A Progress Report to

The California Air Resources Board

Integrated Watershed Study

VEGETATION PROCESS STUDIES

by

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ABSTRACT

This final contract report describes research and field investigations undertaken to supply baseline data about ecosystem processes in the Emerald Lake basin which could potentially be impacted by acid deposition and air pollution. This is the second contract report covering a continuing project, over a five-year period. The first report covered the period from May 24, 1984 to August 23, 1985. This report covers field work for the period from July 1985 through 1987. A third final report, prepared later in 1988, will cover data collected during the 1987 field season, and will integrate the data from all five years of study into an overall framework. A more detailed discussion of the full data set will be made in that report.

The investigations included in this report cover four areas--below-ground processes, above-ground processes, forest trees in the Emerald Lake basin, and floristics and vegetation structure. Below-ground biomass, phenology of growth, and productivity have been estimated for a variety of shrub and community-types based on data from both the 1985 and 1986 field seasons at Emerald Lake. Data are presented for willow thicket (Salix), chinquapin (Chrysolepis) shrub, mountain heather (Phyllodoce) and wet meadow communities.

Above-ground biomass and productivity are presented for the same four communities, and compared in biomass to the below-ground data. The greatest above-ground biomass occurred in stands of Chrysolepis, but Phyllodoce mats had slightly higher rates of net primary production per unit area. Litter biomass is much greater in the Chrysolepis stands than in any other community studied.

Pinus monticola (western white pine) is the dominant forest tree in the Emerald Lake basin. It comprises more than 70% of the 1206 trees censused in the basin. Pinus contorta ssp. murrayana (lodgepole pine) is second in

importance with 17% of the trees, and _P. balfouriana_ (fox-tail pine) third with 9.5%. Tree species are unevenly distributed throughout the basin, with _P. monticola_ most abundant on the mesic bench and southwest-facing ridge, _P. contorta_ ssp. _murrayana_ dominant around the lake itself, and _P. balfouriana_ largely restricted to the north-facing ridge on the western margin of the basin.

The vascular plant flora of the Emerald Lake basin now includes 204 species, distributed in 132 genera and 41 families. Herbaceous perennials comprise nearly 80% of these species. Eight plant community types are present in the basin. These are dry forest, willow thicket, wet meadow, dry meadow, wet rock crevice, dry rock crevice, colluvium, and fell field communities.

ACKNOWLEDGEMENTS

We acknowledge with thanks the continuing cooperation and logistic support of the staff of Sequoia and Kings Canyon National Parks, particularly Dr. David Parsons, Dr. David Graber and Thomas Stohlgren. This support has been an essential element in the success of our research program. Our work could not have been carried out without the field assistance of a number of individuals. Michael Neuman, Peter Rabenold, Peggy Moore and Evan Edinger carried the major part of the field work included in this report.

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SUMMARY AND CONCLUSIONS

Because this final report contains an interim discussion of data on a continuing project of investigations, it is premature to draw a final set of conclusions. Such conclusions will be developed in considerable detail in an upcoming final project report in 1989 which will summarize all of the data collected over four field seasons of research at Emerald Lake.

Our conclusions at this stage of research, presenting data for the 1985 and 1986 field seasons, are as follows:

a) Vegetation is relatively sparse in the Emerald Lake basin, but nevertheless plays an important role in the biogeochemical fluxes of many elements.

b) Root production in shrub communities is a highly variable process, but appears to generally continue throughout the summer growing season.

c) Root/shoot ratios vary greatly between communities, ranging from 0.6 in willow and chinquapin communities to 10.6 in wet meadows.

d) Above-ground productivity per unit of canopy coverage is similar in all of the shrub and meadow communities, ranging from 274-499 g $m^{-2}y^{-1}$.

e) Litter accumulation is virtually absent from the wet meadow communities, and as high as 4500 g m^{-2} in the chinquapin community.

f) Allocation of biomass to new growth in shrub species is 30-50% to leaves, 47-66% to woody tissues, and 2-3% to reproductive tissues.

g) *Pinus monticola* (western white pine) is the dominant tree in the basin, comprising more than 70% of the total trees. *Pinus contorta* ssp. *murrayana* (lodgepole pine) comprises 17% of the trees and *P. balfouriana*, 9.5%.

h) The vascular plant flora of the basin includes 204 species, distributed in 132 genera and 41 families. Herbaceous perennials comprise nearly 80% of the species.

RECOMMENDATIONS

Final recommendations related to the impact of acid deposition on vegetation systems in the Emerald Lake watershed must await analysis of data from the 1987 field season and the integration of results from all four years of study. This report will be completed in 1989.

INTRODUCTION

This report covers the second period of work on vegetation processes at Sequoia National Park, carried out between July 1, 1985 and September 30, 1986. Our work was undertaken as a study of the base level processes of growth and nutrient dynamics that may be influenced in coming years by acid deposition.

Detrimental effects of acid deposition on plant communties have been documented elsewhere and have been described in reviews and symposia by Mudd and Kozlowski (1975), Hutchinson and Havas (1980), Miller (1980), and Smith (1981). Although research has focused more in Europe and the eastern United States, acid deposition has been shown to occur in California (Lawson and Wendt 1982). The Sierra Nevada lie in the path of pollutant-laden air from major metropolitan areas, and include the most sensitive ecosystems of California. There is reason to expect the possibility of future effects on tree growth and vigor phenology, soil chemistry, soil microbiology, and nutrient cycling processes (Alexander 1980, McColl 1981b, Hutchinson and Havas 1980). Acid deposition in California differs from that in Europe and the eastern United States, in that a larger proportion is deposited as dry deposition and there appears to be a higher ratio of NO_x to SO_x in deposition here.

Net primary productivity (NPP), the ecosystem-level expression of forest growth, is a fundamental process that is sensitive to any stress-inducing environmental factor. The effects of acid deposition and air pollution in California could be seen in the future. Smith (1981) listed recent papers documenting effects of these influences on forest growth. The mechanisms by which acid deposition and air pollution may supress NPP include both direct and indirect pathways. The direct pathways are those involving increased physiological stress and tissue damage; they have been discussed by Jacobson

(1980). The indirect pathways usually involve soil processes. Damage to roots and symbionts, while often difficult to detect and quantify, may be the earliest manifestations of pollution-related damage to forests. One example of such damages is the effect of aluminum on roots (Foy 1974). Aluminum has been reported by Ulrich (1983) to sometimes accumulate to toxic levels in soils subject to acid precipitation.

Not only roots, but the vital root symbionts known as mycorrhizae may be damaged. Both vesicular-arbuscular mycorrhizae (VAM) and ectomycorrhizae (ECM) may be intolernt of pH changes (Mosse 1975, Graw 1979, Bauch 1983, Marx and Krupa 1978). Further, VAM fungi may be intolerant of low levels of toxic elements (Killham and Firestone 1983, Gildon and Tinker 1983a, b, McCool and Menge 1983, Trappe et al. 1973). There may also be damage to the nonsymbiotic, but still vital, microflora and microfauna that carry out the processes of decomposition and mineralization of nutrient elements (Coleman 1983). Such damage could be brought about by the changes in soil chemistry and increases in aluminum ion concentration thought to attend prolonged exposure to acid deposition. Among the possible modifications to essential element cycles are inhibition of nitrogen fixation and inhibition of nitrogen transformation (Seip and Freedman 1980, Strayer et al. 1981, Cook 1983). There may also be decreases in the availability of phosphorus linked to any changes in soil pH (Cook 1983).

Project Objectives

Our specific objectives in this project are to establish baseline levels of above-ground and below-ground production, against which future changes due to acid deposition and air pollution may be assessed and to quantify the nutrient pools in the Emerald Lake study site. Concisely stated, the objectives for this project are:

..to establish quantitative baseline data on above-ground NPP for the dominant species at Emerald Lake;

..to establish quantitative baseline data on below-ground NPP by fine roots and mycorrhizae for the dominant species at Emerald Lake;

..to determine pool sizes and fluxes of N, P, S, and Al in terrestrial vegetation;

..to aid in the production of a quantitative model of terrestrial element cycles, as a portion of a model of watershed processes;

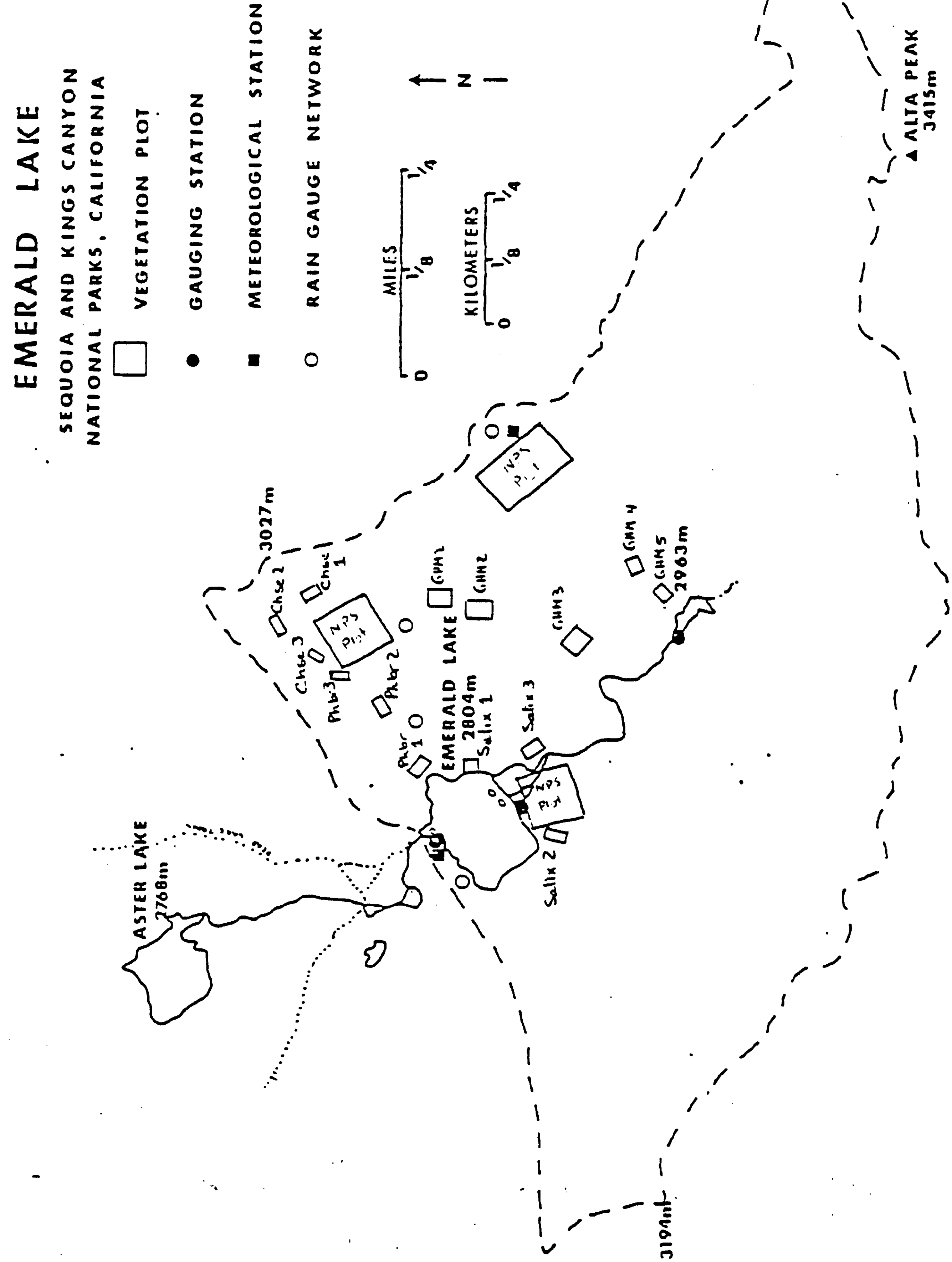
..to characterize the community types and the species composition of the important terrestrial vegetation types at Emerald Lake.

Study Area

Emerald Lake at 2780 m elevation is the subalpine site used by this and related studies (Figure 1). It occupies a granitic drainage about 120 ha in size. The Emerald Lake watershed includes permanent vegetation plots, streamflow gauging stations, rain gauges, and meteorological stations. Most of the terrain at Emerald Lake consists of variously jointed exposures of granodiorite and granite. Most of the soils have formed in localized regions defined by rock joints. All have a cryic temperature regime and sandy or coarse-loamy textures. Most are classified as lithic cryumbrepts and entic cryumbrepts. Soil depths to underlying rock range from 10 to 50 cm.

Vegetation is sparse and much of the basin is exposed granite. Coniferous trees occur in scattered clumps. The species include *Pinus contorta* var. *murrayana* (lodgepole pine), *P. monticola* (western white pine), *P. jeffreyi* (Jeffrey pine), and *P. balfouriana* (foxtail pine). Locally common shrubs are *Phyllodoce breweri* (mountain heather), *Chrysolepis sempervirens* (chinquapin), and *Salix orestera* (willow). Four vegetation types at Emerald Lake have been identified as recipients of detailed study. The choice was based on their relative importance in terms of surface area and biomass. The first of these is designated as "wet meadow." It is a mixture of grasses and herbs in a mesic setting, and has been referred to in our internal communications and notes as "GHM." The second is "willow thicket," composed largely of *Salix orestera*, which has in certain other documents, been called by an acronym for the dominant species "SAOR." The next is a heather scrub, which will be referenced here by the dominant species *Phyllodoce breweri* (PHBR). The last vegetation type, also denoted by its dominant species, is *Chrysolepis sempervirens* (CHSE). The structure and diversity of plant communities within the Emerald Lake basin is discussed in more detail later in this report.

Figure 1. Location of vegetation sample plots and National Park Service permanent plots in the Emerald Lake basin.



BELOW-GROUND PROCESSES

Introduction

The objectives of the below-ground portion of this study are as follows:

1) Estimate the yearly production of fine roots in four Emerald Lake vegetation types.
2) Obtain an estimate of the fraction of new root length colonized by ecto- land vesicular-arbuscular mycorrhizal fungi.
3) Using a correction factor for weight of fungal tissue per unit of colonized root length, estimate yearly production of symbiotic fungal tissue.

Methods for Determining Root Biomass and Production

In studies of net primary production (NPP), the fine root compartment is arguably both the most difficult to study and the most important in terms of its contribution to ecosystem NPP (Fairley and Alexander 1985). We have suggested elsewhere that these parameters are likely to be among the most sensitive of the parameters of terrestrial vegetation to the changes anticipated to accompany increasing acid deposition. The below-ground biomass can be as much as 75-98% of total plant biomass, although it is substantially smaller in most ecosystems (Fogel 1985). Mycorrhizae make up as much as 6% of the total tree biomass in Douglas fir (Fogel 1985).

Fine root production is usually measured by sequential biomass estimates. The methods of calculating production have been reviewed recently (Fairley and

Alexander 1985) and will be discussed in detail in a later section. In general, production is derived from the differences between subsequent sample periods.

Production has also been estimated by other methods, including dilution of a radiotracer (Caldwell and Camp 1974), rhizotrons (root boxes) of various types (Atkinson 1985), and a "plane intercept" technique (see earlier reports from this project). Each of these methods has its own limitations.

Fine-root contribution is the hardest to study of the quantifiable biomass and production compartments (Fairley and Alexander 1985). Fogel (1985) gave as sources of error in measurements the non-uniformity in size of roots, the separation of roots from soil, the variable and localized nature of growth and death processes, differentiating live from dead roots, and accounting for exudates and volatiles.

Fogel (1985) reported that separation of roots from soil is a major source of error. Wet sieving, for instance, can give values 30% larger than hand sorting of the same material.

Root growth in the field is notoriously variable in both time and space (Fairley and Alexander 1985). Productivity occurs at localized microsites, which are not necessarily in phase with each other (Santantonio and Grace 1987). Roots growth responds to localized deposits of organic matter and to other factors that define relatively rich microsites in the soil volume (St. John 1983). These factors are reflected in variability of field data. The growth of roots into screens placed in the soil in a mixed conifer forest and a shortgrass steppe could be described by the negative binomial distribution, a distribution that often describes the occurrence of spatially aggregated phenomena in biology (St. John, unpublished).

Distinguishing of live and dead roots will be treated in greater detail in a later section.

In our own case, the difficulty of determining below-ground production is reflected in the fact that in the 1985 and 1986 field seasons, below-ground determination absorbed 70% of the combined field and laboratory time of our field crew.

Alternative Methods of Calculation

The previous section gives an introduction to the kinds of error that are inherent in existing methods for determining below-ground production. These sources of error have been specifically discussed, and in some cases partially quantified, by several authors. The most important single factor is undoubtedly the fact that productivity and mortality are of similar magnitude and occur simultaneously. In view of the fact that annual productivity can greatly exceed standing crop (Santantonio and Grace 1987), all biomass-based methods suffer from the simultaneous occurrence of production and mortality processes between sample dates. This source of error clearly leads to an underestimate of production: consider that two sequential sample dates might give equal biomass figures (and therefore indicate zero production) even though a large amount of both production and mortality (turnover) had occurred during the interval. Kurz and Kimins (1987) proposed as the three most important sources of error the concurrence of productionn and mortality, the distinction of live and dead biomass, and the timing of sample dates to coincide with peaks and troughs of root biomass.

Several authors, however, have proposed that certain kinds of calculations can lead to overestimates of production (McClaugherty et al. 1982, Singh et al. 1984, Lauenroth et al. 1986). Their premise is that sampling errors can accumulate in the summing of biomass increments. These difficulties are minimized by the consideration only of peak-trough differences that are statistically different, and by the avoidance of unnecessary sampling frequency (Vogt et al. 1986).

It has also been correctly pointed out that the high variability inherent in root measurements leads to a requirement for huge sample sizes if one is to determine productivity with small confidence intervals (Singh et al. 1984). This practical reality is probably an insurmountable problem; the relatively high cost of these determinations in labor and time force us to accept large confidence intervals in this kind of work. However, it is not clear that greater statistical precision is warranted in view of the uncertainty about the (probably large) biases inherent in the available methods.

Vogt et al. (1986) have suggested that high variability can be reduced by calculating production on the basis of live biomass only instead of live plus dead as assumed by Singh et al. (1984). However, the distinction between live and dead biomass is tenuous at best in most ecosystems (see discussion in a later section). They have also made the important point that the key times for field sampling are at the highest and lowest biomass of the year. More frequent sampling may even degrade data quality because of the possibility of introducing random fluctuations. However, frequent sampling is required to find the peak and trough times, which may vary from year to year, and in any case infrequent sampling increases the error associated with simultaneous production and mortality.

Fairley and Alexander (1985) considered that below-ground dynamics could be resolved into three simultaneous processes: production (the increase in fine root biomass), mortality (the death of live roots), and disappearance (the fragmentation and decomposition of roots so that they become unrecoverable). They traced the use of several alternative calculations, all based on sequential biomass estimates. The best method for estimating each process depends on the direction of change in each one between sample dates. They proposed a decision matrix for determining which set of calculations is appropriate with each increment or decrement in standing crop. All of their methods require that live and dead biomass be distinguished, a requirement that introduces substantial uncertainty into the procedure. Fairley and Alexander (1985) proposed that only significantly different peaks and troughs be considered. Earlier work that incorporated all changes, significant or not, produced some serious overestimates. In their example, they overestimated production by a factor that ranged from 1 to 4 times the "known" correct value. Kurz and Kimins (1987) used computer-generated data to test two methods of calculation, including the decision matrix and computational procedures recommended by Fairley and Alexander (1985). Neither of two methods dealt adequately with simultaneous production and mortality, and there was little clear superiority of Fairley and Alexander's complex method over a simpler one, even in optimum circumstances.

Distinguishing Live and Dead Roots

All of the more sophisticated calculations require that live and dead biomass be distinguished. As pointed out above, there is substantial reason to believe that the distinctions are very subjective and vary considerably between observers (Fogel 1983). Since a large number of decisions must be made to process any root sample, the judgement of live or dead must be made quickly on each piece of root in a sample. Methods based on vital stains or uptake of radioactive label do not lend themselves to processing large samples which must later be weighed, and most such methods are of questionable accuracy (Fogel 1985). Visual examination is the method almost always employed and is based on turgor, color, integrity of root tip, association of mycorrhizae with hyphae, and the color of the tissue in cross section (Fogel 1985). A continuum exists in all of these qualities within a given root sample, and the judgement of which indicate live and which dead state is a subjective one, often made differently by different operators. We have found that even after training and initial testing, two or more of our workers will rate similar root samples very differently with respect to live and dead biomass. Adding to the uncertainty, it is fairly common to judge a section of root dead on the basis of these qualities, then discover a vigorous new live root growing distal to the "dead" portion. Our policy has been to obtain live/dead estimates where feasible, but in general to perform production calculations on the basis of total, or live plus dead material.

Emerald Lake Calculations

Fogel (1983) described three general ways of making an estimate of below-ground production, and the assumptions implicit in each method. We accept the premise of his first method, which assumes that live from dead fractions cannot be reliably separated. In other methods, one must have confidence in estimates of live and dead standing crops. The estimates are available for 1986 and 1987 by applying the proportions of live and dead roots from the nearest phenology dates, and an alternative calculation will incorporate the 1986 live/dead ratios. However, we consider the more conservative estimate, based on live plus dead, to be more appropriate in this case.

Production is based on the difference between significantly different peaks and troughs in periodic (in this case seasonal) biomass estimates, where the biomass used in the calculations includes both live and dead roots. With four vegetation types, a short annual period during which the site is accessible, and a large number of samples to process at each sample date, it was impossible in this project to sample monthly. Instead we sampled as early as possible in each growing season and again as late as possible. It is likely that the early sample date falls shortly after the annual maximum in root biomass. Inaccessibility of the site prevents definitive confirmation of off-season dynamics, but 1987 root phenology samples, when analyzed, will give a higher-resolution picture of root dynamics during the growing season. Our two seasons of data, in two very different years, suggest that annual variation may swamp out within-year changes in a short-term study. Because of the small number of available sample dates, exclusion of all but statistically significant changes would impose an unacceptable loss of information in this study. Thus, our calculations consist of the sum of increments between early season 1985 and early season 1986. Late season 1986 will not be included in productivity calculations until 1987 data allow completion of a second annual cycle.

This method of estimating productivity is being supplemented by an ingrowth core method, in which mesh sleeves left in the soil indicate amount of root growth during the term. When analyzed with the 1987 data, the ingrowth cores will provide an independent check on the peak-trough method.

We are estimating fungal biomass in this project through percent colonization (length of colonized root divided by total fine root length, x 100). Harley, in various publications cited by Reid (1984), Vogt et al. (1982), and others, determined that 40% of the biomass of beech mycorrhizae is fungal tissue. This figure has been widely accepted as a general value and is used in our calculations. We have assumed that the 40% accounts for both internal and external mycelium.

Hepper (1977) found in her experiments with VAM that internal fungal tissue constituted 2.5% of the weight of colonized roots. This falls within the range reported by Kucey and Paul (1982), who found that VAM fungi accounted for 0.5% of the total root mass at 16% colonization and 5% of the total root mass at 62%

colonization. We have used Hepper's value for our calculations. The analyses of VAM condition, on material collected during the 1986 season, have not yet been completed, but the values so far available range from 10 to 60% colonization. The roots of our woody species may be denser than those used in the experiments of Hepper (1977) and Kucey and Paul (1982), and an equivalent amount of fungal tissue may contribute a lower percentage of the total. No single conversion factor is likely to be an optimum approximation for all samples, but we have selected 1% as a conservative figure.

Methods

Biomass: Sampling was carried out in late July, and again at the end of the growing season in 1985 and 1986. The first set was taken within two weeks of snow melt on each plot, and the second set corresponded with above-ground sampling on each plot. Dates for each vegetation type, given in the tables for biomass, indicate the initiation of the sampling process. Sampling required several days for each vegetation type.

The cores taken in 1986 were 10 cm diameter instead of the 20 cm diameter used in 1985, except that a few of the early season cores were 8 cm. The change was adopted to reduce the impact of the sampling. Three cores per plot were taken in 1985 and five per plot in 1986.

The material removed from each core was sieved through a 1/4 inch screen. A separate trial, designed to determine whether significant amounts of roots were lost through the 1/4 inch screen, indicated that losses were unmeasurable. The root material thus removed was stored frozen in plastic bags pending further processing. At the time of final sorting, root material was separated by hand from organic debris. In 1986 a tentative separation of live and dead material was made using subsample constituting a known fraction of the colonization. The remaining material was oven-dried to constant weight at 70°C. Portions of the root material were later ground for elemental analysis.

Production: Field methods and laboratory methods were given for biomass determination, since the cores were also used for production estimates. A detailed discussion of analysis of production data was given in the introduction. Our primary method is summing increments in biomass from the beginning of the 1985 season until the beginning of the 1986 season.

Phenology: Seasonal changes in the proportion of live and dead roots were followed over the growing season in four vegetation types. Small cores, 2 by 30 cm, were taken separately from biomass cores beginning in 1986. Samples were taken at approximately two week intervals. Five cores per plot were taken in most cases, but snow cover prevented the full sampling regime in some of the earliest and latest sample dates. The roots were washed free of soil and separated by hand in water from organic debris. Dead roots were distinguished on the basis of appearance. The live root category was subdivided into new, older, and mycorrhizal roots. A line-intercept method (Marsh 1970) was used to quantify the fraction of length contributed by each physiological category. The separations were made under a dissecting microscope with fields repeatedly re-randomized by swirling, in a method that constitutes sampling with replacement. New fields were counted until the total number of intercepts approximated 300. The data were expressed as percent of intercepts in each physiological class.

Mycorrhizae: Ectomycorrhizae (ECM) we determined in two ways: as structures distinguishable in the phenology cores, and after clearing and staining (Phillips and Hayman 1970) subsamples of the 1986 biomass samples. Vesicular-arbuscular mycorrhizae were determined only by the second method, since they are not visible without staining. Roots with a fungal mantle were considered to be ECM. Internal structures such as vesicles and arbuscules, together with characteristic internal and external mycelium indicated VAM.

Results

Biomass: The seasonal progress of below-ground biomass can be traced through the two growing seasons on a plot-by-plot basis in Tables 1-7. The means of the plots, separated by vegetation type, are shown in Table 11 and in Figures 2-5. Several proofreading errors in the spreadsheets have been found over the course of the project, and these values replace the ones reported in quarterly reports. In each case the errors have resulted in a misplaced decimal point. The seasonal trends indicate generally higher live-plus-dead biomass in 1985 except in the *Chrysolepis sempervirens* plots, where the larger root size classes were higher in 1986. An approximation of live biomass only, for combined plots within vegetation types, is given in Table 8. Live/dead separations were not available for 1985, so 1986 ratios from the nearest calendar date were applied to both years.

Production: Estimates of production were made in several ways, some of which correspond to alternative methods discussed in the introduction. The primary method has been calculated in Table 9 from the data shown in Tables 1-7. Production was based on the sum of increments, which were variable between plots, and indeed there were cases where one plot incremented during the same period that another plot declined. These expressions of variability and sensitivity to temporary environmental factors underscore the fundamental difficulty of these determinations and the inadequacy of the available methods. The sum of decrements could as easily have been chosen, and the result would have been markedly different. In Table 10 the hypothetical live-only result is calculated from the data in Table 8. There is little resemblance between these calculations and the ones presented above.

Phenology: The course of the physiological state of roots over the 1986 growing season has been presented in earlier reports. The data are given here in Table 12. Mycorrhizae in the table refer only to ECM. The live/dead ratios over the 1986 growing season show the greatest proportion of live roots in late August in wet meadow, and in early summer in willow thicket and Chrysolepis sempervirons. The proportion stayed relatively constant in Phyllodoce breweri.

