribution overall, 50 percent of the total epiphyte biomass for the tree is bryophytes (table 4). However, there is a decrease in the proportion of total epiphyte weight represented by bryophytes from larger diameter to smaller diameter stem sections. Bryophytes make up 86 percent of the epiphyte biomass on the trunk, 47 percent of that on the axes of the branch systems ($>$4 cm diameter), and only 3 percent of that on the branchlets ($<$4 cm diameter). Nearly one-half of the *Lobaria oregana* is found on branchlets; most of the remainder is found on axes.

Standing Crop of Fixed Nitrogen

Results of nitrogen analyses show that those lichens which have *Nostoc* as their phycobiont and fix atmospheric nitrogen have

Table 1.—Epiphyte biomass on the trunk of tree 1 in watershed 10[1]

Height (*m*)	Trunk surface area	Species: *Scapania bolanderi*	*Hypnum circinale*	*Dicranum* spp.	*Sphaerophorus globosus*	*Cladonia* spp.	*Peltigera aphthosa*	*Alectoria sarmentosa*	*Platismatia glauca*	*Platismatia herrei*	*Nephroma bellum*	*Lobaria oregana*	All species	
	*dm*²	*g*											*g*	*g/dm*²
TRUNK 1:														
0—4	1,500	300	470	340	—	+	—	—	—	—	—	—	1,120	0.75
4—8	1,240	80	210	740	—	—	—	—	—	—	—	—	1,040	.83
8—12	1,130	20	200	90	30	—	—	—	—	—	—	—	340	.30
12—16	1,110	50	150	40	20	+	—	—	—	—	—	—	270	.24
16—20	1,060	140	140	70	20	—	—	—	—	—	—	—	360	.34
20—24	1,010	20	110	10	—	10	—	—	—	—	—	—	150	.15
24—28	960	+	+	10	—	—	—	—	—	—	—	—	10	.01
28—32	900	20	60	20	—	—	—	—	—	—	—	—	90	.10
32—36	860	+	10	10	+	—	—	+	—	—	—	—	20	.02
36—40	820	200	30	50	+	+	—	—	—	—	—	—	290	.36
40—44	750	—	+	+	+	+	—	—	—	—	—	—	10	.01
44—48	670	10	110	10	—	—	—	—	—	—	—	—	130	.19
48—52	580	—	+	30	+	—		+	+	—	—	—	40	.07
52—56	490	—	+	+	+	—	10	50	—	—	—	—	70	.13
56—60	402	—	—	—	—	—	—	50	10	—	—	+	60	.14
60—63	250	—	—	70	10	10	+	10	—	—	—	—	100	.39
TRUNK 2:														
41—45	440	—	10	+	10	—	—	+	—	+	—	—	10	.03
45—49	310	—	60	+	20	—	—	—	—	10	—	—	90	.28
49—51	120	—	—	+	+	—	—	—	10	+	10	310	330	2.84
Total	14,610	850	1,570	1,480	120	20	10	110	20	10	10	320	4,530	

[1] Weights for each species of epiphyte are to the closest 10 g; + indicates the presence of less than 5 g. Entries have been rounded and will not necessarily add to the total.

Table 2.—Epiphyte biomass on axes of branch systems sampled[1]

