

# Bryophyte Occurrence on Decayed Logs Under a Range of Microclimate Conditions

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**Abstract.** *Bryophyte occurrence on decay class IV and V logs was compared between wide thinning, a one-acre patch cut, and no treatment, in a sixty year old Douglas-fir stand in the Oregon Coast Range. Sampled logs were near points where microclimate variables have been measured two late- summer periods since timber harvest occurred in 1997. Total bryophyte coverage and species richness and abundance were compared between the two treatments and nearby unharvested stream buffers. Coverage was found to be highest in the buffers, 12% lower in the wide thinning, and 55% lower in the patch cut area. Species richness followed a similar pattern, but with less variation between treatments. Three species found in the control and wide thinning were absent in the patch cut, and three additional species were found much less frequently there. A summary of microclimate data on the sample points is presented and shows much lower relative humidity minimums in the patch cuts compared to the thinning and buffers.*

## Introduction

Young stands comprise a very abundant age class in Coast Range. (Cite Wayne Elliot's info from young stands study, including statistics for federal lands.) Federal land managers are charged with protecting biodiversity on these forests, an effort that has focused largely on old-growth forest habitat. However, there is also a recognition of the need to maintain or enhance the structural, compositional and functional attributes typically associated with old growth in younger stands (Franklin and Spies, 1991). The predominant treatments prescribed on federal lands in stands of this age class are thinnings. Much of the thinning is carried out with the objective of creating old growth characteristics. Coarse wood is recognized for its importance as a structural characteristic contributing to biodiversity (Franklin and Spies, 1991), and for this reason, there are requirements for coarse wood retention during thinning operations. In an effort to develop thinning methods that may be more effective in creating old-growth like structure, managers are experimenting with methods that involve wider and more variable spacing, and creation of openings and leave islands (Tappeiner et al, 1997). Such innovations affect microclimate differently than conventional thinning. As with conventional thinning, bryophytes may be directly affected by microclimate changes and increased solar radiation resulting from these new thinning techniques, but the range of effects may be greater. In addition to the direct effects of thinning, there may be indirect effects from increased ground vegetation and changes in coarse woody debris moisture balance. Effects on bryophyte community succession, including the persistence and dispersal of individual species under a range of treatments could have important implications to 'survey and manage species' and for biological diversity in general. Previous studies have found that the most important influences on bryophyte community

succession are microclimate and the characteristics of the substrate (Rambo and Muir, 1998), factors certainly affected by forest thinning.

## Study Site

The Bottomline density management study site lies southwest of the city of Eugene, (43°46'N, 123°13'W), on the eastern slope of the Coast Range. The stand lies at an elevation of 200-300m. Rainfall recorded at the Cottage Grove Dam, about 17 km from Bottomline receives mean annual rainfall of 1,222 mm (Taylor, 1993), most falling in the winter months. Mean annual temperature at the nearby dam is 10.7°C.; mean low is 3.9°C (January) and mean high is 18.5°C (August) (Rambo and Muir, 1998).

The vegetation type from Franklin and Dyrness, 1973 that best fits the site is the *Psuedotsuga Menziesii*/ *Holodiscus discolor* – *Gaultheria shallon* type (Rambo and Muir, 1998).

Following the 'seed tree' harvest in the 1930's, the stand developed from natural regeneration. Remnant large *Psuedotsuga Menziesii* seed trees still remain. The bulk of the young stand consists of *Psuedotsuga Menziesii* as well, with an occasional and *Calocedrus decurrens*. There is a minor hardwood component of *Acer macrophyllum*, *Castanopsis chrysophylla*, *Cornus nuttallii*, and *Corylus cornuta*.