Discussion

Biomass: Below-ground biomass in the wet meadow vegetation is concentrated in the finest size classes, reflecting both the small size of the component species and their finely divided root systems. The distribution of biomass in root size classes is similar in each year, with all but Chrysolepis sempervirens concentrated in the smallest size class. The high root biomass probably reflects the slow decomposition rate in this cold environment. It is likely that dead roots remain indistinguishable from live roots for months, perhaps for several seasons. There was generally less root biomass in 1986 than in 1985, probably reflecting a difference in precipitation in the two years. Such year-to-year variation is a primary factor limiting the precision of estimates of below-ground biomass and production. Wet meadow and willow thicket vegetation occupy saturated or nearly saturated soils, further reducing decomposition rate. Thus the dead-root component is high in all vegetation types. The biomass values for willow thicket and Phyllodoce breweri are likewise high, while that for Chrysolepis sempervirens is susbstantially lower. Chrysolepis sempervirens was different from the other vegetation types in showing higher biomass in 1986.

Production: Only one plot's data are available for the 1986 wet meadow area, so no standard errors are shown for wet meadow at those times. In both years, late season biomass tended to be higher than early season biomass, reflecting root growth during the summer. At the lower elevation Log Meadow site (see earlier reports for our related Log Meadow project) root growth occurs primarily outside the summer season. In the wet meadow vegetation type, root biomass in most size classes declined over the summer. This indicates that root production was slower than decomposition during that period.

The 1986 estimates agree reasonably well with the 1985 estimates. When the 1987 data have been analyzed, including the ingrowth cores, the picture of both growing season and winter root production may become clear.

Phenology: Root phenology was studied in willow thicket, Chrysolepis sempervirens, Phyllodoce breweri, and wet meadow vegetation. New roots do not account for all of the live roots that appeared during July, no doubt indicating that new roots cannot always be distinguished, and that there is continuous transfer between new, live, and dead categories between sample dates. Nonetheless, the shape of the live root curve was mirrored in the appearance of new roots. The proportion of ectomycorrhizal roots was always small and in all cases there was considerable difficulty distinguishing live from dead mycorrhizal roots. Most of the mycorrhizal roots were likely contributed by Salix orestera.

In the Chrysolepis sempervirens vegetation-type the peak in percentage of live roots was later and less marked than in willow thicket. The proportion of live roots generally remained lower than in willow thicket, probably reflecting faster decomposition of dead roots in the wetter willow thicket vegetation. There was a marked rise in new roots in the fall, which may have continued after the field season. Chrysolepis sempervirens and most associated species are ectomycorrhizal.

The very steady proportion of live roots in Phyllodoce breweri may indicate that roots are produced continuously through the growing season. Since new roots constituted only a small fraction of live roots, it is also possible that roots are long-lived, and that both production and decomposition rates are low. No attempt was made to distinguish mycorrhizae in Phyllodoce breweri, as they require staining.

The wet meadow is a mixture of numerous herbaceous species. Live roots appeared throughout the growing season. There may be several seasonal patterns interacting in wet meadow. New roots were not easily distinguished in wet meadow. None of the common species are expected to be ectomycorrhizal, so it is likely that roots from other vegetation types have found their way into these areas.

Table 1
Wet meadow biomass
(g/m² by root diameter class in mm)

July 20, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	2810.7	1022.5	353.7	153.5	0.0
Standard error	76.0	311.6	190.3	78.0	0.0
PLOT 2					
Mean	2541.5	830.1	426.1	0.0	0.0
Standard error	572.9	151.5	119.9	0.0	0.0
PLOT 3					
Mean	2243.5	726.5	175.6	0.0	0.0
Standard error	536.0	362.3	158.3	0.0	0.0
Combined plots					
Mean	2531.9	859.7	318.5	51.2	0.0
Standard error	163.8	86.7	74.4	51.2	0.0
August 27, 1985					
PLOT 1					
Mean	2620.3	1143.7	269.2	4.6	0.0
Standard error	747.3	472.6	231.9	4.6	0.0
PLOT 2					
Mean	3055.7	674.2	770.9	0.0	0.0
Standard error	899.3	247.9	234.0	0.0	0.0
PLOT 3					
Mean	2478.0	229.5	21.5	0.0	0.0
Standard error	418.7	146.0	17.9	0.0	0.0
Combined plots					
Mean	2718.0	682.4	353.9	1.5	0.0
Standard error	173.8	263.9	220.4	1.5	0

Table 2
Willow thicket biomass
(g/m^2 by root diameter class in mm)
July 31, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	633.6	116.9	52.6	135.5	125.7
Standard error	200.4	37.0	16.6	42.8	39.8
PLOT 2					
Mean	889.3	254.3	322.4	185.3	0.0
Standard error	51.2	95.2	208.3	53.1	0.0
PLOT 3					
Mean	543.4	0.0	0.0	0.0	0.0
Standard error	150.9	0.0	0.0	0.0	0.0
Combined plots					
Mean	688.8	123.7	125.0	106.9	41.9
Standard error	103.6	73.5	99.9	55.4	41.9

September 9, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	716.4	126.6	181.2	50.7	0.0
Standard error	221.4	40.2	113.8	45.1	0.0
PLOT 2					
Mean	1264.8	255.3	227.4	523.2	0.0
Standard error	296.8	99.6	73.5	285.3	0.0
PLOT 3					
Mean	938.7	47.4	67.9	73.3	1199.2
Standard error	304.5	20.7	43.6	73.3	1199.2
Combined plots					
Mean	973.3	143.1	158.8	215.7	399.7
Standard error	159.3	60.6	47.4	153.9	399.7

Table 3
Phyllodoce breweri biomass
(g/m^2 by root diameter class in mm)
July 23, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	1700.6	517.6	654.0	546.7	63.9
Standard error	219.2	220.0	195.5	298.5	63.9
PLOT 2					
Mean	1605.1	276.9	459.7	574.7	0.0
Standard error	269.6	98.8	363.2	473.0	0.0
PLOT 3					
Mean	1014.3	500.8	812.1	127.2	0.0
Standard error	408.0	138.1	417.2	105.3	0.0
Combined plots					
Mean	1440.0	431.8	641.9	416.2	21.3
Standard error	214.7	77.6	101.9	144.7	21.3

September 20, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	2063.0	434.0	601.9	435.2	0.0
Standard error	277.2	21.6	261.4	368.0	0.0
PLOT 2					
Mean	2238.2	1635.1	1289.3	767.9	0.0
Standard error	345.3	292.5	605.3	575.9	0.0
PLOT 3					
Mean	920.3	306.0	155.1	167.0	0.0
Standard error	546.7	100.5	115.1	91.9	0.0
Combined plots					
Mean	1740.7	791.7	682.1	456.7	0.0
Standard error	413.3	423.3	329.9	173.8	0.0

Table 4
Chrysolepis sempervirens biomass
(g/m^2 by root diameter class in mm)
July 29, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	349.2	245.4	289.0	575.8	207.7
Standard error	50.8	70.9	80.8	356.9	207.7
PLOT 2					
Mean	215.9	66.5	118.3	323.9	0.0
Standard error	46.0	22.3	118.3	162.2	0.0
PLOT 3					
Mean	235.3	39.6	0.0	0.0	0.0
Standard error	16.7	30.7	0.0	0.0	0.0
Combined plots					
Mean	266.8	117.2	135.8	299.9	69.2
Standard error	41.6	64.6	83.9	166.7	69.2

September 25, 1985

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	378.5	612.2	983.8	810.2	558.3
Standard error	65.6	273.8	353.7	279.6	558.3
PLOT 2					
Mean	206.8	127.4	349.5	556.2	1226.1
Standard error	110.4	114.8	190.8	259.6	942.9
PLOT 3					
Mean	450.6	85.0	227.7	23.8	597.2
Standard error	180.2	30.2	24.1	23.8	597.2
Combined plots					
Mean	345.3	274.9	520.3	463.4	793.9
Standard error	72.3	169.1	234.4	231.7	216.4

Table 5
Wet meadow biomass
(g/m^2 by root diameter class in mm)
July 1, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	0.0	0.0	0.0	0.0	0.0
Standard error	0.0	0.0	0.0	0.0	0.0
PLOT 2					
Mean	0.0	0.0	0.0	0.0	0.0
Standard error	0.0	0.0	0.0	0.0	0.0
PLOT 3					
Mean	1524.3	884.5	368.4	73.9	0.0
Standard error	862.0	333.3	207.4	73.9	0.0
Combined plots					
Mean	1524.3	884.5	368.4	73.9	0.0
Standard error	508.1	294.8	122.8	24.6	0.0

September 7, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	0.0	0.0	0.0	0.0	0.0
Standard error	0.0	0.0	0.0	0.0	0.0
PLOT 2					
Mean	0.0	0.0	0.0	0.0	0.0
Standard error	0.0	0.0	0.0	0.0	0.0
PLOT 3					
Mean	661.5	391.5	127.7	31.8	0.0
Standard error	69.2	122.1	63.6	31.8	0.0
Combined plots					
Mean	661.5	391.5	127.7	31.8	0.0
Standard error	220.5	130.5	42.6	10.6	0.0

Table 6
Willow thicket biomass
(g/m^2 bv root diameter class in mm)

July 21, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	311.2	250.8	844.2	570.5	1128.2
Standard error	171.6	55.5	439.3	427.0	1128.2
PLOT 2					
Mean	851.2	137.6	229.1	93.0	0.0
Standard error	169.9	42.8	119.6	93.0	0.0
PLOT 3					
Mean	213.5	64.9	107.0	149.0	0.0
Standard error	92.4	24.0	56.0	91.7	0.0
Combined plots					
Mean	458.6	167.8	393.4	270.8	376.1
Standard error	198.3	54.6	228.1	150.7	376.1

August 30, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	87.5	94.2	138.8	81.5	1128.2
Standard error	52.0	42.0	75.2	49.9	1128.2
PLOT 2					
Mean	554.0	247.9	217.2	302.3	0.0
Standard error	49.2	73.9	205.1	302.3	0.0
PLOT 3					
Mean	354.5	40.2	29.6	131.9	395.7
Standard error	196.7	14.6	29.6	85.5	395.7
Combined plots					
Mean	332.0	127.5	128.5	171.9	508.0
Standard error	135.2	62.2	54.4	66.8	330.5

Table 7
Phyllodoce breweri biomass
(g/m^2 by root diameter class in mm)
July 18, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	328.9	183.4	338.7	90.4	153.3
Standard error	382.3	90.6	140.3	90.4	153.3
PLOT 2					
Mean	673.6	105.7	178.3	299.2	0.0
Standard error	309.7	72.7	113.8	183.3	0.0
PLOT 3					
Mean	573.1	390.5	159.5	205.6	0.0
Standard error	141.9	158.6	117.5	205.6	0.0
Combined plots					
Mean	691.9	226.5	225.5	198.4	51.1
Standard error	74.4	85.0	56.9	60.4	51.1

September 12, 1986

	<2 wt/sq. m	2-5 wt/sq. m	5-10 wt/sq. m	10-20 wt/sq. m	20-50 wt/sq. m
PLOT 1					
Mean	961.9	202.5	105.6	73.3	0.0
Standard error	88.4	78.3	75.8	73.3	0.0
PLOT 2					
Mean	613.0	132.4	179.3	0.0	0.0
Standard error	150.9	47.6	79.5	0.0	0.0
PLOT 3					
Mean	573.5	609.2	451.3	0.0	0.0
Standard error	121.8	445.5	451.3	0.0	0.0
Combined plots					
Mean	716.1	314.7	245.4	24.4	0.0
Standard error	123.4	145.6	105.1	24.4	0.0

Table 7
Chrysolepis sempervirens biomass
(g/m^2 by root diameter class in mm)
July 4, 1986

	<2 wt/sq. m	2–5 wt/sq. m	5–10 wt/sq. m	10–20 wt/sq. m	20–50 wt/sq. m
PLOT 1					
Mean	304.3	721.8	1177.8	767.8	2905.8
Standard error	66.7	244.3	359.6	262.6	873.8
PLOT 2					
Mean	296.7	202.5	1156.2	1910.0	5327.7
Standard error	93.3	74.3	339.9	702.3	3768.3
PLOT 3					
Mean	362.5	109.2	285.2	0.0	0.0
Standard error	139.4	40.2	184.5	0.0	0.0
Combined plots					
Mean	487.9	364.5	873.1	892.6	2744.5
Standard error	187.4	210.4	294.0	554.9	1540.1

September 1, 1986

	<2 wt/sq. m	2–5 wt/sq. m	5–10 wt/sq. m	10–20 wt/sq. m	20–50 wt/sq. m
PLOT 1					
Mean	713.5	318.9	269.2	24.2	1432.4
Standard error	103.1	203.9	84.6	24.2	1320.0
PLOT 2					
Mean	608.3	300.1	353.4	547.4	2943.0
Standard error	129.7	100.0	199.9	323.2	2389.9
PLOT 3					
Mean	954.5	153.7	27.1	304.9	1522.8
Standard error	282.3	61.7	27.1	304.9	1413.9
Combined plots					
Mean	758.8	257.6	216.6	292.2	1966.0
Standard error	102.4	52.2	97.8	151.2	489.2

Table 8

FINE ROOT BIOMASS CORRECTED FOR FRACTION LIVE AT NEAREST PHENOLOGY SAMPLE DATE

Live/dead ratios from 1986 applied to both years

	G/SQ. M LV + DEAD	% LIVE ON DATE	LIVE BIOMASS (g/m^2)
Wet meadow biomass. 1985			
Mean	2531.9	52.3	1420
Standard error	163.8		
Late Sample date Combined plots			
Mean	2713.0	40.0	1090
Standard error	173.8		
Willow thicket biomass, 1985 Combined plots			
Mean	688.3	63.6	438
Standard error	103.6		
Late Sample date Combined plots			
Mean	973.3	27.2	265
Standard error	159.3		
***Phyllodoce breweri* biomass, 1985 Combined plots**			
Mean	1440.0	32.0	461
Standard error	214.7		
Late Sample date Combined plots			
Mean	1740.7	22.3	328
Standard error	413.3		
***Chrysolepis sempervirens* biomass, 1985 Combined plots**			
Mean	266.8	27.3	72.8
Standard error	41.6		
Late Sample date Combined plots			
Mean	345.3	31.1	107
Standard error	72.3		

Wet meadow biomass, 1986
Combined plots

Mean	1524.3	40.9	623
Standard error	508.1		

Late Sample date
Combined plots

Mean	661.5	44.0	291
Standard error	220.5		

Willow thicket biomass, 1986
Combined plots

Mean	458.6	63.6	292
Standard error	198.3		

Late Sample date
Combined plots

Mean	332.0	46.6	155
Standard error	135.2		

Phyllodoce breweri biomass, 1986
Combined plots

Mean	691.9	32.0	221
Standard error	74.4		

Late Sample date
Combined plots

Mean	716.1	22.3	160
Standard error	123.4		

Chrysolepis sempervirens biomass, 1986
Combined plots

Mean	487.9	21.2	103
Standard error	187.4		

Late Sample date

Mean	758.8	31.1	236
Standard error	102.4		

Table 9
PRODUCTION: DIFFERENCES BETWEEN SAMPLE DATES
From tables 1-7
Plots separated to give and estimate of variance
(g/m^2)

Wet meadow
PLOT 1

DATE	<2	2-5	5-10	10-20	20-50
EARLY85					
LATE85	-190.5	121.2	-84.6	-149.0	0.0
EARLY86	-2620.3	-1143.7	-269.2	-4.6	0.0
LATE86	0.0	0.0	0.0	0.0	0.0
SUMMED INCREMENTS	0	121.2	0	0	0

Wet meadow
PLOT 2

DATE					
EARLY85					
LATE85	514.2	-156.0	344.8	0.0	0.0
EARLY86	-3055.7	-674.2	-770.9	0.0	0.0
LATE86	0.0	0.0	0.0	0.0	0.0
SUMMED INCREMENTS	514.2	0	344.8	0	0

Wet meadow
PLOT 3

DATE					
EARLY85					
LATE85	274.5	-497.0	-154.1	0.0	0.0
EARLY86	-1593.5	138.9	52.3	0.0	0.0
LATE86	-492.9	-240.7	-42.1	0.0	0.0
SUMMED INCREMENTS	274.5	138.9	52.3	0	0

Willow thicket
PLOT 1

DATE	<2	2-5	5-10	10-20	20-50
EARLY85					
LATE85	82.8	9.7	123.6	-84.8	-125.7
EARLY86	-465.5	717.6	389.2	1077.5	0.0
LATE86	-156.6	-705.4	-489.0	0.0	0.0
SUMMED INCREMENTS	82.8	727.3	517.8	1077.5	0

Willow thicket
PLOT 2

DATE					
EARLY85					
LATE85	375.5	1.0	-95.1	337.9	0.0
EARLY86	-1077.2	-26.2	-134.3	-523.2	0.0
LATE86	60.3	-11.9	209.2	0.0	0.0

SUMMED					
INCREMENTS	435.8	1.0	209.2	337.9	0

Willow thicket
PLOT 3

DATE					
EARLY85					
LATE85	395.2	47.4	67.9	73.3	1199.2
EARLY86	-273.7	59.5	81.1	-73.3	-1199.2
LATE86	-24.7	-77.3	-17.1	395.7	0.0
SUMMED					
INCREMENTS	395.2	106.9	149.0	469.0	1199.2

Phyllodoce breweri
PLOT 1

DATE	<2	2-5	5-10	10-20	20-50
EARLY85					
LATE85	362.4	-33.6	-52.1	-111.5	-63.9
EARLY86	-1379.7	-95.2	-511.5	-221.9	0.0
LATE86	19.1	-233.1	-17.1	-153.3	0.0
SUMMED					
INCREMENTS	381.5	0	0	0	0

Phyllodoce breweri
PLOT 2

DATE					
EARLY85					
LATE85	633.7	1358.2	829.6	193.1	0.0
EARLY86	-2133.1	-1456.9	-990.1	-767.9	0.0
LATE86	26.7	1.0	-299.2	0.0	0.0
SUMMED					
INCREMENTS	660.4	1359.2	829.6	193.1	0

Phyllodoce breweri
PLOT 3

DATE					
EARLY85					
LATE85	-94.0	-194.8	-657.0	39.8	0.0
EARLY86	-529.3	-146.5	50.5	-167.0	0.0
LATE86	213.7	291.3	-205.6	0.0	0.0
SUMMED					
INCREMENTS	213.7	291.3	50.5	39.8	0

Chrysolepis sempervirens
PLOT 1

DATE	<2	2-5	5-10	10-20	20-50
EARLY85					
LATE85	29.3	366.3	694.7	234.4	350.6
EARLY86	403.4	565.6	-215.9	2095.6	-558.3
LATE86	-463.0	-908.6	-743.7	-1473.4	0.0

SUMMED INCREMENTS	432.7	932.4	694.7	2330.0	350.6

Chrysolepis sempervirens
PLOT 2

DATE					
EARLY85					
LATE85	-9.1	60.9	231.2	232.3	1226.1
EARLY86	-4.3	1028.8	1560.5	4771.5	-1226.1
LATE86	97.7	-802.8	-1362.6	-2384.7	0.0
SUMMED INCREMENTS	97.7	1089.7	1791.7	5003.8	1226.1

Chrysolepis sempervirens
PLOT 3

DATE					
EARLY85					
LATE85	215.3	45.4	227.7	23.8	597.2
EARLY86	-341.5	200.2	-227.7	-23.8	-597.2
LATE86	44.6	-251.0	304.9	1522.8	0.0
SUMMED INCREMENTS	259.9	245.6	532.6	1546.6	597.2

Table 10
Fine root production
Fine root biomass from estimated live fraction, table 8
(g/m^2)

Wet meadow	
1985 early	1480
1985 late	1090
1986 early	623
Sum of increments	0
Sum of decrements	857
Willow thicket	
1985 early	438
1985 late	265
1986 early	292
Sum of increments	27
Sum of decrements	173
Phyllodoce breweri	
1985 early	461
1985 late	325
1986 early	221
Sum of increments	0
Sum of decrements	240
Chrysolepis sempervirens	
1985 early	72.8
1985 late	107
1986 early	103
Sum of increments	34.2
Sum of decrements	4

Table 11
PRODUCTION:
BIOMASS AND SUMMED INCREMENTS BETWEEN SAMPLE DATES,
Based on means of three plots
(g/m^2)

Wet meadow

Date	< 2	2-5	5-10	10-20	20-50
Jul 20, 1985	2531.9	859.7	318.5	51.2	0.0
Aug 27, 1985	2718.0	682.4	353.9	1.5	0.0
Jul 1, 1986	1524.3	884.5	368.4	73.9	0.0
Sum of increments	186.1	202.1	49.9	72.4	0.0

Willow thicket

Date	< 2	2-5	5-10	10-20	20-50
Jul 31, 1985	688.8	123.7	125.0	106.9	41.9
Sep 9, 1985	973.3	143.1	158.8	215.7	399.7
Jul 21, 1986	458.6	167.8	393.4	270.8	376.1
Sum of increments	284.5	44.1	268.4	163.9	357.8

Phyllodoce breweri

Date	< 2	2-5	5-10	10-20	20-50
Jul 23, 1985	1440.0	431.8	641.9	416.2	21.3
Sep 20, 1985	1740.7	791.7	682.1	456.7	0.0
Jul 18, 1986	691.9	226.5	225.5	198.4	51.1
Sum of increments	300.7	359.9	40.2	40.5	51.1

Chrysolepis sempervirens

Date	< 2	2-5	5-10	10-20	20-50
Jul 29, 1985	266.8	117.2	135.8	299.9	69.2
Sep 25, 1985	345.3	274.9	520.3	463.4	793.9
Jul 4, 1986	487.9	364.5	873.1	892.6	2744.5
Sum of increments	221.1	247.3	737.3	592.7	2675.3

Table 12
Seasonal course of root physiological states in four Emerald Lake vegetation types, 1986

Wet meadow

Sample Date	% new Mean	% new s	% mycorrhizal Mean	% mycorrhizal s	Live/dead ratio Mean	Live/dead ratio s
Jul 7, 1986	8.19	8.70	6.58	12.31	0.693	0.163
Jul 22, 1986	7.35	6.75	5.10	6.63	1.398	1.302
Aug 8, 1986	2.27	2.99	0.0	0.0	0.566	0.221
Aug 19, 1986	7.00	25.74	0.0	0.0	0.666	0.221
Sep 2, 1986	0.06	0.25	0.35	0.97	0.785	0.225
Sep 15, 1986	0.06	0.23	0.0	0.0	0.534	0.387
Oct 3, 1986	0.0	0.0	0.0	0.0	0.345	0.202
Nov 6, 1986	0.19	0.74	0.13	0.50	0.341	0.212

Willow thicket

Sample Date	% new Mean	% new s	% mycorrhizal Mean	% mycorrhizal s	Live/dead ratio Mean	Live/dead ratio s
Jul 7, 1986	9.35	5.00	11.0	9.60	0.723	0.269
Jul 22, 1986	7.65	9.43	8.74	7.65	1.745	1.361
Aug 8, 1986	1.81	2.96	5.99	7.80	1.507	0.804
Aug 19, 1986	4.95	6.48	1.33	2.08	0.558	0.298
Sep 2, 1986	1.81	1.96	1.71	2.61	0.874	0.310
Sep 15, 1986	0.39	1.03	0.55	1.32	0.373	0.181
Oct 3, 1986	2.42	4.33	1.70	4.37	0.254	0.113
Nov 6, 1986	0	0	2.21	4.60	0.433	0.291

Phyllodoce breweri

Sample Date	% new Mean	% new s	Live/dead ratio Mean	Live/dead ratio s
Jul 7, 1986	1.38	2.07	0.509	0.128
Jul 22, 1986	1.98	1.47	0.471	0.076
Aug 8, 1986	3.52	2.21	0.542	0.097
Aug 19, 1986	2.44	2.35	0.563	0.167
Sep 2, 1986	0.89	1.66	0.510	0.162
Sep 15, 1986	0.0	0.0	0.287	0.125
Oct 3, 1986	0.0	0.0	0.497	0.365
Nov 6, 1986	0.0	00	0.483	0.123

Chrysolepis sempervirens

Sample	% new		% mycorrhizal		Live/dead ratio	
Date	Mean	s	Mean	s	Mean	s
Jul 7, 1986	8.76	9.40	15.15	13.07	0.422	0.147
Jul 22, 1986	7.10	4.83	8.14	6.95	0.520	0.224
Aug 8, 1986	3.40	4.05	12.97	15.59	0.376	0.260
Aug 19, 1986	1.91	4.41	9.03	10.26	0.766	0.442
Sep 2, 1986	1.15	3.64	12.34	16.00	0.452	0.343
Sep 15, 1986	0.0	0.0	6.44	9.58	0.203	0.160
Oct 3, 1986	0.0	0.0	5.87	15.45	0.141	0.156
Nov 6, 1986	0.0	0.46	0.31	0.83	0.497	0.232