Branch system	Section of axis			Epiphyte biomass	
	Distance from beginning of axis	Diameter at base	Surface area		
	dm	*cm*	*dm*^{2}	*g/dm*^{2}	*g*
7[2]					
33	0–3.5	9.0	9.62	0	0
	3.5–7.5	8.5	10.37	0	0
	7.5–11.5	8.0	9.74	.01	.1
	11.5–15.5	7.5	8.80	.02	.2
	15.5–19.5	6.5	8.17	.02	.1
	19.5–23.5	6.5	7.38	.02	.1
	23.5–27.5	5.2	6.28	.02	.1
	27.5–31.5	4.8	5.66	.02	.1
	31.5–33.5	4.2	2.59	.04	.1
Total			68.6		.9
61	0–2.5	8.0	6.28	.24	1.5
	2.5–4.5	8.0	5.34	.30	1.6
	4.5–8.5	9.0	11.00	.31	3.4
	8.5–12.5	8.5	10.21	2.50	25.6
	12.5–16.5	7.8	9.27	2.97	27.6
	16.5–18.5	7.0	4.30	1.48	6.4
	0–3.0*	4.5	4.01	.25	1.0
Total			50.4		67.1
93	0–1.5	12.0	5.54	.52	2.9
	1.5–5.5	11.5	14.14	1.13	16.0
	5.5–9.5	11.0	13.35	1.17	15.7
	9.5–13.5	10.2	11.94	.97	11.5
	13.5–17.5	8.8	11.15	1.30	14.4
	17.5–21.5	9.0	11.15	1.68	18.7
	21.5–25.5	8.8	10.52	2.03	21.4
	25.5–29.5	8.0	9.11	1.28	11.1
	29.5–33.5	6.5	8.48	1.40	11.8
	33.5–37.5	7.0	8.80	2.26	19.9
	37.5–41.5	7.0	7.39	1.38	10.2
	41.5–45.5	4.8	5.97	2.25	13.4
	45.5–49.5	4.8	5.81	2.39	13.9
	49.5–53.5	4.5	5.34	.54	2.9
	53.5–56.0	4.0	3.14	.36	1.1
	0–2.0*	6.5	4.01	.23	.9
	2.0–6.0*	6.2	7.38	.35	2.6
	6.0–10.0*	5.5	6.28	.26	1.7
	10.0–14.0*	4.5	5.34	.10	.5
	0–4.0**	4.5	5.34	1.38	7.3
Total			160.2		198.0
116	0–2.5	10.0	7.66	.04	.3
	2.5–6.5	9.5	11.50	.23	2.6
	6.5–10.5	8.8	10.56	.37	3.9
	10.5–14.5	8.0	9.55	.67	6.4
	14.5–18.5	7.2	8.61	.69	6.0
	18.5–22.5	6.5	7.67	.25	2.0
	22.5–26.5	5.7	6.72	.26	1.7
	26.5–30.5	5.0	5.78	.24	1.4
	30.5–32.0	4.2	1.93	.12	.2
Total			70.0		24.4

[1] Asterisks (*, **) denote secondary axes.

[2] No axes greater than 4 cm diameter.