The timber harvest at Bottomline was completed in 1997. Thinning was prescribed at various levels of residual densities (40, 80 or 120 trees per acre), in randomized blocks of several acres each. Patch cuts and leave islands of ¼, ½ or 1 acre in size were scattered throughout the thinning. Unharvested buffers were left on streamcourses, either one site-tree width (210'), two site-tree width, or variable width. Patch cuts were planted in 1998, to 15 foot spacing with an even mix of two-year-old *Psuedotsuga Menziesii*, *Tsuga heterophylla*, *Thuja plicata*, and *Abies grandis* planting stock (Peter O' Toole, pers. com. 2002).

Planted seedlings and ground vegetation form abundant cover in the patch cuts today. At the time of sampling, planted trees were from 2-8' in height with patchy stocking. Ground vegetation averages approximately 3' in height, consisting primarily of *Gaultheria shallon*, *Holodiscus discolor*, *Corylus cornuta*, *Pteridium aquilinum*, *polystichum munitum*, and *Rubus ursinus*. Logs were difficult to locate at times due to the heavy cover. Cover in the thinning areas and buffers was also greater than 60% coverage and 2-3 feet in height.

## Methods

Twelve transects were established at the site in 1995 to measure microclimate along a gradient from streams to ridgetop. The transects varied from 290 to 630 feet in length, taking in unharvested stream buffers, and one or more treatment type upslope. Points were established at regular intervals for placement of data loggers. Points along the transects were selected that represented treatments and buffers at distances intended to limit edge effects to the greatest extent. Points were selected in the centers of two 1 acre patch cuts (nearly circular in shape, but slightly elongated east to west), in the end of a 4 acre area thinned to 40 trees per acre, and paired with points 60-180 feet within unharvested stream buffers (Table 1, below).

**Table 1:** Sample Plots on Microclimate Transects

<b>Transect/Plot</b>	<b>Description</b>
<b>4A</b>	<b><i>One tree buffer into a one-acre patch opening</i></b>
4A - 90	Buffer: 90' upslope from stream, 120' north of edge of one-acre patch opening
4A - 270	Patch Opening: 60' south from buffer edge, 120' north from variable buffer.
<b>5</b>	<b><i>Variable break buffer into 40 trees per acre thinning</i></b>
5 - 90	Buffer: 90' upslope from stream, 60' north of edge of 40 tpa thinning
5 - 270	40 tpa thinning: 120' south of variable buffer edge
<b>8</b>	<b><i>Unharvested microclimate control buffer for entire 630' length</i></b>
<b>9</b>	<b><i>Two-tree height buffer into one-acre patch cut</i></b>
9 - 270	Buffer: 270' upslope from stream, 180 feet east of one-acre patch opening
9 - 570	Patch opening: 120' west of buffer edge, 60 east of road and buffer.

From these points, the four nearest pieces of decay class IV and V downed wood in the four cardinal directions were sampled. Decay classes used are based on characteristics of decaying *Psuedotsuga menziesii* (Maser et al, 1998). Class IV logs have very little if any remaining bark, xylem has softened with decay and the log rests on the ground, but its general shape is retained. In decay class V, the most advanced stage, the log has collapsed and formed a low mound of rotted wood melting into the soil profile. The sampled logs were divided in thirds, and at the center of each third of the log, a plot was established. The plot width included the entire exposed area of the log, and length sufficient to total one square meter. Within the plot, all bryophyte species and an ocular estimate of their percentage cover within the plot was recorded.

Decay class IV and V decayed logs were chosen for sampling for several reasons. Their long period of continuity on the site would increase the likelihood of a well-established community of bryophytes. Having been on-site prior to harvest, the bryophyte community would have been in place and experienced the change in microclimate from the harvest, affording an attempt at chronosequence comparison with similar logs in the unharvested buffer. As wood decomposes, it becomes softer and spongier and has a higher capacity to capture and hold moisture, serving to buffer its microenvironment from moisture fluctuations. This quality helps to provide the humid microclimate favored by epixylic liverworts (Rambo and Muir, 1998), a group likely to respond to microclimate changes. Furthermore the range of species detected could be greater, as decay class IV and V logs would include both lignicolous and humicolous bryophyte communities, and potentially a few remnants of the corticolous community from earlier decay classes. In the Botany 466 lab exercise on April 30, 2002 bryophyte species richness on both decay class IV and V logs was found to be greater than the earlier decay classes.