Figure 2
WET MEADOW
Root standing crop in five size classes

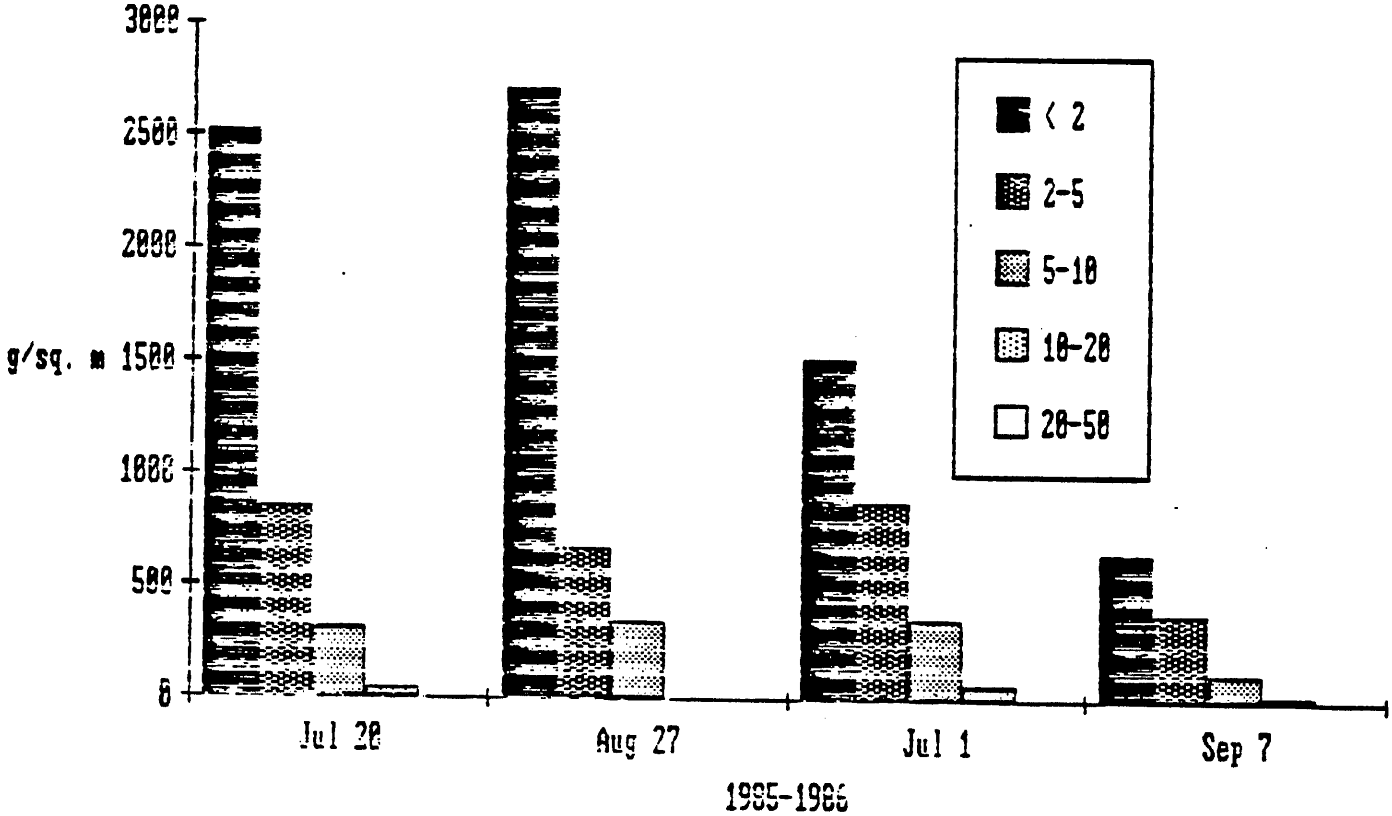


Figure 3
WILLOW THICKET
Root standing crop in five size classes

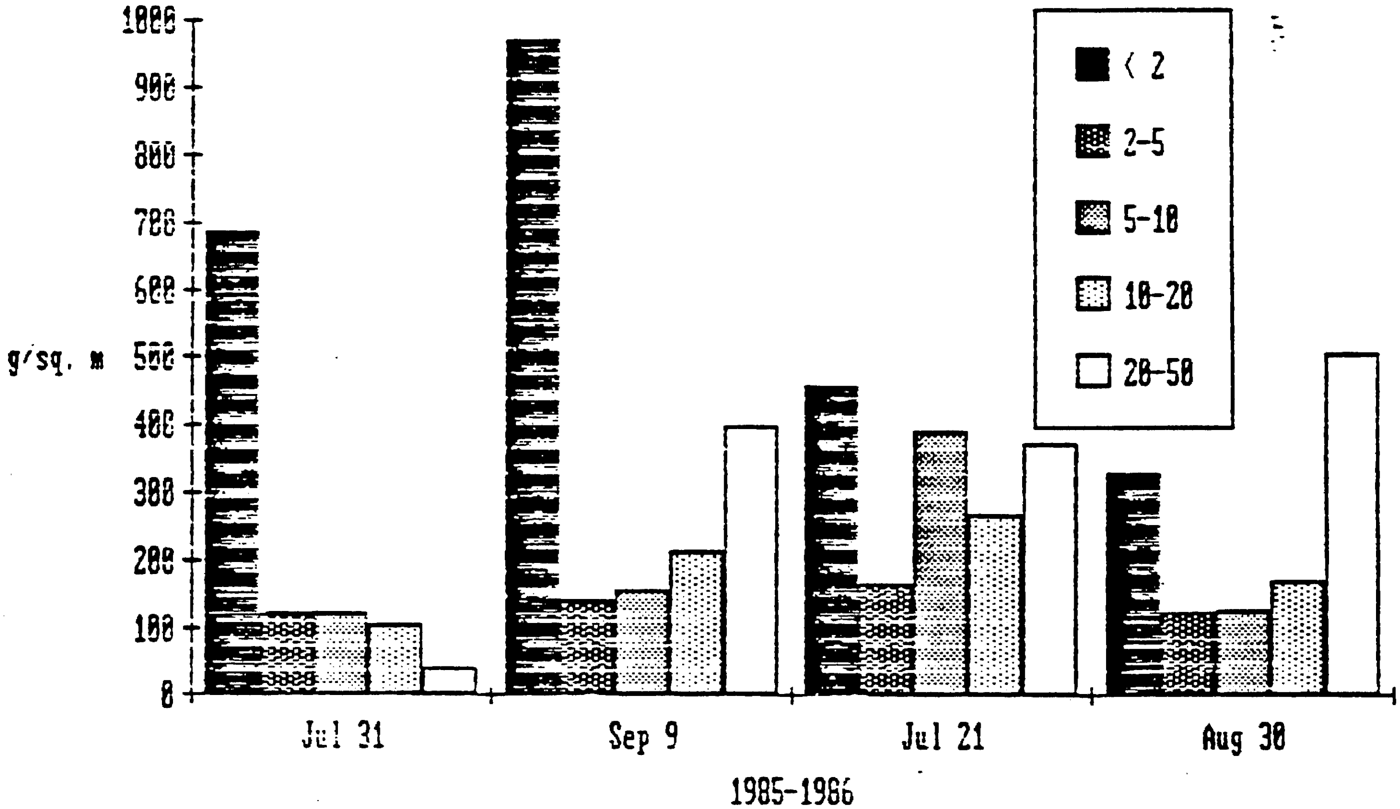
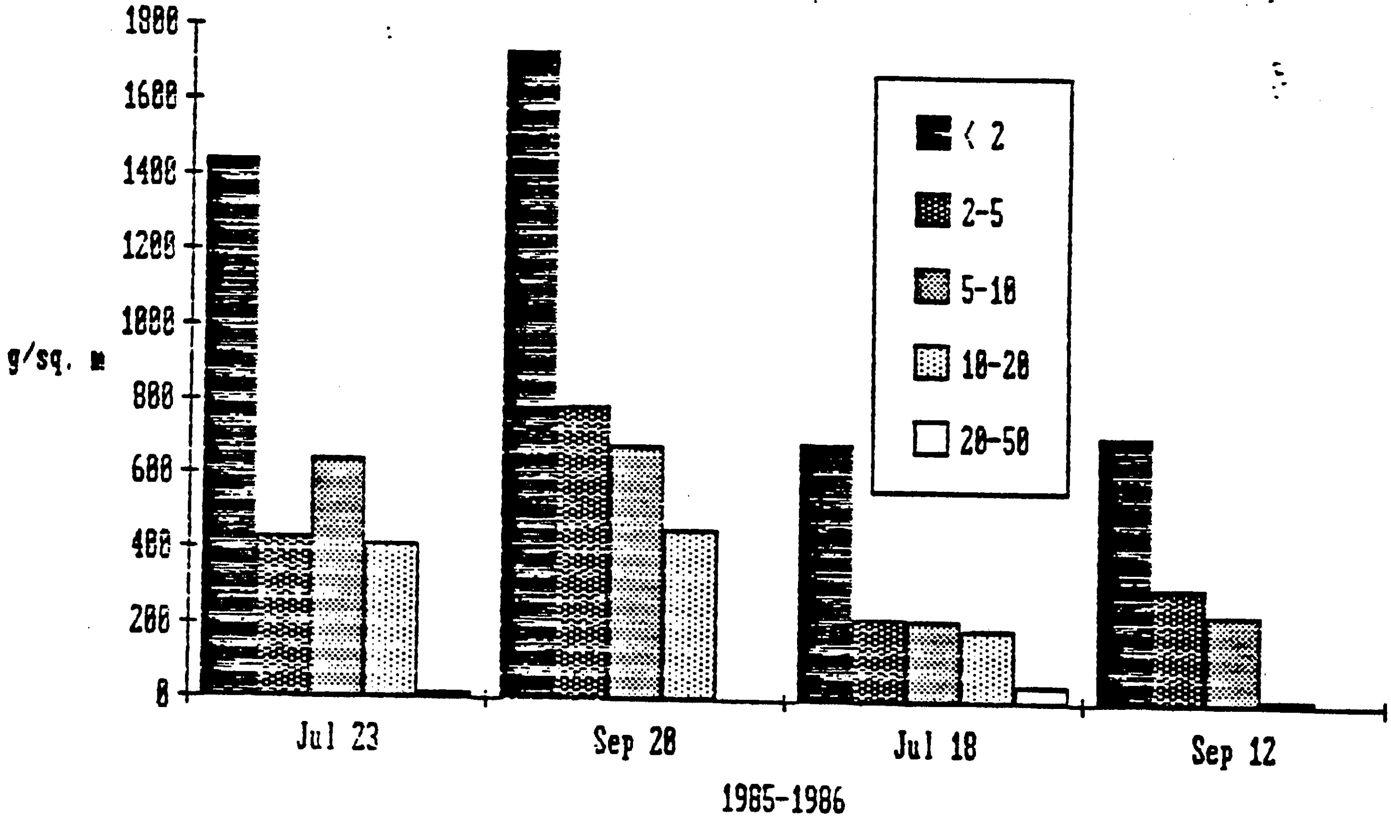


Figure 4
PHYLLODOCE BREWERI
Root standing crop in five size classes



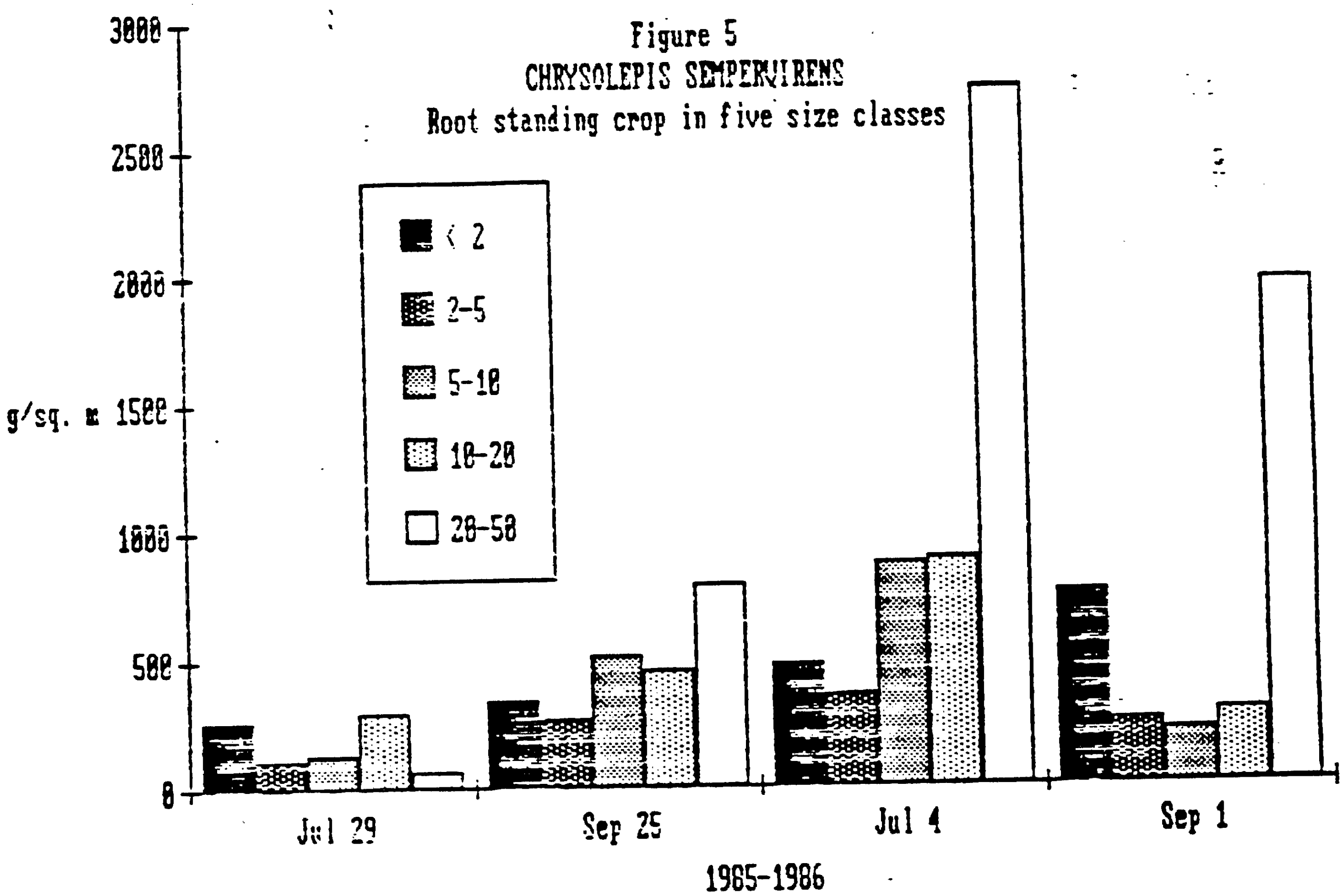


Figure 5
CHRYSOLEPIS SEMPERVIRENS
Root standing crop in five size classes
< 2
2-5
5-10
10-20
20-50
g/sq. m
3000
2500
2000
1500
1000
500
0
Jul 29
Sep 25
Jul 4
Sep 1
1985-1986

ABOVE-GROUND PROCESSES

Introduction

Field studies of above-ground biomass and nutrient fluxes followed parallel approaches to those used in previous studies. Again, the focus has been on willow thicket, chinquapin shrub, mountain heather and wet meadow communities.

Methods

The protocols used for determining above-ground shrub biomass pools and productivity were as follows. In 1985, biomass samples of 1 m^2 of canopy area for Chrysolepis sempervirens and Salix orestera, and 0.0314 m^2 (20 cm diameter plot) for Phyllodoce breweri were collected from three sites for each species in the Emerald Lake watershed (see Figure 1). The following year, 1986, representative branch samples (from top to ground-level) were sampled for each species to determine relative allocation of new production.

Biomass samples were first separated into categories of current-year foliage, old foliage, reproductive tissues, current-year twigs, dead tissues, and finally older woody tissues. In order to determine the increment of current-year woody tissue growth on older stems, these woody tissues were first cut and separated into a series of diameter size classes. For Chrysolepis and Salix, up to 10 size classes were used. Only a single size class was necessary for the small stems of Phyllodoce. The total length and mean diameter of stems in each size class were measured to 0.1 mm and 1 mm respectively. Ten twigs from each diameter class were subsampled, and a 30-mm length (l) cut from each. Using a dissecting microscope, the overall branch diameter, total wood diameter

(D_n), and wood diameter beginning with the previous year (D_{n-1}) were measured. The volume of the current-year wood increment (Vn) was calculated as:

$$V_n = \frac{\pi}{4} l \, (D_n - D_{n-1})^2$$

The biomass increment of current year woody growth on these old stems is then the product of this volume calculated and summed for all of the lengths of stems, times the mean wood density. Experimental trials that we have completed have demonstrated that wood density is not a function of stem diameter.

Under this protocol, current-year bark is included within the current-year twig pool and bark on older twigs is included in the pool of old wood.

The distribution of dead tissues on the above-ground stems was highly variable between species. Virtually all of this pool consists of dead stem material, but small amounts of dead foliage and dried reproductive structures from previous years was also included when it was encountered. In _Salix orestera_, dead tissues were relatively scattered in distribution, and large dead branches were uncommon. The situation was very different in _Chrysolepis sempervirens_ where large areas of dead canopy were localized in distribution.

For _Salix_ and _Phyllodoce_, the reproductive pool includes only current-year tissues. The small size of this pool in 1986 reflects early senescence of these tissues rather than a poor reproductive year. For _Chrysolepis_, the bulk of the reproductive pool is matured fruits from the previous growing season.

Prostrate, rooting stems are common in both _Salix_ and _Chrysolepis_, apparently the result of winter snow compaction. Often these stems were growing beneath a thin layer of soil. For the purposes of our work, these stems were classified as rooting tissues. The major part of the >20 mm diameter root pool, as well as a smaller portion of the 10-20 mm diameter pool, were formed from such rooting stems.

In the meadows, clip locations were not truly random: two 0.0314 m^2 plots (one with a core beneath it) were placed in each major subtype occurring in the plot, with the intention of comparing the biomass and productivity of the different meadow sub-types. Clip and core locations in the Phyllodoce heath were pseudo-randomly selected by tossing a small spade. In all cases, clipped material was separated by species and separated current growth from previous growth or litter.

Results and Discussion

The above-ground biomass in the four communities studied during 1985 was highest in the Chrysolepis sempervirens stands. The mean biomass here was 3857 g m^{-2}, 71% of which was live tissue (Table 12, Figure 6). Thickets of Salix orestera were a close second in biomass with 3360 g m^{-2} (66% live tissue), followed by mats of Phyllodoce breweri with 1614 g m^{-2} (87% live tissue). The wet meadow community had a low above-ground biomass of only 353 g m^{-2}

The above-ground production in these four communities showed quite a different pattern. Mats of P. breweri had a net primary production (NPP) of 499 g m^{-2} y^{-1}, the highest of any of the communities (Table 12, Figure 6). Its ratio of biomass to NPP was a low 3.2 (Figure 6), reflecting a relatively large amount of leaf to total plant biomass. The wet meadow community with a respectable 318 g m^{-2} y^{-1} NPP had an even lower ratio of 1.1. Virtually all of the above-ground tissue in this community reflects current years growth. Only a few species of low mat-forming perennials retain such above-ground tissue from year to year. In our samples these included Vaccinium nivictum, Penstemon heterodoxus, Eriogonum incanum and Kalmia pohlifolia.

Chrysolepis sempervirens had a relatively high above-ground NPP of 443 g m^{-2}, but because of its high biomass its ratio of biomass to productivity (B/P) was 8.7. The Salix thickets had surprisingly low productivity of only 274 g m^{-2} y^{-1}, making a B/P of 12.3.

Despite large differences in above-ground biomass, the estimated below-ground biomass was relatively similar in all four communities. Values were higher in the wet meadow (3760 g m^{-2}) and Phyllodoce heath (3760 g m^{-2}) communities, and lowest in the Chrysolepis (2400 g m^{-2}) and willow (2070 g m^{-2}) thickets (Table 12, Figure 6). Comparing the ratio of below-ground to above-ground biomass in these communities, the highest value by far is the wet meadow with a ratio of 10.65 (Figure 6). This value is in keeping with results from studies in other subalpine and alpine communities of similar structure in North America and Europe.

The litter biomass in the Chrysolepis stands was 4553 g m^{-2}, three times the amount in any other community (Figure 6). In both this community and the Phyllodoce mats the litter accumulation beneath the canopy is as great or greater than the standing above-ground biomass. This situation suggests relatively slow litter decomposition in these more xeric habitats. The Salix thickets and wet meadow communities have an above-ground biomass averaging 2.5 times the litter biomass.

The comparative distribution of biomass within each of the four comunities is shown in Figure 7. This figure summarizes the same data described above, with the addition of figures for herbaceous species present under the Salix and Phyllodoce canopies. No herb cover was present under Chrysolepis sempervirens in our samples.

Allocation patterns of biomass in the three shrub species studied showed interesting patterns of differences. Approximately 95% of the biomass of *Salix orestera* lies in woody tissues, compared to only 60% in the low-growing *Phyllodoce breweri* (Table 13). In the latter species, 30% of the biomass form leaves, compared to less than 3% in *Salix*. *Chrysolepis sempervirens* is intermediate.

The two evergreen species, *C. sempervirens* and *P. breweri*, each allocate 50% of their new growth to leaves, compared to only 31% in the deciduous *S. orestera*. This is the reverse of the expected pattern. *Salix* has a much larger percent of its new growth to woody tissues (wood and twigs) than either of the other two species. Reproductive allocation was relatively low in all three species.

The data presented in this progress report will be critical in evaluating standing pools of nutrients and carbon in the Emerald Lake watershed. We are currently completing the necessary nutrient analyses on each biomass fraction for each community. Data on leaf biomass per unit area will be used in calculating total transpirational fluxes for the hydrological models of the basin.

Biomass distribution data, separated by subplots, are shown in Tables 14-20 for the three shrub species. The 1985 data are presented in units of g m^{-2}, reflecting the sampling procedures discussed above. The 1986 data are based on full branch units (ground to tip) to provide relative numbers for comparisons of patterns of allocation. These data, collected at the very end of the contract period, will be analyzed and discussed in more detail in the final project report for the current contract. This discussion will include data from the 1987 growing season.

Biomass and productivity data for wet meadows in 1986 are shown in Tables 21-22 , broken down by subplot clipped and dominant species. Note the large variation between subplots in this vegetation unit. This variation is largely a result of aspect dominance by individual species. Both above- and below-ground biomass for dry meadow associations in 1986 are presented in Table 23.

The relative contribution of individual herb species to biomass was measured by clipping small plots and separating all herbaceous biomass by species. These 1985 data are presented for the *Phyllodoce breweri* plots (Table 24) and *Salix orestera* plots (Table 25).

Table 12. Biomass productivity and litter pool sizes in four shrub and herb communities in the Emerald Lake watershed, Sequoia National Park. Values are in g m^{-2} for biomass and litter and g m^{-2} y^{-1} for productivity

Pool	*Chrysolepis sempervirens*	*Phyllodoce breweri*	*Salix orestera*	Wet meadow
Above-ground biomass				
Live	2746	1409	2230	
Dead	1111	205	1130	
Total	3857	1614	3360	353
Above-ground productivity	443	499	274	318
Biomass/productivity	8.7	3.2	12.3	1.1
Below-ground biomass	2400	3670	2070	3760
Root/shoot	0.62	2.27	0.61	10.65
Herb biomass	-	54	-	NA
Litter	4553	1618	1441	137
Above-ground biomass/litter	0.85	1.00	2.33	2.58
Above-ground productivity/litter	0.10	0.31	0.19	2.32

Table 13. Relative allocation of above-ground biomass and net primary production (%) to individual tissue compartments in three shrub species in the Emerald Lake watershed, Sequoia National Park during 1985. Standard deviations of means are shown in parentheses

	Chrysolepis sempervirens	Phyllodoce breweri	Salix orestera
Relative biomass allocation			
New leaves	6.5 (3.1)	15.4 (3.4)	2.7 (1.7)
New twigs	1.2 (0.4)	4.7 (1.3)	1.8 (0.9)
New wood	4.5 (1.1)	9.8 (1.6)	3.8 (1.3)
New reproduction	0.3 (0.4)	0.5 (0.5)	0.1 (0.1)
Old leaves	3.5 (2.4)	14.5 (3.7)	-
Old wood (live and dead)	83.8 (5.3)	52.6 (3.5)	91.5 (2.4)
Relative allocation of new growth			
Leaves	49.8 (9.6)	50.6 (5.5)	30.9 (13.9)
Twigs	10.0 (1.3)	15.3 (3.3)	20.9 (7.1)
Wood	37.1 (8.2)	32.7 (7.0)	45.7 (11.3)
Reproduction	3.0 (3.9)	1.8 (1.7)	2.5 (3.4)

Table 14. Biomass distribution (g m^{-2}) in three sample plots of <u>Chrysolepis sempervirens</u> in the Emerald Lake basin on September 25, 1985. Each subplot is 1 m^2.

	New growth				Old growth			1985	Total	
Subplot	Leaves	Twigs	Wood	Reprod.	Leaves	Old wood	Dead	biomass	biomass	Litter
1-1	127.41	19.48	42.13	2.40	86.97	375.19	332.84	191.42	986.60	6963.60
1-2	135.66	20.37	73.71	0.23	121.48	820.62	1490.6	229.97	2662.67	3876.80
1-3	157.67	23.27	85.15	0.25	78.68	631.66	682.70	266.34	1659.38	4255.60
2-1	332.50	54.41	241.90	10.55	36.05	2252.10	1095.72	639.36	4023.23	3339.60
2-2	197.60	54.80	151.13	50.58	76.99	2295.28	739.73	454.11	3567.24	5474.36
2-3	198.92	45.90	186.79	35.42	229.25	2883.73	1885.77	467.03	5465.78	3757.28
3-1	300.19	64.72	334.56	6.69	128.51	4033.17	1237.34	706.16	6105.18	5042.00
3-2	160.90	45.83	181.52	0.06	62.27	1068.79	1639.20	388.31	3158.57	3677.52
3-3	266.21	69.30	275.31	29.87	171.22	5478.46	895.94	640.69	7186.31	4594.92

Table 15. Biomass distribution (g m^{-2}) in three sample plots of Phyllodoce breweri in the Emerald Lake basin on September 20, 1985. Each subplot is 314 cm^2.

Subplot	Leaves	Twigs	Wood	Reprod.	Leaves	Old wood	Dead	1985 biomass	Total biomass	Litter
1-1	167.43	56.66	89.13	0.0	122.86	347.91	127.64	313.22	920.23	1832.19
1-2	107.90	36.61	76.71	3.81	113.64	299.21	206.90	225.05	994.72	524.26
1-3	155.65	62.39	69.39	6.37	102.81	271.20	196.72	284.25	894.45	1355.36
2-1	431.63	119.37	377.52	0.0	349.50	1473.46	189.08	928.51	3031.27	2353.58
2-2	293.48	81.48	330.09	31.19	488.92	1287.88	448.50	736.25	2980.97	4167.63
2-3	365.42	101.22	148.33	11.46	219.32	578.05	295.07	626.43	1829.96	816.15
3-1	243.19	64.93	148.65	0.0	340.27	728.61	101.22	456.77	1487.78	945.70
3-2	292.53	77.67	172.84	11.14	255.92	674.18	107.90	554.18	1631.66	1586.46
3-3	176.34	46.79	127.32	15.60	188.76	497.52	168.39	366.06	1235.68	984.85

Table 16. Biomass distribution (g m^{-2}) in three sample plots of _Salix orestera_ in the Emerald Lake basin on September 10, 1985. Each subplot is 1 m^2.

	New growth				Old growth		1985	Total	
Subplot	Leaves	Twigs	Wood	Reprod.	Old wood	Dead	biomass	biomass	Litter
1-1	77.90	101.60	169.70	3.67	2676.27	540.50	352.87	3029.14	596.00
1-2	66.30	97.77	160.64	1.55	2102.28	1725.50	326.26	2428.54	2388.80
1-3	62.41	104.02	189.13	5.85	2010.69	548.31	361.41	2372.10	2428.00
2-1	71.21	91.01	205.73	0.0	3789.67	1980.50	367.95	4157.62	987.20
2-2	77.18	31.07	87.02	4.98	2159.04	517.52	200.25	2359.29	988.08
2-3	91.08	28.20	96.62	0.71	1311.30	1509.07	216.61	1527.91	3047.16
3-1	75.21	57.30	188.68	0.0	2342.66	1289.10	321.19	2663.85	1134.40
3-2	45.34	19.81	48.12	11.74	758.88	1077.3	125.01	883.89	883.89
3-3	114.63	26.20	40.02	14.33	456.40	982.49	195.18	651.58	518.20

Table 17. Biomass distribution on 1986 branches of Chrysolepis sempervirens in the Emerald Lake basin. Values are given in g branch^{-1} for five samples from each of three shrubs. Samples were collected in late September 1986.

	New growth				Old growth			New/old
Sample no.	Leaves	Twigs	Wood	Reprod.	Leaves	Old wood	Dead	(%)
1-1	11.19	1.28	2.86	0.0	11.50	41.54	12.32	28.9
1-2	15.22	1.68	4.32	0.0	9.56	29.75	2.54	54.0
1-3	3.10	0.46	0.77	0.0	1.53	3.61	0.36	84.0
1-4	6.59	0.63	1.70	0.0	5.46	40.39	0.95	19.5
1-5	8.21	0.87	2.14	1.21	8.23	34.53	2.92	29.1
								43.1
2-1	5.51	1.13	5.92	0.01	8.28	86.23	54.13	13.3
2-2	5.51	1.69	7.13	0.0	6.33	26.21	1.60	44.0
2-3	17.43	3.20	6.67	0.34	9.92	107.76	13.82	23.5
2-4	4.30	0.83	1.28	0.0	4.63	19.47	9.10	26.6
2-5	7.16	0.89	5.46	0.58	4.79	44.50	2.22	28.6
								27.2
3-1	1.68	0.17	1.09	0.0	1.31	45.07	60.84	6.3
3-2	47.02	12.42	32.63	0.0	51.35	271.42	28.42	33.1
3-3	7.44	3.18	3.52	0.0	6.12	30.57	0.0	44.0
3-4	6.69	2.27	3.18	0.0	4.72	37.43	2.12	28.8
3-5	48.38	11.13	42.76	17.70	57.97	349.40	53.27	29.4
								28.3

Table 18. Biomass distribution on 1986 branches of *Phyllodoce breweri* in the Emerald Lake basin. Values are given in g branch^{-1} for ten samples from each of three shrubs. Samples were collected in mid-September 1986.