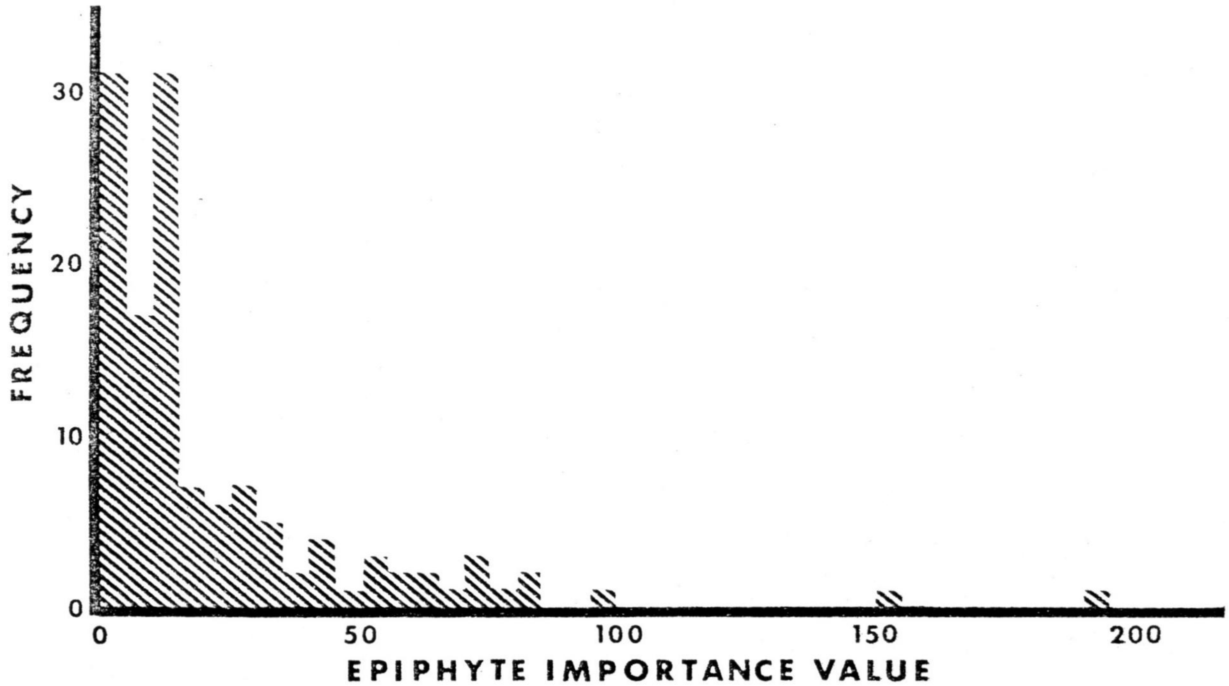

Figure 1. Frequency distribution of branch systems by epiphyte importance value. EIV is an estimate of the total area (dm^2) covered by epiphytes on the axes of the branch system.

Table 3.—Number of branchlets and epiphyte weights on branchlets for branch systems sampled from tree 1 in watershed 10

Branch system number	Number of branchlets sampled	Total weight of epiphytes on branchlet number 1	2	3	Mean epiphyte weight per branchlet	Total number of branchlets in branch system	Estimated total weight of epiphytes on branchlets
		g			g		g
7	1	0.40			0.40	3	1.2
33	3	.01	0.08	0.51	.20	13.5 ± 1.5[1]	2.7
61	1	15.99			15.99	3	48.0
93	1	4.14			4.14	4	16.6
116	3	.14	5.62	1.72	2.48	12.5 ± 1.5[1]	31.0

[1] Estimated. Total number of branchlets not recorded.

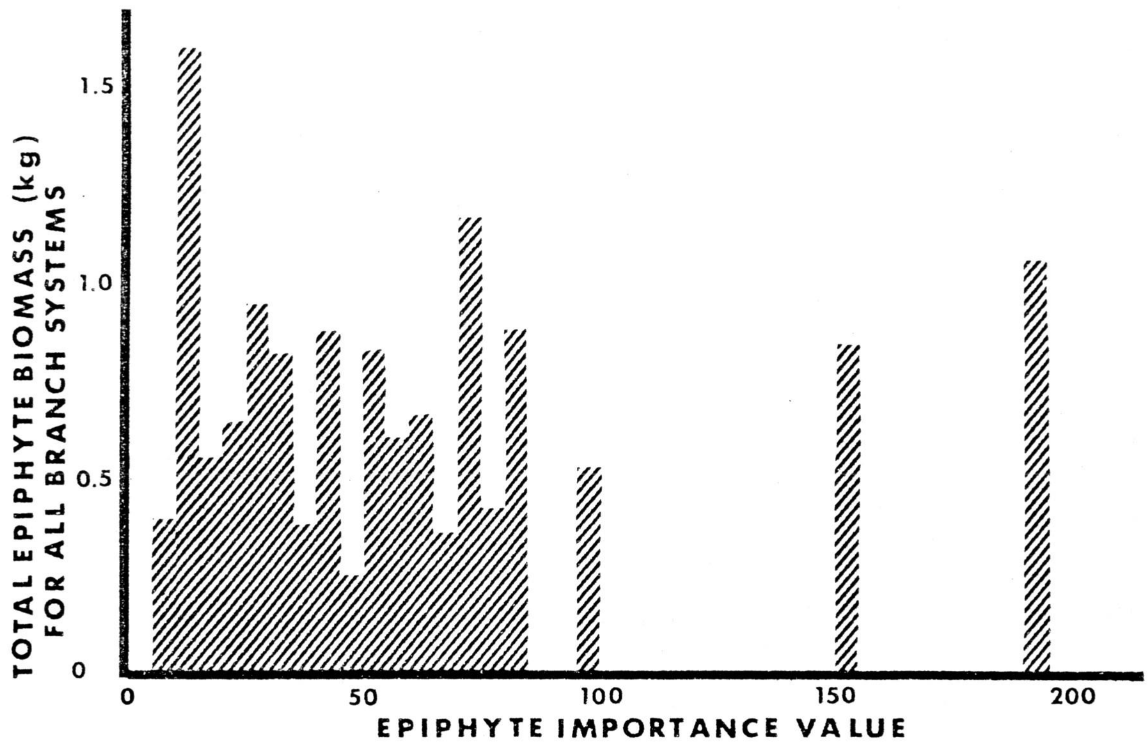

Figure 2. Relationship between epiphyte importance value and total epiphyte biomass for the five branch