Microclimate data was collected in 1999, after harvest, and again in 2001. The data was collected hourly and recorded with automatic data loggers located at each sample point along the transects. Readings were recorded hourly for 23 days in 1999: from 1200 on September 16 to 1300, October 8. In 2001 data was collected earlier, for 9 days from 0700, August 13 to 2300, August 21. Air temperature, soil temperature, relative humidity, and absolute humidity were recorded. Temperature measurements are accurate to within 2/10<sup>ths</sup> of a degree. Relative humidity measurements are accurate to within 2% in the range of 20-80% relative humidity, slightly less accurate at the extremes. Data was collected along the transects prior to harvest to establish baseline information on litter, downed wood, woody vegetation, herbaceous cover, basal area of conifers and hardwoods, slope, and microclimate variables. The data allow comparisons of how these variables differ by distance from streams.

Fish-eye photographs were taken at each sample point in 1998 and 2002. These spherical, 180 degree angle photographs are analyzed using a computer to measure the percentage of open sky, the inverse of canopy cover.

## Results

### *Bryophyte Occurrence*

#### *Species Richness*

Perhaps owing to the relatively young stand age and consequently short stand continuity (Muir and Rambo, 1998), bryophyte species richness was quite low – only sixteen species were encountered throughout the treatments and two species were only located on one sample each. This may be due also to the narrowly limited substrate type in the sample, consisting only of decay class IV and V logs, or the fact that the three treatments sampled were within proximity (within an approximate 5 ha. area).

Species richness varied between treatments. In the uncut buffer, an average of 4.5 species per log were found, with a standard deviation of 1.16. In the thinned area, 5 species per log were found (.82 standard deviation), while in the patch cuts, the average was only 3.75 (1.64 standard deviation).

#### *Bryophyte condition*

Two species, *Rhytidiadelphus triquetrus* and *Eurhynchium oreganum*, were bleached and apparently damaged by exposure. Only one occurrence was found for each species, however, the former in the thinning treatment, and the latter in the patch cut. Considering the four-year period since cutting, it is likely that more widespread mortality and damage occurred earlier but is no longer evident.

The following table displays the species occurrence frequency and percent cover among the three treatments.

**Table 1, Bryophyte Frequency and Cover**

		Frequency Percent	Percent Cover

Species	LifeForm	Buffer	40 TPA thin	Patch Cut	Buffer	40 TPA Thin	Patch Cut
Aulacomnium androgynum	acrocarp	17	0	25	Trace	0	Trace
Cephalozia spp.	leafy liverwort	0	0	12	0	0	Trace
Dicranum fuscescens	acrocarp	33	50	37	0.6	0.6	Trace
Dicranum tauricum	acrocarp	8	25	12	Trace	Trace	Trace
Eurhynchium oreganum	pluerocarp	100	100	100	22	29	19
Hypnum circinale	pluerocarp	8	25	0	Trace	Trace	0
Hylocomnium splendens*	pluerocarp	8	0	0	Trace	0	0
Isothecium myosuroides	pluerocarp	17	0	37	Trace	0	Trace
Leucolepis acanthanueron	acrocarp	25	75	12	1.3	3.5	1.3
Plagiothecium undulatum	pluerocarp	25	25	12	1	Trace	Trace
Polytrichum juniperinum*	acrocarp	0	0	12	0	0	Trace
Porella navicularis	leafy liverwort	8	25	25	Trace	Trace	Trace
Rhizomnium glabrescens	acrocarp	50	50	0	1	Trace	0
Rhytididelphus loreus	pluerocarp	50	25	12	8	Trace	Trace
Rhytididelphus triquetus	pluerocarp	83	100	75	16	11	2.5
Scapania bolanderi	leafy liverwort	17	0	0	Trace	0	0
<b>Occurrence/Total Cover</b>		<b>14</b>	10	12	51	45	23

\* Species with only one occurrence found.