	New growth				Old growth			New/old
Sample no.	Leaves	Twigs	Wood	Reprod.	Leaves	Old wood	Dead	(%)
1-1	0.427	0.102	0.136	0.0	0.376	0.510	0.032	75.1
1-2	0.076	0.016	0.040	0.0	0.028	0.150	0.054	74.2
1-3	0.098	0.025	0.081	0.0	0.232	0.303	0.032	38.1
1-4	0.254	0.051	0.175	0.0	0.260	0.655	0.016	52.5
1-5	0.072	0.005	0.058	0.0	0.054	0.218	0.010	49.6
1-6	0.204	0.041	0.059	0.0	0.111	0.219	0.033	92.1
1.7	0.467	0.084	0.296	0.0	0.549	1.107	0.316	51.1
1-8	0.342	0.106	0.097	0.0	0.274	0.363	0.0	85.6
1-9	0.111	0.040	0.129	0.334	0.541	0.482	0.078	60.0
1-10	0.172	0.045	0.125	0.0	0.226	0.467	0.020	49.4
								62.8
2-1	0.006	0.023	0.013	0.0	0.016	0.047	0.009	66.7
2-2	0.306	0.051	0.070	0.0	0.095	0.262	0.015	119.6
2-3	0.102	0.015	0.041	0.0	0.096	0.153	0.022	63.5
2-4	0.374	0.077	0.419	0.0	0.316	1.566	0.096	46.2
2-5	0.094	0.022	0.064	0.0	0.111	0.240	0.019	51.3
2-6	0.480	0.094	0.170	0.0	0.331	0.636	0.166	76.9
2-7	0.448	0.089	0.105	0.0	0.322	0.393	0.067	89.8
2-8	1.104	0.276	0.772	0.0	1.364	2.889	0.200	38.8
2-9	0.023	0.004	0.016	0.0	0.044	0.062	0.012	40.6
2-10	0.151	0.028	0.060	0.0	0.126	0.224	0.018	68.3
								66.2

Table 19. (Continued)

3-1	0.281	0.030	0.082	0.0	0.190	0.307	0.039	79.1
3-2	0.665	0.131	0.419	0.0	0.954	1.565	0.295	48.2
3-3	0.283	0.033	0.287	0.027	0.445	1.075	0.100	41.4
3-4	0.128	0.030	0.115	0.0	0.385	0.428	0.124	33.6
3-5	0.281	0.088	0.149	0.0	0.364	0.557	0.020	56.2
3-6	0.778	0.116	0.776	0.333	1.693	2.904	0.185	43.6
3-7	1.863	0.231	0.282	0.641	3.749	1.053	0.062	62.8
3-8	0.548	0.101	0.446	0.0	0.775	1.668	0.391	44.8
3-9	0.559	0.077	0.199	0.0	0.325	0.745	0.027	78.0
3-10	0.520	0.165	0.677	0.0	1.163	2.532	0.403	36.9
								52.5
								60.4
								20.2

Table 20 . Biomass distribution on 1986 branches of <u>Salix orestera</u> in the Emerald Lake basin. Values are given in g branch^{-1} for five samples from each of three shrubs. Samples were collected in late September 1986.

	New growth				Old growth		New/old
Sample No.	Leaves	Twigs	Wood	Reprod.	Old wood	Dead	(%)
1-1	19.48	7.76	6.21	0.0	122.85	1.04	36.1
1-2	19.51	3.51	11.11	0.0	198.77	32.04	17.2
1-3	18.93	4.10	8.59	0.0	199.21	107.05	15.9
1-4	20.57	5.34	11.40	0.0	118.38	1.23	31.5
1-5	15.94	3.54	6.34	0.0	149.77	65.33	17.2
Mean							23.6
2-1	28.90	7.34	15.12	8.23	586.57	161.06	10.1
2-2	42.17	9.40	18.81	21.02	506.52	80.18	18.0
2-3	17.06	5.31	19.98	2.99	105.20	1.03	43.1
2-4	19.42	5.75	18.35	2.54	141.61	11.89	32.5
2-5	10.98	3.19	13.27	0.0	299.05	46.62	9.2
Mean							22.6
3-1	51.25	16.60	27.01	0.0	432.27	75.09	21.9
3-2	23.10	3.67	11.78	2.63	228.08	313.64	18.1
3-3	41.71	7.32	19.24	2.94	349.41	73.09	19.5
3-4	27.40	9.22	12.69	0.0	350.13	116.14	14.1
3-5	28.04	8.74	16.42	0.58	371.84	99.87	14.5
Mean							17.6

Table 21. Wet meadow above-ground biomass and productivity for the 1986 growing season in the Emerald Lake basin. All values are in g m^{-2}. See Table 30 for key to abbreviations of dominant species.

Site	Clip	Dominants	1986 Production	Standing Crop	Litter	Total
1	1	CASP	279	302	678	980
	2	POBL	938	944	123	1067
	3	CASP	370	381	147	528
	4	VANI-PEHE	416	533	318	851
	5	JUPA-VANI-PEHE	457	790	161	951
	Mean		492	590	285	875
	SD		258	272	232	209
2	1	SCCR-DOSE-ASAL	114	114	233	346
	2	ASAL	66	66	242	308
	3	VANI-SUPA-DAIN	314	389	155	557
	4	SCCR-ASAL	124	126	351	476
	5	VANI-ASAL	132	146	51	197
	Mean		150	168	206	377
	SD		95	127	111	142
3	1	VANI	352	480	246	746
	2	VANI-ASAL-DEEL	313	380	370	756
	3	VANI-DAIN	377	444	92	536
	4	ELPA-ASAL	267	267	310	577
	5	VANI-ASAL	258	288	282	575
	Mean		313	372	260	638
	SD		52	94	104	164
	Overall	Mean	318	377	251	630
		SD	208	245	153	256
		CV	65.4%	65.0%	61.0%	40.6%

Table 22. Wet meadow above-ground biomass and productivity for the 1986 growing season at two supplemental sites in the Emerald Lake basin not sampled in 1985. All values are in g m^{-2}. See Table 30 for key to abbreviations of dominant species.

Site	Cup	Dominants	1986 production	Standing crop	Litter	Total
4	1	ASAL	73	73	--	73
	2	ASAL	148	148	--	148
	3	MUFI	84	84	--	84
	4	JUME	35	35	--	35
	5	CASP	511	511	341	852
	Mean		170	170	68	238
	SD		195	195	152	345
5	1	CASP	90	90	91	181
	2	JUME	296	296	241	537
	3	PEME	267	279	111	390
	4	ELPA	94	94	43	137
	5	CASP	339	339	255	594
	Mean		217	217	148	368
	SD		117	117	95	205
	μ		194	194	108	303
	SD		154	154	127	276

Table 23. Dry meadow biomass relationships for five 1 m^2 samples collected in August 1986 in the Emerald Lake Basin. All values are in g m^{-2}. Below-ground live biomass includes all roots less than 2 mm diameter, regardless of condition.

Sample No.	Above-ground biomass	Below-ground biomass live	Below-ground biomass dead	Litter	Net production
1	89.13	481.16	-	86.20	570.29
2	347.98	773.75	83.78	181.95	1121.73
3	161.70	448.69	144.90	306.21	610.39
4	595.49	779.61	36.16	154.44	1375.10
5	203.85	989.18	112.43	135.85	1193.03
Mean	279.63	694.48			701.84
S_{n-1}	200.24	227.10			478.73

Table 24. Herb biomass (g m^{-2}) by species in three sample plots of *Phyllodoce breweri* in the Emerald Lake basin on September 20, 1985. Each subplot was 314 cm^2.

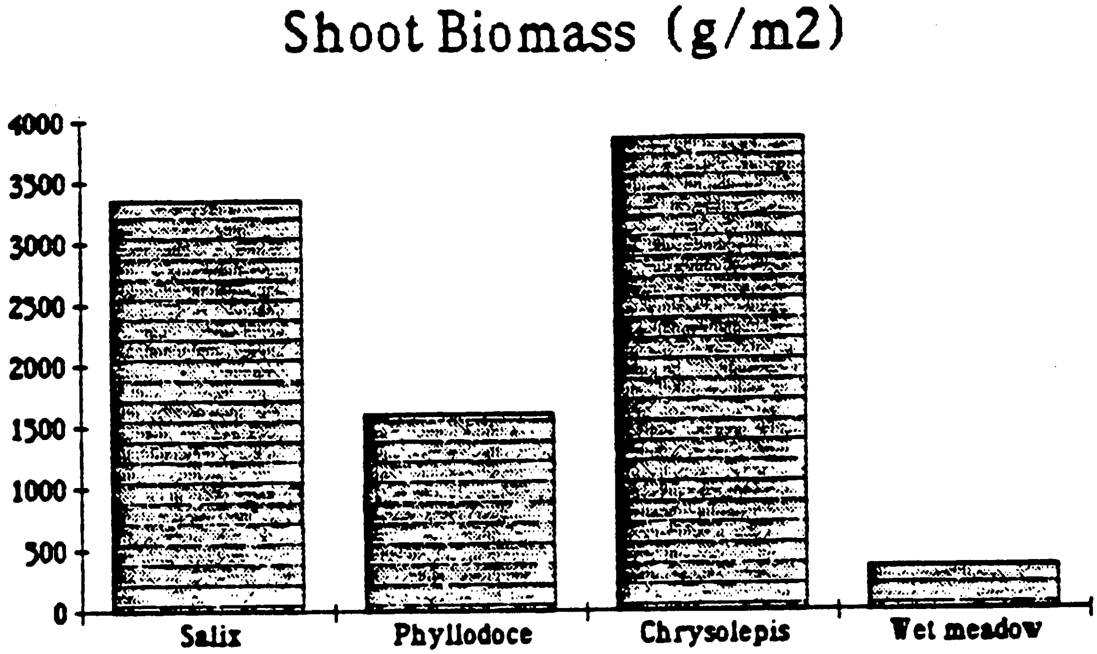
	PHBR-1			PHBR-2			PHBR-3		
	1	2	3	1	2	3	1	2	3
Juncus parryi	7.32	-	31.83	-	-	-	-	-	-
Stipa occidentalis	0.69	-	0.95	14.96	-	-	-	6.37	-
Pensteman heterodoxus	0.23	66.21	-	-	-	-	-	-	-
Carex multicostata	-	83.72	20.69	-	-	-	-	-	-
Phlox diffusa	-	-	14.64	-	-	23.24	9.86	-	14.96
Achillea lanulosa	-	-	-	7.00	0.06	30.55	-	-	-
Monardella odoratissima	-	-	-	53.79	-	5.41	-	24.19	-
Poa epilis	-	-	-	14.96	2.23	-	-	8.91	-
Erysimum perenne	-	-	-	-	13.69	-	-	-	-
Thalictrum fendleri	-	-	-	-	1.59	5.73	-	-	-
Antennaria alpina	-	-	-	-	-	16.23	-	-	-
Total	8.59	149.92	39.47	90.72	19.42	111.09	9.86		14.96

Table 25. Herb biomass (g m^{-2}) by species in three sample plots of *Salix orestera* in the Emerald Lake basin on September 20, 1985. Each subplot was 1 m^2.

	SADR-1			SADR-2			SADR-3		
	1	2	3	1	2	3	1	2	3
Thalictrum fendleri	-	74.32	45.40	-	-	-	123.16	14.08	-
Senecio triangularis	-	-	10.96	-	82.04	32.16	-	-	-
Mertensia ciliolata	-	-	-	-	-	-	-	97.72	6.64
Calamagrostis canadensis	-	-	10.20	-	9.76	37.56	-	-	-
Luzula paruiflora	-	-	48.04	-	-	-	-	-	-
Epilobium angustifolium	-	-	-	6.44	-	2.24	-	-	-
Phacelia frigida	-	-	-	-	-	-	-	-	2.52
Pyrola californica	-	-	0.32	-	-	-	-	-	-
Miscellaneous herbs	-	-	-	-	-	-	-	-	29.88
Total	0.0	83.16	114.92	6.44	91.80	71.96	123.16	111.80	38.44

Table 26. Standing pools of nutrients in above-ground biomass of three species of shrubs in the Emerald Lake Basin. All values are in g m^{-2} of canopy. These data are based on 1985 measurements of biomass and 1986 nutrient concentrations.

	Chrysolepis sempervirens	*Phyllodoce breweri*	*Salix orestera*
Nitrogen	11825	12572	20565
Phosphorus	521	1197	1618
Sulfur	1136	1387	2244
Sodium	23	55	31
Potassium	7680	9044	5444
Calcium	15695	6324	14375
Magnesium	1753	1409	1703
Iron	189	417	135
Manganese	1077	603	380
Aluminum	158	432	118
Silica	874	2765	297



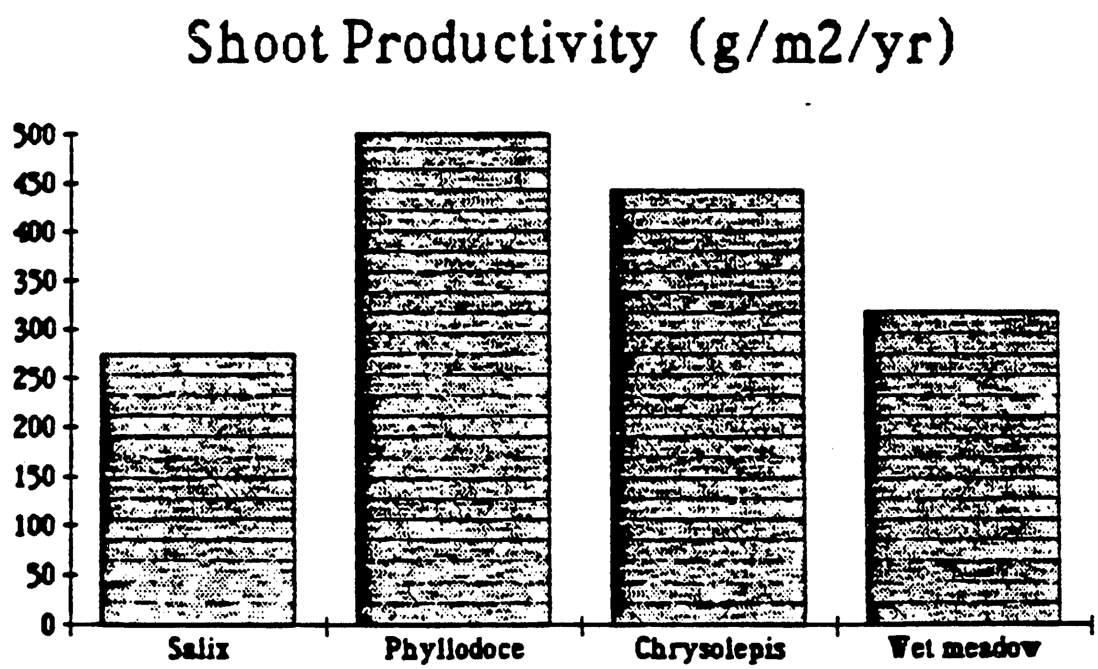
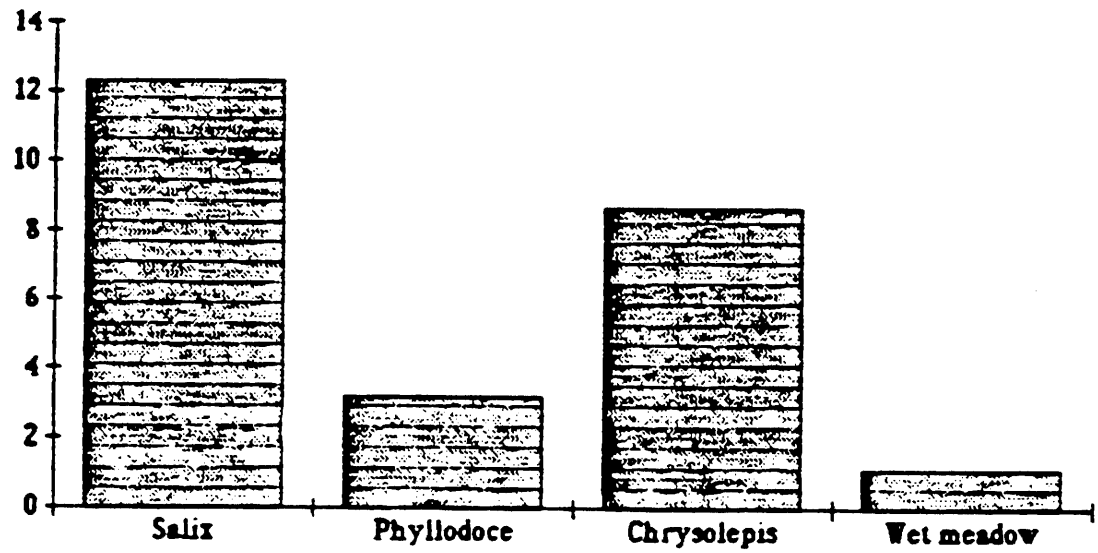
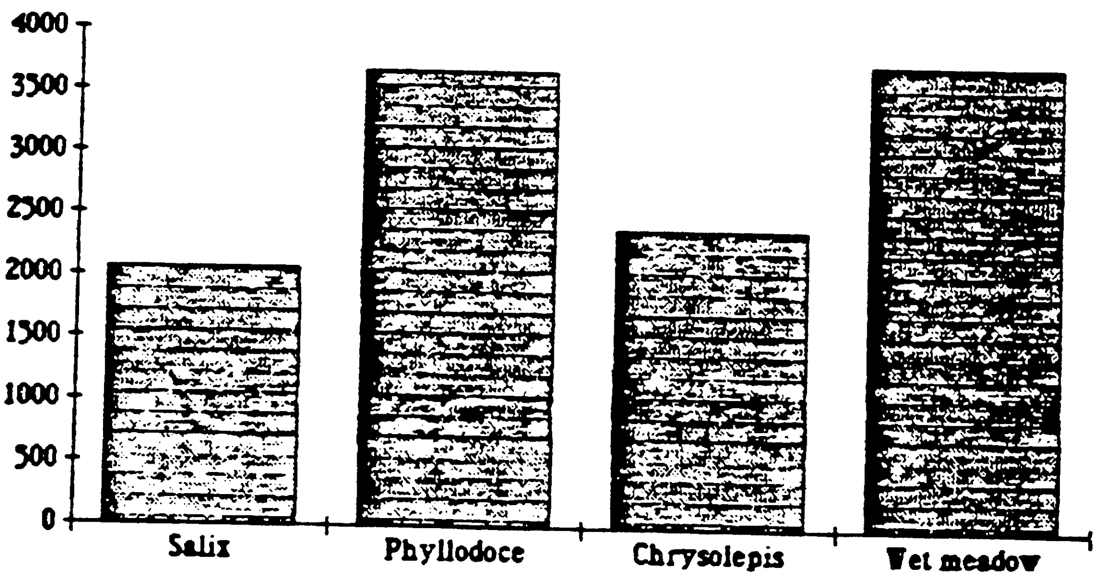


Figure 6. Biomass and productivity relationship for shrub and herb communities in the Emerald Lake basin during 1985; see following pages.

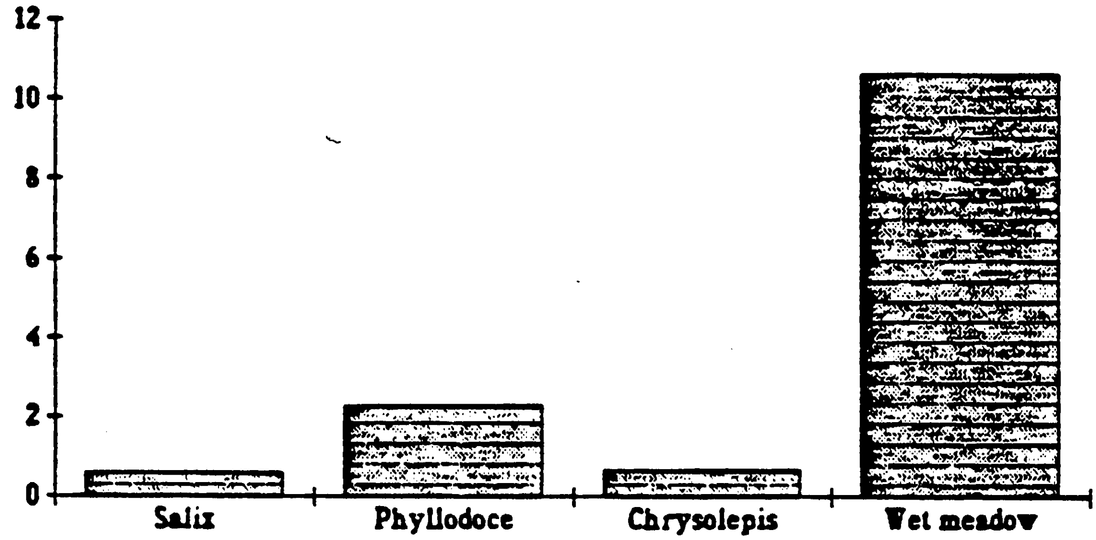
Biomass/Productivity Ratio



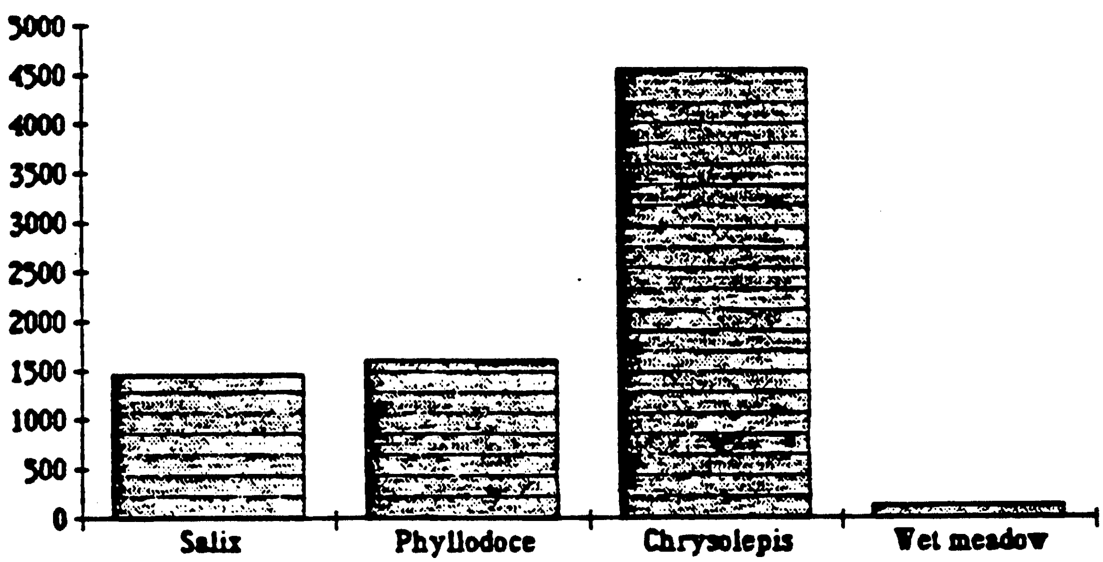
Root Biomass (g/m2)

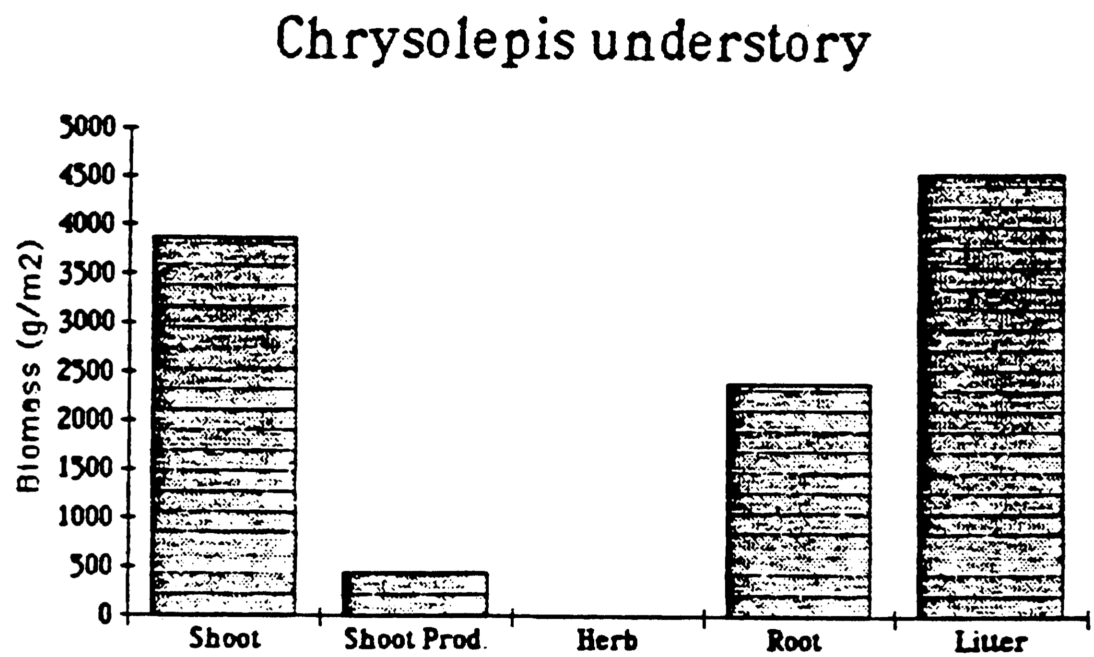


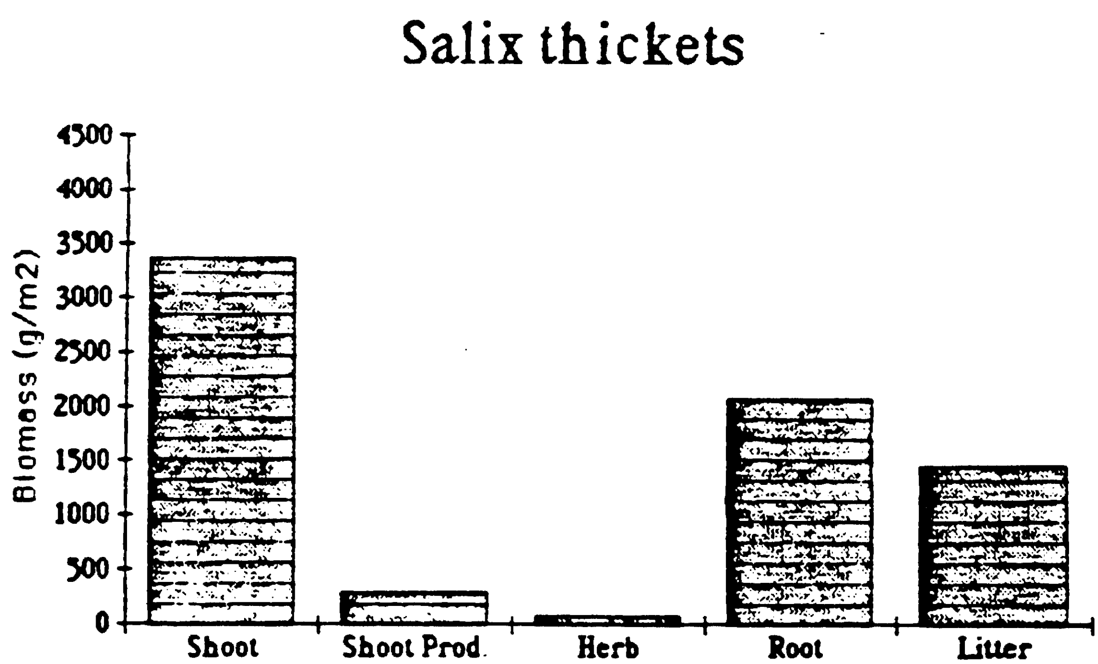
Root/Shoot Ratio



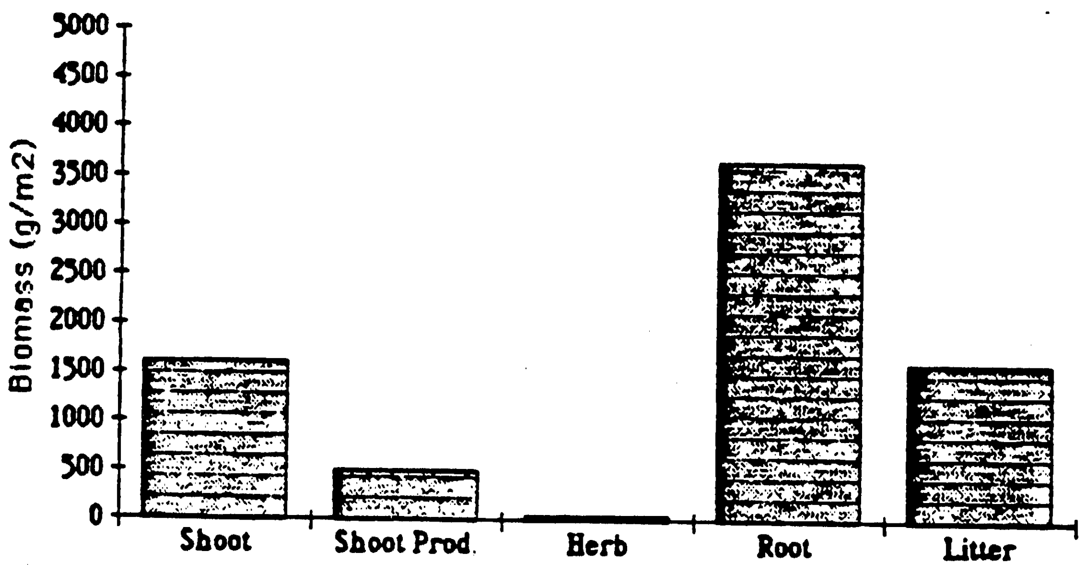
Litter Biomass (g/m2)




Chrysolepis understory
Biomass (g/m2)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Shoot
Shoot Prod.
Herb
Root
Litter


Salix thickets
Biomass (g/m2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Shoot
Shoot Prod.
Herb
Root
Litter

Phyllodoce mats



5

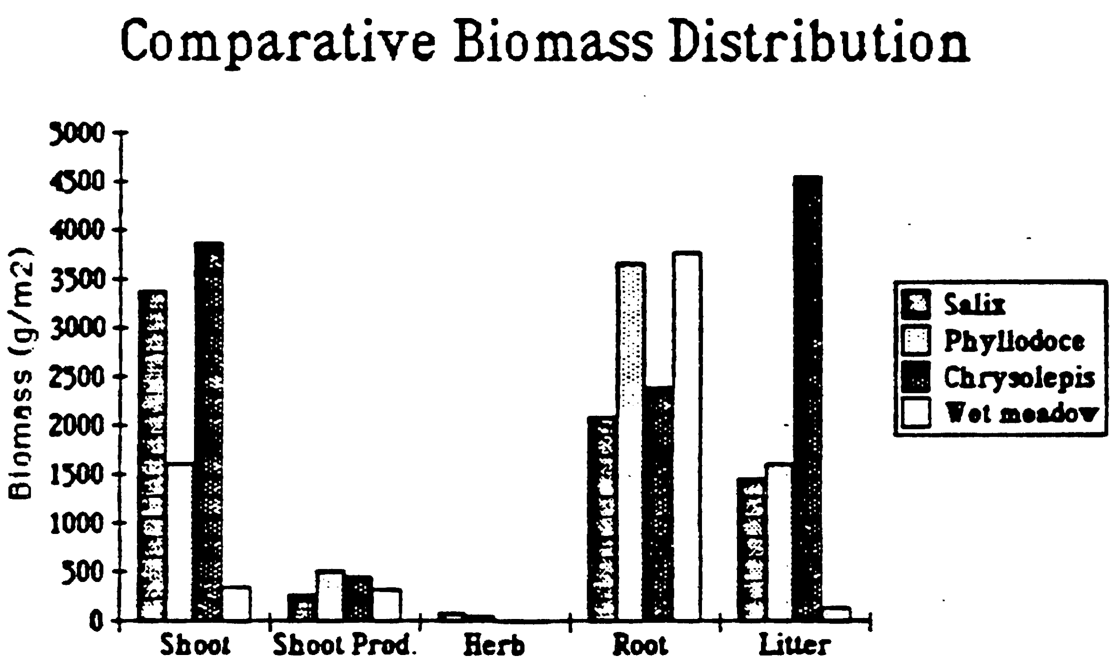


Figure 7-8. Comparative biomass distribution and above-ground productivity for the 1985 growing season at Emerald Lake.

