# FINAL REPORT ON THE MOSS HARVEST MONITORING PLAN

Hebo Ranger District, Siuslaw National Forest

Descriptions and Results for
Special Forest Products Stewardship Areas
SA1 and SA2

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## Summary

This report is a stand-alone description and evaluation of the Moss Harvest Monitoring Plan and contains descriptions of sites, methods, and experimental results as well as interpretation and conclusions for SA1 and SA2 upon the termination of this program.

The conclusions from this program include:

- The results from this project should be generally applicable to all mature mixed forests on the Hebo Ranger District of 50-240 $ft^2$/ac in basal area below 1500 ft in elevation with a history of moss harvest.
- The epiphytic bryophyte communities 100-200 ft from a stream do not differ from those up to 1000 feet from a stream.
- Although species composition differed among conifer and hardwood dominated plots, treatment effects did not differ by overstory composition.
- Patchy harvest at levels up to 100 lbs/ac appears to have no long-term impacts on percent cover, species richness, or species composition in such sites.
- The distribution of harvestable moss on the landscape is unreliably variable.
- The natural rate of host stem loss due to disturbance was 17% over eight years.
- The ecosystem impacts of long-term reductions in volume and biomass, such as on habitat quality and hydrologic buffering, remain unknown.

Management recommendations include:

- District-wide inventories are needed to accurately predict available harvest volumes.
- The current standards and guidelines for moss harvest on the Siuslaw National Forest should be modified as follows:
  - harvest of only every other stem should be a recommendation only,
  - the protected riparian zone should be 100 paced feet,
  - harvest should be prohibited in LSR pending further research,
  - rotation periods on the Hebo Ranger District should be extended to 5 years (leaving 20-25 years for biomass recovery between harvest on any given area).

# Contents

## Overview

In 1996, the Moss Harvest Monitoring Program was begun on the Hebo Ranger District, Siuslaw National Forest, coincident with the establishment of the first Special Forest Products Stewardship Area (SA1). The specific monitoring plan for SA1 and results from the first year of monitoring are given in the 1996 Moss Harvest Monitoring Plan. The specific monitoring plan for SA2, and results from year two in SA1 and year one in SA2, are reported in the 1997 Moss Harvest Monitoring Plan Supplement. Those reports were superceded by the 1998 Moss Harvest Monitoring Plan, which updated methods, locations, and results after the 1998 sampling and included information on the ill-fated SA3. All three reports are available from the Siuslaw National Forest (Corvallis, OR).

The purpose of this report is to serve as a stand-alone document outlining the Program and reporting the methods and final results of all long-term monitoring projects in SA1 and SA2.

## Background

### Development of the Industry

Forest moss has been a minor, special, or non-timber forest product for over 50 years in this region (e.g., Shaw 1949). A recent survey of Pacific Northwest (PNW) land managers found that 37% of respondents had received requests to commercially harvest moss on their land (Muir 2004). Local and migrant subsistence and commercial harvesters work part- to full-time hiking through the woods to mossy spots, peeling thick pelt-like moss mats off trees and shrubs (and increasingly logs), packing the fresh material into burlap sacks, and trudging it back to buying sheds for a quarter to a half dollar a pound (Peck 1990). The sheds generally air-dry the moss, occasionally tumble it to remove dirt, compress it into ~25 lb bales, and sell to large national and international floral greens wholesalers who sell the moss for $2-3 a pound (Peck 1990, Muir 2004). Modern uses of forest moss include filling for topiary, lining for hanging flower baskets, shipping medium for bulbs, and decorative uses in the global floral trade (von Haggen & Fight 1999).

The search for alternative income streams focused increased attention on the nontimber forest product (NTFP) industry as a whole in the 1980's and 1990's. The periodic appearance of articles in the popular literature and government brochures promoting NTFP harvest was followed by studies of the extent and growth potential of the industry (e.g., Schlosser et al. 1992). In addition to what and how, questions also arose about who was involved in this industry (e.g., Love et al. 1992). The rapid growth of NTFP commercialization led to the creation of the Northwest Special Forest Products Association, a coalition of "industry firms, government agencies, organizations and individuals interested in the promotion and development" of this industry (NWSFP brochure, 1996).

Most moss harvest has historically taken place on federal lands, which prompted concern over issues of sustainability and rare species (Liegel 1992). Mosses and liverworts play a variety of ecological roles in forest ecosystems, including providing nesting material and food for birds (USDA FS & USDI BLM 1993) and invertebrates (Peck & Moldenke 1999) and storing and cycling minerals and water (Nadkarni 1984). Many mosses and liverworts are most abundant in old-growth and are rarely or never found in young and mature stands (USDA FS & USDI BLM 1993). Traditionally viewed by many agencies as more of a "service to local communities than a revenue source" (Peck 1990), regulation of NTFPs has been slow to develop. Chronic underfunding has further complicated efforts to meet mandates to protect rare species and species diversity (USDA FS & USDI BLM 1994) and to maintain ecosystem function. Some small help may be on the way, however, as a provision in a pilot program included in the 2000 Appropriations Act (HR 2466, sec. 339; under review in 2004) that returns a portion of NTFP revenues (which for moss alone totaled over $10,000-25,000/year nationally for USDA FS and USDI BLM between 1997-2003, Muir 2004) to local units (Chamberlain et al. 2002).

## Regulation

Recent revisions of national forest management plans and specialty reports in the PNW include sections dedicated to addressing the management of alternative products, but proposed management guidelines are often developed by individuals not familiar with the organisms in question, which often fail to be applicable in the field. Case in point: restricting harvest of epiphytic moss to "every other stem" (USDA FS 1995)—allowing harvesters to remove material from 50% of stems on one day, and return the next to remove material from another 50%, and the next for another 50% and so on without violating their permit guidelines.

Regulations also have unanticipated consequences for neighboring landowners: in the first year after the Siuslaw National Forest in northwestern Oregon set a cap on commercial moss harvest on the Hebo Ranger District at 110,000 lb per year, harvest on nearby Tillamook BLM land increased from 11,000 lb/yr to over 200,000 lb/yr (F. Duran, pers. comm.), prompting Tillamook BLM to reduce the number of permits they sold the following year. Recent increases in illegal harvest from protected areas such as the Olympic National Park (Hutten 1999) may reflect reductions in either available moss supplies, access to these supplies, or both.

There is also debate over continuing to allow the commercial harvest of moss in Late Successional Reserves, which are to be managed toward old-growth condition (USDI BLM & USDA FS 1997), due our lack of understanding about the impacts of commercial harvest on ecosystem functions. This has led some to call for a prohibition of commercial moss harvest in old-growth forests (e.g., Muir 2004). In fact, we have little information on ecosystem impacts of harvest or even the renewability of the resource (Muir 2004). While modern forest management is able to draw on centuries of silvicultural research, moss harvest has been studied for barely a decade.

## Research: The Epiphyte Community

Much of the research into commercial moss harvest has taken place on the Hebo Ranger District of the Siuslaw National Forest, in the coastal fog belt of northwestern Oregon. The first project in the summer of 1994 identified 19 mosses, 6 liverworts, 8 lichens, and 2 vascular plants impacted by harvest from understory trees and shrubs (Peck 1997a). Vascular plants and lichens were relatively rare and almost always found only in mats large enough to accumulate soil. Three groups of species were identified: nontarget species generally avoided by harvesters because they are not saleable (vasculars, lichens, and some mosses and liverworts that are not green or are too hard to harvest in abundance); incidentally harvested species taken opportunistically or when growing entwined with more desirable species; and the target species that grow in sufficient abundance to attract harvesters (*Antitrichia curtipendula*, *Eurhynchium oreganum*, *Frullania* sp., *Isothecium myosuroides*, *Neckera douglasii*, *Porella* sp., and *Rhytidiadelphus loreus*). This study found that large mats dominated by the ubiquitous moss *I. myosuroides* were more abundant in older, conifer dominated stands. Limiting commercial moss harvest to these stands could channel harvest toward moss mats with a few, common species—and hopefully away from mats with higher diversity.

These same species, with a handful of additions varying by region, have been found in other studies from western Oregon. More diverse sites have had more sensitive lichen species (Vance & Kirkland 1997), drier sites have had fewer liverworts and lichens (Peck & Muir 2001a), and moister sites have had more moisture-loving log and ground mosses such as *Rhytidiadelphus loreus* (Hutten 1999). A recent study of commercially sold moss (purchased in plastic bags from wholesalers or retailers) found 28 species of moss, 6 liverworts, and trace amounts of 6 lichens (Muir 2004). These purchased samples seem to have originated from throughout the region, and included some valley species not previously known to be commercially harvested (e.g., *Antitrichia californica*), as well as a number of hardy invertebrates (Peck & Moldenke, unpub. data). To date the only moss species of concern found in harvestable moss mats has been the common and abundant old-growth associate *Antitrichia curtipendula*, which was originally listed as a ROD Survey Strategy 4 (USDA FS & USDI BLM. 1994) species but later removed from the list (USDI BLM & USDA FS 2003). However, these studies have all been done on tree and shrub moss; log moss, which is generally prohibited from harvest on public land, may include many more sensitive species.

## Research: Harvest Impacts

We continue to know little about what impact harvest has on the development and species composition of moss communities. We do know that what is left behind is not the same as what used to be there; fewer species, with very different relative abundances, remained behind after harvest of understory vine-maple shrubs in the Oregon Cascades (Peck & Muir 2001b), suggesting that different communities grow back from what were harvested. Even after three years, the number of species on those stems was still lower than before harvest (R.W. Kimmerer 2004 pers. comm.). A similar reduction in the total number of species and the average number of species *per* sample was found three years after harvest of canopy big-leaf maple limbs in western Washington (Cobb et al. 2001). At least in the short-term, harvest appears to reduce diversity.

When mosses grow back after harvest it is thought that most of the regrowth comes from the bits that are left behind, as well as encroachment from nearby, unharvested areas (Cobb et al. 2001, R.W. Kimmerer 2004 pers. comm.). Diversity may start high, then drop off for a long period of time as the “bully mosses” take over, and increase again after the mats are large enough to develop sufficient soil for more moisture-loving species, including vascular plants, to thrive. Apparently “virgin” moss mats in the Coast Range near Tillamook, OR were overwhelmingly dominated by these bully mosses (Peck 1997c), which are the same as the target species for harvest. The time required for this apparent stabilization, and for the development of soil for greater diversity, is still unknown. However, it may be that harvesting relatively young “second growth” shrub moss on a rotation basis has less of an impact on diversity than harvesting moss mats that span the gamut from young to old.

## Research: Recovery Rates

Early estimates of moss regrowth rates were based on the assumption that the moss mat harvested off a shrub stem was no older than the stem itself. Dividing the weight of the moss mat by the age of the shrub, then, gave a rough estimate of net periodic accumulation. This accumulation rate has been used to estimate likely recovery times and resulted in recommended rotation periods of 10-15 years for wet sites in the Coast Range near Hebo, OR (Peck & McCune 1998) and of 21-23 years for drier areas in the central western Cascades of Oregon (Peck & Muir 2001b). Recently, however, a study of vine-maple shrub stems showed that larger mats tend to be found on more horizontal stems even though those stems may not always be very old (Ruchty et al. 2001), casting doubt on these early regrowth rate estimates.

Better estimates require long-term regrowth studies, but few have been done. Ten years following harvest near Hebo, OR, on average only 50% of the harvested surface area is again covered by moss (Peck 2004). No mats are more than 1/3 inch deep, whereas the original moss mats were well over 3 inches deep. The resulting minimum rotation periods are therefore on the order of 15-35 years (averaging 25). Similarly slow growth was seen on those harvested canopy big-leaf maple limbs in Washington; after three years, only 27% of the surface area had been recolonized (Cobb et al. 2001). These slow growth rates contrast with those based on harvestable mosses hung in the forest in mesh nets, increasing in mass over a 13 month period by 11.8% (*Antitrichia curtipendula*) and 3.7% (*Isothecium myosuroides*)(Rosso et al. 2001).

Recovery following harvest, however, may require additional time just to get large enough (in volume) to retain enough water to promote such rapid growth (D. Norris pers. comm.).

## Research:  Inventory Distribution

Even in fairly wet areas, however, the range of moss abundance is tremendous.  Ten mossy sites near relatively wet Hebo, OR were estimated to have 107-1310 lb/ac (~140-1700 lb/ac at 30% moisture content, which is typical in the Coast Range at the time of harvest)(Peck & McCune 1998).  Drier areas are even more variable; only 29% of sites on the western slope of the Cascades in western Oregon had any moss at all, and harvestable quantities of moss (>110 lb/ac) were only found in six sites (143-478 lb/ac, or ~165-550 lb/ac at 15% moisture content, which is typical in the Cascades at the time of harvest).  Harvestable moss in these areas is only expected to be found in stands less than 1640 ft in elevation and in areas less than 164 ft from perennial water (Peck & Muir 2001a).  Riparian areas tend to have faster growth and recovery than upland areas (Peck & McCune 1998), but harvest in these areas may be incompatible with riparian forest guidelines aimed to protect rare species communities and preserve hydrologic function.