Note: totals include values for trace amounts, therefore column totals shown are less than column sum.

### *Bryophyte Coverage*

There were marked differences in the amount of bryophyte coverage found among the three treatments. Bryophyte coverage on logs in the buffer sample plots averaged 51%, those in the thinning averaged 45% coverage, while those in the patch cuts had only 23% coverage.

Logging operations had shattered some logs in the treated areas: 1 of 4 sampled logs in the 40 tpa thinning and one of 8 sampled logs in the patch cut. This resulted in turning the covered substrate under and exposing new surfaces, greatly diminishing bryophyte coverage (31% coverage in the thinning area log, 4% in the patch cut. If these logs were

not included in the sample average, the coverage would rise to 50% in the thinning and 26% in the patch cuts.

In the patch cuts, bryophyte coverage on many logs was primarily limited to those surfaces more sheltered from exposure. Infrequently in all treatments, shading from heavy ground vegetation (usually *Polystichum munitum*) appeared to be severely limiting bryophyte coverage.

**Microclimate Data**

The two variables that appear to affect microclimate in the study area are distance from streams (and in particular, the steepness of slope above the stream) (Chan, pers. Comm.), and the percent open sky. The effect of distance from streams can be seen in a comparison of the temperature and humidity values for plots along transect 8, a completely unharvested control transect, in table 3 below. The table also displays percent open sky for each of the treatments to compare microclimate data at those plots.

*Open Sky*

Open sky can indicate the extent to which the tree canopy is buffering the macroclimate, or general air mass. It has obvious effects on the amount of sunlight and wind. Nutrient availability from canopy leachates could affect bryophytes also (Rambo and Muir, 1998 (2)). However, while edge effects of wind, relative humidity and temperature can be detected well into buffers, open sky is not detectable until the edge itself or nearly so (Chan, 2000). Open sky was measured on the Bottomline study area after harvest in 1999, and again in 2002, with results shown below. For comparison, values from the Cataract site, a similar density management study in the west-central Coast Range (near Mapleton, Oregon) are shown.

**Table 2, Percent Open Sky After Treatments, Cataract Thinning**

<b>Treatment Type</b>	<b>1995</b>	<b>2000</b>	<b>Change</b>
Control – 220 TPA	3%	3.5%	-.5%
Thin - 104 TPA	20%	12%	-8%
Thin - 60 TPA	40%	36%	-4%
Thin - 30 TPA	60%	57%	-3%

**Table 2A, Percent Open Sky After Treatments, Bottomline Thinning**

<b>Treatment Type</b>	<b>1999</b>	<b>2002</b>	<b>Change</b>
Control – TPA			
Transect 4A Buffer			
Transect 5 Buffer			
Transect 9 Buffer			
Transect 4A Patch cut			
Transect 5 40 TPA			
Transect 9 Patch cut			

*Relative humidity*

Percent open sky had an inverse relationship to afternoon relative humidity. Conversely, due to greater exposure to the air mass in the patch cuts, increased dew caused humidity to peak slightly higher.

Because harvested areas are upslope from streams as well having greater open sky, both factors could be expected to influence microclimate. Table 3, below, shows pre-harvest average minimum relative humidity on forested points along microclimate transects (Chan, pers. comm., 2002). Similarly, relative humidity values shown for the unharvested control transect (#8) in Table 4, below, shows the microclimate gradient from stream to upland plots.

**Table 3** – Average Relative Humidity Minimums in Forested Areas Along Microclimate Transects

Stream	0-40' Upslope	41-90' Upslope	91-250' Upslope	251-350' Upslope
52%	44%	38%	37%	38%

The plots within buffers on the harvested transects lie from 60 to 180 feet from the edge of harvested areas. Relative humidity effects from timber harvest have been found to penetrate unharvested buffers from 1.5 to 2.5 times buffer tree height (Chen, 1993, Chan pers. comm., 2000). All three buffer sample points are within one tree height distance from the cut edge. The relative humidity values below reflect the proximity of the buffer plots to the harvested edge, when compared to plots at the same distance from the stream on the completely unharvested control transect.