FOREST TREES IN THE EMERALD LAKE WATERSHED

The major part of the Emerald Lake Basin lacks coniferous trees. This absence results not from the elevation of the lake basin, but rather from a lack of appropriate substrates. Rocky shelves, dry summer conditions and avalanche activities all act to restrict trees to scattered distribution in areas covering less than one half of the basin.

During the summer of 1985 we carried out a complete census of all trees in the basin. Each tree was identified, measured for diameter at breast height (dbh), and roughly plotted within one of five physiographic tree communities within the basin. We utilized existing sample data for three permanent plots established by the National Park Service. Tree heights are available as well for most of these permanently marked trees.

The Emerald Lake watershed contained 1206 trees within five species, all conifers. This is an average of 9.9 individuals per hectare over the entire basin. The most abundant species was *Pinus monticola* which comprised 71.2% of these individuals (Table 27, Figure 9). *Pinus contorta* ssp. *murrayana* was second most important with 16.7% of the trees, with *Pinus balfouriana* third with 9.5%. A small number of *Abies magnifica* and *Pinus jeffreyi* were also present.

There were 174.5 m^2 of tree basal area in the basin, for a mean basin-wide coverage of 1.43 m^2 basal area per hectare. *Pinus monticola* has an even greater relative dominance than its abundance based on its 82.4% share of the total tree basal area (Table 27, Figure 9). *Pinus balfouriana* jumps to second in relative dominance with 13.7% of the basal area, with *Pinus contorta* ssp. *murrayana* a distant third at 3.5%. The combined relative dominance of *Abies magnifica* and *Pinus jeffreyi* is less than 0.5%.

The distribution of Pinus monticola by size-class showed a typical inverse J-shape distribution for the smaller diameter trees (Figure 10). Above 50 cm dbh, there seems to be a relatively large number of such individuals. This suggests a very low mortality rate for these large trees. The peak in numbers of individuals in the 125- and 150-cm dbh classes is largely a function of the wider diameter categories used for larger trees.

Pinus contorta ssp. murrayana also exhibited a typical inverse J-shape distribution in size classes (Figure 10). In this species there were only a few scattered large individuals. Pinus balfouriana had a population structure heavily weighted toward larger size trees (Figure 11). There were relatively few individuals in the 5-cm dbh class, and unpredictable numbers of indiviuals in the larger size classes. Without a correlation of tree core information on ages, it is difficult to infer a correlation between dbh and age and thus impossible to interpret whether spaced peaks in Figure 1 represent waves of establishment in the past.

Populations of Abies magnifica include at least two cohorts of individuals. One group of smaller individuals falls in the 5- to 15-cm dbh classes, while a second group falls in the 30- to 50-cm dbh categories (Figure 11).

All of the individuals of Pinus jeffreyi are small (Figure 12).

We recognize five physiographic habitats for coniferous trees within the Emerald Lake watershed (Figure 13). The most important of these is the mesic bench area comprising the triangle of the northern corner of the watershed. This is the site of the National Park Service's permanent Pinus monticola plot. This type included 48.2% of the trees and 51.0% of the basal area for the watershed (Figure 14 and 15). All of the P. jeffreyi and the majority of Abies magnifica in the watershed lie in this area, while P. balfouriana is absent.

Next in importance is the SW-facing ridge area along the northeastern margin of the watershed. This area comprised 24.9% of the individual trees and 25.4% of the basal area for the watershed. The National Park Service's ridge permanent plot is located within this area.

The north-facing ridge along the south and southwestern margin of the Emerald Lake Basin comprises 13.9% of the trees and 19.1% of the basal area within the basin. Nearly two-thirds of this basal area is due to Pinus balfouriana which is dominant over P. monticola. Nearly 80% of the individuals of Pinus balfouriana within the entire basin are found in this relatively small area. Only a few individuals of P. contorta ssp. murrayana occur here, and P. jeffreyi and Abies magnifica are absent.

The final two physiographic tree areas are the wet meadow sites in the center of the basin and the steep tallus area along the northwestern margin of the watershed. The National Park Service's permanent willow plot lies in the former of these. These two areas comprise 8.3 and 4.7% of the tree individuals and 3.4 ad 0.1% of the basal area respectively for the Emerald Lake watershed. The composition of the wet meadow communities is comparable to that of the basin as a whole, but the steep tallus slopes are very strongly dominated by Pinus monticola. The remainder of the Emerald Lake watershed, about half its total area, is treeless.

When tree occurrence in the Emerald Lake Watershed is classified by slope exposure, irregardless of physiographic habitat, a strong dominance of southwest-facing exposures is evident. Approximately three quarters of both individual trees and basal area occur on such exposures (Figures 16, 17). These sites would be expected to receive a greater amount of solar radiation than north-facing exposures, resulting in a longer and warmer growing season. Trees on north and northwest facing slopes are most abundant along ridges where snow accumulation is low.

In October and November 1986, 20 actively-growing branches of each of the three most important pine species were harvested to provide quantitative data on the relative growth dynamics over the past five growing seasons. Patterns of needle retention were measured on each branch. At the time of sampling, *P. contorta* ssp. *murrayana* and *P.* balfouriana still retained nearly two-thirds of their 1982 needles, while *P. monticola* retained only 41% (Table 28).

These three species each showed significant year-to-year differences in needle length, twig length and biomass per growing point (Table 29). For each species, 1983 was the poorest year for growth of these five and 1985 the best.

Table 27. Population of all trees with the Emerald Lake watershed in September 1985.

	No of trees	Relative abundance %	Basal area (m)	Relative dominance (%)
Pinus monticola	859	71.2	143.79	82.4
Pinus contorta ssp. *murrayana*	202	16.7	6.19	3.5
Pinus balfouriana	114	9.5	23.96	13.7
Abies magnifica	20	1.7	0.56	0.3
Pinus jeffreyi	11	0.9	0.04	+
	1206	100.0	174.55	100.0

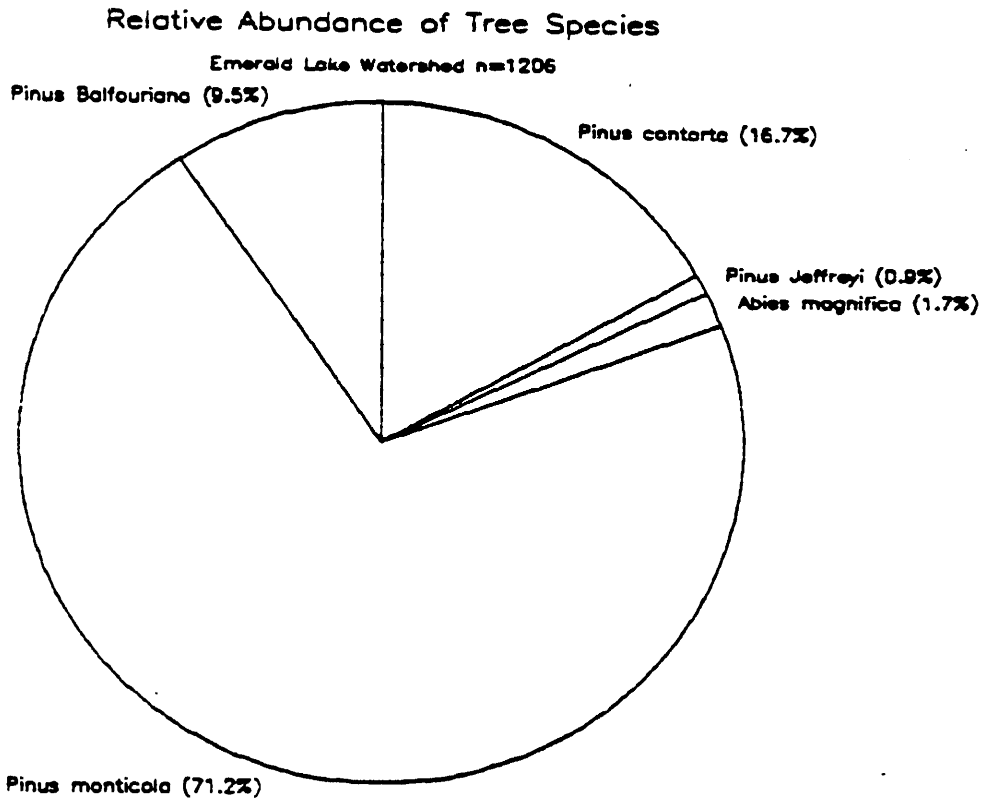
Table 28. Percent needle retention in three species of pines in the Emerald Lake watershed, Sequoia National Park. Data based on 20 branches of each species collected in October and November 1986.

	1986	1985	1984	1983	1982
Pinus balfouriana	100	81.5	82.7	79.7	63.3
Pinus contorta ssp. *murrayana*	98.1	95.3	80.3	78.8	65.8
Pinus monticola	99.7	91.2	83.2	68.4	40.8

Table 29. Five-year growth record for needle length, twig length, and biomass per growing point for _Pinus balfouriana_ (PIB), _P. contorta_ ssp. _murrayana_ (PICO) and _P. monticola_ (PIMO) in the Emerald Lake watershed, Sequoia National Park. Field samples were collected in October and November 1986. Standard deviations of mean values for each of 20 branches are shown in parentheses.

	Needle length (mm)			Twig length (mm)			Biomass/growing point (mg)		
	PIBA	PICO	PIMO	PIBA	PICO	PIMO	PIBA	PICO	PIMO
1986	24 ± 5	33 ± 7	41 ± 6	13.8 ± 6.2	21.6 ± 7.0	22.2 ± 9.4	799 ± 539	1090 ± 418	970 ± 328
1985	25 ± 4	46 ± 8	49 ± 4	16.9 ± 6.1	30.4 ± 9.8	25.9 ± 8.5	962 ± 546	2271 ± 742	1428 ± 399
1984	25 ± 4	39 ± 6	47 ± 5	14.1 ± 5.1	20.6 ± 4.1	21.1 ± 8.6	929 ± 429	1463 ± 380	1087 ± 300
1983	18 ± 5	25 ± 6	30 ± 8	12.1 ± 5.0	20.6 ± 5.2	19.4 ± 7.0	744 ± 640	937 ± 386	698 ± 236
1982	21 ± 5	33 ± 9	41 ± 5	12.3 ± 4.1	21.0 ± 5.4	21.6 ± 11.1	717 ± 507	1217 ± 461	885 ± 359

Figure 9


Relative Abundance of Tree Species
Emerald Lake Watershed n=1206
Pinus Balfouriana (9.5%)
Pinus contorta (16.7%)
Pinus Jeffreyi (0.9%)
Abies magnifica (1.7%)
Pinus monticola (71.2%)

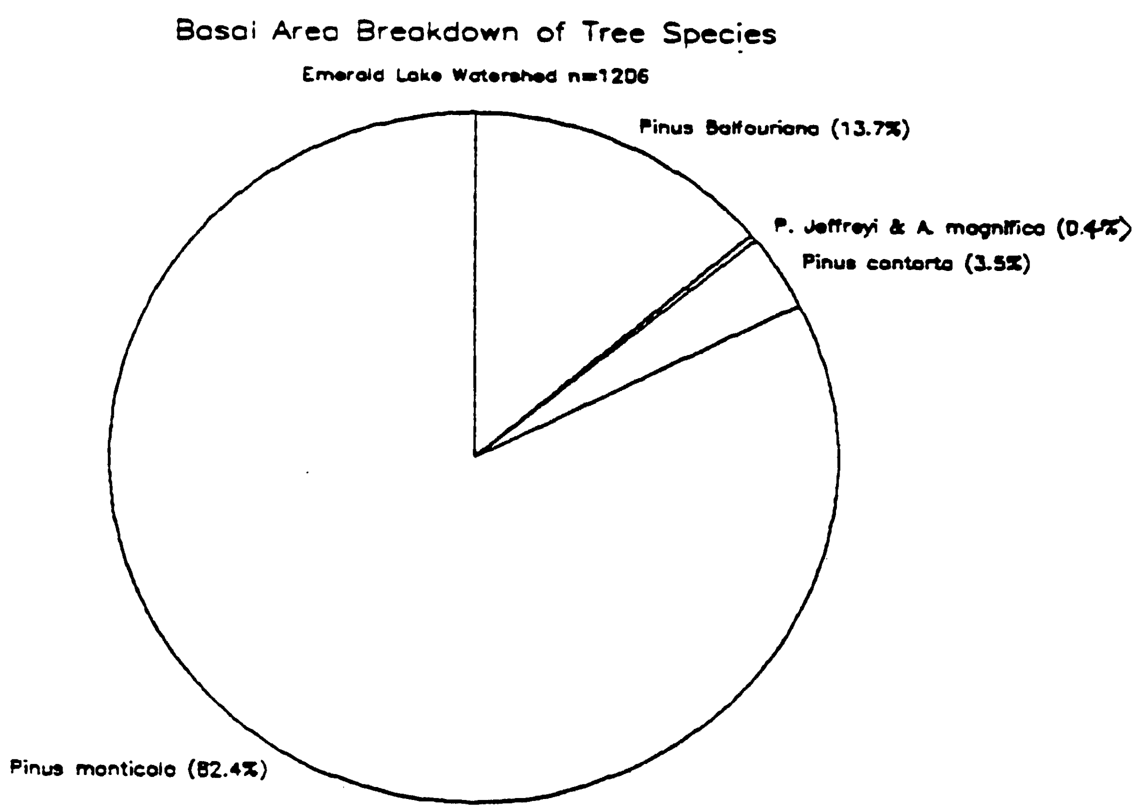
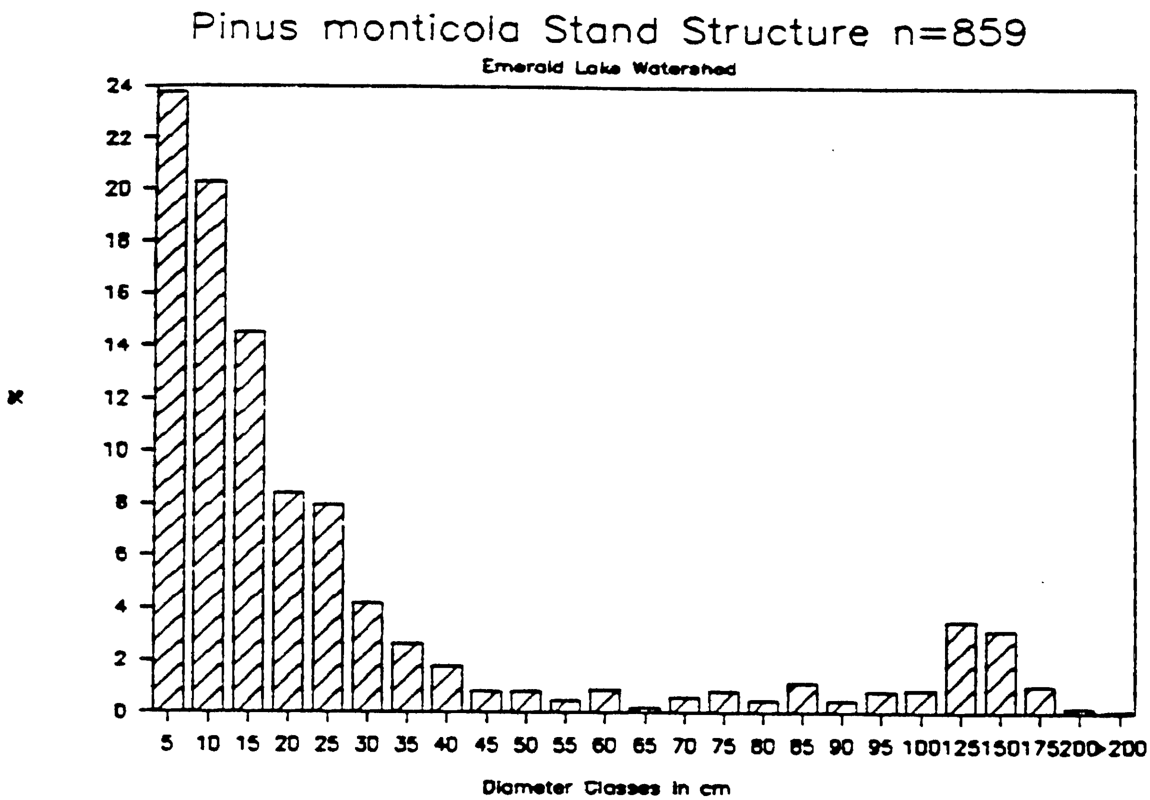

Basal Area Breakdown of Tree Species
Emerald Lake Watershed n=1206
Pinus Balfouriana (13.7%)
P. Jeffreyi & A. magnifica (0.4%)
Pinus contorta (3.5%)
Pinus monticola (82.4%)

Figure 10


Pinus monticola Stand Structure n=859
Emerald Lake Watershed
24
22
20
18
16
14
12
10
8
6
4
2
0
%
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100125150175200>200
Diameter Classes in cm

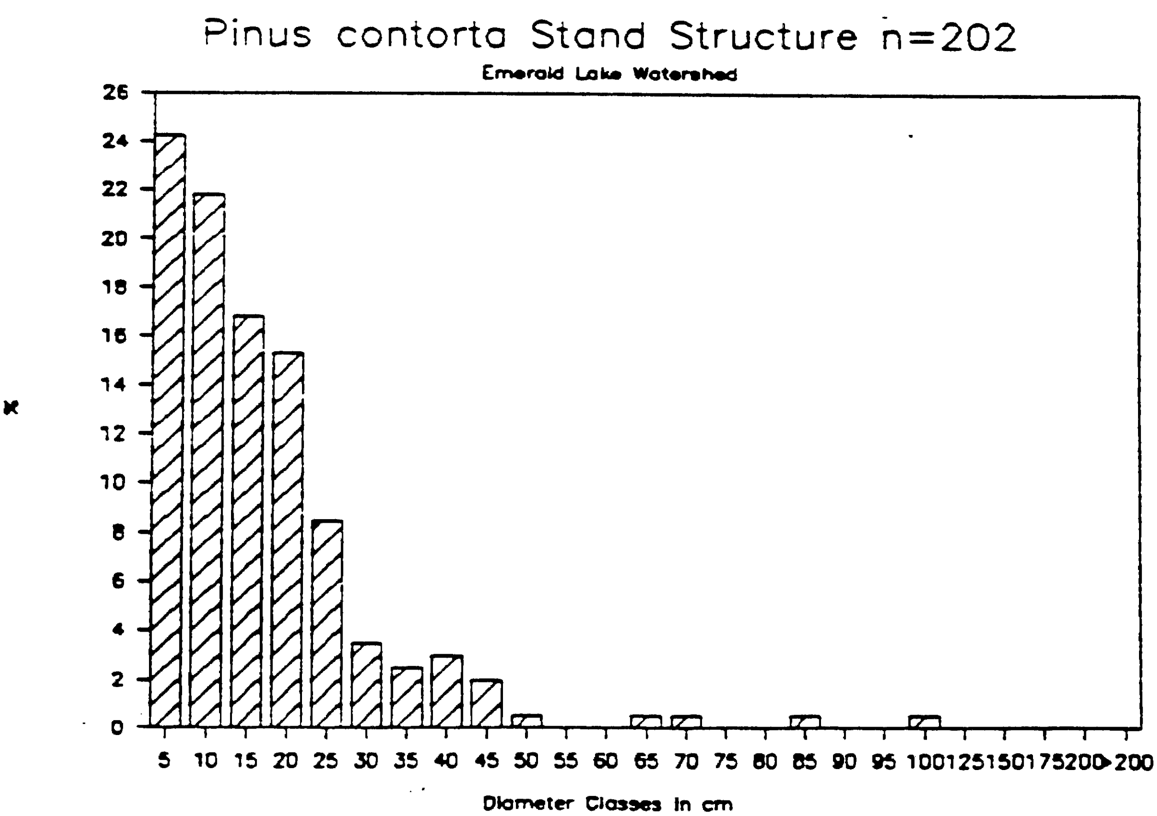
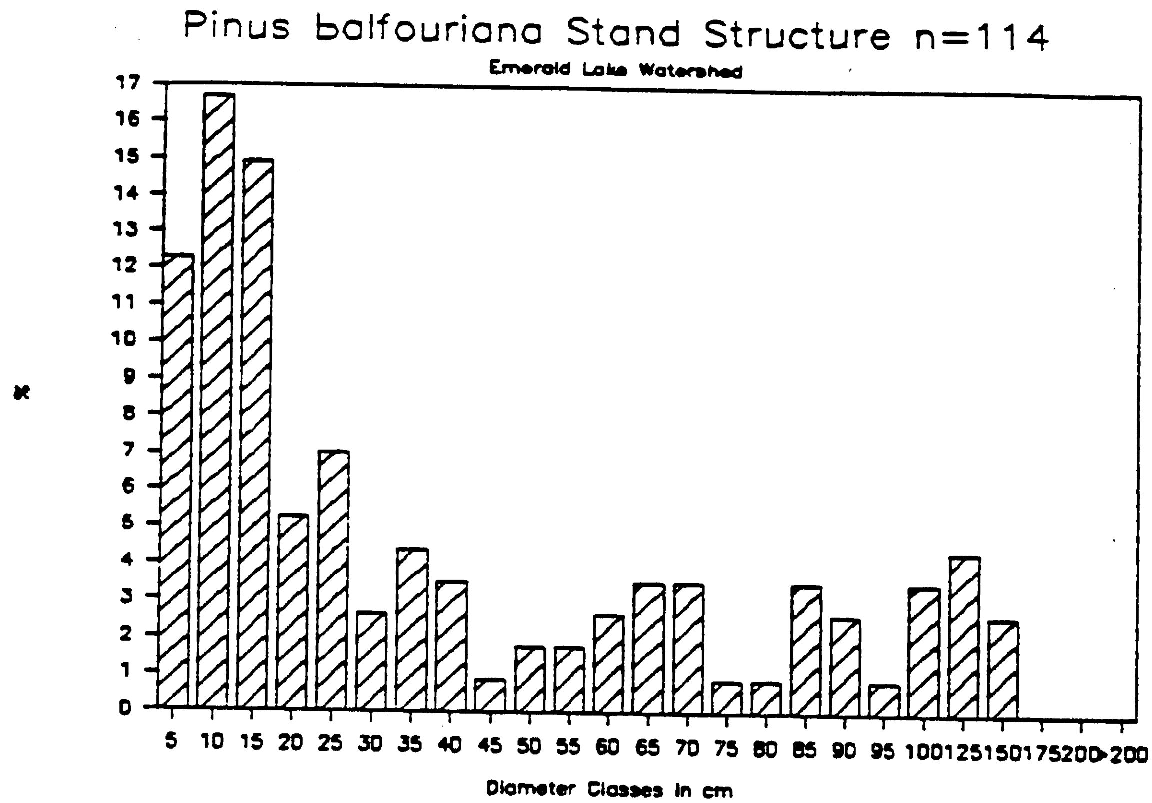

Pinus contorta Stand Structure n=202
Emerald Lake Watershed
26
24
22
20
18
16
14
12
10
8
6
4
2
0
%
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100125150175200>200
Diameter Classes in cm

Figure 11


Pinus balfouriana Stand Structure n=114
Emerald Lake Watershed
%
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 125 150 175 200 >200
Diameter Classes in cm

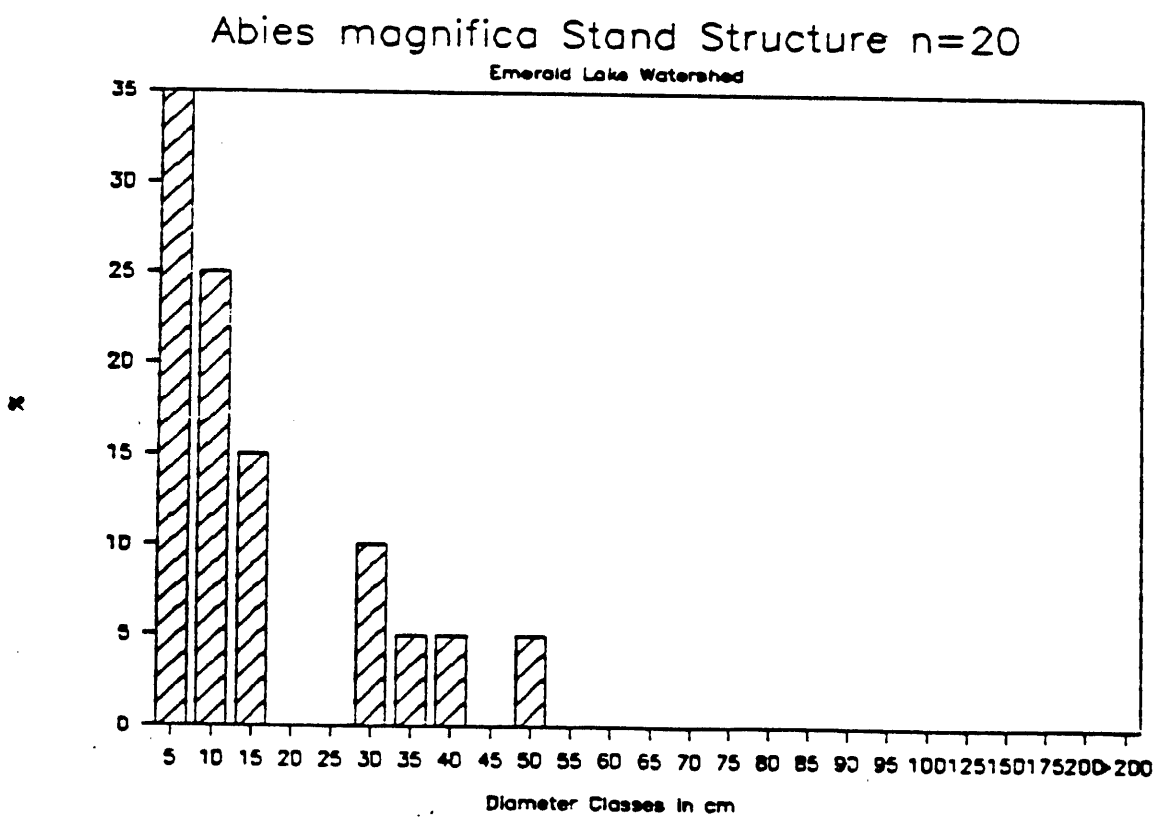

Abies magnifica Stand Structure n=20
Emerald Lake Watershed
%
0
5
10
15
20
25
30
35
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 125 150 175 200 >200
Diameter Classes in cm