The presence and abundance of harvestable moss is also dependent upon the presence and density of suitable host species.  The predominantly observed host for commercially harvestable moss in western Oregon and Washington is vine maple (Peck 1997b, Vance & Kirkland 1997, Hutten 1999, Peck & Muir 2001a).  The tendency for some other host species (e.g., elderberry) to support more diverse moss communities suggests that restricting commercial harvest to only vine maple could reduce the overall impacts of harvest on the epiphytic bryophyte community.  Alternatively, forest management to promote the presence of understory hardwood shrubs and trees could also mitigate moss harvest impacts (Peck & McCune 1998).  The retention of hardwood trees and shrubs provides critical habitat for mosses, liverworts, and lichens (Hazell & Gustafsson 1999), including species that are commercially harvested.  Silvicultural practices that retain these hardwood and shrub species would serve to promote biodiversity, including of the vertebrate and invertebrate populations associated with moss, as well as provide for a future commercial moss resource (Vance et al. 2001, Muir et al. 2002).  For instance, longer rotations would enable more vine maple to reach a horizontal condition, which apparently favors the development of larger moss mats (Ruchty et al. 2001), thus promoting moss abundance.

Another managerial change that has been called for is increased harvester participation in the development of harvest regulations (McLain & Jones 2001).  One approach has been to involve harvesters as stewards in long-term extraction contracts with a required monitoring component. The Moss Harvest Monitoring Program included a Stewardship Area pilot program in which large forested parcels (ca. 2200 acres) were leased for 5-year periods to harvesters who were required to participate in monitoring efforts.

## Stewardship Area 1

Four separate monitoring projects were planned for Stewardship Area 1.  The first involved annual surveys of vine maple stems harvested in 1994, which is reported elsewhere (Peck 2004).  The second project was a case study intended to address the question “Do riparian and upland bryophyte communities differ?” and involved contrasting the species composition from surveys of upland and riparian plots.  The third project was a case-study designed to answer the question “What is the impact of moss harvest within the riparian zone?,” which is excluded from commercial moss harvest on the Hebo Ranger District.  Three levels of harvest intensity were tested (no harvest Control, Rules removal of 30 lbs/ac, and No Rules removal with no restrictions), with replicates, in 1/3 ac plots on four different streams within SA1.  Plots were surveyed prior to, and immediately after, harvest in 1996, and again in 1997, 1998, and 2004.  The fourth project was a landscape-level approach to answering the question “What is the impact of moss harvest at different levels of harvest intensity?” (see SA3 below).

### Stewardship Area 2

Two monitoring projects were planned for Stewardship Area 2 (SA2). The first was a cast-study designed to answer the question "Do moss harvest impacts differ between conifer and hardwood dominated upland forests?" Two levels of harvest intensity were tested: no-harvest Controls and 100 lb/ac Rules (which is comparable in intensity to the No Rules treatment in SA1), with six replicates each, in 1/3 ac plots in both conifer and hardwood dominated upland forest in SA2. Plots were surveyed prior to, and immediately after, harvest in 1997 and again in 1998. The second project was the landscape approach (see SA3 below).

### Stewardship Area 3

Stewardship Area 3 (SA3) was to be the third and final replicate in the landscape-level approach employed in SA1 and SA2. All three Stewardship Areas were divided into three areas (Harvest Level Areas 1-3), each area receiving a different harvest intensity. The harvest intensities were: no harvest ("Control"), harvest without regulation ("No Rules"), and harvest only below 40 ft in height, further than 100 ft from a perennial stream, and with removal of no more than 30 lbs (wet weight) of moss per acre ("Rules"). Moss steward D. Harrison recorded the amount of moss harvested from each HL area in SA1 and SA2. General surveys were conducted prior to harvest in all three Stewardship Areas and after the contract period in SA1.

## Methods

Three areas were chosen for long-term Stewardship contracts on the basis of a) known suitability for non-timber forest product harvest based on past greenery permits, b) adequate road access, and c) sufficient access restrictions to minimize poaching. Five-year moss-harvest (allowing some additional greenery harvest) contracts were put up for bid with the stipulation that contractors participate in monitoring efforts. D. Harrison was awarded a no-cost contract for SA1 in 1996 in exchange for his participation and submitted the winning bid for SA2 in 1997. The winner of the bid for SA3 in 1998 later defaulted on the contract. Location information and maps are in Appendix I and specific field methods are in Appendix II.

General stratified surveys of bryophytes included the portions of the dominant trees and shrubs below 6.6 ft in vertical height and the entire forest floor and all surfaces of all logs. The species of tree or shrub for which data were collected was be noted. The total percentage of all available substrate covered by a particular species was estimated and an appropriate cover class assigned to each species (1=1-2%, 2=3-10%, 3=11-25%, 4=26-50%, 5>51%, after R. Lesher, USDA FS, Gifford Pinchot National Forest). Forest floor surveys also included species typically epiphytic but currently established on the forest floor and still evidently alive. These surveys were conducted by T. Rambo or J. Peck and limited to 30 minutes. Field identifications were done by J. Peck or T. Rambo and vouchers verified by J. Christy. Nomenclature follows Anderson et al. (1990) and Stotler & Crandall-Stotler (1977).

Subsampling involved ten permanently-marked trees or shrubs in each plot. All bryophyte species present below 6.6 ft in vertical height, and their respective cover classes, were recorded. In addition, the number of harvestable mats (>12"x6"x2" volume) on each tree/shrub was estimated. In some cases, shrub branches were tagged; only the branch (rather than extending down the trunk) was the "stem." Forest floor subsampling involved estimating the cover class of all species present in 6.6 ft radius microplots at 32.8 ft from plot center in each of the four cardinal directions. Log subsampling included recording the cover class of all species present in a 9.8 x 9.8 in microplot placed on the upper surface of both ends and the center of each of five haphazardly selected logs.

Plots were also assessed for the visual impact of harvest (low/medium/high), and assigned a harvestability index: the number of harvestable moss mats below 6.6 ft. Harvestable mats were defined as typically >1/2 inch in thickness and relatively easy to remove.

## Harvest Level Areas

All three Stewardship Areas were divided into three Harvest Level Areas (HLA) representing 1) a no-harvest control, 2) harvest allowed according to the 1996 standards and guidelines for commercial moss harvest (the "Rules" plots), and 3) harvest allowed with no restrictions ("No Rules"). The 1996 standards and guides for commercial moss harvest on the Hebo Ranger District stipulated that harvest take place below 20 ft in vertical height but not from rocks, logs, or the forest floor nor within 200 ft (slope-corrected) of perennial surface water. Further, harvest was limited to every other stem each year and a cap was set on District wide permit sales at 25000 bushels (later converted to 110,000 lbs), which was converted to an allowable harvest rate of 30 lbs/ac based on estimated acreages and a 30% moisture content.

Ten 1/3 ac circular plots were randomly placed in upland mature forest in each HLA and were surveyed for bryophytes on the forest floor, logs, conifer trees, hardwood trees, and understory shrubs just prior to the initiation of the contract period in all three Stewardship Areas. The contract Steward provided records of the amount, date, and moisture content of moss harvested from each HLA for SA1 and SA2 (Appendix III). Surveys were repeated in thirty new random plots after the cessation of all harvest activity. Due to logistics, remeasurement did not take place until 2004 although the Steward had ceased harvest activities in 1999.

## Riparian Experiment

Twenty-four permanent 1/3 ac circular plots were established in SA1 to test harvest impacts within the riparian zone excluded from commercial harvest by the 1996 standards and guidelines (less than 200 slope corrected feet from a perennial stream; in this case, all plot centers were within 100 ft). Two replicates of the three treatments were placed along four streams segments within SA1. Thus 2 replicates X 3 treatments X 4 streams = 24 plots. All plots were surveyed for bryophytes on the forest floor, logs, conifer trees, hardwood trees, and understory shrubs prior to treatment and additionally sampled by assessing the bryophytes on ten permanently-tagged tree trunks/shrub stems in each plot. The contract Steward harvested each plot according to the Rules or No Rules restrictions and immediately recorded the weights and moisture content of harvested material. Each plot was remeasured within two weeks of the treatment (1996), then again one, two, and eight years following treatment (1997, 1998, and 2004).

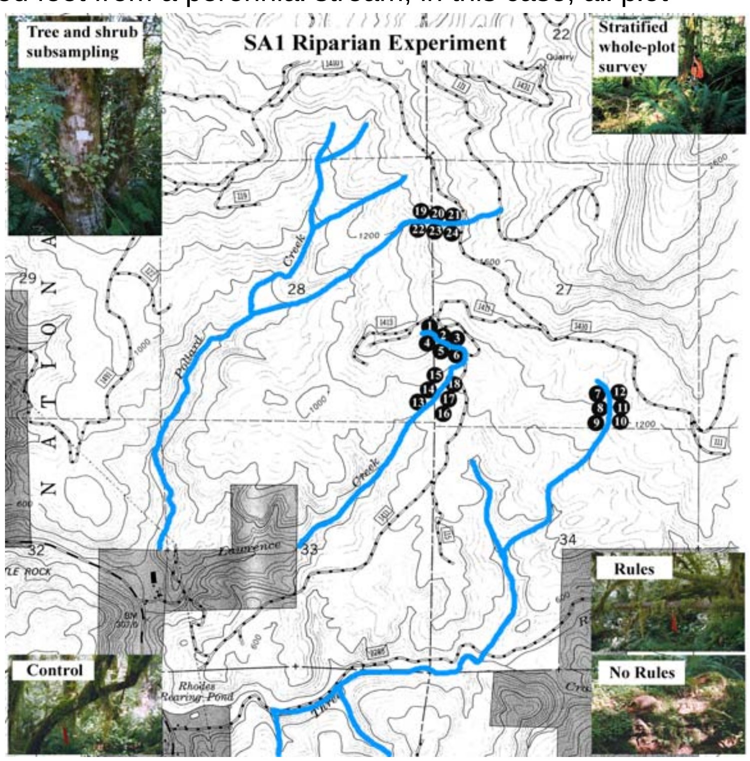


Figure 1. Two replicates of each treatment were randomly assigned to 1/8 ha circular plots along each of four stream segments within Stewardship Area 1.

## Upland vs. Riparian Experiment

Based on the riparian definition from the standards and guidelines for commercial moss harvest on the Siuslaw National Forest, areas further than 200 slope corrected feet from a perennial stream are designated "upland." Eight permanent 1/3 ac circular plots were established in "upland" portions of SA1 for comparison with the eight control plots from the riparian experiment to enable a comparison of upland and riparian bryophyte communities. Thus 8 replicates X 2 conditions = 16 plots. None of the "upland" plots are typical upland forest; they are merely outside the designated riparian zone. All 1/3 ac circular plots were surveyed in 1996 for bryophytes on the forest floor, logs, conifer trees, hardwood trees, and understory shrubs.

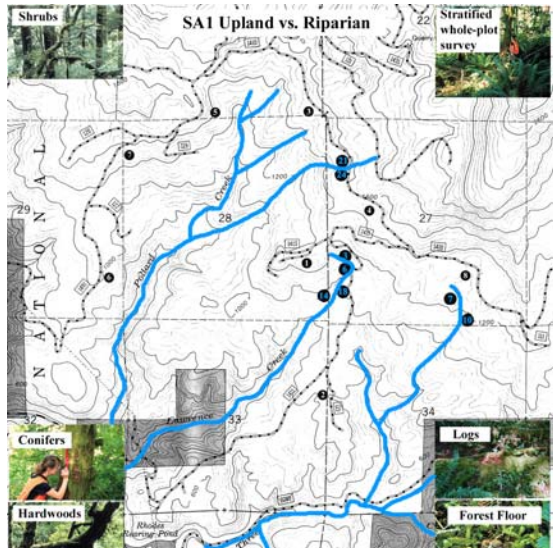


Figure 2. Eight 1/3 ac circular plots were placed outside the riparian zone to contrast with the 8 control plots from the riparian experiment.