Minimum relative humidity differences between control and treatments (at the same distance from streams) were greater in 2001 than differences found during the measurement period in 1999. In 2001, minimum relative humidity was 13 points lower in the uncut buffer plots than the control (52% in transect 8, 39% at the same slope position in the buffers). In the 40 tpa thinning, it measured 13 points less (50% and 37%), and 22.5 points less in the patch cuts (50% vs. 28%, and 46% vs. 27%). In 1999, measurements were taken a month later. Relative humidity was lower overall and it appears that the air mass was so warm and dry that canopy buffer had less effect. Minimum relative humidity was 5.3 points lower in the buffers than the control (34% and an average of 29% in the buffers), 4% lower in the 40 tpa thinning (34% and 27%), and an average of 8.5 points lower in the patch cuts (34% vs. 26% and 32% vs. 23%).

*Air Temperature*

Maximum air temperatures in 1999 showed an increase of 28% in the patch cut and 10% in thinning, when compared to the control (29.5 degrees) at 270' from the stream. Air temperatures in 2001 showed no clear pattern between treatments. In fact, the highest maximums were recorded in buffers and 40 trees per acre thinning. The greatest cumulative hours recorded warmer than 20 degrees Celsius was in the patch cut, but otherwise cumulative temperatures seemed to vary more by transect location than treatment, indicating that local factors may have played a larger role.

**Table 4.** *Summary Microclimate Data 1999, sorted by treatment type.* Recorded from 1200 August 26, 1999 to 1400 September 14, 1999, except transect 9, recorded from 1200 on September 16, 1999, to 1300 October 8, 1999. Values are the cumulative hours

of relative humidity less than 50%, the number of days it occurred, the minimum RH value measured; 90<sup>th</sup> percentile low RH; cumulative hours of air temperature above 20 degrees Celsius; the number of days it occurred; and the maximum air temperature value measured.

Transect	Plot	Treatment/ % sky	Cum RH50	No. Days	MinRh	90th% LowRH	Cum Temp20	No. Days	Max Temp
8	90	Control/	124	6	34	38	184	15	27.9
8	270	Control/	125	6	34	37	189	17	29.5
8	570	Control/	160	14	32	36	194	15	27.9
4A	90	Buffer/	181	17	28	34	200	18	33.2
5	90	Buffer/	173	14	29	36	195	16	32.4
9*	270	Buffer/	198	11	29	32	230	18	25.6
5	270	40TPA/	186	17	27	33	203	18	32.4
4A	270	Patchcut/	203	17	26	32	246	20	37.8
9*	570	Patchcut/	266	24	23	29	245	18	29.1

(\* later measurement period)

**Table 4A.** Summary Microclimate Data, 1999, sorted by transect.

Transect	Plot	Treatment/ % sky	Cum RH50	No. Days	MinRh	90th% LowRH	Cum Temp20	No. Days	Max Temp
4A	90	Buffer/	181	17	28	34	200	18	33.2
4A	270	Patchcut/	203	17	26	32	246	20	37.8
5	90	Buffer/	173	14	29	36	195	16	32.4
5	270	40TPA/	186	17	27	33	203	18	32.4
8	90	Control/	124	6	34	38	184	15	27.9
8	270	Control/	125	6	34	37	189	17	29.5
8	570	Control/	160	14	32	36	194	15	27.9
9	270	Buffer/	198	11	29	32	230	18	25.6
9	570	Patchcut/	266	24	23	29	245	18	29.1

**Table 4B.** Summary Microclimate Data 2001, sorted by treatment type. Recorded from 0700 August 13, 2001 to 2300 August 21, 2001.