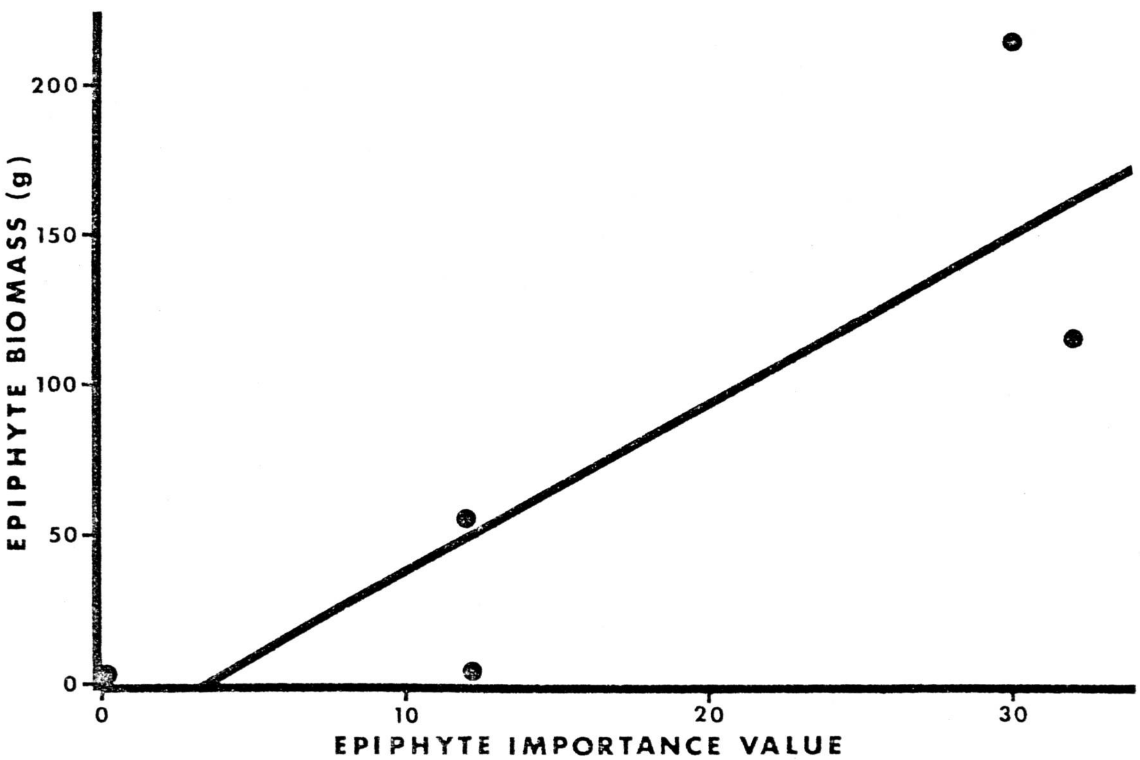

Figure 3. Estimates of total epiphyte biomass on the branch systems in each EIV class.

Table 4.—Biomass estimates (kg) for epiphytes on trunk and branch systems of tree 1 in watershed 10

Epiphyte	Trunk	Branch systems		Total
		Axes	Branchlets	
BRYOPHYTES				
Hypnum circinale	1.6	2.6	—	4.2
Dicranum spp.	1.5	1.5	—	3.0
Other mosses	—	.1	0.1	.2
Scapania bolanderi	.8	.1	—	1.0
Other liverworts	—	.5	—	.6
Bryophyte total	3.9	4.9	.1	8.9
LICHENS				
Sphaerophorus globosus	.1	1.8	—	1.9
Other lichens with green algal phycobionts	.2	.4	.3	.9
Lobaria oregana	.3	3.2	3.0	6.5
Other lichens with *Nostoc* phycobionts	—	.1	—	.1
Lichen total	.6	5.4	3.4	9.4
TOTAL	4.5	10.3	3.5	18.3

a much higher nitrogen content than those which do not (table 5). In two of these associations, *Lobaria oregana* and *Peltigera aphthosa* (L.) Willd., *Nostoc* is a secondary phycobiont located in cephalodia. Levels of nitrogen in the nitrogen-fixing lichens are similar to those previously reported (Pike 1971). The nitrogen contents of the mosses and nonnitrogen-fixing lichens are comparable to those reported by Rodin and Bazilevich (1967) from tundra and conifer ecosystems, but are much lower than those reported from the agricultural Willamette Valley (Pike 1971).