Figure 12

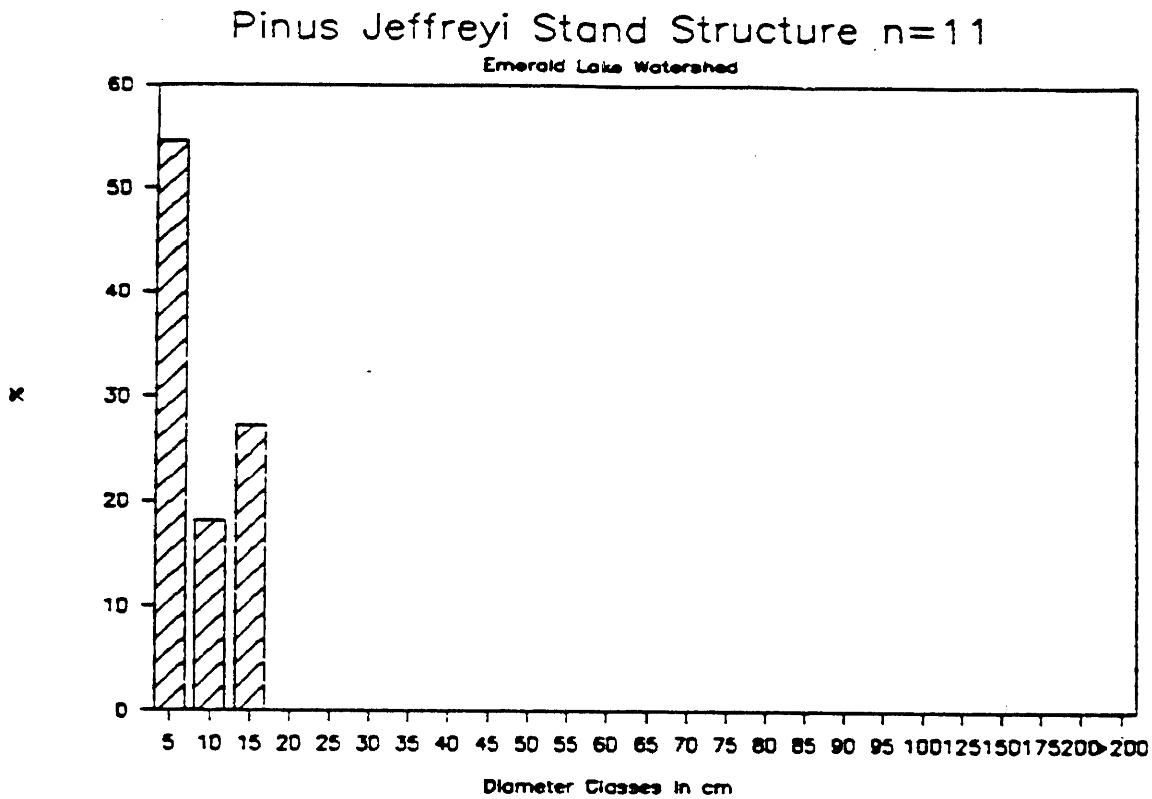

Pinus Jeffreyi Stand Structure n=11
Emerald Lake Watershed
%
60
50
40
30
20
10
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100125150175200>200
Diameter Classes in cm

Figure 13

TREE COMMUNITIES IN EMERALD LAKE WATERSHED

1985

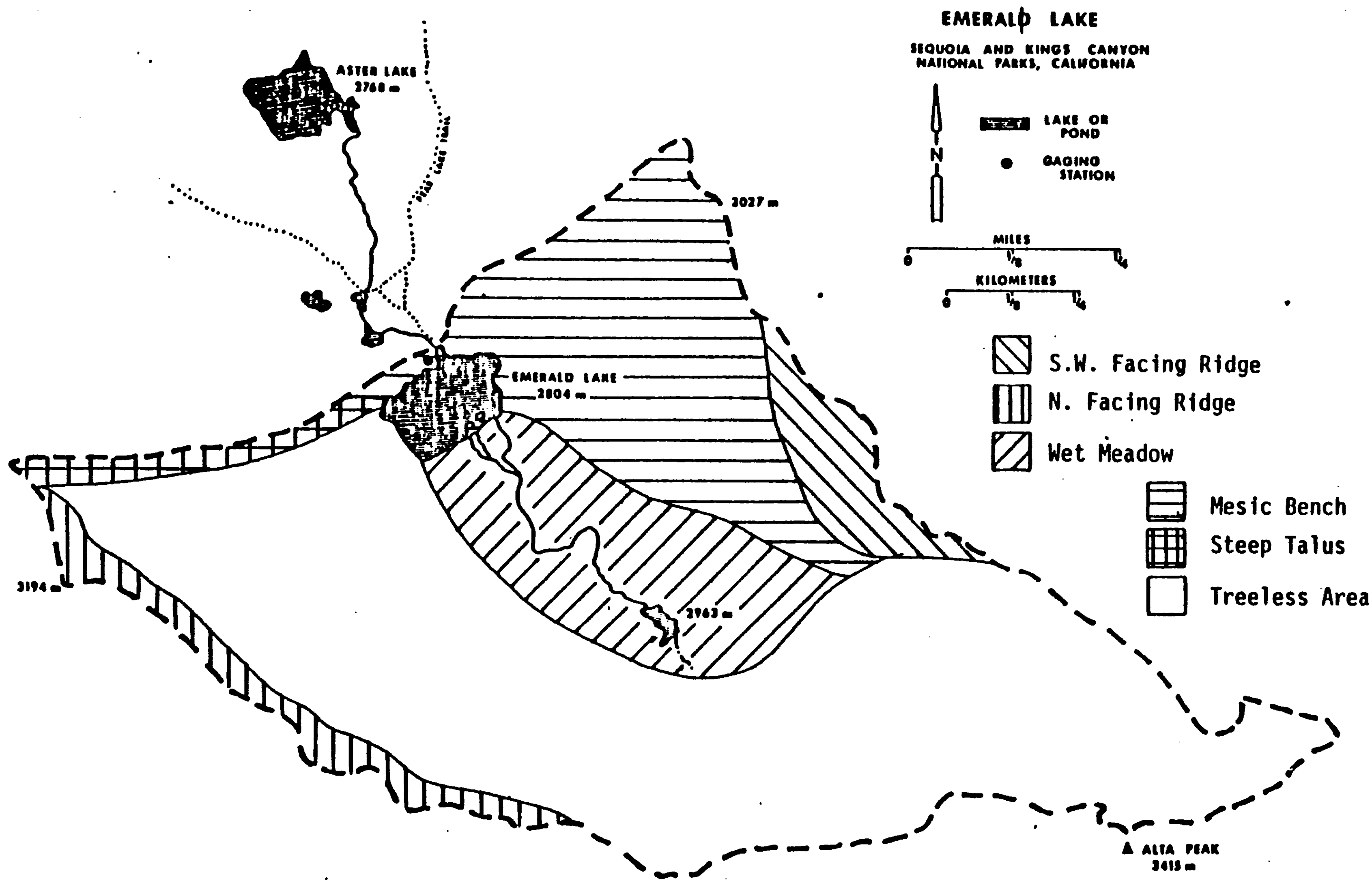
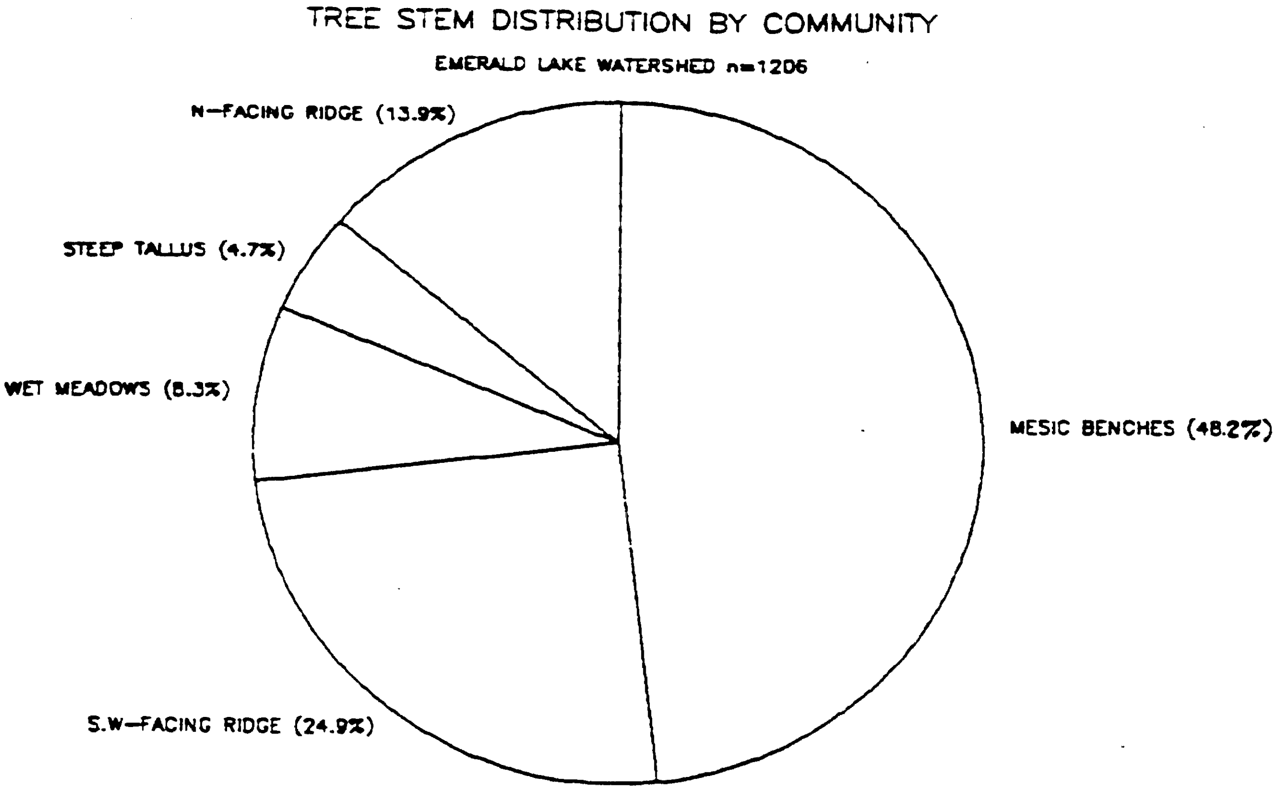


Figure 14


TREE STEM DISTRIBUTION BY COMMUNITY
EMERALD LAKE WATERSHED n=1206
N-FACING RIDGE (13.9%)
STEEP TALLUS (4.7%)
WET MEADOWS (8.3%)
MESIC BENCHES (48.2%)
S.W-FACING RIDGE (24.9%)

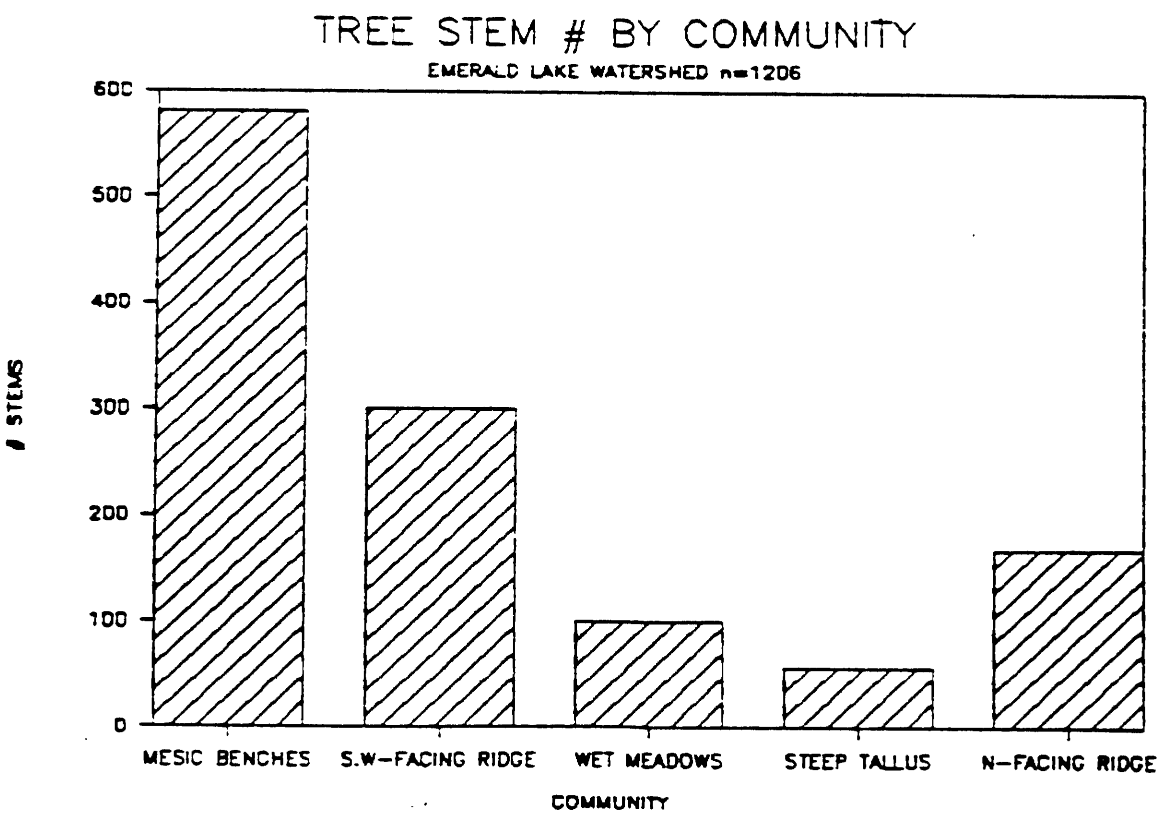
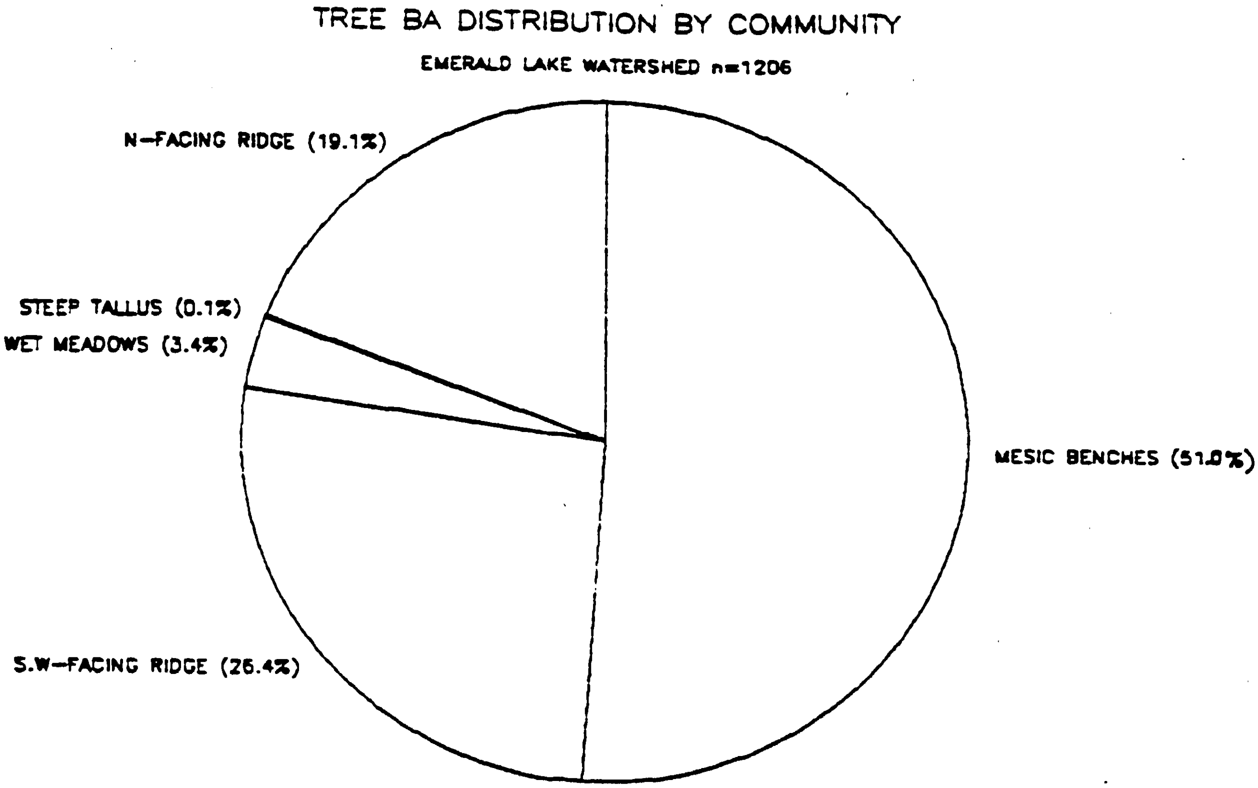

TREE STEM # BY COMMUNITY
EMERALD LAKE WATERSHED n=1206
600
500
400
300
200
100
0
STEMS
MESIC BENCHES
S.W-FACING RIDGE
WET MEADOWS
STEEP TALLUS
N-FACING RIDGE
COMMUNITY

Figure 15


TREE BA DISTRIBUTION BY COMMUNITY
EMERALD LAKE WATERSHED n=1206
N-FACING RIDGE (19.1%)
STEEP TALLUS (0.1%)
WET MEADOWS (3.4%)
MESIC BENCHES (51.0%)
S.W-FACING RIDGE (26.4%)

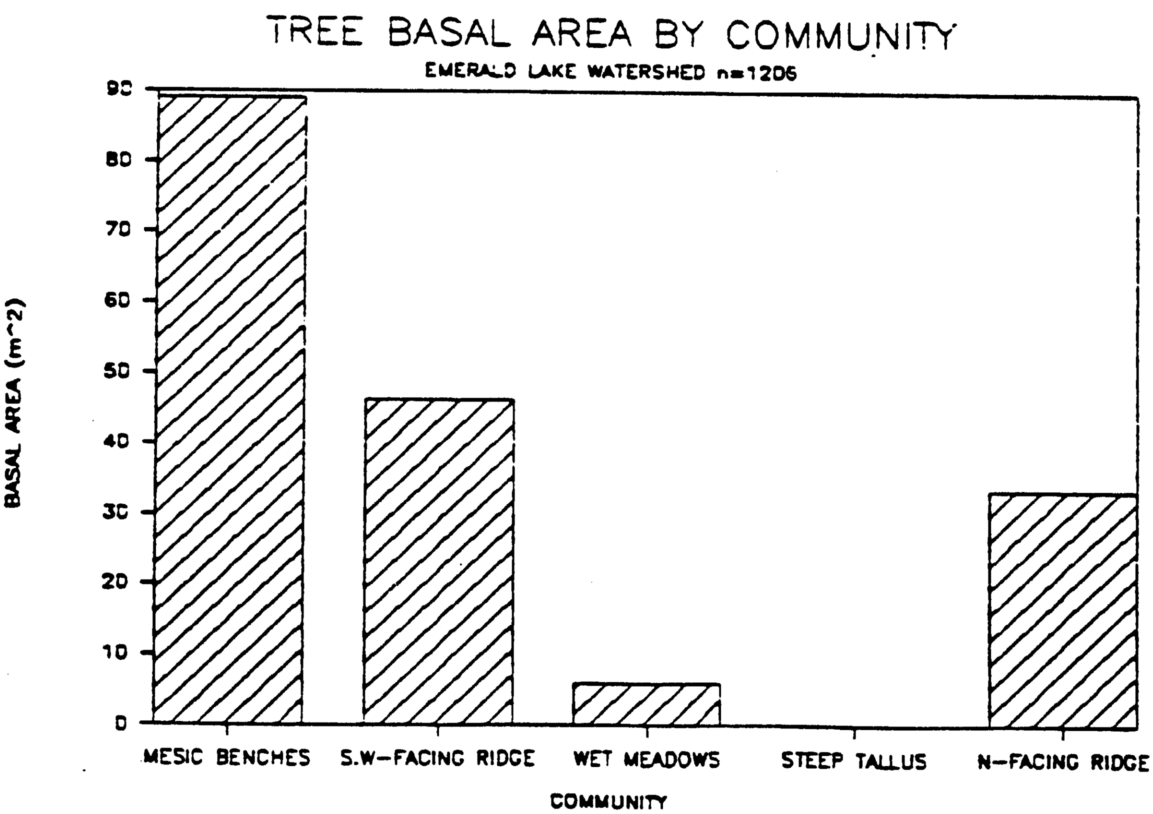
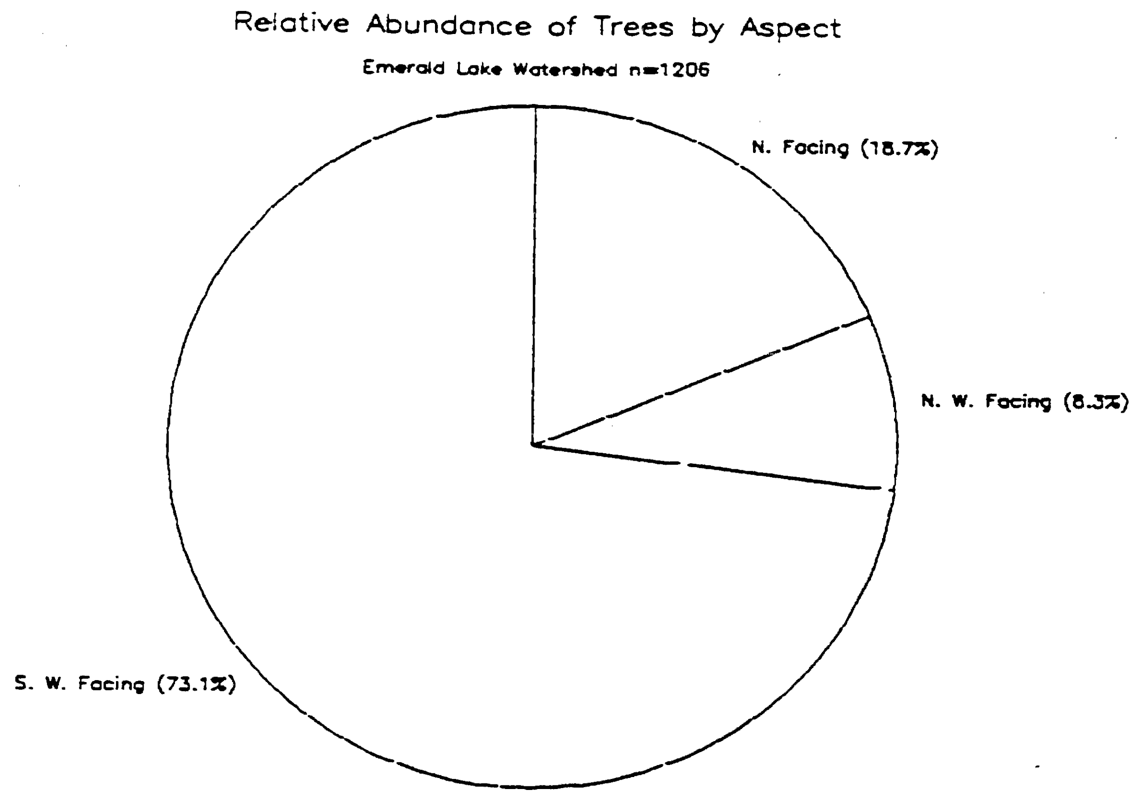

TREE BASAL AREA BY COMMUNITY
EMERALD LAKE WATERSHED n=1206
BASAL AREA (m^2)
90
80
70
60
50
40
30
20
10
0
MESIC BENCHES
S.W-FACING RIDGE
WET MEADOWS
STEEP TALLUS
N-FACING RIDGE
COMMUNITY

Figure 16


Relative Abundance of Trees by Aspect
Emerald Lake Watershed n=1206
N. Facing (18.7%)
N. W. Facing (8.3%)
S. W. Facing (73.1%)