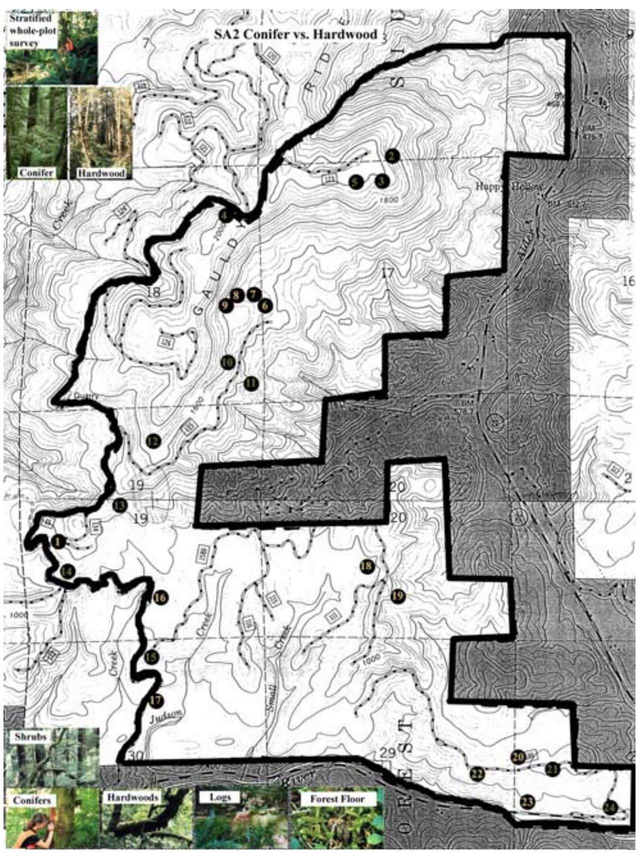


Figure 3. Six replicates of each of the two treatments were randomly assigned to plots in either conifer or hardwood dominated stands within Stewardship Area 2.

## Conifer vs. Hardwood Experiment

Twenty-four permanent 1/3 ac circular plots were established in SA2 to test for differences in harvest impacts between conifer and hardwood dominated forest types. Six replicates of each of two treatments (no-harvest Controls and 100 lb/ac Rules, which is comparable in intensity to the No Rules treatment in SA1) were randomly placed in mature forest dominated by either conifer or hardwood forest in 1997. Thus 6 replicates X 2 treatments X 2 conditions = 24 plots. All plots were surveyed for bryophytes on the forest floor, logs, conifer trees, hardwood trees, and understory shrubs prior to treatment and additionally sampled by assessing the bryophytes on ten permanently-tagged tree trunks/shrub stems in each plot. The contract Steward harvested each plot according to the treatment restriction and immediately recorded the weights and moisture content of harvested material. Each plot was remeasured within two weeks of the treatment (in 1997) and again in 1998.

## Data Analysis

Cover class values were converted to cover class midpoints for analysis. Species of *Dicranum*, *Frullania*, *Homalothecium*, *Orthotrichum*, *Porella, Scapania*, and *Ulota* were lumped at the generic level for analysis to ensure taxonomic consistency from year to year; rarely did more than one species of the same genus appear in a single microplot, so this is expected to have little effect on the analyses.

Parameters of interest included: species richness, mean percent cover (after converting cover classes to midpoints for analysis), relative species composition, and estimates of the number of harvestable mats. Univariate analyses were conducted in SAS v. 8.02 (SAS 1999). Treatment differences for univariate parameters were evaluated using ANOVA (PROC GLM in SAS), taking pre-treatment conditions into consideration and transforming the response variable when necessary (typically a natural log transformation). Significant or suggestive treatment responses were further investigated using the Tukey procedure in a multiple comparisons test. Responses with unequal variances were analyzed using the Wilcoxson (Kruskal-Wallis) rank-sum test (PROC NPAR1WAY in SAS). Errors are expressed as standard deviation (std.) or by indicating the range of the 95$^{th}$ percentile confidence intervals.

Multivariate species composition analyses were conducted in PC-ORD v. 4.33 (McCune & Mefford 1999). In all cases, matrices were composed of cover class midpoint data and were analyzed after species occurring in fewer than two observations (i.e. only once) were deleted. Analyses were conducted lumping across substrates and for each substrate separately (forest floor, logs, vine maple (*Acer circinatum*) stems, huckleberry (*Vaccinium parvifolium* and occasionally *V. ovatum*) stems, red alder (*Alnus rubra*) boles, and Douglas-fir (*Pseudotsuga menziesii*) boles). Because no differences in species composition among streams (SA1 Riparian Experiment) or randomly allocated plots (SA1 and SA2 Experiments) were found, analyses were not stratified by these variables. Differences in species composition among groups was evaluated using multi-response permutation procedures (MRPP in PC-ORD) based on the Sørensen distance measure or blocked MRPP based on the Euclidean distance measure, which requires a balanced design (equal sample sizes). Significant results were followed up with Indicator Species Analysis, which identifies those species with significantly (here $p>0.05$) higher frequency and abundance in a particular group.

### Harvest Level Areas

Percent cover and species richness from substrate stratified survey data were contrasted among treatments using ANOVA. The matrices of 1996 pre-harvest and 2004 post-harvest survey data were relativized by species maximas prior to multivariate analysis to de-emphasize highly frequent species. Treatment differences for each year were evaluated using MRPP. Differences among years taking treatment effect into account were evaluated using blocked MRPP on several randomly chosen subsets of the data (in order to meet the requirement of a balanced design).

### Riparian Experiment

Percent cover and species richness from substrate stratified survey and subsampling data were compared among treatments using ANOVA on absolute values and on the difference immediately prior to, and after, treatment in 1996. A class variable indicating on which stream each plot occurred was retained in the model when significant. Survey and subsampling data of post-treatment (1996, 1997, 1998, and 2004) cover class midpoints were evaluated separately for treatment effects on species composition using MRPP. Subsampling data were relativized by species maximas to de-emphasize highly frequent species prior to multivariate analysis.

Upland vs. Riparian Experiment

Percent cover and species richness from substrate stratified survey data were compared between riparian and upland plots using ANOVA. Differences in species composition between riparian and upland plots in a matrix of 1996 pre-harvest cover class midpoints, excluding species occurring fewer than twice in the dataset, were evaluated using MRPP.

Conifer vs. Hardwood Experiment

Percent cover, species richness, and the number of harvestable mats from substrate stratified subsampling data were compared between conifer and hardwood plots and among treatments using ANOVA. Differences in species composition between conifer and hardwood plots, and among treatments within conifer and hardwood plots, in matrices of 1997 pre-harvest, 1997 post-harvest, and 1998 post-harvest data were evaluated using MRPP. Differences in treatment effects between conifer and hardwood plots were evaluated using blocked MRPP on randomly chosen subsets of the data.

# Results

## Baseline Bryophyte Community Descriptions

General descriptive information about the dominant bryophyte communities on the Hebo Ranger District was obtained through the pre-treatment general surveys. Substrate stratified surveys enable summaries of species richness and abundance by substrate (Table 1) and by species for SA1 and SA2 (Appendix IV). The species recorded in these tables had abundances estimated to be at least 1% on a particular substrate in at least one plot; many other species were present in these plots, but in such low abundance as to preclude their observation during a rapid survey. Because virtually all of Stewardship Area 1 had been previously commercially harvested for moss (~15 years prior to the study), and 23% of the upland plots were estimated to have been harvested within five years of sampling, these surveys do not reflect the composition of undisturbed communities, but rather of communities in varying successional stages. A comparable level of harvest impact prior to initiation of the study is expected for SA2.

Table 1. Summary of Pre-Treatment General Survey Plots, SA1 and SA2
Mean alpha diversity is the average number of species per plot. Values in parentheses are standard deviations.
Cover classes are 1=1-2%, 2=3-10%, 3=11-25%, 4=26-50%, 5>51%.

| | Species Richness | Mean alpha diversity | Mean cover class |
|---|---|---|---|
| **SA1** | | | |
| Red alder | 17 | 4.6 (2.8) | 5 |
| Conifers | 14 | 3.4 (1.5) | 4 |
| Shrubs | 15 | 3.5 (2.2) | 5 |
| Logs | 21 | 4.1 (2.7) | 5 |
| Forest Floor | 7 | 2.0 (1.1) | 3 |
| **SA2** | | | |
| Red alder | 15 | 6.5 (2.5) | 5 |
| Conifers | 8 | 3.9 (1.2) | 4 |
| Vine maple | 13 | 7.1 (1.3) | 5 |
| Huckleberry | 10 | 4.0 (0.9) | 5 |
| Logs | 17 | 5.7 (1.7) | 5 |
| Forest Floor | 12 | 3.6 (1.3) | 4 |

## Harvest Level Areas

No significant treatment differences in average percent cover were observed for the forest floor, logs, vine maple, or huckleberry survey data (ANOVA, p>0.1). A suggestive difference was seen for red alder (p=0.08), but failed to remain in a multiple comparisons test. A significant difference in cover was seen for Douglas-fir (p=0.003), which had notably higher cover in the control area than either the Rules or No Rules areas. No significant treatment differences in species richness were observed for the forest floor, logs, vine maple, huckleberry, or Douglas-fir (ANOVA, p>0.1). A significant difference in species richness was seen for red alder (p=0.008), which was lower in the Rules plot than either the Control or No Rules plots. No treatment effect was seen for visual impact in 1996 (p=0.79) or 2004 (p=0.22) or for the harvestability index in 1996 (p=0.30) or in 2004 (p=0.15).

No *a priori* differences in species composition were observed for all substrates combined or any individual substrate in the 1996 pre-treatment data (MRPP p>0.1). Five years after the cessation of harvest activity in SA1 (2004), no differences in species composition were observed for all substrates combined or any epiphyte-bearing substrate or the forest floor (p>0.1). Some differences were seen on logs (p=0.06), but these may be related to coarse woody debris decay class (although lower abundances of *Antitrichia* and *Rhytidiadelphus* in the Rules and No Rules areas suggest possible log-moss harvest effects). Contrasting species composition in 1996 and 2004, taking treatment into account, revealed no significant differences for all substrates combined or any individual substrate (blocked MRPP, p>0.05).

The Moss Harvest Steward had five years in which to complete his harvest of SA1 and SA2, but due to concerns about poaching he completed his harvest within 45 months for SA1 and 35 months for SA2. Over the 48 months of harvest activity, his one to two person crew harvested in all but 10 months (Figure 4), which were generally dedicated to his other business activity (hauling holly boughs before Christmas). The most moss was harvested during dry spells in late spring and summer. Monthly totals ranged from 40-6800 lbs (corrected to an average moisture content of 26%), averaging 1883 lbs (which at $0.35/lb grosses approximately $659/month). A total of 145,000 lb of moss was removed by the Steward; 127,000 lbs from SA1 and 18,000 lbs from SA2. Although not estimated, SA1 is thought to have had substantially more moss at the initiation of the contract period. The average harvest rate in the No Rules area of SA1 was 166 lbs/ac, while only 19 lbs/ac in SA2. Over the five year contract period, this averaged to 18 lbs/ac/year. At an allowable harvest rate of 20 lbs/ac/year, the allowable harvest for SA1 would have been 71,300 lbs, which is 71% of what was actually harvested. For SA2, however, the allowable harvest would have been 76,300 lbs, over 530% of what was actually harvested.

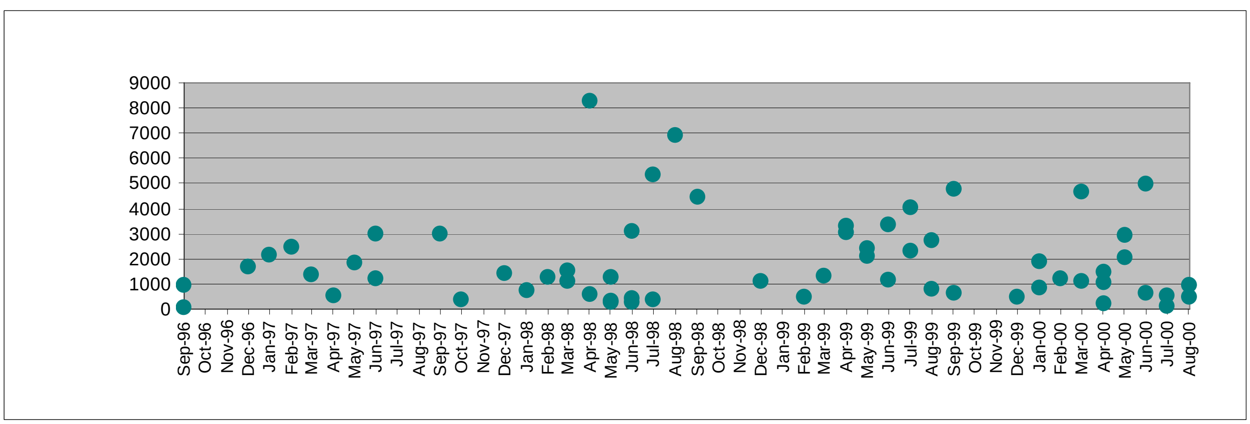


Figure 4. Total pounds of moss harvested from SA1 and SA2 (Y-axis) over the course of the Stewardship Areas Contracts (X-axis) (corrected to 26% moisture content).