Transect	Plot	Treatment/ % sky	Cum RH50	No. Days	MinRh	90th% LowRH	Cum Temp20	No. Days	Max Temp
8	90	Control/	0	0	52	64	17	2	23.4
8	270	Control/	1	1	50	63	17	2	23.8
8	570	Control/	4	2	46	60	17	2	24.2
4A	90	Buffer/	16	4	37	54	18	2	27.2
5	90	Buffer/	18	4	35	52	16	2	25.6
9	270	Buffer/	9	2	44	60	15	2	24.2
5	270	40TPA/	16	3	37	53	18	2	26.8
4A	270	Patchcut/	31	8	28	44	33	4	25.3
9	570	Patchcut/	22	8	27	49	15	2	23.8

**Table 4A.** *Summary Microclimate Data, 2001, sorted by transect.*

<b>Transect</b>	<b>Plot</b>	<b>Treatment/ % sky</b>	<b>Cum RH50</b>	<b>No. Days</b>	<b>MinRh</b>	<b>90th% LowRH</b>	<b>Cum Temp20</b>	<b>No. Days</b>	<b>Max Temp</b>
4A	90	Buffer/	16	4	37	54	18	2	27.2
4A	270	Patchcut/	31	8	28	44	33	4	25.3
5	90	Buffer/	18	4	35	52	16	2	25.6
5	270	40TPA/	16	3	37	53	18	2	26.8
8	90	Control/	0	0	52	64	17	2	23.4
8	270	Control/	1	1	50	63	17	2	23.8
8	570	Control/	4	2	46	60	17	2	24.2
9	270	Buffer/	9	2	44	60	15	2	24.2
9	570	Patchcut/	22	8	27	49	15	2	23.8

## **Discussion**

### *Data limitations*

Certainly the limited amount of data collected on bryophyte occurrence in this sampling effort is a potential source of incomplete information. For example, additional species were encountered within the project area in a 1997 study conducted by Rambo and Muir that were not encountered on similar substrate in these plots. The limited number of plots diminishes robustness of the results. Statistically, each plot was a large enough proportion of the sample to skew the results. For example, logs shattered by yarding operations affected sampling results in the treated areas, but it is difficult to say if they truly represent 17% of the logs in the Bottomline study area due to the small sample size. Furthermore, the edge effect on microclimate would likely have some effect on the bryophytes found in the buffer plots paired with the treated plots. Samples collected on the unharvested control transect would provide a baseline for comparison for microclimate effects on bryophytes, without edge effects.

### *Effects*

The data suggests that even a small sample is adequate to detect the differences in bryophyte species occurrence caused by microclimate changes between patch cuts and stream buffer sample points lying an average distance of 120 feet within the canopy.

Thinning has some direct effects on bryophytes, but these are generally somewhat limited in nature. Sample plots found two of the twelve sampled decay class IV and V logs shattered by yarding activities, greatly diminishing bryophyte coverage on those logs. This effect is probably not significant unless it is widespread. In Bottomline, Class IV and V logs are fairly abundant, and the great majority are intact. Obviously thinning removes tree boles providing bryophyte substrate, but trees remain on site with similar corticolous bryophyte communities intact. Canopy epiphytes may be somewhat diminished initially by limb breakage and whipping on remaining trees, and wide thinning could limit inter-tree dispersal.

In the late summer sampling period, there were significant differences in observed microclimate between the treatments, and this doubtless was the primary effect of thinning on bryophyte occurrence and coverage. Accounting for the effect of distance from the stream using the relative humidity values on the control transect, the 90<sup>th</sup> percentile low relative humidity was about 9% lower in the patch cuts than adjacent buffers, but not significantly lower in the 40 trees per acre thinning than its adjacent buffer. The primary evidence of microclimate effects in sample plots was the lack of bryophyte coverage on the tops of exposed logs – bryophytes were more abundant on the more shaded sides of logs. Two sun-bleached specimens were found in exposed sites, one in a patch cut and one in the thinning.