Using these values of nitrogen content, the biomass estimates were converted to estimates of the total quantity of nitrogen in the epiphytes on this one tree (table 6). These results indicate that 65 percent of the total epiphyte nitrogen is located in lichens and that 55 percent of the total is found in a single species, *Lobaria oregana*. Since one-half of the *Lobaria oregana* occurs on branchlets, more than 25 percent of the epiphyte nitrogen is found there.

Discussion

Our estimate of 18.3 kg of epiphyte biomass on the one Douglas-fir tree sampled is considerably higher than the average 0.3 kg per tree found in a stand of *Picea engelmannii* and *Abies lasiocarpa* in British Columbia (Edwards et al. 1960) and the 0.4 to 1.3 kg per tree found in stands of *Pinus banksiana* and *Picea mariana* in Saskatchewan (Scotter 1962). This high epiphyte biomass is related to the tremendous size of old-growth Douglas-fir. When wet, the epiphyte load on this tree is probably three to four times the dry weight and may be a significant factor affecting branch fall. (See Barkman (1958) for water capacity of lichens and bryophytes.)

There are approximately 60 old-growth Douglas-fir trees per hectare of forest in

Table 5.—Nitrogen contents of common epiphytes in watershed 10. Analyses were performed on air-dry material; results are expressed on an ovendry-weight basis

Epiphyte	Percent nitrogen
Lichens with green algal phycobionts:	
Alectoria sarmentosa	0.49
Hypogymnia enteromorpha	.50
Hypogymnia imshaugii	.66
Platismatia glauca	.41
Platismatia herrei	.50
Platismatia stenophylla	.52
Sphaerophorus globosus	.42
Lichens with *Nostoc* phycobionts:	
Lobaria oregana	1.93
Peltigera aphthosa	2.84
Pseudocyphellaria anomala	3.07
Pseudocyphellaria anthraspis	2.62
Sticta weigelii	3.78
Bryophytes:	
Dicranum scoparium	.87
Hypnum circinale	.95
Isothecium spiculiferum	1.10

Table 6.—Estimates of the total quantity of nitrogen contained in the epiphytes on tree 1 in watershed 10

Epiphyte	Nitrogen
	g
BRYOPHYTES	
Hypnum circinale	40
Dicranum spp.	26
Other bryophytes	17
Bryophyte total	82
LICHENS	
Sphaerophorus globosus	8
Other lichens with green algal phycobionts	4
Lobaria oregana	127
Other lichens with *Nostoc* phycobionts	4
Lichen total	143
TOTAL	225

watershed 10 (C. T. Dyrness, personal communication). Our 18.3 kg of epiphytes per tree would then correspond to 1.1 metric tons per hectare, a figure well within the range of values reported from northern conifer forests (Edwards et al. 1960, Scotter 1962, Rodin and Bazilevich 1967). Our estimate is only for the overstory Douglas-fir trees, however, and does not take into account the considerable biomass of epiphytes that is located on understory trees and shrubs.

For comparison, our estimate of the total dry weight of needle biomass on the tree sampled is 84 kg, a figure 4.6 times as high as the estimate of epiphyte biomass.

Our finding, that a large proportion of epiphyte biomass is present on small branchlets, indicates the importance of adequate sampling of this part of the tree and demonstrates the importance of nondestructive sampling because the branchlets are particularly likely to be destroyed when a large, old-growth Douglas-fir tree is felled. Since the contribution from the branchlets is significant, EIV should be modified to include a component from the branchlets to avoid underestimating the portion of epiphyte biomass located on small branch systems.

Our methodology does not include estimates of biomass of crustose lichens or free-living algae. We have observed, even on twigs smaller than 1 cm in diameter, that cover of crustose lichens is regularly greater than 50 percent of the total surface area of the twigs. Our estimates must be considered underestimates since they include only bryophytes and foliose and fruticose lichens.

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