## Riparian Experiment

No treatment differences were observed for cover or species richness on any substrate in any year for the substrate stratified survey data, including differences immediately before and after treatment in 1996 (ANOVA, p>0.08). No *a priori* differences in percent cover or species richness were observed for the substrate stratified subsampling data (p>0.2). Immediately following harvest, significant treatment differences were noted for percent cover only on vine maple shrubs (p=0.02), which declined in Rules plots by 5% (-3 to 13%) and in No Rules plots by 20% (10-30%). Treatment differences for percent cover persisted into years two and three following harvest (p<0.001) but were no longer observed in year eight (p=0.46). The same pattern was observed for percent cover and the number of harvestable mats when examining only those vine maple stems known to have been harvested. Immediately following treatment, these stems had reductions in percent cover of 27% (12-43%) in the Rules plots and 50% (35-64%) in the No Rules plots (p=0.4). The number of harvestable mats *per* stem also declined (-5, std. 5; equivalent to ~2.5 lbs at 15% moisture content), although no treatment differences were observed (p=0.64). Harvestable volume was also lower following treatment by 704 $in^3$ (std. 760 $in^3$), but again no treatment differences were observed (p=0.64). No other significant treatment effects were observed for percent cover, the number of harvestable mats, or harvestable volume for any substrate in any year (p>0.05).

No significant differences were noted for species richness on any substrate immediately following harvest (p>0.05), although a suggestively lower species richness on vine maple stems in No Rules plots as compared to Rules and Control plots was observed (p=0.06). Relatively lower species richness in the No Rules plot on vine maple stems continued into the first year following harvest (p=0.06), but dissipated by year two (p=0.24). No other significant treatment effects were observed for species richness for any substrate in any year (p>0.05).

No *a priori* differences in species composition were observed for the 1996 survey or subsampling data for all substrates combined or for any individual substrate (MRPP, p>0.05). No treatment effects were detected for post-treatment survey or subsampling data for all substrates combined or any individual substrate in any year (p>0.05). When examining only those stems known to have been harvested, species composition was significantly different between Rules and No Rules plots on shrubs (p=0.0012) immediately after harvest in 1996. However, this difference disappeared by 2004 (p=0.72). Comparing unharvested stems in the Control plots to harvested stems in the Rules and No Rules plots, species composition on shrubs was significantly different immediately following treatment (p<0.0001) due to a greater frequency and abundance of “large mat” species (*Antitrichia*, *Isothecium*) in the control plots. One year following harvest, only a suggestive difference in species composition on harvested stems remained (p=0.08), and by two years (and eight years) following harvest, none at all (p>0.7).

Immediately following treatment, the harvestability index decreased by a significantly larger margin in the No Rules than the Rules plots (ANOVA, p<0.5). This corresponds with the visual impact of medium or high for both Rules and No Rules plots. By 1998, the differences among treatments, although substantial (~40 fewer 12”x6”x2” harvestable mats in the No Rules plots than the Rules or Control plots in 1996), were no longer significant (p=0.3). After two years, the Rules plots had only a low or medium visual impact from harvest, while most No Rules plots still had a medium or high visual impact. Eight years after harvest, although roughly half the plots still had a medium visual impact, no treatment difference remained.

Of the 240 stems tagged and measured in 1996, 40 (17%) had died by the time they were remeasured eight years following treatment. Although some of the stems simply died, most were killed by falling overstory trees.

## Upland vs. Riparian Communities

No differences in percent cover, maximum percent cover, or species richness were observed between upland and riparian plots for the survey data from the forest floor, vine maple, red alder, or Douglas-fir substrates (ANOVA, $p>0.2$). Percent cover was significantly higher on logs in upland plots than in riparian plots ($p=0.001$), with a median difference of 31% (95$^{th}$ percentile confidence interval from 24-40%). Despite a strong relationship between the number of years since apparent harvest and the harvestability index ($R^2=0.32$, $p=0.02$), neither were significantly different among riparian or upland plots ($p>0.11$). Plots with higher hardwood basal area, however, tended to have been harvested more recently ($p=0.04$) and to have a higher harvestability index ($p=0.01$), but no pattern was seen with shrub basal area ($p>0.16$).

No differences in relative species composition for all substrates combined was observed between upland and riparian plots (MRPP, $p=0.19$). Comparing the two habitat types for each substrate type separately, species composition on logs tended toward more epiphytes in upland plots and more moisture loving species in riparian plots ($p=0.04$). No apparent pattern in species distributions was evident despite the significant difference in relative species composition between upland and riparian plots for Douglas-fir boles ($p=0.02$). Comparing the upland and riparian plots while taking substrate into consideration revealed a significant difference (blocked MRPP, $p=0.014$), but substrate separation appears to be far more important than differences between riparian and upland conditions.

## Conifer vs. Hardwood Experiment

No *a priori* differences in average percent cover or species richness were observed for any substrate in the 1997 pre-harvest survey data in conifer or hardwood dominated plots (ANOVA, $p>0.1$). No treatment effects were observed for any substrate in the 1997 or 1998 post-harvest survey data in either conifer or hardwood plots ($p>0.2$). Suggestive differences in the treatment effect were observed between conifer and hardwood plots in the survey data for logs, red alder, and huckleberry ($0.05<p<0.08$).

Subsampling data on vine maple shrubs indicated no difference in percent cover ($p=0.09$) but a significant difference in species richness (0.0001) between the conifer and hardwood plots in pre-harvest data, with roughly one more species per sample in the hardwood plots than conifer plots (averaging 5.1 (4.7-5.4) in the former and 4.3 (3.9-4.7) in the latter). Because of significant pre-harvest differences among the treatment plots, pre-harvest levels were also included in post-harvest treatment effects models. Immediately following harvest, percent cover differed significantly among treatments ($p<0.0001$) and the treatment effect was significant ($p<0.001$). Rules plots averaged 16% lower cover following harvest than control plots (8-24%). Although species richness differed significantly among conifer and hardwood plots and among treatments following harvest ($p<0.01$), the treatment effect was not significant ($p>0.4$). One year following harvest, treatment was no longer significant for percent cover either ($p=0.2$). No differences were found in the estimated number of harvestable mats between conifer and hardwood plots, pre- to post-treatment, or among treatments ($p>0.05$).

Subsampling data on red alder boles indicated no difference in percent cover, species richness, or the number of harvestable mats between the conifer and hardwood plots in pre- or post-harvest data for any year ($p>0.21$). Similarly, no treatment differences were observed and treatment effects were non-significant ($p>0.12$). Most tree boles were unimpacted by harvest.

Significant differences in species composition were observed between conifer and hardwood dominated plots for all survey data combined (MRPP, $p<0.01$). Differences for vine maple stems ($p=0.001$) reflected somewhat higher frequency and abundance of *Isothecium* in conifer plots and *Antitrichia* and *Claopodium* in hardwood plots. Differences on logs ($p=0.01$) reflected a higher frequency and abundance of *Rhytidiadelphus* in hardwood plots, while that on the forest floor ($p=0.002$) reflected a higher frequency and abundance of *Eurhynchium* in conifer plots. No *a priori* (1997 pre-treatment) differences among treatments were observed within either conifer or hardwood plots (p>0.06). Immediately following treatment (1997 post-treatment), significant treatment effects in the conifer plots were observed for vine maple (p=0.05) and huckleberry (p=0.01), possible due to lower frequency and abundance of several moss harvest target species (although none were significant, probably due to the low sample size). One year after harvest (1998), significant treatment effects were no longer observed (p>0.3). No significant treatment effects were observed for any substrate in any year in hardwood plots (p>0.1). No differences in treatment effects were observed between conifer and hardwood plots for any year (blocked MRPP on vine maple, p>0,16).

Significant differences in species composition were observed between conifer and hardwood dominated plots for shrub subsampling data prior to, immediately after, and one year following treatment (MRPP, p<0.036). These differences reflected the tendency for higher frequency and abundance of *Antitrichia*, *Dicranum*, *Hypnum*, *Leucolepis*, *Neckera*, and *Rhytidiadelphus* in hardwood plots, and *Porella* in conifer plots. No differences were observed for trees (p>0.17). When blocking by conifer-hardwood cover type, no treatment differences were observed for any year for either substrate (p>0.06). However, it should be noted that relatively few of the permanently tagged stems were actually harvested during treatment.

## Discussion

The results from this project confirm many basic suppositions regarding commercial moss harvest. First, the list of species encountered in this project is extremely similar to those derived from other studies of PNW epiphyte communities subject to commercial harvest, including those identified from commercially sold bags of moss. The pattern of a handful of dominant species covering the majority of available growing surfaces in SA1 and SA2 is typical of bryophyte communities in western Oregon. Although previous work has found significant differences in species composition in harvestable bryophytes from the Coast and Cascade Mountain Ranges, these differences are so subtle that it is not possible to conclusively identify the source of material. This kind of shared similarity gives rise to the presumption that we can realistically extrapolate the results of these projects throughout the impacted regions of western Oregon.

These results do conclusively demonstrate that the designation of “riparian” zones within 200 slope corrected feet of a perennial stream is not a meaningful delineation for harvestable bryophyte communities on this portion of the Hebo Ranger District. Not only were no differences in cover, species richness, or species composition observed for communities designated as riparian or non-riparian (“upland”) condition, but no relationship whatsoever was observed between distance to water and these parameters for plots ranging from 32-2250 feet from a stream. The most significant relationship with respect to distance to water is the increase in salmonberry in the immediate riparian zone, which substantially reduces light to the lower understory and forest floor. Although lower cover and species richness were observed in plots in which salmonberry was present, these were not always those closest to water. This suggests that in the heavily fog-impacted Mt. Hebo area light may be more important than moisture. This would explain the lower diversity of log species in the salmonberry-filled riparian plots, which I believe causes reduced diversity on confer boles due to a decrease in propagule availability. Although asexual reproductive structures may be spread several feet in a heavy downpour and spores many feet by wind, many log species are sufficiently dispersal limited that a patch of salmonberry ten feet deep may effectively serve as a propagule block.

The zone bearing the greatest volume of harvestable material available with the least effort (i.e., not having to machete through salmonberry) is most susceptible to (and suitable for) harvest, and this zone appears to be somewhere between 100 ft and 1000 ft from the stream.

True upland sites were not examined in this project, for the simple reason that harvestable moss does not occur in such sites. Given that no differences in cover, species richness, species composition, or harvestability were seen between riparian and "upland" sites for harvestable epiphytes, extrapolations of results from the riparian experiment to this larger quasi-riparian zone may be acceptable.

Despite the association of harvestability with hardwood basal area, overstory composition cannot be used to identify this zone; half of the plots in SA2 within this quasi-riparian zone were dominated by hardwoods and half by conifers. Although harvestable epiphyte communities differed slightly with respect to species composition and diversity between conifer and hardwood dominated plots, these differences are again so subtle that the source could not be determined for moss harvested from either forest type. Thus, extrapolation of the results from these experiments to all mixed conifer-hardwood forests of ~50-240 $f^2$/ac in basal area on the Hebo Ranger District may be acceptable.

Given the very low amount of material harvested from SA2, it is highly unlikely that any kind of post-harvest treatment effects would have been observable. Despite visual signs of harvest in 77% of randomly placed plots and high visual impact in over a third of plots (including refuse in three) in SA1, the only apparent treatment effect from the HL experiment was lower cover on the low hanging limbs of Douglas-fir. The extremely patchy nature of harvest, even within a harvested site, leaves enough epiphytic material behind to not fundamentally alter the structure of the community. The relatively minor impact of harvest on these parameters in both the riparian experiment and conifer/hardwood experiment confirm that although harvest can be locally highly impactuous, at the stand level the effect is minor. Further, these local effects do not appear to have long-term impacts with respect to these parameters. Cover is reduced temporarily on those stems that were harvested, but returns to pre-harvest levels within a few years. Harvest, centered on the handful of dominant species, has little impact on species richness or overall species composition. This may be particularly the case in areas with a past-history of harvest, which appears to be the majority of the Hebo Ranger District. Given the paucity of unharvested sites, we may never know the impact of harvest on "virgin" moss.