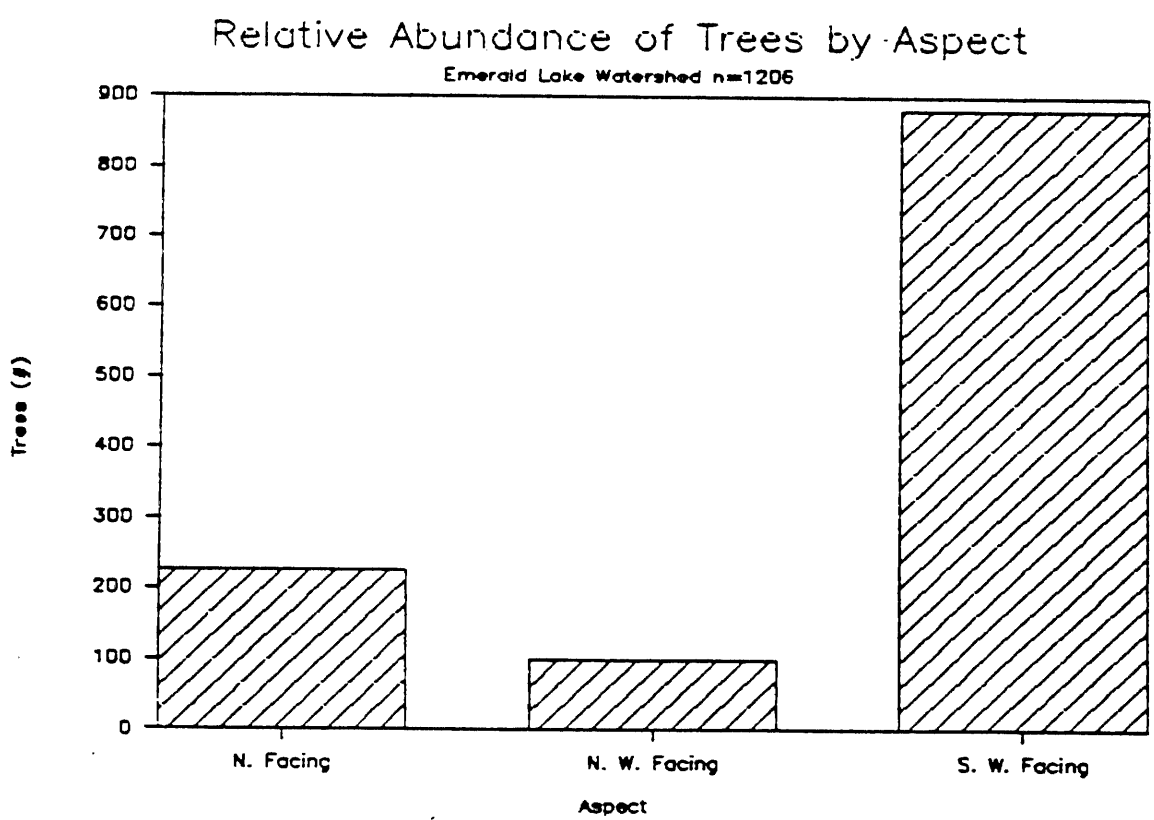
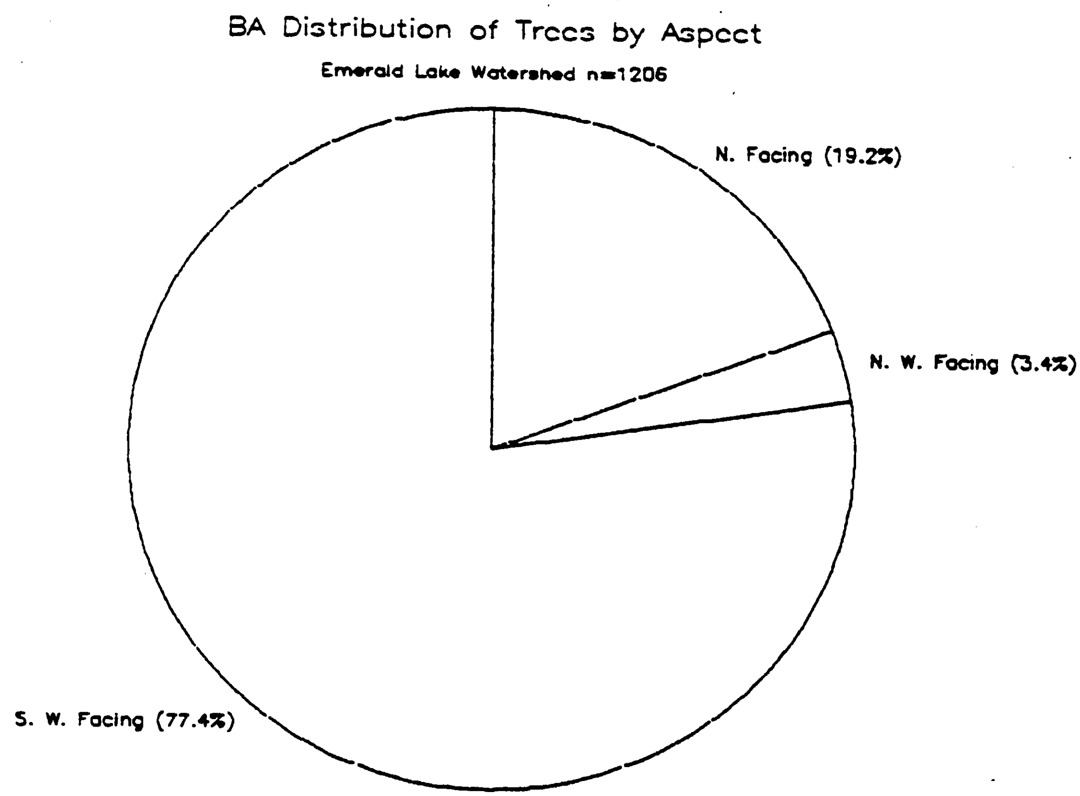
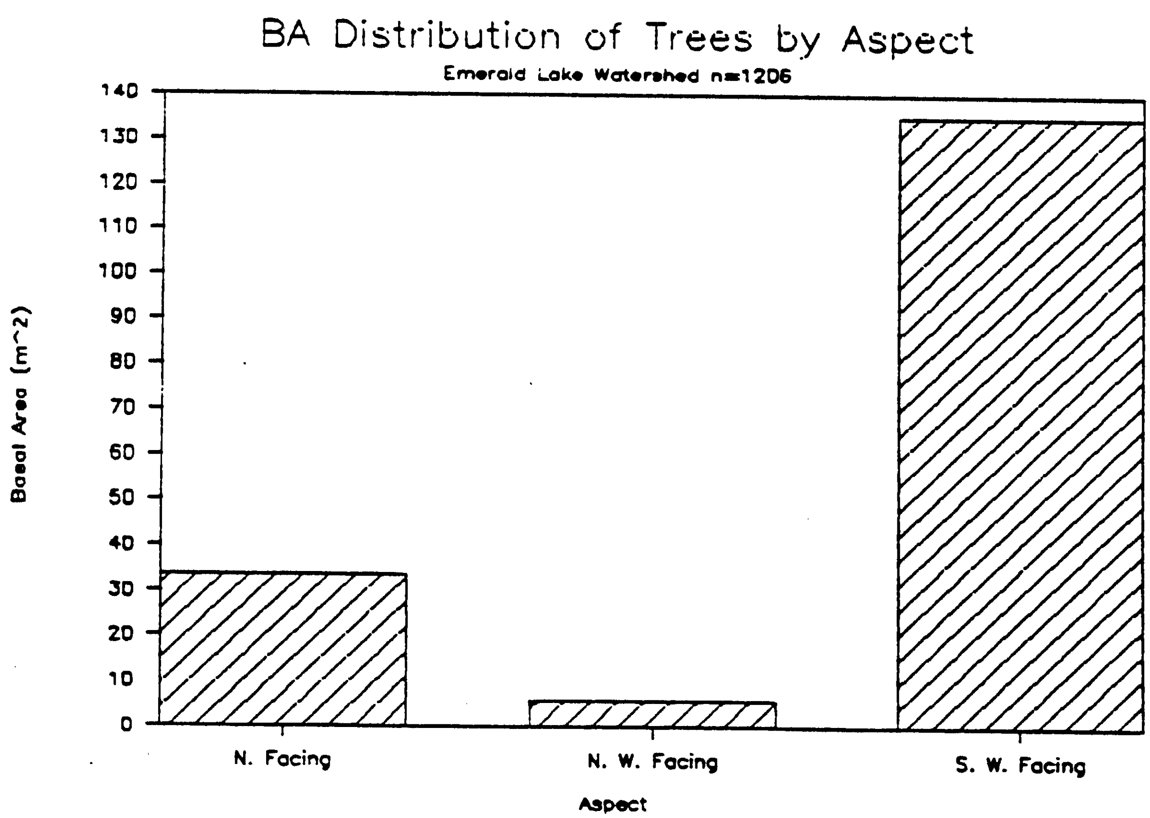

Relative Abundance of Trees by Aspect
Emerald Lake Watershed n=1206
900
800
700
600
500
400
300
200
100
0
Trees (#)
N. Facing
N. W. Facing
S. W. Facing
Aspect

Figure 17


BA Distribution of Trees by Aspect
Emerald Lake Watershed n=1206
N. Facing (19.2%)
N. W. Facing (3.4%)
S. W. Facing (77.4%)


BA Distribution of Trees by Aspect
Emerald Lake Watershed n=1206
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Basal Area (m^2)
N. Facing
N. W. Facing
S. W. Facing
Aspect

FLORISTICS AND VEGETATION STRUCTURE

Vascular Plant Flora

Our checklist of the vascular plant flora of the Emerald Lake Basin currently includes 204 species, distributed in 132 genera and 41 families. This checklist is present in Table 30, with a list of species by family, and indication of characteristic communities of occurrence (see below), and the frequency of occurrence (common, occasional or rare).

The largest family of vascular plants in the Emerald Lake basin is the Compositae with 25 species, followed in order by the Graminae (24 species), Scrophulariaceae (16 species), Cyperaceae (12 species), Rosaceae (11 species), and Saxifragaceae (9 species). These six families together comprise nearly 50% of the total flora of the basin. An unusual floristic note is the apparent absence of legume species of the Fabaceae from the basin.

The herbaceous perennials include eleven species of ferns and fern relatives in the Emerald Lake basin. These are most important in wet meadow and mesic rock crevice habitats where Cryptogramma acrostichoides, Athyrium alpestre, Cystopteris fragilis and Woodsia scopulina may all be common.

Five species of coniferous trees, as described later in this report, are present in the basin. Over 70% of these are Pinus monticola. Pinus contorta ssp. murrayana and P. balfouriana comprise 17% and 9.5% of the trees, respectively. A few individuals of Abies magnifica and P. jeffreyi are also present.

Among the angiosperms which comprise more than 90% of the vascular plant flora, the monocotyledons are an important element. A total of 51 of the

186 species of angiosperms are monocotyledons, with the grasses, sedges, and rushes most apparent.

Vascular Plant Growth-forms

The flora of the Emerald Lake basin is numerically dominated by herbaceous perennials which comprise nearly 80% of the total flora. Five species of trees are present, all conifers. These include five species of pines plus a few individuals of Abies magnifica. Seventeen species of woody shrubs are present. These include six evergreen shrubs--Chrysolepis sempervirens, Arctostaphylos nevadense, Ledum glandulosum, Phyllodoce breweri, Kalmia polifolia, and Eriogonum wrightii. The first two of these are largely restricted to the relatively xeric stands of pines in the basin. Ledum and Phyllodoce are common and widespread in the basin in a variety of communities. Eriogonum wrightii is a low-growing dry-meadow species, while Kalmia polifolia grows in wet meadows and in willow thickets.

There are 13 species of deciduous shrubs in the basin. The most prominent of these is Salix orestera, but a number of other species of lower stature are also common. These include Holodiscus microphyllus, Sorbus californica, Sambucus microbotrys, Prunus emarginata, Spiraea densiflora, Ribes montigenum, Vaccinium nivictum, Lonicera conjugalisll, and L. involucrata.

Seven species of vascular plants in the basin can be classified as suffrutescent--that is woody at the base but not truly shrubby. These are Chrysopsis breweri, Haplopappus macronema, Zauschneria californica, Leptodactylon pungens and Phlox diffusa. This growth-form is most characteristic of the more xeric habitat types within the basin. They are usually found in xeric pine forest, dry meadow, dry rock crevices and colluvium habitats.

Despite the dominance of herbaceous growth-forms in the flora, only eleven species of annuals are present. These are Cryptantha sp., Phacelia eisenii, Gayophyton humile, Gilia capillaris, Saxifraga bryophoral, Collinsia torreyi, Mimulus breweril, M. laciniatus, M. whitneyi, and Galium bifolium. With the exception of Mimatus laciniatus and Galium bifolium, which are wet crevice species, the annual herbs are largely confined to the dry meadow associations of the basin.

The remaining 162 species, 79% of the total flora, are herbaceous perennials which die back to ground level at the end of each growing season. These include seven species of parasitic plants--Pedicularis attollens, P. semibarbata, Castilleja disticha, C. miniata, C. nana, Orobanche uniflora, and Cuscuta occidentalis. In addition there is one species of "saprophyte," Pterospora andromeda, which is epiparasitic on vascular plant roots through fungal mycelium.

Vascular Plant Communities

We have divided the vegetation of the Emerald Lake basin into eight community types on the basis of our field studies. These communities, described below, have been mapped for the basin with the exception of the fell field association. This association is relatively diffuse in coverage in the upper basin and contributes no significant amount of biomass.

Dry Forest

The dry forest community (TX) is wide-spread in the Emerald Lake basin, with three species comprising the bulk of the trees: Pinus contorta ssp. murrayana near the lake, P. monticola on the mesic benches of the northern triangle of the basin, and P. balfouriana on the west ridge. The sandy soils vary, but are generally very poor in organic content in the area dominated by P. monticola. Pinus contorta within the watershed is largely confined to crevices near the lake, while P. balfouriana is characterized by thin soils of decomposed granite. The P. monticola forest on the north face of the basin forms the most extensive area of dry forest and contains all of our study plots. It typically has an understory dominated by Chysolepis sempervirens or a low cover of dry meadow herbs, most notably Ivesia santolinoides and Achillea lanulosa. In addition to its primary dominance of the northern faces above the Emerald Lake, P. monticola occurs as scattered trees on the flat dry meadows below the cirque of Alta Peak. The community appears to be expanding into adjacent crevice and dry meadow communities in several parts of the basin.

None of the dry forest associations have a unique understory flora. Rather the understory of these areas typically contain species typical of dry meadow, dry crevice or colluvial communities. Wet meadow species and willow thicket species may occur in proximity to P. contorta in the lower basin.

The Chrysolepis sempervirens understory of the dry forest stands of P. monticola has 80-100% coverage. It interdigitates with Phyllodoce breweri on the lower slopes where this association merges with the dry meadow in the eastern fault trace. There are some regions of bare ground, but many appear to be trodden paths rather than natural features of distribution.

Sixteen herbs were found here in 1985. The shrubs species (besides C. sempervirens and P. breweri) were Arctostaphylos nevadensis, Amelanchier pallida, Prunus emarginata, and Sorbus californica. Lonicera conjugialis, sometimes present in this association, is much more common on more mesic sites in rock cracks and rock piles.

Willow Thicket

The willow thicket community (SWT)is the most wide-spread of the community types and dominates significant areas of the basin, particularly high in the drainage and along the west face. Along with Salix orestera, the indicator species, is a characteristic set of understory herbs and shrubs which provide 100% of groundcover. These include Ledum glandulosum, Calamagrostis canadensis, Epilobium angustifolium, and Senecio triangularis. The high production of leaf litter quickly leads to development of rich hydric organic soils. Salix appears to be colonizing wet meadow and mesic crevice communities in several areas, and in almost all areas the willow thicket community intergrades into wet meadow associations.

Wet Meadows

The wet meadow community type (GHM) is the most diverse in the basin, with a number of distinctive association types. These associations are distributed in flat areas where soils accumulate to moderate depths and remain moist for much or all of the growing season. Soil texture, organic matter content, and seasonal moisture dynamics appear to be the primary factors separating these association types. The largest areas of wet meadow are high in the basin, adjacent to and above Parson's Pond, where snowmelt keeps the soil saturated. Another important group of wet meadows lies on a bench running southwest from the extensive stands of Pinus monticola. Wet meadows also interdigitate with willow stands along the main drainage. The diversity of the meadows makes for a large number of indicator species. We consider the most important to be Senecio triangularis, Calamagrostis canadensis, Carex spectabilis, Carex nigricans, Vaccinium nivictum, Aster alpigineus, Scirpus criniger, Juncus mertensianus and the moss Polytrichum juniperinum. While there is significant species overlap with the dry meadows, high total cover is a consistent distinguishing characteristic.

A heather turf association (PHBR), concentrated in the joint along the east face of the basin, appears to be a transition type between wet and dry meadow communities. Phyllodoce breweri itself is found in nearly every community of the basin, but is only dominant in the heather turf. Characteristic associates are Vaccinium nivictum, Juncus parryi, and several dry meadow herbs.

Dry Meadows

Dry meadow communities (GHX) occupy a large part of the basin. The largest single area of this type occurs on the plateau below the northeast ridge and boundary of the basin. There are also meadows northeast of Parson's Pond, adjacent to the Pinus monticola stand in the northernmost corner of the basin, and in the northeast fault, as well as on small areas on the south-facing slope wherever it is flat. Soils typically are shallow decomposed granite with low organic content and usually dry out early in the season. Indicator species are Juncus parryi, Ivesia santolinoides, Dicentra nevadensis, Eriogonum incanum, Calyptridium umbellatum, and several graminoids with Sedum obtusatum. Species diversity is commonly high in this community, with 69 species encountered in the course of our study.

Density apparently varies with drainage. The areas below the ridge are most sparse, with about 20-25% cover. The meadows near the pond and in the fault may have 50% or more cover. The Phyllodoce breweri stand in the east fault had close to 100% cover, but this stand covers a relatively small area. Some stands of Dicentra nevadensis, high on the east slope on loose sloping gravel, also approach 100% cover.

Wet Rock Crevice

The wet rock crevice community (RCM) is concentrated on the east face of the basin, along one side of the joint and in various talus pockets. It consists of talus areas or benches below wet meadows which maintain inputs of moisture to support a set of mesic shrubs and large herbs. These include Sambucus microbotrys, Lonicera involucrata, Aquilegia pubescens, Mertensia ciliata, Thalictrum fendleri, and a variety of herb species characteristic of the wet meadows associations. While plant cover in the crevices is 100%, the crevices themselves comprise less than 5% of the surface areas of the rock faces. On our vegetation map, we have separated out a mesic boulder association (MB) as a segregate of the mesic rock crevice community. A group of characteristic species grow between large 1-3 m boulders in slide areas where mesic conditions are maintained through the summer. In addition to the species above, Aquilegia formosa and Helenium bigelovii are commonly present. Smaller herbs are largely absent.

Dry Rock Crevice

The dry rock crevice community (RCX) is widespread in the Emerald Lake basin, but diffuse in coverage. It is frequently encountered in crevices along the granite faces of the basin where conditions are less mesic than in the previous community type. Xeric rock crevices support dense populations of Penstemon newberryi, Holodiscus microphyllus, Sedum obtusatum, and Spiraea densiflora in narrow (up to 0.5 m) cracks in the granite faces of the east slope. Eriogonum nudum, Ivesia pygmaea and other herbs common to the xeric meadows also occur here, but are numerically eclipsed by the larger shrubs. Where the cracks occur, plant cover is close to 100%. However, the cracks themselves probably cover no more than a few percent of the granite faces.

Colluvium

The colluvium association (CO) occurs in the fault trace on the southwestern boundary of the watershed, and in two smaller regions to the south, where large boulders give way to smaller granitic rocks 0.3 - 1 m long along the major axis. The substrate is steeply sloped, with some soil development. Plant density is determined by rock distribution. The colluvium is vegetated almost entirely by small (20 cm) perennial herbs or suffrutescent species whose growth is limited to areas between the rocks. There are a few isolated Salix orestera and Ribes cereum in the southern part of the lower quarter, and a stand of stunted (about 1 m tall) Pinus monticola on the northwest margin of the fault. A patch of Phyllodoce breweri is adjacent to and south of the Pinus monticola stand.

The species which dominate the colluvium both in number and density are Senecio fremontii, Eriogonum incanum, Carex lanuginosa (or C. sartwelliana), Phlox diffusa, Erysimum perenne, and an unidentified grass. These six species occur in two thirds of the transects and comprise two thirds of the individuals counted. Senecio fremontii is particularly important, accounting for almost 20% of the cover. An additional 11 species make up the remaining third. Cryptogramma acrostichoides and Selaginella watsonii, both of which grow along the margins of the larger rocks, are widely dispersed but occur in low densities, accounting for 4% and 2% of the cover, respectively. Two species, Primula suffrutescens and Anaphalis margaritacea are restricted to the colluvium association in the basin.

The plant cover is about 25%, with a range of 6-31% in six transects. The standard deviation is about 22% when sample point is considered separately, but only 3% when the six transects are compared. This reflects the local heterogeneity (due to the nature of the substrate) as well as the overall uniformity of cover. The Phyllodoce breweri stand is most dense, covering 30% of the substrate.

Fell Field (FF)

The fell field is found on the plateau below Alta Peak, overlooking Pear Lake. It is geomorphologically similar to the colluvium, but it is flat and has a northerly aspect. Rocks are slightly smaller and are much farther apart, exposing bare soil. Unlike the colluvium, where plants have colonized all bare soil, the fell field is very sparsely vegetated. Distribution is patchy; nowhere is the plant cover more than 10%. Average coverage is about 5%, with much of the area completely bare. Six species occur here: Chaenactis alpigenus, Carex helleril, Ranunculus eschscholtzii, Arenaria nutallii ssp gracilis, Eriogonum incanum, and Saxifraga tolmiei. The first two are unique to this habitat.

TABLE 30

VASCULAR PLANT CHECKLIST FOR THE EMERALD LAKE DRAINAGE, SEQUOIA NATIONAL PARK, CALIFORNIA

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
	SELAGINELLACEAE										
SEWA	*Selaginella watsonii*				X		X			+	
	OPHIOGLOSSACEAE										
BOSI	*Botrychium simplex*			X						R	X
	PTERIDACEAE										
ADPE	*Adiantum pedatum* var *aleuticum*					X				R	X
CHGR	*Cheilanthes gracillima*						X			R	
CRAC	*Cryptogramma acrostichoides*			X	X	X		X		C	X
PEBW	*Pellaea breweri*							X		+	
PEBG	*P. bridgesii*				X			X		C	X
ONDE	*Onychium densum*				X		X			+	X
	ASPIDACEAE										
ATAL	*Athyrium alpestre* var *americanum*		X	X		X		X		C	
CYFR	*Cystopteris fragilis*			X		X				C	
WOSC	*Woodsia scopulina*			X		X				C	
	PINACEAE										
ABMA	*Abies magnifica* var *shastensis*	X								C	
PIBA	*Pinus balfouriana*	X								C	
PICO	*P. contorta* var *murrayana*	X								C	
PIJE	*P. jeffreyi*	X								+	
PIMO	*P. monticola*	X								C	
	ACERACEAE										
ACGL	*Acer glabrum* var *torreyi*						X			R	X
	BORAGINACEAE										
CRNU	*Cryptantha nubigena*							X		+	X
CRYPT	*Cryptantha* sp. (*affinis*, *glomeriflora*, or *humilis*?)				X					R	
MECI	*Mertensia ciliata* var *stomatechoides*		X			X				C	*
	CAPRIFOLIACEAE										
LOCO	*Lonicera conjugialis*	X				X				C	
LOIN	*L. involucrata*					X				C	X
SAMI	*Sambucus microbotrys*					X				C	X

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
		COMMUNITY									
	CARYOPHYLLACEAE										
ARNU	Arenaria nuttallii ssp gracilis				X			X	X	C	X
SISA	Silene sargentii						X			C	X
STCR	Stellaria crispa		X			X				C	X
	COMPOSITAE (ASTERACEAE)										
ACLA	Achillea lanulosa ssp alpicola			X						C	X
ANMA	Anaphalis margaritacea							X		+	X
ANAL	Antennaria alpina var media		X	X						C	X
ANRO	A. rosea				X					C	X
ARPA	Arnica parryi var sonnei					X				R	X
ASAL	Aster alpigineus var andersonii			X						C	X
CHAL	Chaenactis alpigena								X	C	
CHBR	Chrysopsis breweri var breweri	X								C	X
ERBR	Erigeron breweri var breweri						X			C	X
ERPR	E. peregrinus var angustifolius			X						C	X
ERPT	E. petiolaris	X				X	X			C	X
EUOC	Eupatorium occidentale							X		+	
GNPA	Gnaphalium palustre			X						+	
HAMA	Haplopappus macronema						X			C	X
HEBI	Helenium bigelovii			X		X				C	X
HIAL	Hieracium albiflorum	X								C	
HIGR	H. gracile var gracile			X						+	X
HIHO	H. horridum	X			X					C	X
MINU	Microseris nutans				X					C	X
RAAR	Raillardella argentea							X		+	X
SEFR	Senecio fremontii var fremontii				X	X		X		C	X
SEIN	S. integerrimus var major				X					+	X
SETR	S. triangularis		X	X		X				C	*
SOMU	Solidago multiradiata							X		+	X
STTE	Stephanomeria tenuifolia	X								+	X
	CRASSULACEAE										
SEOB	Sedum obtusatum ssp obtusatum				X		X			C	X
SERO	S. rosea ssp integrifolium					X				C	X
	CRUCIFERAE (BRASSICACEAE)										
ARDA	Arabis davidsonii			X				X		C	
ARPH	A. platysperma var howellii				X					C	
ARPP	A. p. var platysperma	X								C	X
DRBR	Draba breweri					X				+	X
DRCR	D. crassifolia var crassifolia					X				+	X
DRLE	D. lemmonii var lemmonii							X		C	X
ERPE	Erysimum perenne	X			X			X		C	X
STTO	Streptanthus tortuosus var orbiculatus				X					+	
	CONVOLVULACEAE										
CUBR	Cuscuta occidentalis				X					C	X

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
	ERICACEAE										
ARNE	Arctostaphylos nevadensis	X								C	
KAPO	Kalmia polifolia var microphylla		X	X						C	X
LEGL	Ledum glandulosum var californicum		X	X		X				C	
PHBR	Phyllodoce breweri	X	X	X	X					C	X
VANI	Vaccinium nivictum		X	X						C	X
	FAGACEAE										
CHSE	Chrysolepis sempervirens	X								C	
	FUMARIACEAE										
DINE	Dicentra nevadensis	X			X					C	X
	GENTIANACEAE										
GENE	Gentiana newberryi			X						C	
	HYDROPHYLLACEAE										
PHEI	Phacelia eisenii var eisenii				X					C	X
PHFR	P. frigida ssp dasyphylla			X	X		X			C	X
	HYPERICACEAE										
HYAN	Hypericum anagalloides		X	X						C	
	LABIATAE (LAMIACEAE)										
MOOD	Monardella odoratissima ssp parvifolia	X			X					C	X
	MALVACEAE										
SIOR	Sidalcea oregana ssp spicata			X		X				C	X
SIRA	S. ranunculacea			X		X				C	X
	ONAGRACEAE										
EPAN	Epilobium angustifoium var ?		X			X				C	
EPLA	E. lactiflorum		X	X						C	X
EPOR	E. oregonense			X						+	
GAHU	Gayophytum humile	X			X					C	X
ZACA	Zauschneria californica var latifolia						X			C	X
	OROBANCHACEAE										
ORUN	Orobanche uniflora var occidentalis				X					C	X
	POLEMONIACEAE										
GICA	Gilia capillaris				X					C	X
LEPU	Leptodactylon pungens ssp pulchriflorum				X					C	X
LICI	Linanthus ciliatus var neglectus				X					C	X
PHDI	Phlox diffusa	X			X			X		C	X
	POLYGONACEAE										
ERIN	Eriogonum incanum				X		X	X	X	C	X

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
	POLYGONACEAE (cont'd)										
ERNU	Eriogonum nudum var scapigerum				X			X		C	X
ERWR	E. wrightii var subscaposum				X					C	X
OXDI	Oxyria digyna					X				C	X
POBI	Polygonum bistortoides			X						C	X
POKE	P. kelloggii			X						C	
POMI	P. minimum				X					C	X
RUPA	Rumex paucifolius ssp gracilescens			X	X					C	X
	PORTULACACEAE										
CAUM	Calyptridium umbellatum var umbellatum				X			X		C	X
LENE	Lewisia nevadensis			X		X				C	
LEPY	L. pygmaea					X				C	
LETR	L. triphylla			X		X				C	X
	PRIMULACEAE										
DOJE	Dodecatheon jeffreyi		X	X						C	X
DOSU	D. subalpinum			X						C	X
PRSU	Primula suffrutescens							X		C	X
	PYROLACEAE										
PTAN	Pterospora andromedea	X								+	
PYCA	Pyrola californica		X							+	X
	RANUNCULACEAE										
ACRU	Actaea rubra ssp arguta		X							C	X
ANOC	Anemone occidentalis				X			X		C	X
AQFO	Aquilegia formosa var pauciflora					X				C	
AQPU	A. pubescens					X				C	X
DEPR	Delphinium pratense					X				C	X
RAES	Ranunculus eschscholtzii			X		X		X	X	C	X
THFE	Thalictrum fendleri		X	X		X				C	X
	ROSACEAE										
AMPA	Amelanchier pallida	X								R	
HOMI	Holodiscus microphyllus var microphyllus						X			C	X
IVPY	Ivesia pygmaea						X			R	X
IVSA	I. santolinoides				X					C	X
POBR	Potentilla breweri			X						+	X
POFL	P. flabellifolia var flabellifolia		X	X						C	X
POGL	P. glandulosa ssp nevadensis			X	X					C	X
PREM	Prunus emarginata	X								C	
SIPR	Sibbaldia procumbens			X		X				C	X
SOCA	Sorbus californica	X					X			+	X
SPDE	Spiraea densiflora					X	X			C	X
	RUBIACEAE										
GABI	Galium bifolium					X				+	X
KEGA	Kelloggia galioides				X	X				+	

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
		COMMUNITY									
	SALICACEAE										
SAOR	*Salix orestera*		X							C	X
	SAXIFRAGACEAE										
HERU	*Heuchera rubescens* var *pachypoda*					X	X			C	X
JAAM	*Jamesia americana* var *californica*						X			R	X
LIBO	*Lithophragma bolanderi*						X			R	X
LIGL	*L. glabrum*					X				R	X
RICE	*Ribes cereum*							X		+	
RIMO	*R. montigenum*			X	X	X				C	
SAAP	*Saxifraga aprica*			X						C	X
SABR	*S. bryophora*			X	X					C	X
SANI	*S. nidifica*					X				+	
SATO	*S. tolmiei*			X					X	C	X
	SCROPHULARIACEAE										
CADI	*Castilleja disticha*	X			X			X		C	X
CAMI	*C. miniata*		X			X				C	X
CANA	*C. nana*				X					C	X
COTT	*Collinsia torreyi* var *torreyi*			X	X					C	X
COTW	*C. t.* var *wrightii*			X	X					C	X
MIBR	*Mimulus breweri*				X					C	X
MIMO	*M. moschatus* var *moschatus*			X		X				C	X
MIPR	*M. primuloides* var *pilosellus*			X						C	X
MITI	*M. tilingii*					X				C	
MIWH	*M. whitneyi*				X					C	X
MIMSP	*Mimulus* sp. - *Mimulus laciniatus*					X				R	X
PEAT	*Pedicularis attollens*			X						C	X
PESE	*P. semibarbata*	X			X					C	X
PEHE	*Penstemon heterodoxus* ssp *cephalophorus*		X	X		X				C	X
PENE	*P. newberryi* ssp *newberryi*				X		X			C	X
VEAL	*Veronica alpina* var *alterniflora*			X						R	
	UMBELLIFERAE (APIACEAE)										
LIGR	*Ligusticum grayi*		X	X						C	X
LOTO	*Lomatium torreyi*			X						+	
PEPA	*Perideridia parishii* var *latifolia*			X						C	X
	VIOLACEAE										
VIMA	*Viola macloskeyi*			X						C	X
VIPU	*V. purpurea* var *xerophyta*			X	X					C	X
VIOLA	*Viola* sp.							X		R	
	AMARYLLIDACEAE										
ALOB	*Allium obtusum*				X					C	X
ALIUM	*Allium* sp. -(two-leaved; *campanulatum*?)									?	
	CYPERACEAE										
CABR	*Carex brevipes*			X	X					C	X
CABW	*C. breweri*								X	+	X
CACO	*C. congdonii*							X		+	X

CODE	SPECIES	TX	SWT	GHM	GHX	RCM	RCX	CO	FF	STATUS	VOUCHER
		COMMUNITY									
	CYPERACEAE (cont'd)										
CAHE	*Carex helleri*								X	C	X
CAHT	*C. heteroneura*		X	X	X	X				C	X
CALA	*C. lanuginosa*			X						C	X
CAMU	*C. multicostata*			X	X					C	X
CANI	*C. nigricans*			X						C	X
CASP	*C. spectabilis*		X	X	X	X				C	X
CAST	*C. straminiformis*			X	X					C	X
ELPA	*Eleocharis pauciflora* var *pauciflora*			X						C	X
SCCR	*Scirpus criniger*			X						C	X
	GRAMINEAE (POACEAE)										
AGPR	*Agropyron pringlei*						X			C	
AGID	*Agrostis idahoensis*				X					C	
AGTH	*A. thurberiana*			X						C	
AGVA	*A. variabilis*			X	X					C	X
BRMA	*Bromus marginatus* var *marginatus*	X								C	X
CACA	*Calamagrostis canadensis* var *canadensis*		X	X						C	
DACA	*Danthonia californica* var *americana*				X					+	X
DAIN	*D. intermedia*		X	X						C	X
DEEL	*Deschampsia elongata*			X						C	
MEBU	*Melica bulbosa* var *bulbosa*				X					+	X
MEST	*M. stricta* var *stricta*				X					+	X
FEBR	*Festuca brachyphylla*						X			+	X
MUFI	*Muhlenbergia filiformis*			X	X					C	X
MUMO	*M. montana*				X					C	X
MURI	*M. richardsonis*				X					+	X
ORKI	*Oryzopsis kingii*			X						C	
PHAL	*Phleum alpinum*			X						C	X
POEP	*Poa epilis*				X					C	X
POGR	*P. gracillima*				X					C	X
POIN	*P. incurva*			X						C	X
SIHY	*Sitanion hystrix*				X					C	X
STCO	*Stipa columbiana*			X						C	X
STOC	*S. occidentalis*	X			X					C	X
TRSP	*Trisetum spicatum* var *congdonii*	X			X		X	X		C	X
	JUNCACEAE										
JUDR	*Juncus drummondii*			X						C	X
JUME	*J. mertensianus* var *gracilis*			X						C	X
JUPA	*J. parryi*				X					C	X
LUPA	*Luzula parviflora* var *parviflora*		X			X				C	X
LUSP	*L. spicata*					X				C	X
	LILIACEAE										
FRPI	*Fritillaria pinetorum*				X					+	X
LIKE	*Lilium kelleyanum*		X							+	
SMRA	*Smilacina racemosa* var *glabra*	X								C	X
VECA	*Veratrum californicum*		X	X						C	
ZIVE	*Zigadenus venenosus*			X						C	X

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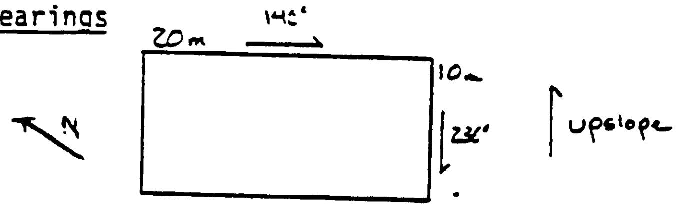
APPENDIX: Detailed descriptions of vegetation sample plots.

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Neuman/Edinger
Plot Code: Chse 1

Dimensions and Bearings



Site Description

Plot lies above P. monticola reference stand directly below gap in ridge between Pear Lk. and Emerald Lk., just North of fault line. W exposure, slope 70-80 %, plot contains 2 large down logs and four standing P. monticola. Shallow rocky soils, with several large boulders covering about 10% of the plot area. Average height of Chrysolepis .75m. About 15m² in NW (lower) corner is rocky dry meadow.

Species list

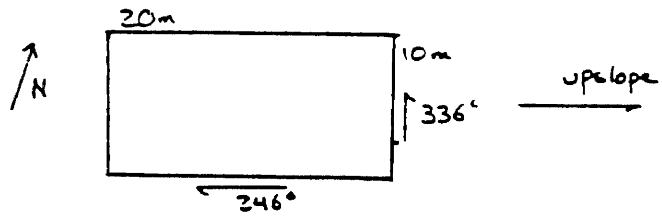
Chrysolepis sempervirens	4.5	
Pinus monticola	4.1	(overstory)
Castilleja disticha	+	
Penstemon heterodoxus	+	
Phlox diffusa.	+	
Hieracium horridum	+	
Monardella odoratissima	+	
Arabis platysperma	+	
Chrysopsis breweri	1.1	

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Newman/Edinger
Plot Code: Chse 2

Dimensions and Bearings



Site Description

Plot lies above NE corner of P. monticola reference stand , North of large rock face. No trees in plot, but two P. monticola at E corners. Shallow rocky soil, with one large boulder in center of plot, W exposure, 70-80% slope. Fairly dense stand of Chrysolepis, average height less than 1m.

Species list

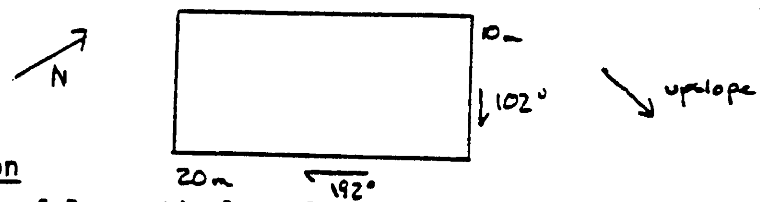
	Braun-Blanquet Cover class, 7/28/85	
Chrysolepis sempervirens	5.5	fl
Chrysopsis breweri	+.1	fl
Monardella odoratissima	+.1	fl
Hieracium horridum	+.1	fl/v
Cryptograma acrostichoides	r.1	v
Penstemon newberryi	r.1	fr
MOSS	r	v

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Newman/Edinger
Plot Code: Chse 3

Dimensions and Bearings



Site Description

Plot lies North of P. monticola reference stand, highly exposed on shallow rocky soil with some boulders in plot. No trees in plot. Fairly dense stand of Chrysolepis, average height less than 1m. W exposure, 50-60% slope.

Species list

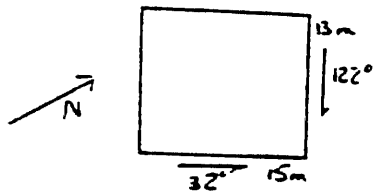
Chrysolepis sempervirens	5.5	v
Monardella odoratissima	2a.2	fl
Smilacina racemosa	2a.1	fl/v
Phlox diffusa	+.1	v/fr
Arabis platysperma	+.1	fr
Lonicera conjugialis	1.1	fr
Carex brevipes	2a.2	v
Pellaea bridgesii	+.2	v
Antennaria rosea	+.2	fr
Achillea lanulosa	+.1	fl
Castilleja disticha	+.2	fl/fr
Eriogonum nudum	+.2	fl
Chrysopsis breweri	+.1	fl
Hieracium horridum	+.1	v
Erysimum perenne	+.1	fr
Viola purpurea	+.1	v
Stipa occidentalis	1.2	fl
MOSS	+	v
ROCK	2a	

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/04/85
Personnel: Newman / Edinger
Plot Code: Phbr 1

Dimensions and Bearings



Site Description

Plot lies in lower end of trace of Graber's Fault, fairly close to lake. Shallow rocky soils, 30% slope toward SW corner, SW exposure. Heterogeneous vegetation structure, fading into dry meadow along N side ($5m^2$) and into wet rock crevice along South side.

Species list

Phyllodoce breweri	5.5
Spiraea densiflora	2b.5
Erysimum perenne	+.1
Smilacina racemosa	+.1
Thalictrum fendleri	2a
Penstemon heterodoxus	1.5
Carex phaeocephala	1.5
Eriogonum nudum	+.1
Antennaria alpina	+.2
Juncus parryi	2b.5
Monardells odoratissima	1.2
Ivesia santolinoides	+.1
Erigeron petiolaris	r.1
Danthonia intermedia	+.2
Sitanion hystrix	+.2

Wet rock crevice association contains

Aquilegia pubescens (X A. formosa)
Spiraea densiflora
Sambucus racemosa
Thalictrum fendleri
Penstemon heterodoxus
P. newberryi
Lonicera involucrata
Carex spectabilis
Castilleja miniata

Other species of Phbr type:

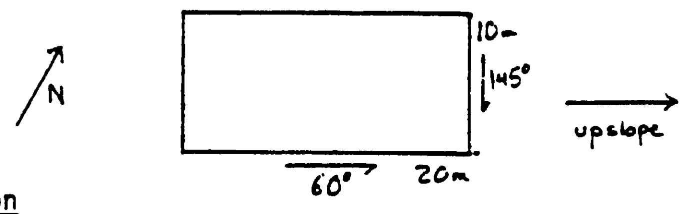
Carex brevipes	1.2
Phlox diffusa	1.2
Fritillaria pinetorum	+.1
Trisetum spicatum	+.1
Holodiscus microphyllum	r.1
Achillea lanulosa	2m.1

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/04/85
Personnel: Newman/Edinger
Plot Code: Phbr 2

Dimensions and Bearings



Site Description

Plot lies in trace of Graber's Fault about ½ way between lake and P. monticola reference stand. Shallow rocky soil with dry channal along S side, SW exposure, 70-80% slope.

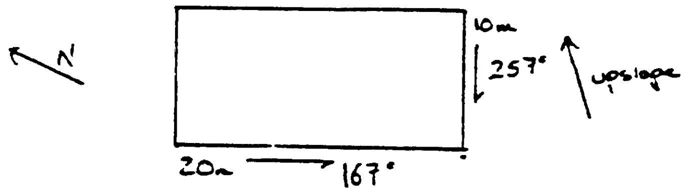
Species list	Braun-Blanquet Cover Class: 7/23/85	
Phyllodoce breweri	5.5	fr
Penstemon heterodoxus	1.2	fl/fr
P. newberryi	+.2	fr/v
Lanicera involucrata	1.2	v/fr
Sidalcia oregana var. spicata	2a.2	fl
Thalictrum fendleri	1.2	v
Ledum glandulosum	1.5	v
Castilleja disticha	+.1	fl
Achillea lanulosa	2m.2	fl
Microseris nutans	+.1	v/fl
Potentilla glandulosa	+.1	fl
Monardella odoratissima	2m.2	fl
Senecio fremontii	+.1	v
Viola purpurea	2m.2	v
Perideridia parishii	2m.1	fl
Poa sp.	2m.1	fl
Helenium bigelovii	1.2	fl
Bromus marginatus	2m.1	fl
Cystopteris fragilis	r.2	v
Ribes montigenum	+.1	v
Antennaria alpina	2m.2	fl
Carex phaeocephala	+.2	fl
Eriogonum nudum	2m.1	fl
Carex spectabilis	+.1	fl/fr
Delphinium pratense	2m.1	fl/fr
Ligusticum grayi	r.1	fl
Sitanion hystrix	r.1	fl

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/04/85
Personnel: Newman/Eliason
Plot Code: Phbr 3

Dimensions and Bearings



Site Description

Plot lies directly adjacent to NW corner of P. monticola reference stand. Dry rocky soil, SW exposure, 60-70 % slope, adjacent to UC Riverside litter decomposition bags. Nine small P. monticola along NW (lower) edge. Stand not very dense, but nearly pure stand of Phyllodoce.

Species list

Phyllodoce breweri	5.5	fr
Pinus monticola	1.1	v
Abies magnifica	1.1	v
Castilleja disticha	1.3	fl
Phlox diffusa	1.1	flse
Monardella odoratissima	1/3	fl
Eriogonum nudum	1.1	fl
Chrysopsis breweri	1.3	fl
Ligusticum grayi	r.1	fl
Carex phaeocephala	1.3	v
Trisetum spicatum	+.1	fl
Sitanion hystrix	+.1	fl
Carex brevipes	1.3	fl
Pedicularis atollens	+.2	v
Erysimum perenne	+.1	fr
Poa incurva	+.2	v
Viola purpurea	+.1	v
Lonicera involucrata	r.1	v
Juncus parryi	+.2	fr
Smilacina racemosa	+.1	flse
Hieracium albiflorum	+.1	v/fl
Arabis platysperma	+.1	v
Thalictrum fendleri	+.1	v

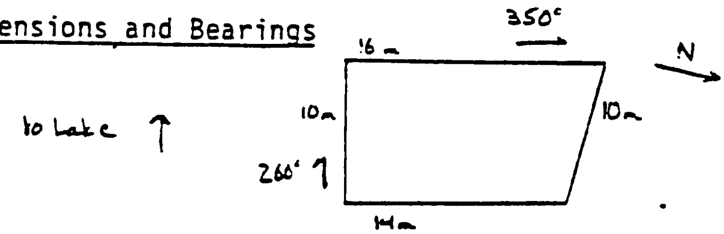
Braun-Blanquet cover classes: 7/24/85

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Neuman /Edinger
Plot Code: Salix 1

Dimensions and Bearings



Site Description

Salix orestera stand on flat, organic soil adjacent to Southeast corner of Emerald Lake. Slightly impacted by paths from 1984 phenology studies. Fairly homogenous vegetation structure, except 1 young Pinus monticola and sparse herb understory, some change along edge of lake.

Species list

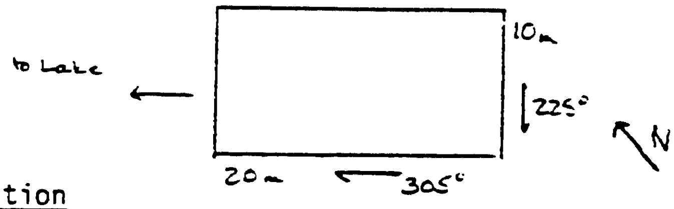
Salix orestera
Ledum glandulosum
Sidalcia oregana var spicata
Senecio triangularis
Viola mackloskyi
Carex spectabilis
Penstemon heterodoxus
Luzula parviflora
Scirpus criniger
Potentilla flabellifolia
Mertensia ciliata
Thalictrum fendleri
Helenium bigelovii
Juncus mertensianus
Ribes montigenum
Epilobium sp.
Lonicera involucrata

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Neuman / Edinger
Plot Code: Salix 2

Dimensions and Bearings



Site Description

Dense, fairly pure stand of Salix orestera on first bench in SSW corner of Emerald Lake, just W of Salix reference stand and UCRiverside lysimeter. Organic soil with some boulders, generally covered in litter or growing plants. Mostly homogeneous vegetation structure with some understory herbs, average Salix height about 2.5m.

Species list

Salix orestera	5.4	fl/fr
Senecio triangularis	3.3	fl
Calamagrostis canadensis	2b.3	fl
Luzula parviflora	2m.1	fr
Thalictrum fendleri	+.1	fr
Actaea rubra	2b.2	v/fl
Stellaria crispa	2m.2	v/fl
Epilobium angustifolium	1.1	v
Castilleja miniata	+.1	fl
Ledum glandulosum	+.1	v
Viola macloskeyi	+.2	v
Pyrola californica	1.2	v/fl
MOSS	1.4	v

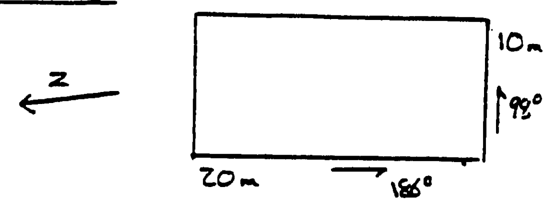
Braun-Blanquet Cover Classes: 7/31/85

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Neuman /Edinger
Plot Code: Salix 3

Dimensions and Bearings



Site Description

Fairly wet plot along Eastern edge of Salix reference stand, adjacent to Rain gauge. Stream channel cuts through center of plot, small patch of wet meadow along SE edge. Shallow organic soils at Southern (uppermost) end, with gravel below organic layer lower in plot. Stand structure and species composition rather heterogeneous.

Species list

Thalictrum fendleri	2b.3	fr
Mertensia ciliata	2a.3	fr/ plants dying
Senecio triangularis	2b.3	fl
Penstemon heterodoxus	1.3	fl
Ribes montigenum	+.1	v
Antennaria alpina	+.2	v
Epilobium lactiflorum	+.1	fr
Carex spectabilis	1.2	fl/fr
Poa incurva	+.1	fr
Agrostis variabilis	+.1	fr
Saxifraga nidifica	r.1	v
Epilobium anugustifolium	+.1	v
Saxifraga bryophora	r.1	v/fr
Mimulus primuloides	+.2	v
Potentilla flabellifolia	+.1	v
Sibbaldia procumbens	+.2	
Cryptograma acrostichoides	+.1	
Trisetum spicatum	None	
Lewisia triphylla	r.1	v
Calyptridium umbellatum	r.1	v
Luzula parviflora	+.1	fl
Pedicularis atollens	+.1	v
Ligusticum grayi	r.1	v
Phleum alpinum	+.1	fr
Juncus mertensianus	+.1	fr
Salix orestera	4.4	frd
Perideridia parishii	+.1	fl
Carex phaeocephala	2a.3	fr
Stipa columbiana	+.2	fl
Castilleja miniata	+.1	fl

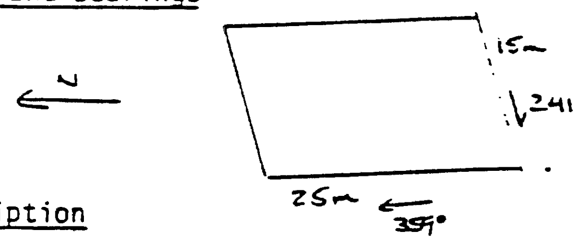
Braun-Blanquet Cover Classes: 7/31/85

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 07/05/85
Personnel: Neuman/Edinger
Plot Code: RHM 1

Dimensions and Bearings



Site Description

Wet meadow plot on bench directly South of NPS reference stand. Plot is fairly flat, but not completely (slope = 5%). Western exposure, varying in soil moisture from sub-saturated to standing water. Heterogeneous mixture of plant associations.

Species list

* indicates less than 1% cover

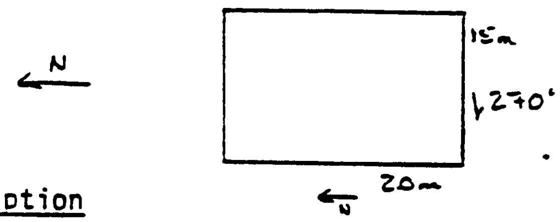
Antennaria alpina	*
Arabis sp.	*
Aster alpigineus	2.24%
Erigeron peregrinus	*
~~Carex brevipes~~	11.2
Carex spectabilis	26.5
Carex phaeocephala(?)	2.3
Calyptridium umbellatum	*
Dodecateon jeffreyi	11.2
Eriogonum incanum	*
Juncus parryi	5.3
Juncus mertensianus	3.32
Juncus drummondii	*
Ledum glandulosum	*
Lewisia nevadensis	*
Lewisia triphylla	*
Mimulus primuloides	*
Pedicularis atollens	*
Penstemon heterodoxus	*
Phacelia frigida	*
Phleum alpinum	2.3
Phyllodoce breweri	1.94
Poa incurva	16.9
Polygonum bistortoides	*
Potentilla flabellifolia	*
Ribes montigenum	
Helenium bigelovii	1.76
Rumex paucifolius	*
Sambuccus racemosa	*
Scirpus criniger	13.0
Sedum roseum	*
Spiraea densiflora	*
Trisetum spicatum	*
Vaccinium nivictum	49.3
Moss	10.1
Gravel	7.33
Rock	6.03
Dead Standing matter	*
Down wood	*

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 07/06/85
Personnel: Neuman /Eckinger
Plot Code: GHM 2

Dimensions and Bearings



Site Description

Wet meadow on bench directly south of GHM 1. Plot is roughly bowl-shaped, sloping 5-10 % to South, SW exposure. Standing water in center, draining to South. Southwest corner, middle of east side have large rocks surrounded by dry-type plants, covering less than 5 m^2 area. Vegetation structure mostly homogeneous; spatial pattern of differences clearly related to drainage pattern.

Species list

* indicates less than 1 % cover.

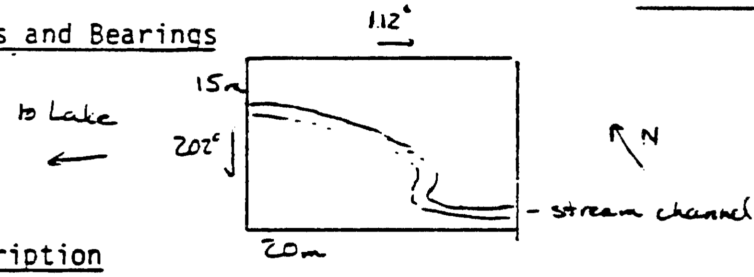
Agrostis variabilis	*
Arabis sp.?	*
Aster alpigineus	60.3 %
Erigeron peregrinus	3.61
Carex brevipes	4.87
Carex spectabilis	7.07
Cryptograma acrostichoides	*
Danthonia intermedia	5.79
Dodecatheon jeffreyi	26.3
Draba sp.?	*
Erysimum perenne	*
Helenium bigelovii	2.24
Heleocharis pauciflora	16.9
Juncus mertensianus	*
Juncus parryi	1.7
Kalmia polifolia	3.81
Ledum glandulosum	1.93
Lewisia triphylla	*
Pedicularis atollens	1.89
Penstemon heterodoxus	1.41
Phacelia frigida	*
Phyllodoce breweri	2.19
Poa incurva	2.04
Polygonum bistortoides	3.29
Potentilla flabellifolia	*
Unknown 2	*
Ranunculus alismaefolius	*
Saxifraga bryophora	*
Scirpus criniger	57.8
Sedum obtusatum	*
Spiraea densiflora	1.19
Thalictrum fendleri	*
Vaccinium nivictum	36.5
Veratrum californicum	1.56
Viola purpurea	*
MOSS	11.1
Gravel	1.4
Rock	1.26
Standing Water	1.0

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/03/85
Personnel: Neuman/Edinger
Plot Code: GHM 3

Dimensions and Bearings



Site Description

Wet meadow on lowest part of smae bench as GHM 1 and 2. Close to stream and waterfall. Small stream course goes through plot. Plot is nearly level, Southern exposure, shallow organic soil with gravel beneath. Plot seems to have had later snowmelt than GHM 1 and 2, perhaps because of its more protected location. Vegetation structure fairly homogeneous except for stream course and drier areas of plot around some rocks.

Species list

* indicates less than 1 % cover

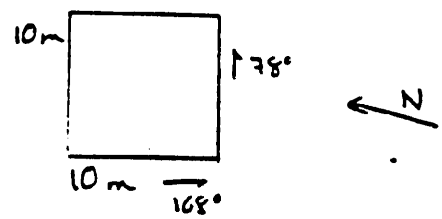
Antennaria alpina	*
Aster alpigineus	67.3 %
Erigeron peregrinus	*
Carex brevipes	1.13
Carex spectabilis	9.39
Danthonia intermedia	3.17
Dodecatheon jeffreyi	15.3
Epilobium lactiflorum	*
Grass #17	26.7
Grass #18	*
Heleocharis pauciflora	31.3
Hypericum anagaloides	*
Juncus parryi	*
Kalmia polifolia	2.95
Lewisia triphylla	*
Ligusticum grayi	*
Mimulus primuloides	*
Muhlenbergia filiformis	1.28
Pedicularis atollens	*
Penstemon heterodoxus	2.66
Phyllodoce breweri	*
Polygonum bistortoides	4.33
Potentilla flabellifolia	*
Potentilla glandulosa	*
Unknown #2	*
Salix orestera	1.85
Saxifraga bryophora	*
Sibbaldia procumbens	*
Vaccinium nivictum	51.4
Veronica alpina var. alterniflora	*
Viola mackloskyi	*
MOSS	37.0
Gravel	4.19
Rock	5.86
Stream course	5.31
Mud	*
Carex nigricans	*

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/06/85
Personnel: Neuman /Eckinger
Plot Code: GHM 4 ag

Dimensions and Bearings



Site Description

On bench directly North of Parsons Pond, above, North of GHM 5. Fairly flat meadow, with dry stream course along NW side. Shallow sandy soil with very little organic content except moss mats. Relatively dry. Approx. 20 m from snow depth pole.

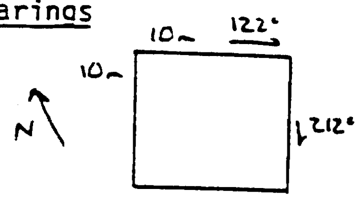
Species list	(Braun-Blanquet Cover Class)
Pedicularis atollens	2a
Penstemon heterodoxus	+
Muhlenbergia filiformis	2b
Poa incurva	1
Juncus parryi	1
Antennaria alpina	2b
Juncus mertensianus	3
Calyptridium umbellatum	r
Lewisia triphylla	2m
Aster alpigineus	2m
Eriogonum incanum	r
Erigeron peregrinus	1
Saxifraga bryophora	2m
Rumex paucifolia	r
Lewisia nevadensis	+
Spiraea densiflora	1
Ligusticum grayi	+
Polygonum kelloggii	2m
MOSS	3
Carex spectabilis	3

Emerald Lake Acid Deposition Vegetation Study

Study Plot Description

Date: 7/06/85
Personnel: Neuman/Edinger
Plot Code: 6HM5 ag

Dimensions and Bearings



Site Description

Adjacent, slightly North of Parsons Pond. Flat meadow on shallow snady soil, lwo organic content except moss mats, poorly drained, quite wet. Nearly complete cover, fairly homogeneous vegetation structure.

Species list	(Braun-Blanquet Cover Class)
Juncus mertensianus	2b
Heleocharis pauciflora	3
Dodecatheon jeffreyi	1
Carex spectabilis	4
Hypericum anagalloides	+
Agrostis variabilis	2a
Pedicularis atollens	2a
Lewisia triphylla	2m
Antennaria alpina	2b
Penstemon heterodoxus	1
Rumex paucifolius	+
Poa incurva	+
Unknown #2	+
Erigeron peregrinus	+
Lewisia nevadensis	+
Saxifraga bryophora	+
Carex brevipes	+
Sibbaldia procumbens	2b
Saxifraga aprica	+
Carex phaeocephala	+
Ranunculus alismaefolius	r
Ligusticum grayi	+