The reduced coverage on exposed logs may be a direct effect of increased sunlight, decreased humidity and moisture buffering after harvest. It is probably an indirect effect of the change in moisture balance of the log – the log substrate now dries more quickly inducing photosynthetic dormancy in bryophytes. Another indirect effect has been increased ground vegetation in the treated areas due to increased light availability. Ground vegetation overhanging logs and shading out bryophytes was found in sample plots along all transects, but was more common in the treated areas.

It is notable that even in the patch cuts, the north sides of large logs partially sheltered by vegetation contained higher bryophyte coverage and the greatest proportion of species diversity. This may indicate the value of large, intact logs to buffer microclimate sufficiently to function as refugia in created openings. A study of epiphytic mosses on isolated *Quercus garryana* is somewhat analogous: species coverage and abundance are strongly influenced by relative moisture conditions on the sides of tree boles (Merrifield, 2000). A study of canopy epiphytes in an old growth stand found that exposure to microclimate change did not dramatically alter biomass or species richness. Epiphytes assemblages, including bryophytes, found on trees in an old-growth *Psuedotsuga menziesii* stand exposed to twenty years of exposure along a clear-cut edge were comparable to those of the forest interior (Sillett, 1995). Perhaps the two decades of exposure had allowed adaptation or selection for individuals to the altered conditions, or may show that forest continuity is as important for bryophyte succession as microclimate.

The changed microclimate appears to have differential effects on species. *Hypnum circinale*, *Rhytidiadelphus loreus*, *Rhizomnium glabrescens*, and *Scapania bolanderi* were absent or greatly diminished in patch cuts and are apparently less tolerant of the drier conditions found in the treated areas. There may be autecological factors influencing this. (moisture retention features – papillae, alar cells, structure, etc.?) Species absent from cutting areas – correlations in Muir and Rambo with structural components and microclimate factors.

Relationship to microclimate effects cited in Muir and Rambo

#### *Long-term effects*

As the remaining forest canopy and new seedlings grow, microclimate and light conditions will change. It is evident from fish-eye photo data at Cataract and Bottomline

that open sky is decreasing annually at a rate of about 1%, though the effect on microclimate is not entirely clear. In the patch cuts, open sky will quickly drop as seedlings close ranks within fifteen years. Light may well become the limiting factor for growth at that time (Rambo and Muir, 1998). If conditions do improve for the survival and increase of bryophytes, it appears that some species will have residual populations in place on class IV and V logs. Dispersal rates and life history strategies will certainly have an effect on future distribution. Forest floor bryophytes have limited dispersal ability due to the layer of still air near the surface (Rambo and Muir, 1998 (2)), a factor that would affect dispersal from logs, but somewhat less so.

Based on the preliminary results of the density management studies such as Bottomline, and work by Tappeiner and Pogue (Citation??), managers are beginning to implement wide and variable thinning on an operational scale. Variable thinning usually features leave islands and patch cuts of various sizes, and the retention of snags and downed logs. The variable densities and patch sizes create a range of microclimate conditions, but at relatively fine scale. With retention of downed log substrate for bryophyte continuity, and the likelihood of a loose network of favorable microclimate conditions occurring in such treatments, it appears likely that variable thinning can create conditions suitable for the survival and increase of a wide range of species.

## **Conclusions**

Forest openings, even small patch cuts create microclimate conditions that clearly do not favor the survival of certain bryophyte species, compared to unharvested adjacent forest. The results of sampling bryophyte occurrence on class IV and V logs in small (.4 ha) patch cuts shows consistently lower bryophyte coverage and species diversity. However, there are many species that can persist on the most sheltered portions of substrate, in decreased abundance, which may be in place when forest growth creates more favorable microclimate conditions. Thinning operations that retain coarse wood and create a range of microclimate conditions through variable spacing and the retention of leave islands may provide habitat sufficient to maintain species that occurred prior to disturbance. However, if certain species with narrow microclimate affinity are found in project areas, it may be necessary to design buffers that maintain current microclimate conditions. If such species also have limited occurrence and dispersal rates, they could be eliminated from the area for long periods of time.

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