Despite the lack of significant treatment effects, a reduction in harvestable volume/biomass was observed and results from the regrowth study indicate that these impacts may be much longer term. The Moss Steward completed his harvest of SA1 and SA2 prior to the enddate of his contracts. He did not cease harvest because of time constraints or other opportunities, but because he had harvested all there was to take. The subsequent management implications of this are twofold. First, areas contracted for harvest in this fashion will not be suitable for harvest again for many years; small mats must have time to develop and become "harvestable." Second, no studies exist to guide management decisions on the ecological impacts of the removal of large volumes of epiphytic moss. In addition to implications for the macroinvertebrates that have been documented to reside in and utilize these mats, the hydrologic properties of large moss mats may be important for the forest ecosystem.

Finally, the difference in the harvested volume from SA1 and SA2 demonstrates the extreme variability in the availability of harvestable moss on the Hebo Ranger District. Even in areas where we expect to find "good moss," there can be too little to support a long term harvest contract. Until a current resource inventory on the entire district is conducted, it will be impossible to accurately predict the available inventory of harvestable moss.

## Conclusions

1. Because harvestable moss is similar across upland and riparian conditions and conifer and hardwood overstories, the results from this project should be generally applicable to all mature mixed forests over 50 years in age on the Hebo Ranger District of 50-240 $ft^2$/ac in basal area below 1500 ft feet in elevation within the 100-1000 ft quasi-riparian zones.
2. Patchy harvest at levels up to 100 lbs/ac appears to have no long-term impacts on percent cover, species richness, or species composition in such sites.
3. The implications of the reductions in volume/biomass following harvest remain unknown.
4. A District-wide inventory is needed to accurately predict available harvest volumes.

## Evaluation of the Standards & Guidelines for Moss Harvest on the Siuslaw National Forest

Although not specifically designed to address all aspects of the standards and guidelines for commercial moss harvest on the Hebo Ranger District, field observations and results from this program provide some insight into their appropriateness and utility. Further, it is noted that the success of self-patrolled S&Gs relies on the willingness of the harvester to obey the rules; for that to happen, S&Gs must be reasonable and easy to follow. Recommendations on each S&G are listed below each evaluation.

<u>No harvest of moss from rocks, logs, or the forest floor</u>

This S&G does not appreciably reduce the available volume of moss for harvest, as these substrates provide only a small proportion of harvestable moss in the Coast Range (this situation may be quite different in other regions). Data from the baseline surveys indicates that these strata have diverse bryophyte communities. Loss of diversity in other ecosystems has been attributed to the patchy quality (e.g., paucity) of these strata for bryophyte colonization (Söderström 1987), which is further confounded here by the decreasing supply of large coarse woody debris in managed forests. Further, significant damage to vascular plants, including regenerating tree seedings on nurse logs, is incurred with the harvest of log-moss.

- There is no justification for altering this standard and guideline.

<u>No harvest above 20 ft in vertical height.</u>

This S&G was intended to protect canopy dwelling mosses (i.e., *Antitrichia curtipendula* for marbled murrelet nests) and lichens (particularly cyanolichens; Bill Denison, OSU), which occur occasionally in the lower canopy but are predominant in the upper canopy, and to provide a source of propagules and litterfall to repopulate disturbed strata in the lower canopy (Bruce McCune, OSU). This standard and guideline reduces the available volume of moss for harvest, in some cases substantially. However, to harvest above this height requires either climbing or the use of rakes, both of which are already (and should remain) prohibited for reasons of personal safety as well.

- There is no justification for altering this standard and guideline.

<u>Harvest only every other trunk/stem each year</u>

This S&G does not achieve its intended goal of ensuring that some moss biomass remains after harvest, as different harvesters on different days can subsequently harvest the same area of all moss within a few visits. This is further complicated by the fact that fewer than half of tree trunks and shrubs stems may have harvestable moss to begin with. This S&G is also completely unenforceable and unlikely to be followed by most commercial harvesters, thus breeding an attitude of acceptability in ignoring the standards and guides.

- I recommend that this standard and guideline be changed to a recommendation only.

<u>No collection within 200 ft (slope corrected) of perennial surface water</u>

This standard and guideline affords two general types of protection:

1. Protection of the hydrologic and other ecosystem processes afforded by substantial moss mats in riparian areas. Unfortunately, to date no data exist that demonstrate the extent of these processes in the understories of temperate forests.
2. Protection of a unique or rare stream and forest floor bryoflora present in riparian areas (i.e., protection from trampling disturbance, erosion from trails, etc.). The bryophyte flora within 100 ft of a stream channel is often unique (see Jonsson 1996). This measure of protection is appropriate, and should have very little impact on harvest volume.

In much of the Coast Range, the first 100 ft from a stream is often steep and filled with salmonberry, harboring very little *harvestable* moss but a high diversity of bryophytes not typically seen in the nearby upland forest (especially on the forest floor and stream banks). Therefore, restricting moss harvest in this area should not substantially affect harvest volumes and will protect this source of diversity. However, few harvesters are able to estimate how far 200 *slope-corrected* feet are from a stream and most wander into the 100 to 200 ft region, where substantial harvestable moss is often present. Based on surveys conducted the SA1 experimental plots, the epiphytic bryophyte community in the 100 to 200 ft region does not differ from that of the surrounding upland forest. It may therefore be acceptable to harvest moss within this region. In addition, many streams on Hebo are seasonal and this S&G currently provides no protection for these streams, which also harbor unique bryophyte communities.

- I therefore recommend altering this S&G to 100 ft, not-slope corrected, from a stream bed (wet or dry).

<u>Harvest in the LSR's</u>

One feature of old-growth ecosystems is the development of highly complex and diverse epiphyte communities within the understory, as well as in the canopy. These understory communities can only develop if human disturbance is minimized, suggesting that commercial moss harvest in LSR’s is not appropriate. There are very few places within the Hebo District where moss has not been harvested within the past 20 years; most areas have only “second-growth,” or younger, moss. Old-growth moss mats, and their associated lichens (see Rosso 1998), vascular plants, and invertebrate communities, are virtually absent. These large moss mats may also contribute substantially to water cycling in coastal forests, an ecosystem function that ceases to occur in the absence of large mats.

- I strongly recommend that moss harvest be prohibited in Late Successional Reserves.

<u>One-year rotation period</u>

Currently, 1/5 of the District is open for moss harvest in any given year, rotating each area every year. This allows five years for recovery between harvest periods. Based on the recent regrowth data analysis (Peck 2004), moss mats require up to 25 years to recover their biomass.

- I recommend that the rotation period be increased to five years, starting in 2005.

110,000 lb/year limit

The current cap on moss harvest on the Hebo District is below the historic harvest (illegal + legal) and below current demand, prompting widespread poaching and a disregard for S&Gs. In all likelihood, the only S&G that is in any way enforceable is the annual cap. It appears that roughly 30,000 acres on the Hebo Ranger District are suitable for commercial moss harvest (subtracting plantations < 50 years in age, riparian areas, roads, rock outcrops and other non-forested areas, and LSR), leaving roughly 6000 acres open at any one time. Assuming an average inventory of 200 lbs/ac (for moderately mossy sites from Peck & McCune 1998), 1,200,000 lbs would be available for harvest. The district as a whole, however, has never been inventoried for moss and no estimates exist for "average" conditions. However, assuming that harvest should not take place in these areas at a level greater than our contract Stewards "No Rules" treatment rate of 100 lbs/ac, harvesters could remove 600,000 lbs of moss over the five year contract period (120,000/yr).

- There is no justification for altering this standard and guideline at this time.

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## Appendix I.  Plot Locations and Maps

**Location of SA1**

Stewardship Area #1 (formerly greenery area #16) is ~2300 acres in size and is bordered by FS1491 to the west and north, FS1411 to the east, and FS2285 and private land to the south.  The area consists of clearcuts and young conifer forest, young to mature hardwood and mixed forest, and some older conifer forest (LSR).  Stewardship Area 1 includes most of Pollard Creek and much of Lawrence Creek and is bordered to the south by Three Rivers.

<u>Harvest Level Area 1</u>:  Bordered by 1410 to the east, private property and 2285 to the south, 1411 to the north and west, and a stream drainage connecting 1411 and 2285.  This area is to be harvested according to the following standards and guidelines (Rules):

- No harvest within 100 ft of a perennial stream
- No harvest above 40 ft in height
- Harvest less than 30 lbs of moss per acre (wet weight)

<u>Harvest Level Area 2</u>:  Bordered  by 1411 to the east and south, private property to the south and west, power lines to the west, and Pollard Creek to the west and north.  This area is to be harvested at the discretion of the Steward.  No restrictions apply to moss harvest (No Rules).

<u>Harvest Level Area 3</u>:  Bordered by 1410 to the east, Pollard Creek to the south, and 1491 to the west.  This area is to be left unharvested (Control).

**Location of SA1 Riparian Experimental Plots**

The boundaries of all permanent plots are flagged using long strips of solid red flagging.  Red and white stripped flagging marks the trail from the road to the center of each permanent plot.  Each permanent plot is marked at the center with a cedar stake.  It is advisable for these stakes to be marked with plot numbers upon subsequent visits, and for bearings to be recorded from nearby tagged trees to the centerpoint.  Yellow flagging marks the boundaries where two adjacent plot meet.  Three adjacent plots lie on both sides of each stream.

Stream 1 = Park at the spur just past the intersection of FS 1411 and 1413.  Walk along 1413 past the spur to where red flagging marks trees to the south.

The boundary of plot #1 abuts the road; thus the flagging seen from the road marks the northern edge of this plot.  Plot #2 is adjacent to plot 1, to the east.  Plot #3 is adjacent to plot #2, to the east.  Flagging from the 1411 road will lead to this plot, but access is easier from 1413.  Plot #4 is accessed by crossing the drainage near plot 1 and heading upslope toward the red flagging.  Plot #5 is adjacent to plot 4, to the east.  Plot #6 is adjacent to plot 5, to the east.

Stream 2   = Park in a spur north of a plantation to the southwest of 1410, below 1411 and above the 111 spur.

To access Plot #7, follow the flagging in from 1410 until you cross the stream.  This plot is the furthest north plot on the west side of the stream.  Plot #8 is adjacent to plot 7, to the south.  Plot #9 is adjacent to plot 8, to the south.  Plot #10 is the furthest south plot on the east side of the stream.  Plot #11 is adjacent to plot 10, to the north.  Plot #12 is adjacent to plot 11, to the north.  You pass through this plot to cross the stream.

Stream 3   = Park at the flagging on the northwest side of 1411 below 1413.

To access Plot #13, follow the flagging in from 1411, downslope and across the stream, and to the furthest extent west.  This plot is the furthest west on the north side of the stream.
Plot #14 is adjacent to plot 13, to the east.  You pass through this plot to get to plot 13.  Plot #15 is adjacent to plot 14, to the east.  You enter this plot after crossing the stream.  Plot #16 is the furthest west plot on the south side of the stream.  Access is best directly from 1411 at the third set of flagging.  Plot #17 is best accessed directly from 1411 at the second set of flagging.  Plot #18 is accessed from 1411 at the first set of flagging.  You pass through to cross the stream.

Stream 4 = Park at the wide spot near the Alder log where Pollard Cr. crosses 1410, above 1411.

Plot #19 is the furthest north on the north side of the stream. Access from flagging on 1411 and follow flagging to furthest northern extent. Plot #20 is adjacent to plot 19, to the south. You pass through this plot, following the flagging, to get to plot 19. Plot #21 is adjacent to plot 20, to the south. You enter this plot first from the road. Plot #22 is the furthest west on the south side of the stream. Enter from 1410 at the waterbar and follow deer trail to the furthest extent of flagging. Plot #23 is adjacent to plot 22, to the east. Plot #24 is adjacent to plot 23, to the east.

The Control plots are: 3, 6, 7, 10, 14, 18, 21, 24
The No Rules plots are: 2, 4, 9, 11, 13, 16, 20, 22
The Rules plots are: 1, 5, 8, 12, 15, 17, 19, 23

| Access Point | Location | UTM |
|---|---|---|
| Stream 1; nearest Plot 1, at turnaround with spur to landing | 10 T 0438472 | 5004527 |
| Stream 2; nearest Plot 12, at turnaround with spur to landing | 10 T 0439760 | 5004014 |
| Stream 3; nearest Plots 16 & 17 | 10 T 0438710 | 5004190 |
| Stream 3; access to rest of plots just south of curve in road | 10 T 0438677 | 5004259 |
| Stream 4; opposite log (downslope) from curve in the road | 10 T 0438500 | 5003517 |

**Location of SA2**

Stewardship Area 2 (which includes half of the former greenery area #28) is ~2200 acres in size and is bordered by private land to the west, FS15 to the east and north, and the Little Nestucca Hwy. to the south. The area consists of plantations and young conifer forest, young to mature hardwood and mixed forest, and some older conifer forest (LSR). Stewardship Area 2 includes small sections of several small streams, including most of Small Creek and much of Judson Creek.

<u>Harvest Level Area 1</u>: The southern most Area, HL1 is bordered by private land to the east and north, the Little Nestucca Hwy. to the south, and Small Creek and 1586-116 to the west. This area is to be harvested according to the following standards and guidelines (Rules):

- No harvest within 100 ft of a perennial stream
- No harvest above 40 ft in height
- Harvest less than 30 lbs of moss per acre (wet weight)

<u>Harvest Level Area 2</u>: HL2 is sandwiched in between HL1 and HL3, bordered by the Little Nestucca Hwy. to the south, FS15 to the west, Small Creek, 1586-116, and private land to the east, and the drainage of a Bear Creek tributary to the north. This area is to be harvested at the discretion of the Steward. No restrictions apply to moss harvest (No Rules).

<u>Harvest Level Area 3</u>: The northern most Area, HL3 is bordered by private land to the east, the drainage of a Bear Creek tributary to the south, and FS15 and a drainage to the west and north. This area is to be left unharvested (Control), which will be facilitated by the presence of a locked gate on the only road leading into this area (FS15-123).

Location of Experimental Plots

The boundaries of all permanent plots were originally flagged using long strips of candy-striped (red and white) flagging, with orange flagging marking the trail from the road to the center of each permanent plot. Each permanent plot was marked at the center with a cedar stake labeled with the plot number. The locations of these plots are marked on the map for SA2. However, it is not expected that these plots will be able to be relocated, as the flagging has deteriorated and cedar stakes used in other parts of this study were found to disappear at a high frequency.

The Control plots are: 2,3,8,9,10,11,16,17,20,21,22
The Rules plots are: 4,5,6,7,12,13,14,15,18,19,23,24

Figure I.  Map of all moss harvest research sites on the Hebo Ranger District.  Numbered plots indicate long-term regrowth sites.

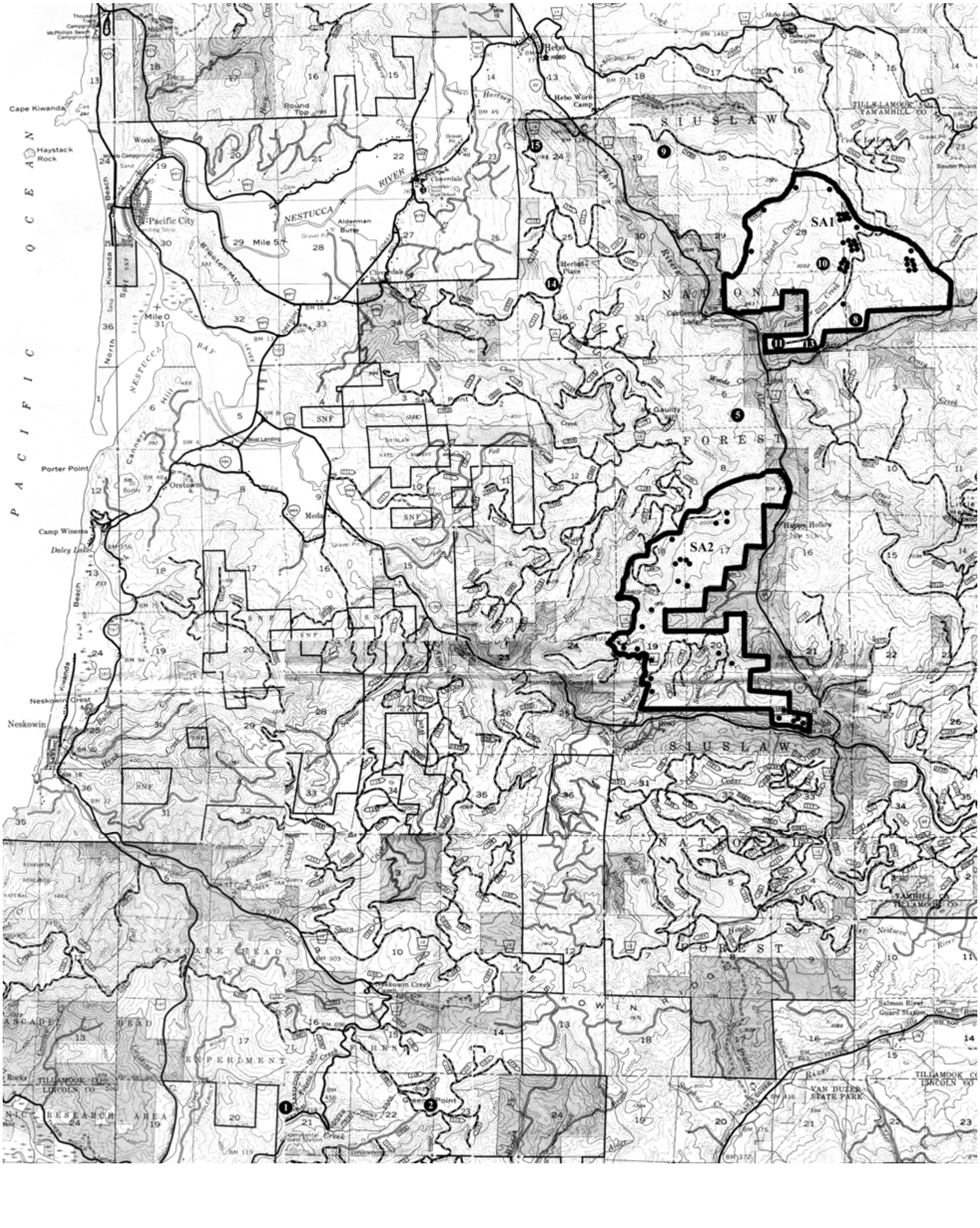


Figure II.  Map of all permanent plots on Stewardship Area 1.

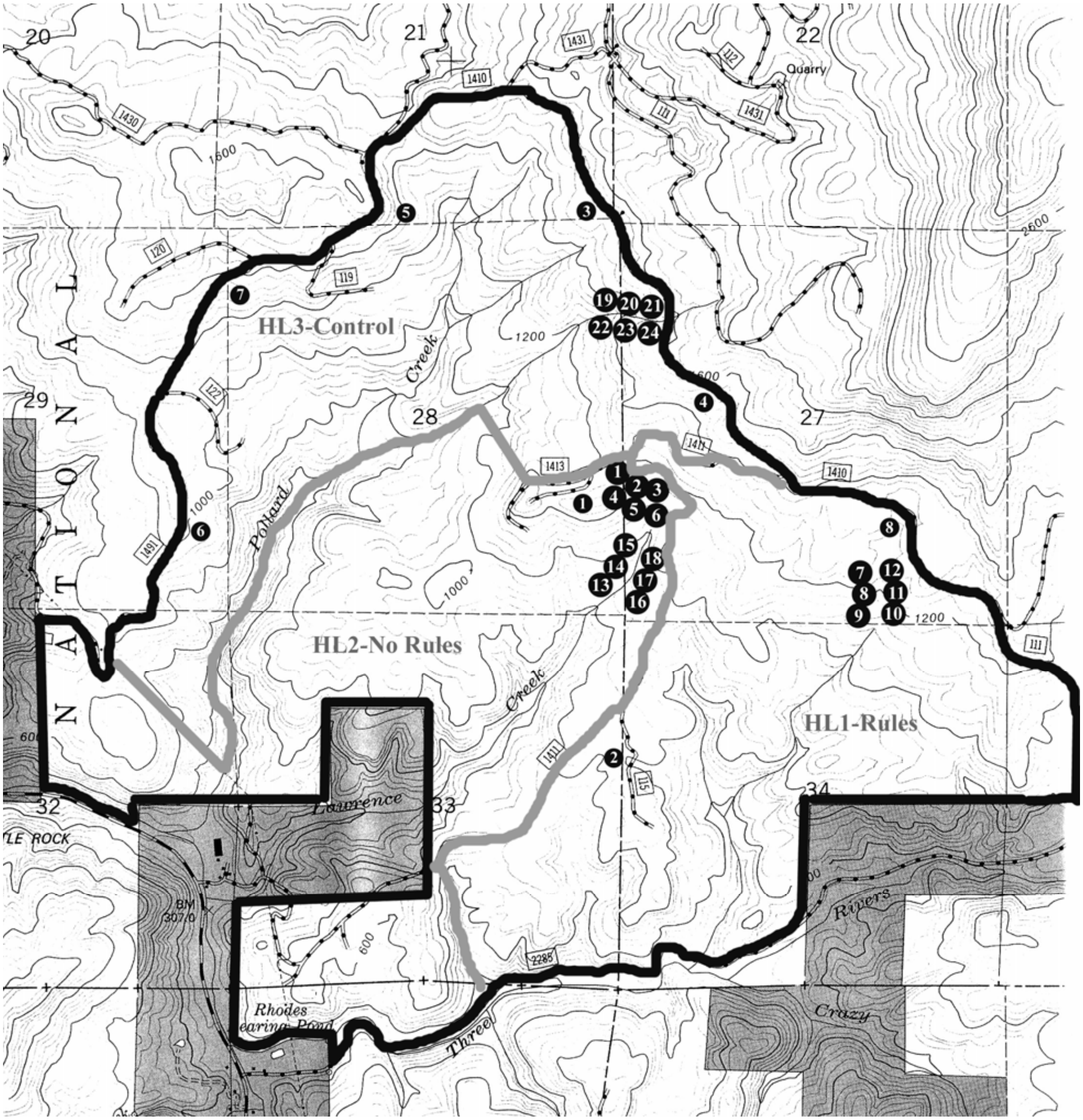
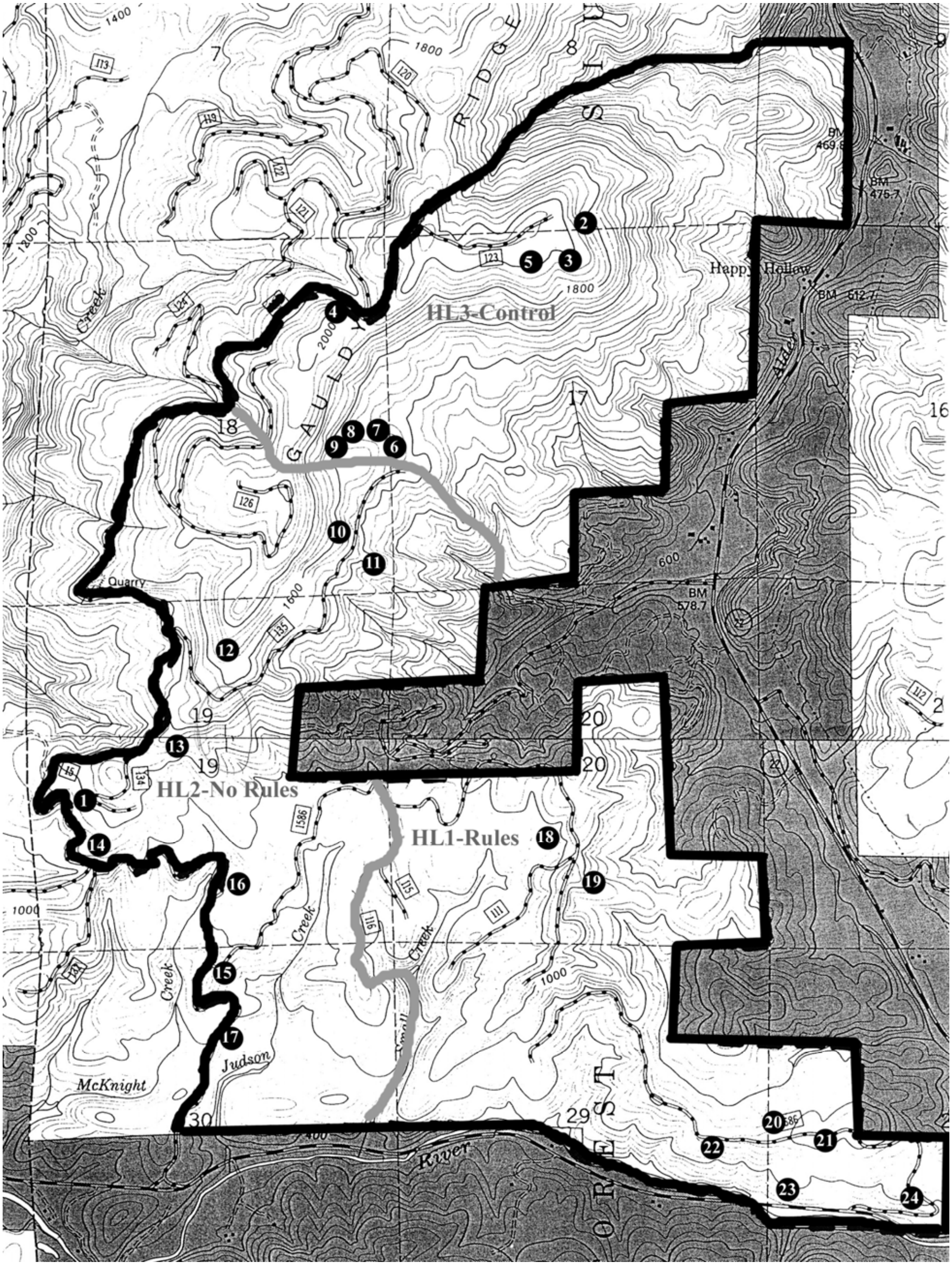


Figure III.  Map of all permanent plots on Stewardship Area 2.



## Appendix II.  Field Protocols

Survey:

- Measure 20 m from plot center in each of four cardinal directions (use metal centerpin to hold tape measure at plot center).
- Flag edge of plot in each direction and measure BA in full circle with wedge prism, counting overlap as 1 and touching edges as 1/2.  Measure canopy cover with densiometer, counting 1/4 squares of open sky as 1 and measure facing all four directions at same spot.
- Measure BA and canopy cover at plot center; record dominant trees and shrubs, aspect with compass, % slope with clinometer (average of upslope and downslope readings), and topographic position (write in type of geomorphology, e.g. ridge, midslope, bottomland).
- Examine forest floor in entire plot, recording all species of bryophyte first.  When finished, estimate percent of area in plot covered by each species.  It is not necessary to record species with less than 1% cover (can use “T” if already on datasheet).
- Examine all surfaces of all logs in entire plot, recording all species of bryophyte first.  When finished, estimate percent of log surface area in plot covered by each species.
- Examine all shrubs of the dominant shrub species (1 or 2) after recording shrub species. Record all species of bryophyte first; when finished, estimate percent of shrub surface area in plot below 2 m covered by each species.
- Examine all trees of the dominant tree species (1 or 2) after recording tree species. Record all species of bryophyte first; when finished, estimate percent of tree surface area in plot below 2 m covered by each species.
- After completion of survey, estimate the Harvestability Index:  how many 12”x6”x2” harvestable moss mats are present in the plot?
- Note if there are signs of previous harvest or recent disturbance in the plot.

Subsampling:

- Place a 2 m radius circular plot on the forest floor at 10 m from plot center in each of four cardinal directions.  Record all species present in microplot and estimate the percentage of area in the microplot covered by each species.
- Haphazardly locate 5 logs within the plot and place an 25 by 25 cm microplot on the upper surface at the center of each log.  Record all species present in microplot and estimate the percentage of area in the microplot covered by each species.
- Select or relocate ten trees or shrubs in each plot that have, if possible, harvestable quantities of moss. Measure the diameter at breast height of new trees and shrubs.  Examine the trunk and branches of each tree below 2 m in height and record all species.  Estimate the percent of the surface area of each tree covered by each species.  Repeat for shrubs; note that only the stem with the tag should be measured for shrubs.

## Appendix III. Contract Steward Moss Harvest Records

| **TOTAL SA1** | | | **136,937** |
|---|---|---|---|
| **Date** | **HL** | **Pounds** | **MC** |
| Sep-96 | No Rules | 1099 | 10 to 18 |
| Sep-96 | Rules | 46 | 10 to 18 |
| Dec-96 | No Rules | 2370 | +30 |
| Jan-97 | No Rules | 3292 | +30 |
| Feb-97 | No Rules | 3762 | +30 |
| Mar-97 | No Rules | 1764 | 18 to 30 |
| Apr-97 | No Rules | 796 | +30 |
| May-97 | No Rules | 2440 | 18 to 30 |
| Jun-97 | No Rules | 962 | +30 |
| Jun-97 | No Rules | 640 | 10 to 18 |
| Jun-97 | Rules | 3462 | 10 to 18 |
| Mar-98 | No Rules | 1589 | +30 |
| Mar-98 | No Rules | 559 | 10 to 18 |
| Apr-98 | No Rules | 5774 | +30 |
| Apr-98 | No Rules | 2572 | 10 to 18 |
| Apr-98 | No Rules | 1136 | 18 to 30 |
| May-98 | No Rules | 1562 | +30 |
| May-98 | No Rules | 296 | 18 to 30 |
| Jun-98 | No Rules | 3293 | +30 |
| Jun-98 | No Rules | 506 | 10 to 18 |
| Jun-98 | No Rules | 671 | 18 to 30 |
| Jul-98 | No Rules | 4245 | +30 |
| Jul-98 | No Rules | 2991 | 10 to 18 |
| Aug-98 | No Rules | 7963 | 10 to 18 |
| Sep-98 | No Rules | 5159 | 10 to 18 |
| Dec-98 | No Rules | 1730 | +30 |
| Feb-99 | No Rules | 687 | +30 |
| Mar-99 | No Rules | 2012 | +30 |
| Apr-99 | No Rules | 3378 | +30 |
| Apr-99 | No Rules | 991 | 10 to 18 |
| Apr-99 | Rules | 3547 | +30 |
| Apr-99 | Rules | 1159 | 10 to 18 |
| May-99 | No Rules | 2896 | +30 |
| May-99 | No Rules | 592 | 10 to 18 |
| May-99 | Rules | 1988 | +30 |
| May-99 | Rules | 913 | 10 to 18 |
| Jun-99 | No Rules | 4288 | +30 |
| Jun-99 | No Rules | 623 | 10 to 18 |
| Jun-99 | Rules | 1634 | +30 |
| Jun-99 | Rules | 112 | 10 to 18 |
| Jul-99 | No Rules | 3989 | +30 |
| Jul-99 | No Rules | 1088 | 10 to 18 |
| Jul-99 | No Rules | 626 | 18 to 30 |
| Jul-99 | Rules | 314 | +30 |
| Jul-99 | Rules | 310 | 0 to 10 |
| Jul-99 | Rules | 2067 | 10 to 18 |
| Aug-99 | No Rules | 2353 | 10 to 18 |
| Aug-99 | No Rules | 906 | 18 to 30 |
| Aug-99 | Rules | 196 | 10 to 18 |
| Aug-99 | Rules | 793 | 18 to 30 |
| Sep-99 | No Rules | 578 | +30 |
| Sep-99 | No Rules | 1347 | 10 to 18 |
| Sep-99 | No Rules | 4643 | 18 to 30 |
| Sep-99 | Rules | 719 | 10 to 18 |
| Dec-99 | No Rules | 720 | +30 |
| Jan-00 | No Rules | 2870 | +30 |
| Feb-00 | No Rules | 1827 | +30 |
| Mar-00 | No Rules | 7144 | +30 |
| Apr-00 | No Rules | 2239 | +30 |
| Apr-00 | Rules | 1606 | +30 |
| May-00 | No Rules | 4494 | +30 |
| May-00 | Rules | 3113 | +30 |
| Jun-00 | No Rules | 4254 | +30 |
| Jun-00 | No Rules | 2522 | 10 to 18 |
| Jun-00 | Rules | 720 | 10 to 18 |

| **TOTAL SA2** | | | **19,827** |
|---|---|---|---|
| **Date** | **HL** | **Pounds** | **MC** |
| Sep-97 | No Rules | 635 | +30 |
| Sep-97 | No Rules | 2001 | 10 to 18 |
| Sep-97 | No Rules | 1090 | 18 to 30 |
| Oct-97 | No Rules | 548 | +30 |
| Dec-97 | No Rules | 897 | +30 |
| Dec-97 | No Rules | 988 | 10 to 18 |
| Jan-98 | No Rules | 1102 | +30 |
| Feb-98 | No Rules | 1969 | +30 |
| Mar-98 | No Rules | 1667 | +30 |
| Apr-98 | No Rules | 176 | +30 |
| Apr-98 | No Rules | 507 | 10 to 18 |
| May-98 | No Rules | 517 | +30 |
| May-98 | Rules | 314 | 10 to 18 |
| Jun-98 | No Rules | 673 | +30 |
| Jun-98 | Rules | 317 | 10 to 18 |
| Jul-98 | No Rules | 587 | +30 |
| Jan-00 | No Rules | 1321 | +30 |
| Mar-00 | No Rules | 788 | +30 |
| Mar-00 | No Rules | 805 | 18 to 30 |
| Apr-00 | No Rules | 247 | 10 to 18 |
| Jul-00 | No Rules | 828 | +30 |
| Jul-00 | Rules | 143 | 10 to 18 |
| Aug-00 | No Rules | 644 | 18 to 30 |
| Aug-00 | Rules | 1063 | 10 to 18 |

## Appendix IV. Species Summaries

John Christy, Oregon Natural Heritage Program, verified specimens from both the survey and experimental plots. Nomenclature follows Anderson *et al.* (1990) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. %ν = frequency of occurrence across all plots; cc = cover class midpoint averages converted to cover class. Conifers=Douglas-fir or Sitka spruce; Shrubs=Vine maple or huckleberry. Cover Classes: 1=1-2%, 2=3-10%, 3=11-25%, 4=26-50%, 5>51%.

**Table A. 1996 SA1 Harvest Level Area Survey Plots (n=30)**

| | LF | Red alder | | Conifers | | Shrubs | | Logs | | Forest Floor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν |
| *Antitrichia curtipendula* | M | 1 | 27 | 0 | 3 | 2 | 56 | 0 | 7 | 0 | 0 |
| *Aulacomnium androgynum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 | 0 | 0 |
| *Cephalozia bicuspidata* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| *Claopodium crispifolium* | M | 1 | 20 | 0 | 0 | 1 | 9 | 0 | 3 | 0 | 0 |
| *Dendroalsia abietina* | M | 0 | 7 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 |
| *Dicranum fuscescens* | M | 0 | 0 | 1 | 27 | 0 | 0 | 0 | 3 | 0 | 0 |
| *Dicranum scoparium* | M | 0 | 17 | 0 | 3 | 0 | 3 | 1 | 23 | 0 | 0 |
| *Eurhynchium oreganum* | M | 2 | 33 | 1 | 23 | 1 | 19 | 4 | 90 | 3 | 97 |
| *Eurhynchium praelongum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 3 |
| *Frullania tamarisci* sub. *nisquallensis* | L | 1 | 30 | 0 | 3 | 1 | 22 | 0 | 10 | 0 | 0 |
| *Homalothecium fulgescens* | M | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| *Hypnum circinale* | M | 0 | 0 | 3 | 87 | 0 | 0 | 0 | 7 | 0 | 0 |
| *Hypnum subimponens* | M | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Isothecium myosuroides* | M | 3 | 80 | 3 | 100 | 4 | 97 | 1 | 23 | 0 | 0 |
| *Lepidozia reptans* | L | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 0 | 0 |
| *Leucolepis acanthoneuron* | M | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 7 |
| *Metzgeria conjugata* | L | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neckera douglasii* | M | 2 | 53 | 0 | 3 | 3 | 91 | 0 | 0 | 0 | 0 |
| *Orthotrichum lyellii* | M | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 |
| *Plagiomnium insigne* | M | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 20 |
| *Plagiomnium venustum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plagiothecium laetum* | M | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plagiothecium undulatum* | M | 0 | 10 | 0 | 13 | 0 | 0 | 2 | 53 | 0 | 10 |
| *Porella navicularis/cordeana* | L | 1 | 23 | 0 | 0 | 1 | 28 | 0 | 7 | 0 | 0 |
| *Rhizomnium glabrescens* | M | 0 | 7 | 0 | 7 | 0 | 3 | 1 | 37 | 0 | 0 |
| *Rhytidiadelphus loreus* | M | 2 | 47 | 0 | 13 | 0 | 6 | 3 | 93 | 1 | 57 |
| *Rhytidiadelphus triquetrus* | M | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 7 |
| *Scapania bolanderi* | L | 0 | 7 | 2 | 50 | 0 | 3 | 1 | 17 | 0 | 0 |
| *Tetraphis pellucida* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| *Ulota megalospora* | M | 0 | 0 | 0 | 0 | 1 | 9 | 0 | 0 | 0 | 0 |

**Table B. 2004 SA1 Harvest Level Area Survey Plots (n=30)**

| | LF | Red alder | | Conifers | | Shrubs | | Logs | | Forest Floor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν |
| *Antitrichia curtipendula* | M | 1 | 30 | 0 | 0 | 2 | 51 | 0 | 17 | 0 | 0 |
| *Cephalozia bicuspidata* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| *Claopodium crispifolium* | M | 2 | 50 | 0 | 0 | 1 | 11 | 0 | 0 | 0 | 0 |
| *Dicranum fuscescens* | M | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Eurhynchium oreganum* | M | 1 | 37 | 0 | 7 | 0 | 0 | 4 | 93 | 3 | 63 |
| *Eurhynchium praelongum* | M | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 20 | 0 | 3 |
| *Frullania tamarisci* sub. *nisquallensis* | L | 1 | 30 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| *Hypnum circinale* | M | 0 | 0 | 2 | 30 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hypnum subimponens* | M | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Isothecium myosuroides* | M | 4 | 63 | 2 | 47 | 5 | 100 | 1 | 27 | 0 | 0 |
| *Metzgeria conjugata* | L | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neckera douglasii* | M | 2 | 60 | 0 | 0 | 3 | 86 | 0 | 3 | 0 | 0 |
| *Plagiomnium venustum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| *Plagiothecium laetum* | M | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plagiothecium undulatum* | M | 0 | 7 | 0 | 3 | 0 | 0 | 1 | 47 | 0 | 0 |
| *Porella navicularis/cordeana* | L | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| *Rhizomnium glabrescens* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 30 | 0 | 0 |
| *Rhytidiadelphus loreus* | M | 2 | 47 | 0 | 3 | 0 | 0 | 4 | 97 | 0 | 7 |
| *Scapania bolanderi* | L | 0 | 0 | 2 | 40 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Scapania umbrosa* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| *Tetraphis pellucida* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |

**Table C. 1997 SA2 Harvest Level Area Survey Plots (n=30)**

| | LF | Conifers | | Vine maple | | Huckleberry | | Logs | | Forest Floor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν |
| *Antitrichia curtipendula* | M | 0 | 10 | 2 | 50 | 0 | 23.33 | 0 | 3 | 0 | 0 |
| *Claopodium crispifolium* | M | 0 | 0 | 1 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dicranum fuscescens* | M | 2 | 63 | 0 | 0 | 0 | 0 | 1 | 17 | 0 | 0 |
| *Dicranum scoparium* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 47 | 0 | 0 |
| *Eurhynchium oreganum* | M | 0 | 17 | 1 | 37 | 0 | 10 | 4 | 97 | 4 | 100 |
| *Eurhynchium praelongum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Frullania tamarisci* sub. *nisquallensis* | L | 0 | 0 | 1 | 53 | 1 | 23.33 | 0 | 0 | 0 | 0 |
| *Hylocomium splendens* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| *Hypnum circinale* | M | 3 | 67 | 1 | 3 | 0 | 3.33 | 2 | 27 | 0 | 0 |
| *Isothecium myosuroides* | M | 2 | 67 | 4 | 67 | 4 | 70 | 1 | 47 | 2 | 57 |
| *Lepidozia reptans* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 |
| *Lophozia incisa* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| *Metzgeria conjugata* | L | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neckera douglasii* | M | 0 | 0 | 2 | 60 | 1 | 33.33 | 0 | 3 | 0 | 3 |
| *Orthotrichum lyellii* | M | 0 | 0 | 1 | 67 | 1 | 60 | 0 | 3 | 0 | 0 |
| *Plagiomnium insigne* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 20 |
| *Plagiothecium laetum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 7 |
| *Plagiothecium undulatum* | M | 0 | 7 | 0 | 0 | 0 | 0 | 3 | 80 | 0 | 37 |
| *Polytrichum juniperum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Porella navicularis/cordeana* | L | 0 | 0 | 1 | 37 | 0 | 3.33 | 0 | 0 | 0 | 0 |
| *Radula bolanderi* | L | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rhizomnium glabrescens* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 47 | 0 | 0 |
| *Rhytidiadelphus loreus* | M | 0 | 3 | 0 | 3 | 0 | 0 | 3 | 77 | 2 | 70 |
| *Rhytidiadelphus triquetrus* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 43 |
| *Scapania bolanderi* | L | 2 | 63 | 0 | 0 | 0 | 0 | 2 | 67 | 0 | 3 |
| *Ulota megalospora* | M | 0 | 0 | 1 | 63 | 1 | 57 | 0 | 3 | 0 | 0 |

**Table D. 1996 SA1 Upland and Riparian Control Plots (both n=8)**

| | | Upland | | | | | | | | | | Riparian | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LF | Vine maple | | Red alder | | Conifers | | Logs | | Forest floor | | Vine maple | | Red alder | | Conifers | | Huckleberry | | Logs | | Forest floor | |
| | | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν |
| *Antitrichia curtipendula* | M | 2 | 83 | 1 | 43 | 0 | 17 | 0 | 13 | 0 | 0 | 2 | 100 | 2 | 40 | 1 | 20 | 1 | 40 | 0 | 13 | 0 | 0 |
| *Aulacomnium androgynum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 38 | 0 | 0 |
| *Brachythecium salebrosum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 |
| *Claopodium crispifolium* | M | 2 | 50 | 2 | 43 | 0 | 0 | 1 | 13 | 0 | 0 | 1 | 33 | 3 | 80 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 13 |
| *Conocephalum conicum* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 | 1 | 13 |
| *Dendroalsia abietina* | M | 0 | 17 | 1 | 29 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dicranum fuscescens* | M | 0 | 0 | 0 | 0 | 1 | 50 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 60 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dicranum scoparium* | M | 0 | 17 | 1 | 71 | 0 | 17 | 1 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 1 | 50 | 0 | 0 |
| *Eurhynchium oreganum* | M | 1 | 50 | 2 | 86 | 1 | 50 | 3 | 75 | 3 | 88 | 0 | 17 | 2 | 60 | 1 | 40 | 1 | 20 | 2 | 75 | 2 | 63 |
| *Eurhynchium praelongum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 13 | 1 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 | 1 | 25 |
| *Frullania tamarisci* sub. *nisquallensis* | L | 2 | 83 | 1 | 43 | 1 | 17 | 1 | 38 | 0 | 0 | 1 | 33 | 1 | 40 | 0 | 20 | 2 | 100 | 0 | 0 | 0 | 0 |
| *Homalothecium fulgescens* | M | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hypnum circinale* | M | 0 | 0 | 0 | 0 | 3 | 100 | 1 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 80 | 0 | 0 | 0 | 13 | 0 | 0 |
| *Hypnum subimponens* | M | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Isothecium myosuroides* | M | 3 | 83 | 3 | 100 | 2 | 100 | 1 | 38 | 0 | 0 | 3 | 100 | 3 | 100 | 3 | 100 | 4 | 100 | 1 | 13 | 0 | 13 |
| *Lepidozia reptans* | L | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 25 | 0 | 0 |
| *Leucolepis acanthoneuron* | M | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Metzgeria conjugata* | L | 0 | 0 | 1 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neckera douglasii* | M | 3 | 100 | 2 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 100 | 2 | 100 | 2 | 40 | 2 | 60 | 0 | 13 | 0 | 0 |
| *Orthotrichum lyellii* | M | 1 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 33 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 |
| *Plagiomnium insigne* | M | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 13 | 1 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 75 |
| *Plagiothecium laetum* | M | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 |
| *Plagiothecium undulatum* | M | 0 | 0 | 1 | 43 | 1 | 50 | 2 | 75 | 1 | 38 | 0 | 0 | 0 | 0 | 1 | 20 | 0 | 0 | 2 | 88 | 0 | 25 |
| *Porella navicularis/cordeana* | L | 2 | 67 | 1 | 57 | 0 | 0 | 0 | 25 | 0 | 0 | 2 | 67 | 1 | 40 | 0 | 20 | 2 | 100 | 0 | 0 | 0 | 0 |
| *Radula bolanderi* | L | 0 | 17 | 0 | 29 | 2 | 100 | 2 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rhizomnium glabrescens* | M | 0 | 17 | 0 | 29 | 1 | 33 | 2 | 88 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 2 | 88 | 0 | 0 |
| *Rhytidiadelphus loreus* | M | 0 | 17 | 2 | 57 | 0 | 0 | 3 | 88 | 2 | 75 | 1 | 33 | 2 | 60 | 1 | 60 | 0 | 0 | 3 | 100 | 1 | 38 |
| *Rhytidiadelphus triquetrus* | M | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 |
| *Scapania bolanderi* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 60 | 0 | 0 | 1 | 38 | 0 | 0 |
| *Ulota* | M | 1 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table E. 1997 SA2 Conifer and Hardwood Experiment Plots (both n=12)**

| | | Conifer | | | | | | | | | | Hardwood | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LF | Red alder | | Conifers | | Vine Maple | | Logs | | Forest floor | | Red alder | | Conifers | | Vine Maple | | Logs | | Forest floor | |
| | | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν | cc | %ν |
| *Antitrichia curtipendula* | M | 1 | 18 | 1 | 8 | 2 | 67 | 0 | 0 | 0 | 0 | 2 | 83 | 1 | 9 | 3 | 91 | 0 | 0 | 0 | 9 |
| *Cephalozia bicuspidata* | L | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Claopodium crispifolium* | M | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 2 | 50 | 0 | 0 | 2 | 64 | 0 | 0 | 0 | 0 |
| *Dendroalsia abietina* | M | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 |
| *Dicranum fuscescens* | M | 0 | 0 | 2 | 83 | 0 | 8 | 1 | 8 | 0 | 0 | 1 | 50 | 1 | 9 | 0 | 0 | 1 | 9 | 0 | 0 |
| *Dicranum scoparium* | M | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 27 | 0 | 0 |
| *Douinia ovata* | L | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Eurhynchium oreganum* | M | 1 | 27 | 0 | 0 | 1 | 17 | 4 | 67 | 5 | 100 | 2 | 33 | 1 | 9 | 1 | 27 | 3 | 91 | 4 | 100 |
| *Eurhynchium praelongum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 17 | 2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 36 | 2 | 36 |
| *Frullania bolanderi* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Frullania tamarisci* sub. *nisquallensis* | L | 1 | 18 | 0 | 8 | 1 | 33 | 0 | 0 | 0 | 0 | 2 | 50 | 1 | 9 | 2 | 73 | 0 | 0 | 0 | 0 |
| *Homalothecium fulgescens* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Homalothecium nuttallii* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hylocomium splendens* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hypnum circinale* | M | 0 | 0 | 3 | 75 | 0 | 0 | 2 | 25 | 0 | 0 | 0 | 0 | 1 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hypnum subimponens* | M | 0 | 0 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 |
| *Isothecium myosuroides* | M | 3 | 27 | 3 | 83 | 5 | 100 | 1 | 33 | 1 | 42 | 4 | 83 | 1 | 9 | 5 | 100 | 1 | 27 | 1 | 36 |
| *Lepidozia reptans* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 |
| *Leucolepis acanthoneuron* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lophocolea cuspidata* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Metzgeria conjugata* | L | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neckera douglasii* | M | 1 | 18 | 0 | 0 | 3 | 92 | 0 | 0 | 0 | 0 | 2 | 42 | 1 | 9 | 3 | 100 | 0 | 0 | 0 | 0 |
| *Orthotrichum lyellii* | M | 0 | 0 | 0 | 0 | 1 | 83 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 9 | 1 | 82 | 0 | 0 | 0 | 0 |
| *Plagiomnium insigne* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 45 |
| *Plagiomnium venustum* | M | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Plagiothecium laetum* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 18 | 0 | 18 |
| *Plagiothecium undulatum* | M | 0 | 9 | 0 | 8 | 0 | 0 | 3 | 83 | 0 | 17 | 1 | 33 | 0 | 0 | 0 | 0 | 3 | 91 | 1 | 18 |
| *Porella cordeana* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Porella navicularis/cordeana* | L | 0 | 0 | 0 | 0 | 1 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 36 | 0 | 0 | 0 | 0 |
| *Radula bolanderi* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rhizomnium glabrescens* | M | 0 | 0 | 0 | 8 | 0 | 0 | 2 | 67 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 2 | 55 | 0 | 0 |
| *Rhytidiadelphus loreus* | M | 1 | 9 | 0 | 8 | 0 | 0 | 2 | 50 | 2 | 67 | 0 | 25 | 1 | 9 | 0 | 18 | 4 | 91 | 3 | 82 |
| *Rhytidiadelphus triquetrus* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Scapania bolanderi* | L | 0 | 0 | 3 | 75 | 0 | 0 | 2 | 67 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 2 | 73 | 0 | 0 |
| *Tetraphis pellucida* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 |
| *Ulota crispa* | M | 0 | 0 | 0 | 0 | 1 | 92 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 1 | 73 | 0 | 0 | 0 | 0 |
| *Ulota megalospora* | M | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |