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Effect of recreation (trampling) on the forest

floor and associated streams of aspen and

conifer forests

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Abstract

Heavy trampling significantly reduced the biomass of understory vegetation in aspen stands subject to different management procedures (thinning, fertilization). Light trampling also resulted in lower understory biomass except where it was performed in a fertilized aspen stand which had an understory community dominated by grasses. The grass community appears to be more resistant to trampling. Coverage by the understory was also reduced by both heavy and light trampling in aspen stands. The sparse understory of spruce-fir forests was not significantly changed. Trampling fragmented the forest floor in aspen but not in spruce-fir.

Still, neither forest floor weight nor forest floor nitrogen content were consistently altered by trampling in either aspen or conifer stands. Higher concentrations of nitrate were found in lysimeters within trampled aspen stands indicating the potential for groundwater contamination. The nitrate concentrations in lysimeters in spruce-fir stands were not elevated by trampling.

The results obtained in streamside trampling studies parallel those from the drier forest interior. Trampling reduced herbaceous biomass along aspen streams but not along spruce-fir streams. Forest floor weight was not reduced along either aspen or spruce-fir associated streams. However, downslope movement of detritus to streams was increased to both aspen and spruce-fir streams. This increase in inputs of particulate organic resulted an increase in the standing stock of detritus within one aspen and one spruce-fir stream.

Trampling increased dissolved neutral organic compounds, mainly terpenoids, in both stream and lysimeter water in aspen. Two of the

compounds increased, citroneloll and citronellyl acetate, would be highly reactive with chlorine at water treatment centers and could pose water quality problems. In contrast, trampling in spruce-fir resulted in no increases in dissolved organics in stream water and was associated with a lower concentration of neutral organics in lysimeter water. In summary aspen forests appear to be much more impacted by trampling than do spruce-fir forests.

INTRODUCTION

Although the use of aspen for recreational areas may provide certain benefits (e.g. aesthetics, ease of regeneration, low fire risk), there are a number of characteristics of this vegetation type which under recreational pressure could lead to adverse water quality. The forest floor of an aspen stand is relatively thin because of the rapid decomposition of its litter (Gosz 1980). Since the forest floor is important in intercepting precipitation and preventing erosion, recreational pressure may cause more adverse effects in aspen than in conifer areas. The herbaceous understory is very productive in aspen stands and not only is important in protecting the soil from erosion but also cycles a large proportion of the nutrient capital; both are important factors in maintaining good water quality. Trampling by recreationists may seriously affect the productivity and nutrient uptake capability of this layer. The soil of aspen stands is more nutrient rich than that of conifers and nitrification ($NH_4^+ \rightarrow NO_3^-$) is an important process (Gosz 1978). In soils with high nitrification rates, disturbance often causes significant losses of NO_3^- and other nutrients (Vitousek et al. 1979). The ease with which the understory and litter layer can be disturbed, the high nitrification rates, and increased water reaching the soil (less interception) may cause larger changes in water quality in aspen than in conifer stands following recreational pressure.

Silvicultural management is necessary to maintain productive, healthy aspen stands, however, this more intense management activity may cause large and/or frequent water quality changes. The results of our thinning and clearcutting experiments show marked differences in water quality.

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Fertilizing an old aspen stand increased understory production (primarily grasses), however, some water quality degradation occurred. The increased grass cover achieved with fertilization is an important objective because it makes the understory significantly more resistant to trampling and erosion (Burden and Randerson 1972). Since a very important recreational effect is simply the "trampling effect" of people, a study was initiated in 1980 to evaluate certain trampling intensities on aspen plots subjected to different silvicultural procedures as well as on a conifer site. Preliminary results show that the heaviest trampling (18 walking passes/week) during the summer caused a 41% decrease in forest floor weight of the natural aspen plot. Even light trampling (3 walking passes/week) caused a 20% decrease. Furthermore, the forest floor changed to a highly fragmented condition, presumably much more subject to erosion. Trampling in the conifer site did not affect forest floor weight. The heavy trampling rate also caused reductions in understory species. Legumes decreased 90%, other forbs 94%, and grasses 29%. The fertilized aspen plot free from trampling had 12 times as much grass biomass as the natural aspen control plot, however, heavy trampling on a fertilized plot still reduced grass biomass by 71%. The remaining grass was largely responsible for the trampled and fertilized plot having 1.4 times more understory remaining at the end of the summer than on the unfertilized plot. The thinned plot also had higher grass cover than natural aspen causing more understory to remain after trampling activity.

Research conducted by Molles (1982) in the Tesuque Watersheds indicates that the standing crop of detritus in conifer forest streams (355.54 mg m^{-2} dry wt) is approximately ten times that of streams associated with aspen

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(43.4 mg m^{-2}). This difference may be the consequence of reduced detrital input to aspen streams as the result of 1) aspen leaves forming a tight mat under winter snow which resists movement into streams by either wind or water, 2) the new understory growing through the matted layer rather than pushing it up (once developed, the stems of the understory further impede the movement of litter), and 3) rapid decomposition of aspen litter. However, trampling by recreationists could dramatically change detrital inputs to aspen-associated streams by destroying understory vegetation thereby disrupting the integrity of the litter mat.

Interestingly, the response of the dissolved organic compounds in streams is the opposite of that shown by particulate organic matter. The concentration of the neutral to slightly acidic fraction is 3-4X higher in streams of undisturbed aspen stands in the fall than in streams of spruce-fir stands, and on a yearly basis, is 66% higher in concentration in streams of aspen stands than in streams of conifer stands. The organic acid content of aspen streams was, on a yearly basis, 99% higher in concentration than that of streams in spruce-fir stands (R. Cates & T. McMurray, Final Report, in prep.). We believe from our current investigations that these trends and significant increases reported above of neutral to slightly acidic compounds (lignin degradation products, lignin monomers, gallotannin, and other phenylpropanoids) and organic acids in aspen streamwater are due to the comparatively rapid and easier decomposition of the litter of aspen and aspen understory. In addition, we believe that disturbance does cause significant increases in the dissolved organic compound content of streams in aspen and conifer stands. For example, the widening of ski runs at the

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Santa Fe Ski Basin in September, 1979, resulted in a highly significant 498% increase in the neutral to slightly acidic organic compounds and about a 50% increase in organic acids. These are the first data reported on the nature and distribution of dissolved natural organics in undisturbed and disturbed aspen and conifer streams.

Objectives

The overall objective was to quantify the relationship between the trampling effect of recreationists, vegetation disturbance, soil disturbance, and water quality in aspen and conifer stands. Specifically:

1. To quantify the influence of a second season of trampling on vegetation, soil, and water quality for a conifer site and aspen sites under different management procedures.

2. To quantify the influence of trampling on the particulate organic matter budgets of streams flowing through aspen and conifer forests.

3. To quantify the influence of trampling on dissolved organic (acids and low molecular weight neutral to high molecular weight neutral to slightly acidic) compounds in streams flowing through aspen and conifer forests during spring, summer, and fall seasons.

4. To quantify the influence of trampling on dissolved organic (acids and low molecular weight neutral to high molecular weight neutral to slightly acidic) compounds in water percolating through soils of streamside aspen and conifer forest plots.

SITE DESCRIPTION

The study sites were located in the Tesuque Watershed Study Area, Sangre de Cristo Mountains, New Mexico. The general vegetation, geology,

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topography, and climatic factors of the area were described by Gosz (1975, 1978, 1980). The aspen study site was at 3150 m elevation on a south facing aspect. The soil is a Typic Cryocrept (Medio cobbly loam) which was developed from parent materials derived from the Embudo granite formation. More detailed soil information is available in Gosz (1980).

The sites selected for the natural, thinned and fertilized aspen stands were very close to each other and within the same watershed. The thinning was performed in 1975. It consisted of a 25% stem reduction (every 4th stem was felled regardless of size). The fertilized stand is located within 50 m of the thinned area and 20 m downslope of the natural stand. Fertilizer (urea) was applied in 1979 at a rate of 609 kg/ha (Grover, unpubl). The uniform nature of the aspen (resulting from an 1886 burn), soil, and topography reduce the likelihood of a significant site or site x treatment interaction factor.

The conifer forest is a spruce-fir forest at 3350 m elevation. It is on a west aspect and the soil is a Dystric Cryocrept (Nambe cobbly loam) derived from the Embudo granite formation.

METHODS

A major factor in our research plan was that a number of management practices (i.e. thinning, fertilizing) have already been performed in our study area and are being evaluated. The "trampling" effect was added and was evaluated immediately.

At each of the four sites (i.e. natural aspen, thinned aspen, fertilized aspen, natural spruce-fir), three contiguous 10m x 10m plots were established with permanent plot markers (fig. 1). One plot served as a

control, one for low intensity trampling and one for high intensity trampling. Low intensity trampling was defined as three walking passes/week (i.e. the entire 10m x 10m plot was walked over three times/week). High intensity trampling was 18 walking passes/week. The trampling treatments were applied weekly throughout the study period of June 1 to Sept. 1, 1980.

Figure 1 shows the layout of the three 10m x 10m plots of each site as well as the location of the individual $1/2m^2$ sampling subplots for various measurements. The 1 m wide strips between subplots and plots allowed access for measurements of the following parameters:

Forest Floor Biomass. Initial (May) and final (August) forest floor biomass was measured by the use of $100cm^2$ templates as described by Gosz et al. (1976). Ten replicates were taken from each 10m x 10m plot at each sampling time. These samples were taken randomly from the $1/2m^2$ subplots. The forest floor samples were analyzed for total N, total P, Ca, Mg, K, and ash content.

Forest Floor Extractable N. At monthly intervals, 10 samples of each the forest floor and 0-10 cm depth soil were collected (with a soil corer) from each plot to monitor: a) KCL extractable NO_3^- and NH_4^+. This estimates rates of N mineralization; b) organic matter content; and c) moisture content. These samples were taken randomly from the $1/2m^2$ subplots.

Herbaceous Biomass. Final above-ground, herbaceous biomass was evaluated on Sept. 1 by clipping five $1/2m^2$ subplots on each of the 10m x 10m plots. These were chosen randomly from the subplots. The herbaceous plants were separated into three groups: grass, legumes, and other forbs.

<u>Soil Solution Chemistry</u>. Porous cup tension lysimeters were installed (1/2m deep) beneath each of the permanent plots to allow sampling of the soil solution. They were installed at an angle (entering from the edge of the plot) to allow routine trampling and vegetation measurements. The ten replicate lysimeters of each plot were sampled biweekly when possible and the sample analyzed for NO_3^- to determine the potential for loss in drainage water.

<u>Herbaceous Vegetation Measurements</u>. Ten $1/2m^2$ herbaceous plots were chosen randomly and sampled monthly in each 10m x 10m plot using a vertical point frame (36 points per $1/2m^2$ plot). No other surface sampling procedures were performed on these subplots. Data collected using this procedure were expressed as;

    species % foliage cover:

$$\frac{\text{number of times a species is hit}}{\text{number of readings (rods)}} \times 100$$

        note - a species is recorded only once/rod

    relative % cover:

$$\frac{\text{\% cover of a species} \times (100-\text{bareground})}{\text{total \% cover/number of readings}} \times 100$$

<u>Chemical Procedures</u>. Forest floor biomass samples were analyzed for total-nitrogen (TN), total phosphorus (TP), Ca, Mg, and K. Total nitrogen and TP analyses were performed using a Technicon Auto Analyzer following wet digestion of forest floor samples using concentrated H_2SO_4, 30% H_2O_2, and $K_2SO_4:CuSo_4$ catalyst with heating until clear (Schuman et al. 1973). Sample preparation for cation analyses using a Perkin Elmer model 306 Atomic Absorption Spectrophotometer required ashing a subsample of forest floor

material (500°C for 2 hrs.), then solubilizing the ashed sample in 6N HCl with heating.

Soluble and exchangeable forest-floor NH_4^+ and NO_3^- were determined using using KCl extraction procedures. While in the field, 2 g subsamples of forest-floor material, or 6 g subsamples of soil (approximate weights) were added to polyethylene bottles containing 100 mls of 2N KCl with PMA (phenyl mercuric acetate) added to suppress biological activity. Simultaneously, equal weights of samples were placed in soil cans for moisture content and organic matter content. Exact sample weights were determined by weighing KCl bottles before and after sample collection. Approximately 24 hours after collection, a sufficient volume of sample + KCl solution was decanted and centrifuged to obtain a clear supernatant for direct NH_4^+ and NO_3^- analyses on the Technicon Auto analyzer. Organic matter content of forest-floor biomass and monthly forest floor and soil collections was determined by ashing 1 g subsamples at 500° for 2 hours.

Soil solution samples were analyzed directly for NO_3^- using the Technicon Auto Analyzer. PMA was added to these samples in the field to suppress biological conversion of sample nitrogen forms before analysis.

Streamside Studies

Experiments were conducted along headwater streams in the Tesuque Watershed Study Area, Santa Fe National Forest. Study sites were established on two streams arising and flowing through uniform aspen forests and on two streams arising and flowing through spruce-fir. The upper 30 m of each study stream provided a control section and a 30 m section below each control section provided a treatment section (fig. 1a). The treatment

plots were used to determine the impact of recreational developments, such as streamside campgrounds, on particulate organic matter budgets and dissolved organic chemicals of streams associated with aspen and conifer forests.

The treatment applied to experimental plots was trampling as operationally defined by the most recent study of J. Gosz (E.C. 365). A moderate level of trampling (10 passes/wk) was applied to all treatment plots for 5 m on both sides of the stream for the entire 30 m length of each treatment section. Sites were trampled from July to September, 1981 - the period of most intense camping and hiking.

Particulate Organic Matter Budgets

Forest Floor Biomass. Initial (June 1) and final (Sept.1) forest floor biomass was measured by the use of 100 cm^2 templates as described by Gosz et al. (1976). Eight to ten randomly located samples were taken from each treatment and control plot at each sampling time and analyzed for dry weight and ash content.

Herbaceous Biomass. Final herbaceous biomass was evaluated on Sept. 1 by clipping five $1/2m^2$ subplots on each of the 5m x 30m plots. These were chosen randomly from within each treatment and control plot.

Litter Fall. Litter inputs into the study stream were sampled with $0.2m^2$ litter traps placed randomly along treatment and control sections. 1.7 m directly above the streams. Three traps per section were used so that sampling would not interfere significantly with detrital inputs to the stream. Dry weights and ash content was determined on all litter samples.

Downslope Movement of Litter. Movement of litter along the forest floor by wind or water can result in appreciable inputs of organic matter to streams

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(Fisher and Likens 1973). This lateral movement of litter into streams was estimated using rectangular boxes (.3 x .5 x .5 m) open on one side and placed parallel to the stream with the open side placed upslope. Three of these samplers were randomly placed along each side of each treatment and control section of the study streams.

Standing crop of Detritus Within Streams. Initial (June 1) and final (Sept. 1) standing crop of particulate organic matter within streams was determined by taking 10 100 cm^2 bottom samples from each control and study section. This constituted approximately 2% of the bottom area.

SAMPLING AND CHEMICAL METHODS FOR ORGANIC ANALYSES

Sampling. The control and treatment plots within each stream site were divided into two equal segments. Thus, each study stream contained an upper and lower control segment, and an upper and lower treatment segment. One stream sample (750 ml) was collected in a brown bottle from each subsite. The contents of the lysimeters, of which there were four per subsite, were emptied into individual glass bottles. All sample containers were packed on ice for transport to the laboratory. Streams in aspen sites were sampled once in each of July and August, 1981, and June and July, 1982. Streams in spruce sites were sampled once in each of July and August of both years.

Sample preparation. Samples were filtered through 0.45-μm Millipore membrane filters. Samples were concentrated on activated Sep-Pak cartridges, using 200 ml for stream samples and 20 ml for lysimeter samples. The eluent from the neutral fraction Sep-Pak cartridges was collected and made 5 x 10^{-3} M in tetrabutylammonium phosphate (PIC A). This solution, which contained the acid fraction, was then concentrated onto separate activated Sep-Pak cartridges.

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<u>Chromatography</u>. Samples were chromatographed by reverse-phase high
pressure liquid chromatography on a Waters C_{18}-μBondapak column. Two Waters
Model 6000A pumps equipped with a Model 660 Solvent Programmer provided a
solvent flow of 1.5 ml/min. Peaks detected at 254 nm by a dual channel
Model 440 Absorbance Detector were recorded on a Linear integrating
recorder.

Filtered samples were used directly to assay the neutral components.
1 ml injections were made for lysimeter samples, while 30 ml of stream sample
were loaded directly onto the column. For 1981 samples, H_2O was pumped
isocratically for 10 min following injection/loading. Two percent CH_3CN was
pumped isocratically for 5 min, followed by a 20-min linear gradient to 32%
CH_3CN. Upon completion of the gradient, 44% CH_3CN was pumped isocratically
for 10 min, followed by a 10 min linear gradient to 100% CH_3CN. The solvent
program for 1982 samples was: 10 min isocratic pumping of H_2O was followed
by a 40 min linear gradient to 40% CH_3CN, then by a 10 min linear gradient
to 100% CH_3CN. The solvent was maintained at 100% CH_3CN until all
components had eluted. The concentration of neutral components, detected at
0.01 AUFS, was determined by summing the integrated peaks that eluted after
the initiation of the solvent program (i.e., after the isocratic H_2O).

Acid fractions were eluted from the Sep-Pak cartridges using 2 ml
CH_3CN. The eluent was concentrated to 0.5 ml and then brought to 2.0 ml
with tetrabutylammonium phosphate. Injections of 1.0 ml for stream samples
and 0.5 ml for lysimeter samples were detected at 0.1 AUFS. The peaks of
components eluting after the initiation of the solvent program were
integrated and summed. Chromatographic conditions for acid fractions were

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identical to those for neutral fractions, except that solvents were 5 x 10^{-5} M in tetrabutylammonium phosphate.

RESULTS AND DISCUSSION

Herbaceous Vegetation

The understory of the aspen stand was affected markedly by the different management procedures (thinning, fertilizing) as well as trampling procedures. Although the total herbaceous biomass at the start of the trampling experiment in 1980 did not vary significantly between the untrampled natural, thinned, and fertilized aspen stands, the relationship between grasses, legumes, and other forbs varied markedly. The natural aspen stand had an understory dominated by legumes (Vicia americana, Lathyrus arizonicus) while the thinned stand was dominated by other non-leguminous forbs and the fertilized stand was dominated by grasses (fig. 2). That pattern continued on the control plots in 1981; nonsignificant differences in biomass among the three stands but marked differences in species importance (fig. 2). On the fertilized control plot, the grass component increased significantly from 1980 to 1981. We feel that this is a result of that component's continued expansion following the fertilization of 1979.

Heavy trampling (18 walking passes/wk) caused highly significant reductions ($p < .01$) in understory biomass on all three stands both in 1980 and again in 1981. The dominant groups showed the greatest reductions. Interestingly, the second season of heavy trampling did not cause a further reduction in total understory biomass (fig. 2). In the fertilized stand the heavy trampling during the second year was associated with a increase in the

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grass component at the expense of the leguminous component. However, this same pattern also occurred in the control therefore we cannot assume it was related to trampling. In the natural stand heavy trampling during a second season was associated with an increase in both non-legumes and grasses at the expense of the legumes. Again, this pattern was also found in the natural control plot. The heavy trampling caused a much greater reduction in the natural and fertilized stands than in the thinned stand. This was in spite of the fact that the fertilized stand was dominated by grasses which have been reported to be more resistant to trampling (Burden and Randerson 1972).

The light trampling (3 walking passes/wk) caused a significant reduction ($P < .05$) in understory biomass for the natural and fertilized stands in 1980; again primarily in the dominant plant group (fig. 2). After a second season of trampling (1981), the natural stand showed a further significant biomass reduction (in legumes) while the fertilized stand showed a significant increase due to an increased grass component. We feel that this is a result of grass continuing to develop in response to fertilization in spite of light trampling. In the thinned plot the reduction caused by light trampling was not significant during 1980 ($P > .05$); however, a second season of trampling resulted in a significant reduction ($P < .05$) with respect to the control. This was partly a result of a slight increase in understory biomass for the thinned control during 1981.

The influence of trampling during the first and second years is shown well by relative coverage data (fig. 3,4). The heavy trampling treatment

caused a near linear reduction in relative cover of all plant groups (legumes, grasses, non-legumes) for all three aspen stands during the first year (1980). The untrampled plots showed either no change in relative coverage (fertilized and natural) or a significant increase (P < .05, thinned). This was due to the difference in dominant groups on the three sites and the phenological differences for those groups. The dominant grasses and legumes of the fertilized and natural stands emerged and began to grow early and by June had attained a high relative cover. The thinned stand, dominated by non-leguminous forbs, showed a continuous increase in relative coverage through the summer.

During the second year (1981) measurements were begun in May and demonstrated significant increases (P < .01) for June for all three stands and trampling intensities. Most interestingly, the relative coverage on heavily trampled plots increased in June 1981, to values significantly higher (P < .05) than those of June 1980. Following the June 1981 peak in relative cover, heavy trampling caused the near linear reduction pattern of 1980. Heavy trampling did not cause a significant difference (P > .05) in relative cover for the natural and fertilized stands during August nor was there a difference for these stands between 1980 and 1981. Heavy trampling did not reduce relative cover on the thinned stand during 1981 as much as it did during 1980.

Light trampling generally caused results intermediate to those of the control and heavily trampled plots for all stands. Since the light trampling treatment is only one-sixth the intensity of the heavy trampling (3 vs 18 walking passes/wk) these results suggest a non-proportional

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relationship between damage and trampling pressure for some plant groups.
The legumes seem most sensitive since light trampling caused nearly as great
a reduction in coverage as heavy trampling. The grass (fertilized stand)
and non-legume (thinned stand) dominated stands showed reductions by light
trampling more similar to those of a proportional response to trampling
intensity.

The conifer forest (spruce-fir) had a small understory component of
non-leguminous forbs (fig. 2). During the first year of study (1980), heavy
trampling significantly reduced the understory over that of the control (p <
.01). However, the second year (1981) showed non-significant differences
between all trampling intensities (p > .05). The large reduction in the
understory biomass between 1980 and 1981 on the control plot demonstrates
that year-to-year variation may be a more important factor than trampling
pressure in this forest (fig. 2).

Forest Floor

Forest floor weight measurements made for the three plots of each stand
in May, 1980 (before trampling) showed no significant differences (p > .05).
This demonstrates the uniform nature within each stand. There were
significant differences among the three aspen stands prior to trampling
which were a result of the thinning and fertilization procedures. the
forest floor dry weight of the fertilized stand was greatest followed by
that of the natural stand followed by that of the thinned stand (table 1).
As expected, the spruce-fir stand had forest floor weights greater than
those of aspen stands.

The August 1980 collections showed several patterns depending on stand and trampling intensity. The untrampled (control) plots for thined, natural, fetilized aspen, and natural spruce-fir stands showed non-significant differences between May 1980, and August 1980 collections. Heavy trampling during the first summer caused significant (p < .05) reductions in the forest floor of the fertilized stand. The reductions in the thinned and natural aspen and spruce-fir stands subject to heavy trampling were not statistically significant (p > .05). The light trampling did not cause significant reductions in forest floor weight in any aspen stand; however, the reduction in spruce-fir was significant.

Regardless of change in weight in the forest floor of trampled aspen plots, the condition of the forest floor was altered greatly after the first season of trampling. The litter material was highly fragmented, almost in a powder form. The summer months of 1980 were relatively dry resulting in minimum erosion. We would expect this fragmented material to be very easily moved by raindrop impaction and surface runoff. In contrast the forest floor of the spruce-fir forest appeared unaltered even after heavy trampling. The rather spongy character of the forest floor and rigid nature of the conifer needles appear to absorb trampling pressure very well. The August 1980 Collections from trampled and control plots of the spruce-fir stand were not significantly different (p > .05).

In addition to a reduction in the forest floor of some stands, trampling caused some redistribution and the appearance of bare ground (table 2). Heavy trampling did not cause significantly more % coverage in bare ground than light trampling (p > .05) but the two trampling intensities

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caused significantly (p < .05) more bare ground exposure than the untrampled control for the natural and thinned aspen stands. The fertilized aspen stand had much more bare ground as a result of higher rodent activity causing non-significant (p > .05) differences between trampled and control plots. This influence of fetilization on rodent activity is very interesting, has not been acknowledged often, and deserves more work.

The forest floor in May 1981, the beginning of the second season of trampling, increased markedly in dry weight over the August 1980 collection for all plots (table 1). The reasons for this increase include leaf and branch litterfall and understory litterfall. The difference in forest floor weights between May 80 and 81 on control plots give some picture of year-to-year variation.

Although trampling during the second season in aspen was responsible for some weight decrease, the larger forest floor mass present during the second summer prevented increased site degradation. In fact, in a number of plots, more forest floor material was present after two summers of trampling than was present before the trampling treatment was started. If litterfall had been very low between the first and second years, very different results may have occurred. Unfortunately, August 1981 samples for the spruce-fir plots were accidently discarded.

Since it is possible that the forest floor samples may have had varying quantities of mineral soil due to our collection techniques, we also present organic content only (g/m^2 table 3). Although fewer significant differences occur, the pattern of results follows that of dry weight data. For aspen, the largest increase between August 1980 and May 1981 is 3000 g/m^2

suggesting some of the large increases discussed earlier were a result of high mineral soil inclusion in the sample.

The influence of trampling on the nutrient content of the forest floor paralleled patterns of forest floor weight in most cases (table 4). This means that concentrations of nutrients were not altered markedly. The generally higher quantities of nutrients in the forest floor during the second summer were a result of the higher litterfall preceeding that period and/or larger mineral soil inclusions in those samples. The fragmentation and mixing of the forest floor and soil by trampling may have contributed to some of the high soil (and nutrient) quantities in some samples.

The litter and soil also were sampled and analyzed for extractable ammonium and nitrate. These measurements identify an influence of trampling on the rate of mineralization and nitrification and the buildup of nitrate in the soil which could be leached to ground water with the advent of moist conditions.

There was a pattern of nitrate accumulation in litter and soil across all of the aspen stands. In 1980, concentrations rose to a maximum during June and early July and fell rapidly in August. Ammonium concentrations remained low or fell in June and July, 1980, then increased significantly in August. These patterns also were reported by Gosz (1978) and are believed to result from the warm, dry, oxidative conditions in the forest floor in June followed by cooler (cloudy), and more moist conditions in July and August. The nitrate decrease in late summer may be due to plant uptake and/or denitrification (fig. 5,6,7).

Heavy trampling caused higher nitrate concentrations in litter in all three aspen stands during 1980; however, the differences were not

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significant because of high variability. There were no significant differences among treatments in ammonium concentrations. The fertilized aspen stand again demonstrated the highest overall nitrate levels. In soil the heavy trampling caused somewhat higher nitrate levels in August, 1980; although the differences were nonsignificant due to high variances (fig. 8). A higher nitrate level late in the summer in trampled plots may be the result of reduced uptake by plants and/or less denitrification.

The spruce-fir stand demonstrated a seasonal litter nitrate pattern as well (fig. 9). Nitrate-N concentrations peaked in August, approximately 2 months later than those of aspen. We expect that this reflects the difference in environmental factors between these forests. The spruce-fir forest often has a snow-pack in June and July. Trampling did not significantly affect nitrate-N concentrations. Soil nitrate-N in spruce-fir did not show a seasonal pattern (fig. 10). Values were low and various trampling intensities did not cause significant differences.

Patterns during the second year of tramplng (1981) were markedly different in aspen stands. Forest floor nitrate concentrations were lower than those of 1980 and without the pronounced peak in June-July (fig. 5, 6,7). There was little difference between the various trampling intensities (p > .05). The levels in the fertilized stand remained several times higher than those of the thinned and natural stands.

In spruce-fir, litter nitrate-N concentrations again increased markedly in August 1981, similar to the 1980 pattern (fig. 9). The differences between plots of various trampling intensities were not significant (p > .05). The soil nitrate-N pattern in 1981 varied much more than that of 1980

(fig. 10). Again trampling intensity did not cause a significant effect. The seasonal and yearly natural variation of both these aspen and spruce-fir forests is large and largely unexplained.

An important consequence of trampling may be altered nitrification rates and leaching of nitrate to the ground water. The spring and summer of 1980 were exceptionally dry resulting in few collections of soil water by lysimeters. Lysimeters were first collected for aspen stands in early August but by that time the soils were sufficiently dry so that only about one-half of the lysimeters sampled soil moisture. In September and October only one-tenth of the lysimeters were able to sample soil moisture. The lack of data prevents meaningful tests on the leaching of nitrate to ground water for 1980. There were several trends, however, that indicate this process may be important during wetter conditions. For thinned and natural aspen stands on Aug. 2, 1980, the order of nitrate concentrations in soil moisture was heavy trampling > light trampling > control. Only in the natural aspen stands were those differences significant (p < .05). The fertilized stand had very high and variable nitrate levels in all of the treatment plots. Another pattern was apparent in the number of lysimeters which collected samples. By early August lysimeters in the natural aspen stand collected samples only from the trampled plots. In September and October all of the aspen stands showed this pattern and in addition the majority of samples came from heavily trampled plots. This data evidences the role of the understory in trampling soil moisture and reducing soil leaching. Trampling reduces this transpiring surface.

Although the spruce-fir stand is in a moister environment, only about one-half of the lysimeters collected soil moisture during the late August to

October period. Nitrate concentrations were very low or non-detectable for these samples and there was no measureable difference between trampled and control plots.

The spring of 1981 proved to be much wetter and allowed lysimeter collections from April through July in Aspen (fig. 11,12,13). The data shows that trampling resulted in markedly higher nitrate concentrations in soil solution for the natural and thinned stands during much of the summer. The nitrate levels in soil water in the fertilized plot were about 5 times higher, more variable, and there were no significant differences due to trampling. Interestingly, these lysimeter samples demonstrated differences due to trampling and fertilization that extractions of the forest floor and soil did not. In other words, under the environmental conditions typical of 1981, analyses of forest floor and soil extractable ammonium and nitrate would not accurately protray nitrogen additions to groundwater of the area. Lysimeters sample soil water continuously and provide an integrated measure of soil water chemistry passing through the soil profile.

Streamside Herbaceous Vegetation

Trampling along aspen streams resulted in significant reductions in herbaceous vegetation along both aspen streams (table 5). This is consistent with the results of two seasons of trampling in the forest interior presented above which demonstrated the vulnerability of this understory. The absence of a detectable affect on the understory of the spruce-fir site is also consistent with results of trampling in the interior of spruce-fir presented above.

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Streamside Forest Floor

There were no significant differences in forest floor ash free dry weight between control and trampled streamside plots (table 6). This was true for both aspen and spruce-fir sites. This failure to show a response to moderate trampling is consistent with the results from the forest interior where on some plots even heavy trampling produced no detectable effect on forest floor weight. As in the forest interior, however, there was considerable fragmentation and movement of the forest floor as the result of trampling.

Litterfall into Streams

As expected there were no significant differences in direct litterfall into streams between control and trampled plots for either aspen or spruce-fir study sites (table 7). In contrast, downslope transport of particulate organic matter was consistently higher in the trampled plots (table 8). The highly fragmented nature of forest floor along with the reduction of herbaceous vegetation in the aspen plots undoubtedly both contributed to increased downslope transport.

Particulate Organic Matter Within Streams

Coarse particulate organic matter was higher stream sections flowing through trampled plots in all four study streams (table 9). The differences between control and trampled sections were great enough to be significant in one aspen and one spruce-fir stream. Fine particulate organic matter was not significantly elevated in any of the streams. This may be the result of fine organic matter being more readily transported downstream. Significantly elevated particulate organic matter within spruce-fir stream 2 may

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indicate that most of the increased input discussed above was transported out of the study sections since this stream dried during the study. Unfortunately, clogging of samplers on the other streams prevented estimation downstream transport of either fine or coarse particulate organic matter.

Aspen Streamwater

Table 10 shows the means, as determined in ANOVA, for the neutral and acid dissolved organic fractions from aspen streamwater. Significant differences were found for the neutrals only. Table 11 suggests significant effects were obtained due to season and year, and due to the interaction among treatment and season, and season and year. The streams were not significantly different in neutral dissolved organics. Trampling in the early season increased the neutral dissolved organics content by 124% as compared to the control. By late season (late July or early August) the neutral dissolved organic content had decreased, based on the control levels, by 40.2%.

Spruce-fir Streamwater

Table 12 shows the means for the neutral and acid dissolved organics found in the spruce-fir streamwater. These data were subjected to a paired t-test analysis since samples were gathered from only one stream (the other stream dried up during the experiment). There were no significant differences between treatment and control or between years.

Aspen Lysimeter Water

Table 13 indicates the means resulting from ANOVA for the neutral and acid dissolved organic fractions from the lysimeters located near the aspen

streams. The only significant difference that was found was in the treatment effects of the neutral fraction. No significant differences were found in the acid fractions.

Spruce-fir Lysimeter Water

Table 14 indicates the means for the neutral and acid dissolved organic fractions from the lysimeters located in the spruce-fir site. These data are the result of a paired t-test analysis. No significant differences were found between controls and treatments or season for the acids. However, the neutrals decreased significantly to about a fourth of the controls in the trampled plots.

When significances were obtained between control and treatment, they were always associated with the neutral fraction. In no case was the acid fraction significantly changed by the treatment or over time. The acid fraction, as compared to the neutral fraction, seems to be a minor component that fluctuated only slightly in either the aspen or the spruce-fir stream or lysimeter water. The acid fraction shows a trend of being higher in concentration in the lysimeter water located at the spruce-fir site as compared to that found in the lysimeters at the aspen site. Overall, the neutral fraction indicates a trend of being higher in the aspen streamwater than in the spruce-fir streamwater.

At the aspen site the effect of trampling increased the neutral fraction significantly during the beginning of the season. This was due to the breaking down of herbaceous vegetative tissues that released the compounds into the soil. This, plus the reduced ability of plants to trap water due to the treatment effects permitted the neutrals to be leached into

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the streams. This is supported by the fact that the neutrals increased significantly in the lysimeter water taken from the aspen site also. However, in the late season there was a decrease in the neutral fraction in the streams. This may have been due to the dry year in which there might not have been water available to carry the neutrals to the lysimeters or the stream, or due to the neutrals being leached out early in the sampling (i.e. in the early season).

In contrast to the aspen site, the dissolved organic neutral fraction was significantly lower in the lysimeter water collected from the trampled spruce-fir site. This may have been due to the trampling packing the litter such that the lower than usual amount of rain for this year was not able to percolate through the litter and soil to the lysimeters.

Although the neutral fraction has not been totally characterized for any aquatic system, we can suggest some of the characteristics and components of this fraction. From previous work on the streams in the same area, aobut 75% of this fraction is terpenoid (Cates, Horner, Gambliel 1983). We have identified the most important constituents, in terms of quantity, and these are citronellol, citronellyl acetate, p-cymene, and thymol. The first two potentially could be very reactive with chlorine at the site of the double bond while the latter are stable compounds under the conditions present in the stream and at chlorine treatment centers. It does appear that the increase in the neutral fraction, particularly in some of the hydrocarbons, may be of interest in future water quality studies, especially if the water may be treated with chlorine and is a source of human drinking water.

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Fig. 1. Design of the 10m x 10m plots and $1/2m^2$ subplots for each forest stand. Trampling intensities were control (0), light (3 walking passes/week) and heavy (18 walking passes/week).

Fig. 1a. Showing arrangement of control (C) and trampling (T) plots downstream from springheads on two aspen and two spruce-fir associated streams. Scale: 1/4" = 5m. * = approximate location of lysimeters (about 2.5m from the edge of the stream depending on topography and other site factors). Lysimeters were placed far enough from the end of each plot so that the edge effects would be minimized.

Fig. 2. Aspen understory biomass (g m^{-2}) after application of different trampling intensities. Different management treatments markedly influenced understory plant composition.

Fig. 3. Changes in % relative coverage of all aspen understory plant groups (legumes, grasses, non-legumes) as influenced by trampling intensity and management treatment.

Fig. 4. Changes in % relative coverage of all aspen understory plant groups (legumes, grasses, non-legumes) as influenced by trampling intensity and management treatment.

Fig. 5. Nitrate-N concentrations (μeq g^{-1}) in the litter of the natural aspen stand under the influence of different trampling intensities.

Fig. 6. Nitrate-N concentrations (μeq g^{-1}) in the litter of the fertilized aspen stand under the influence of different trampling intensities.

Fig. 7. Nitrate-N concentrations (μeq g^{-1}) in the litter of the thinned aspen stand under the influence of different trampling intensities.

Fig. 8. Nitrate-N concentrations (μeq g^{-1}) in the top 10 cm of soil of the thinned aspen stand under the influence of different trampling intensities.

Fig. 9. Nitrate-N concentrations (μeq g^{-1}) in the litter of the spruce-fir stand under the influence of different trampling intensities.

Fig. 10. Nitrate-N concentrations (μeq g^{-1}) in the top 10 cm of soil of the spruce-fir stand under the influence of different trampling intensities.

Fig. 11. Nitrate-N concentrations (mg l^{-1}) in lysimeter samples from the soil of the natural aspen stand under the influence of different trampling intensities.

Fig. 12. Nitrate-N concentrations (mg l^{-1}) in lysimeter samples from the soil of the fertilized aspen stand under the influence of different trampling intensities.

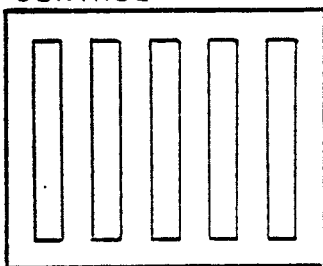Fig. 13. Nitrate-N concentrations (mg l^{-1}) in lysimeter samples from the soil of the thinned aspen stand under the influence of different trampling intensities.

Figure 1
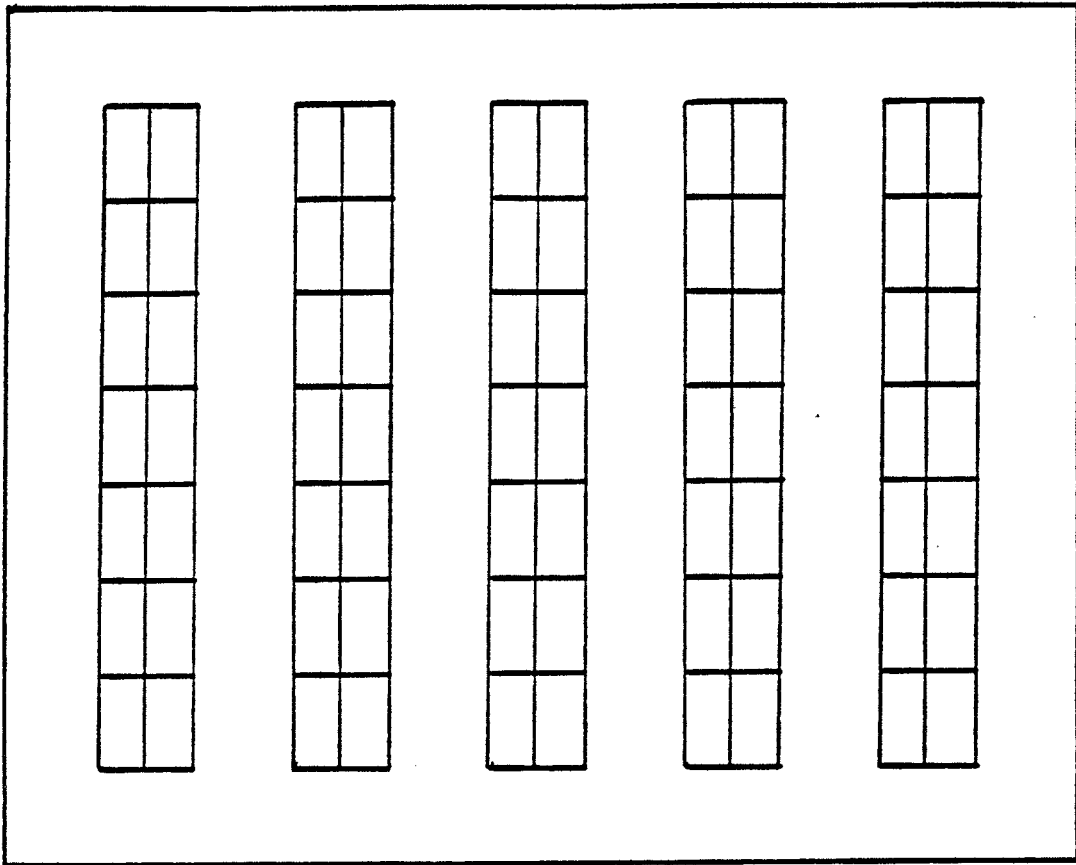
CONTROL   LIGHT TREATMENT   HEAVY TREATMENT
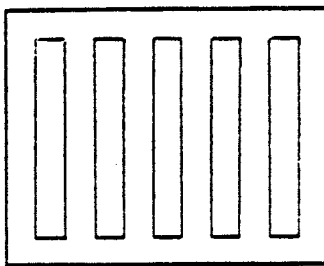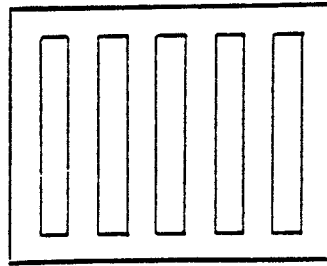
Figure 1a

ASPEN
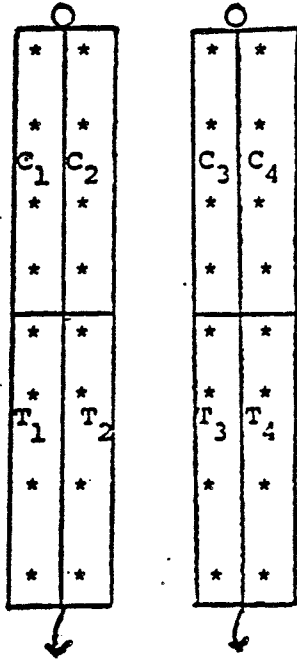
SPRUCE-FIR
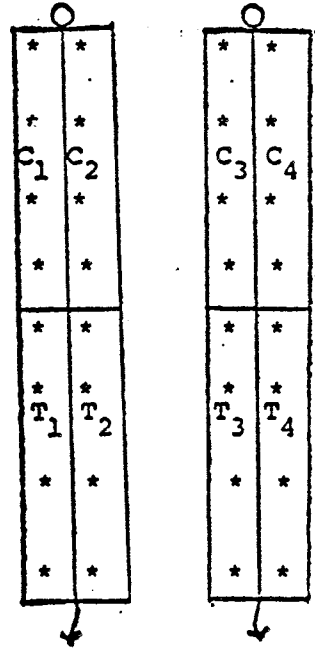
1980 AND 1981 UNDERSTORY BIOMASS

GRASS
NON-LEGUME
LEGUME

G/M²

70
60
50
40
30
20
10

HEAVY TRAMPLING | LIGHT TRAMPLING | CONTROL
FERTILIZED

HEAVY TRAMPLING | LIGHT TRAMPLING | CONTROL
NATURAL
ASPEN

HEAVY TRAMPLING | LIGHT TRAMPLING | CONTROL
THINNED

HEAVY TRAMPLING | LIGHT TRAMPLING | CONTROL
NATURAL
SPRUCE-FIR

'80 '81

36
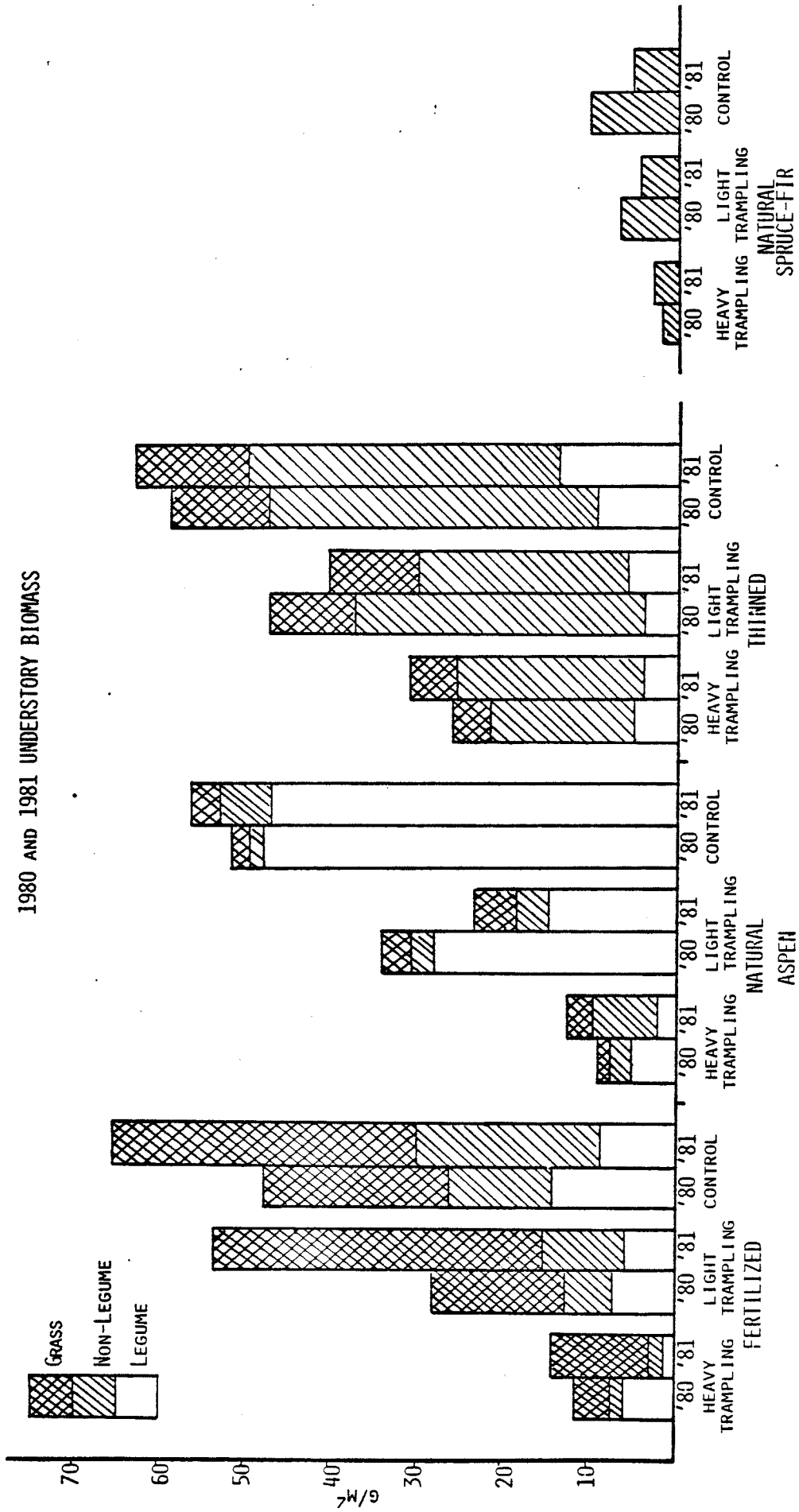
FIGURE 3
RELATIVE COVERAGE

33
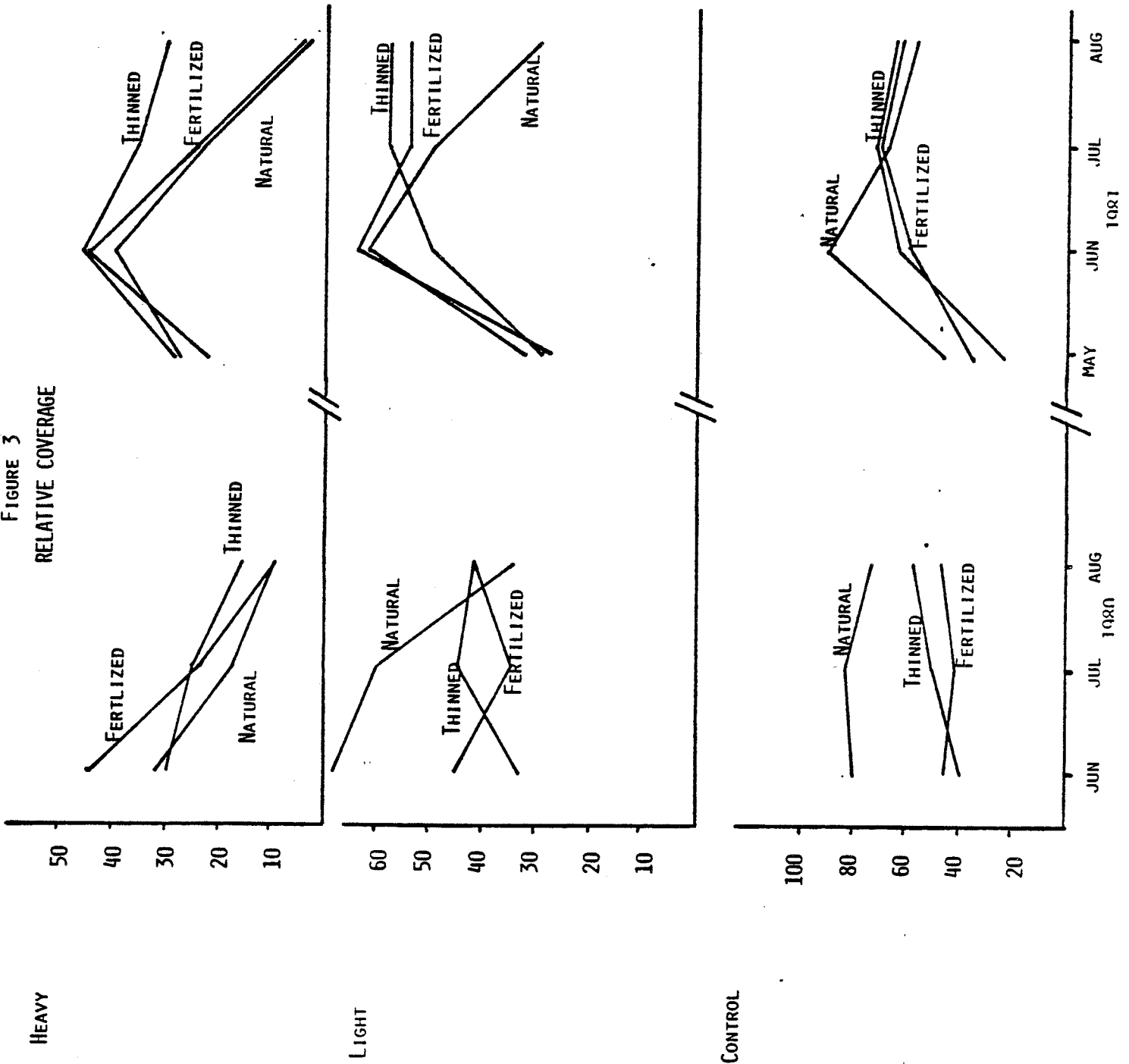
FIGURE 4
RELATIVE COVERAGE

FIGURE 5

LITTER NITRATE-N
FERTILIZED ASPEN STAND
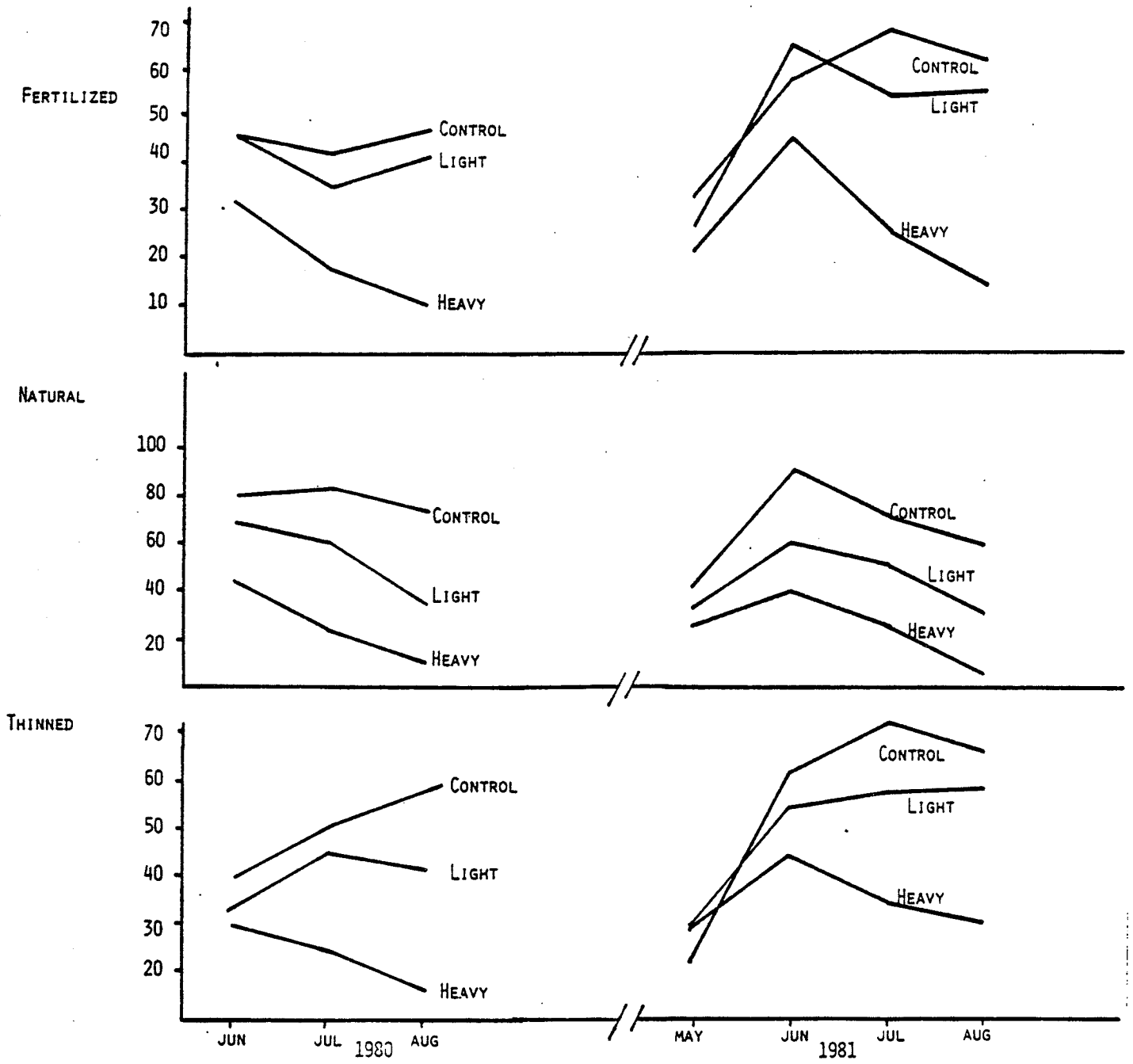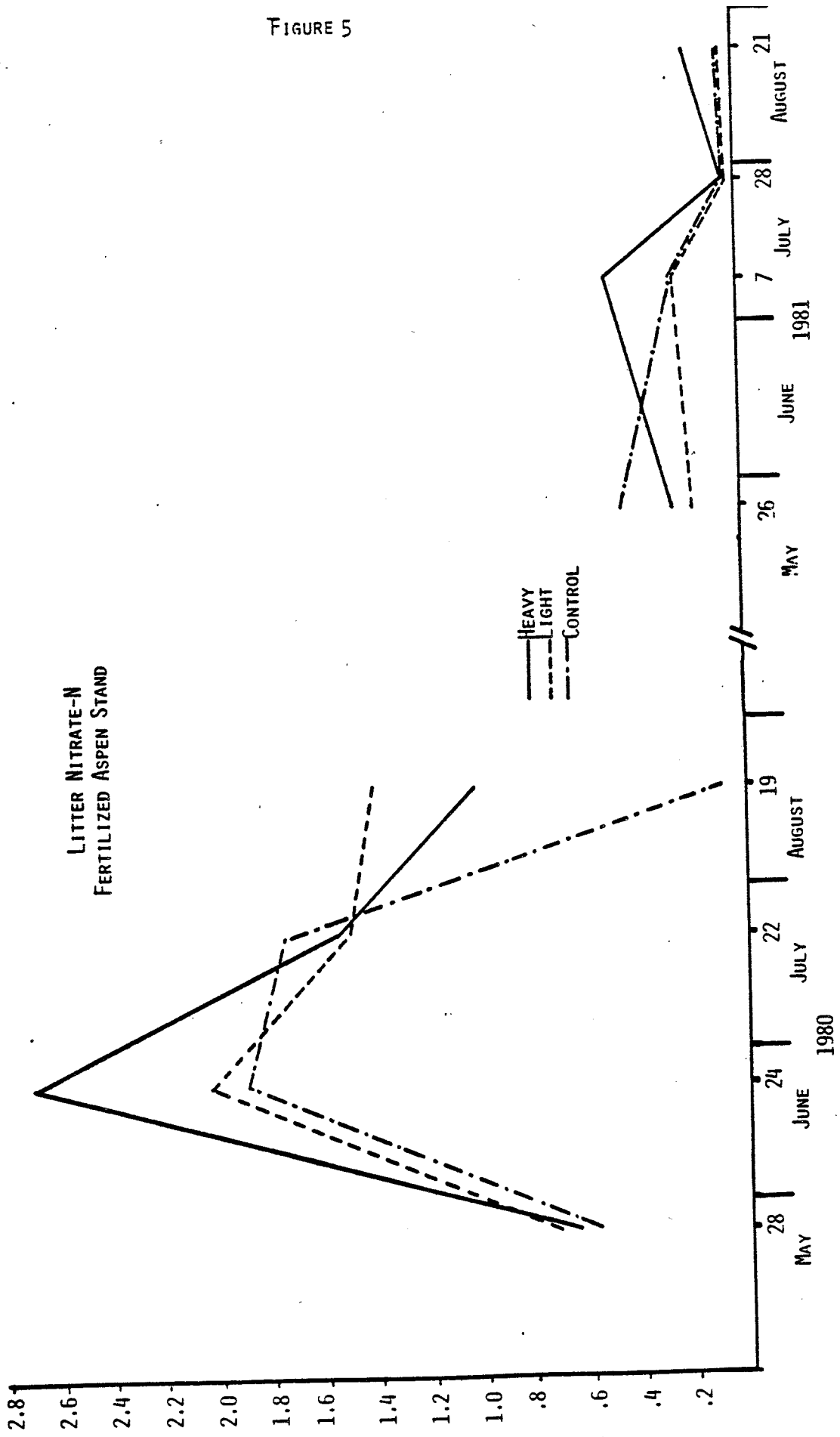
HEAVY
LIGHT
CONTROL
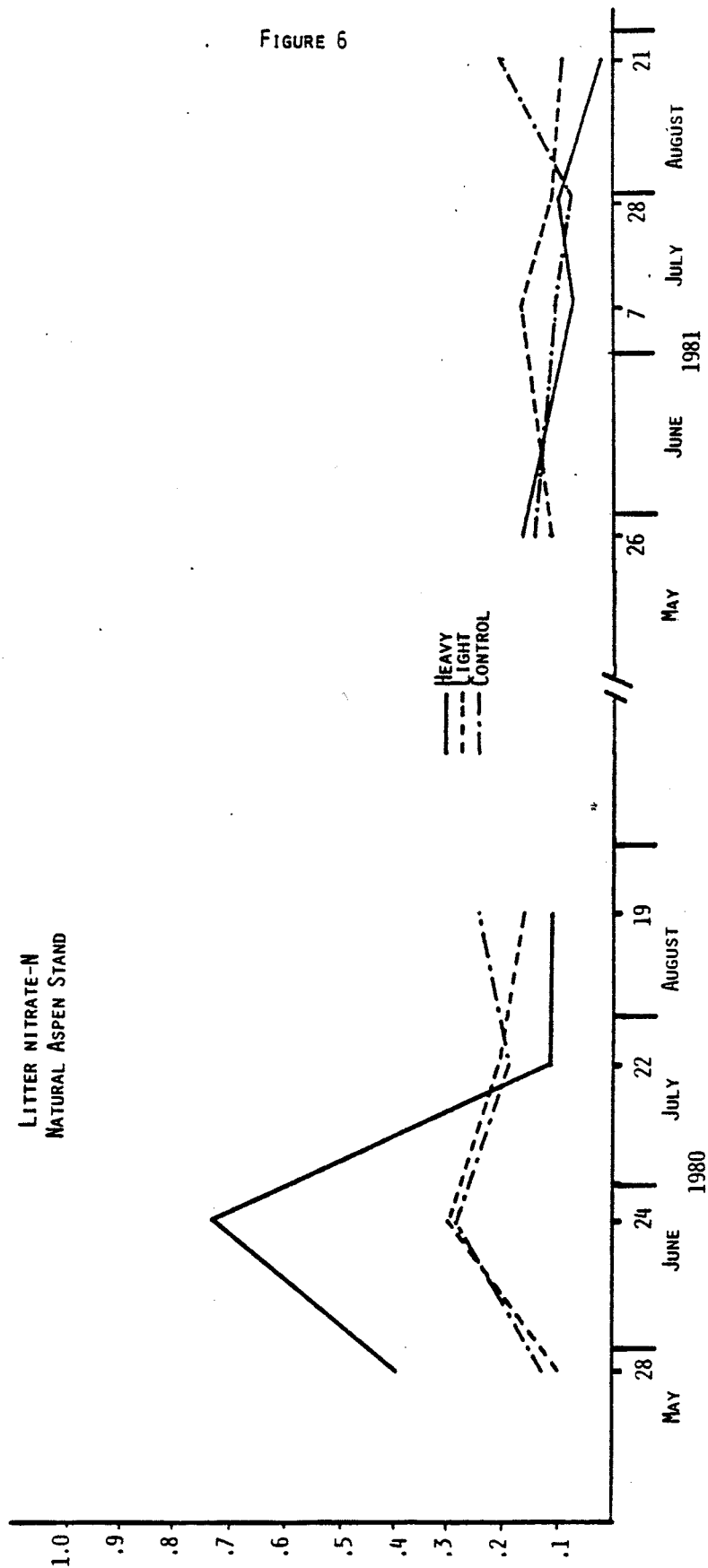
FIGURE 6

LITTER NITRATE-N
THINNED ASPEN STAND

HEAVY
LIGHT
CONTROL
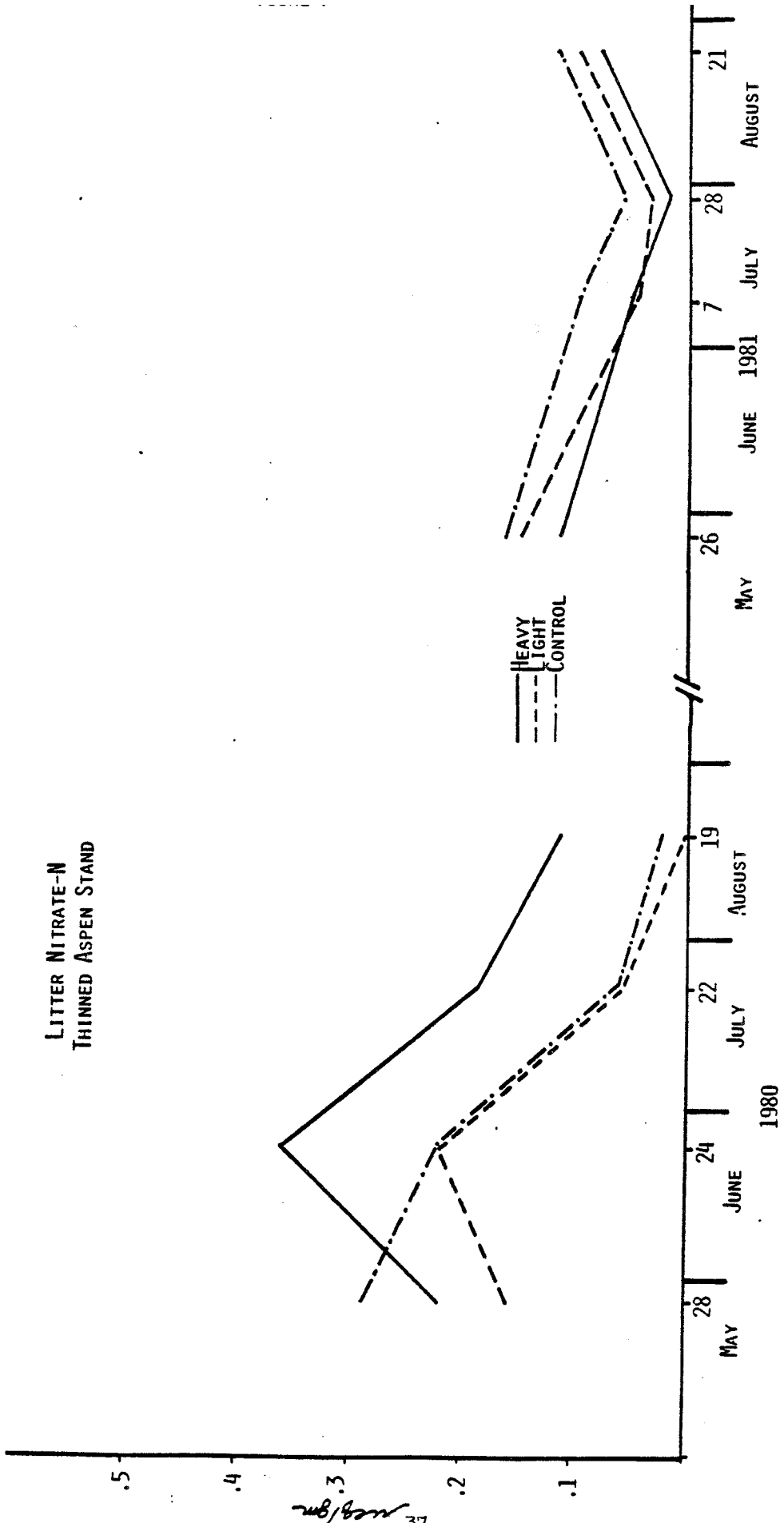
FIGURE 6

SOIL NITRATE-N
THINNED ASPEN STAND
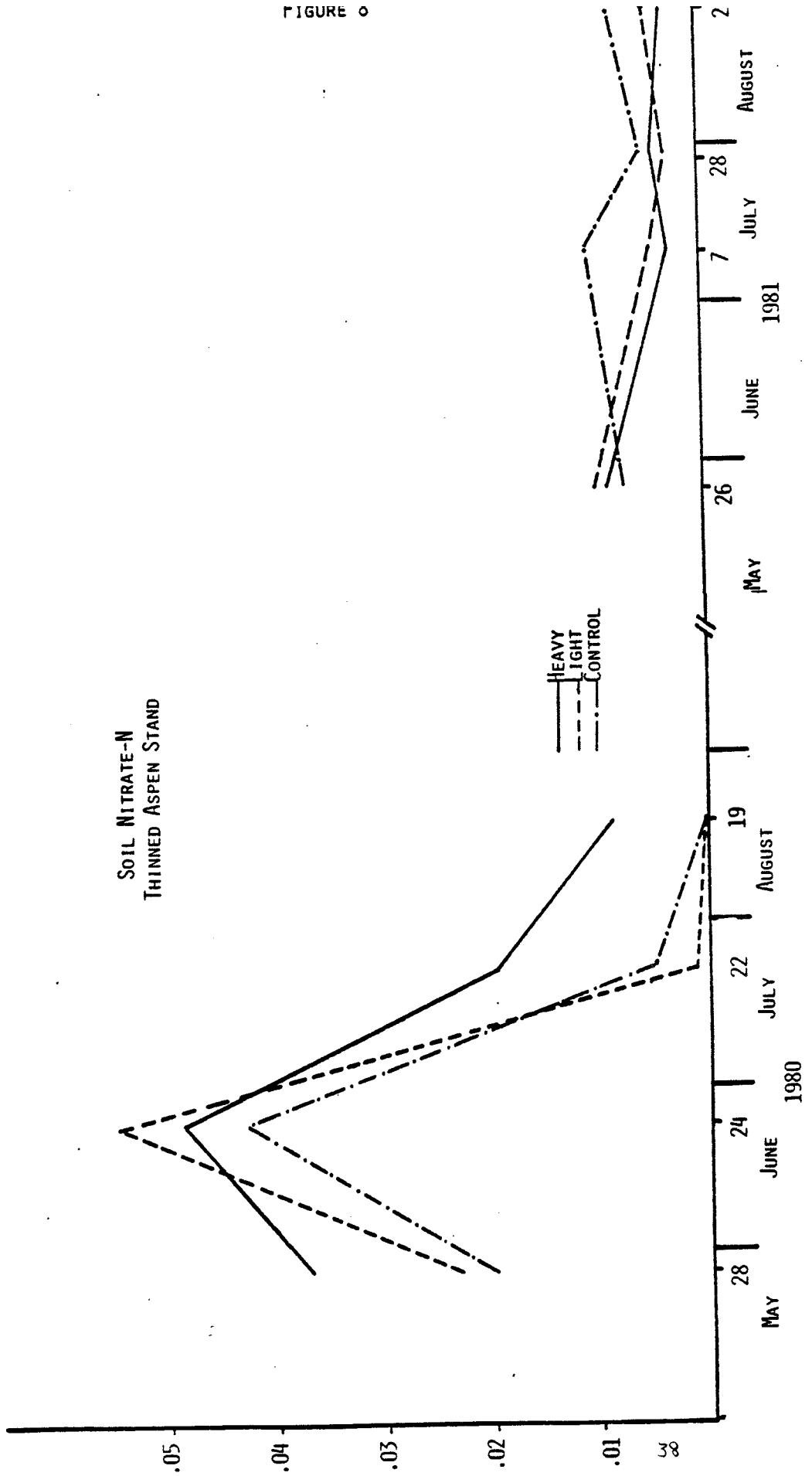
FIGURE 9

LITTER NITRATE-N
SPRUCE-FIR

HEAVY
LIGHT
CONTROL
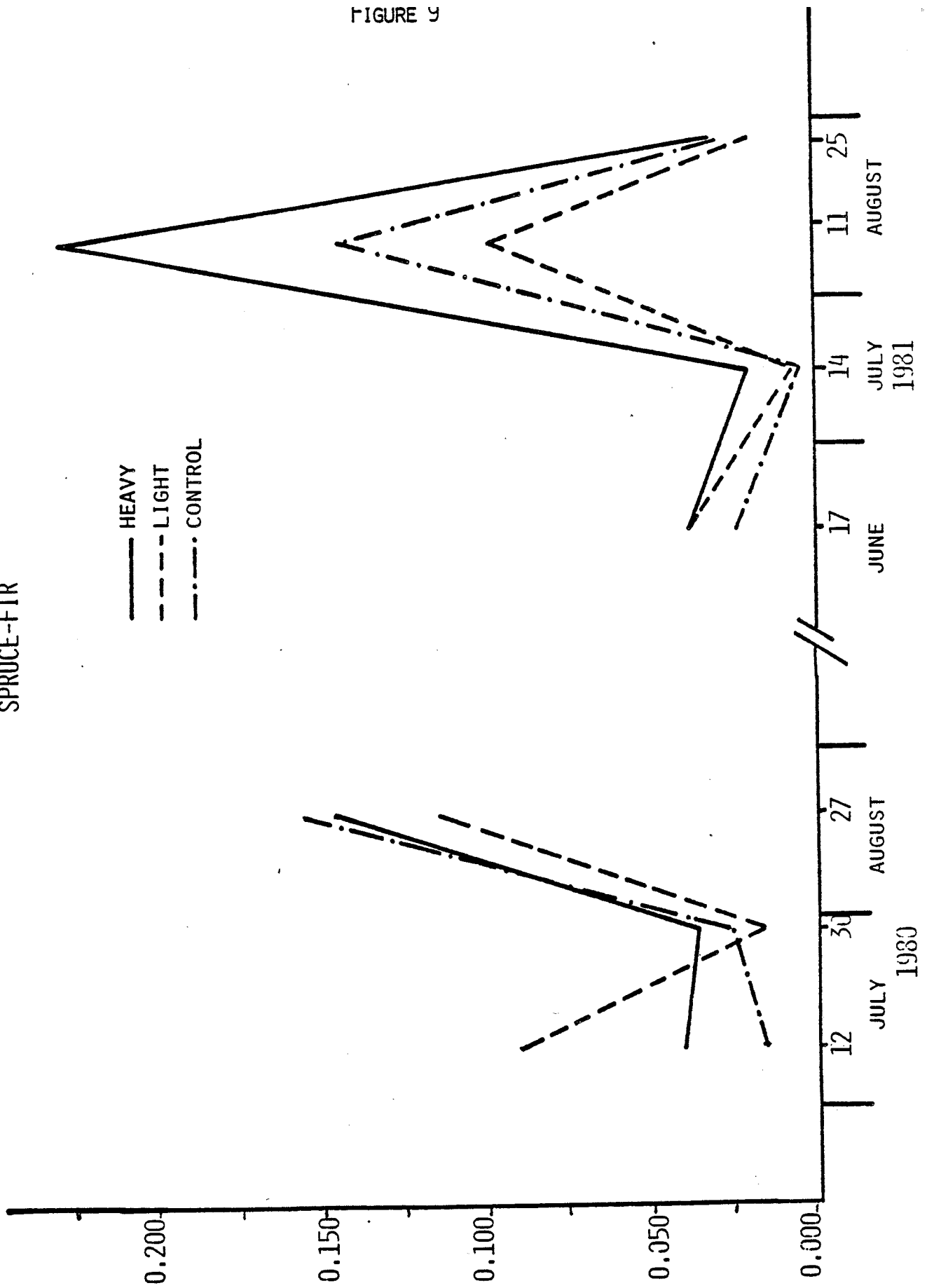
FIGURE 10

SOIL NITRATE - N

SPRUCE - FIR

——— HEAVY
---- LIGHT
—·— ·CONTROL

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FIGURE II

ASPEN CONTROL

MEAN LYSIMETER NITRATE – N

HEAVY
LIGHT
CONTROL

MG/L NO₃-N

1.0 0.8 0.6 0.4 0.2 0.0

10   23   30   13   26   9   23   7
APRIL   MAY 1981   JUNE   JULY

45
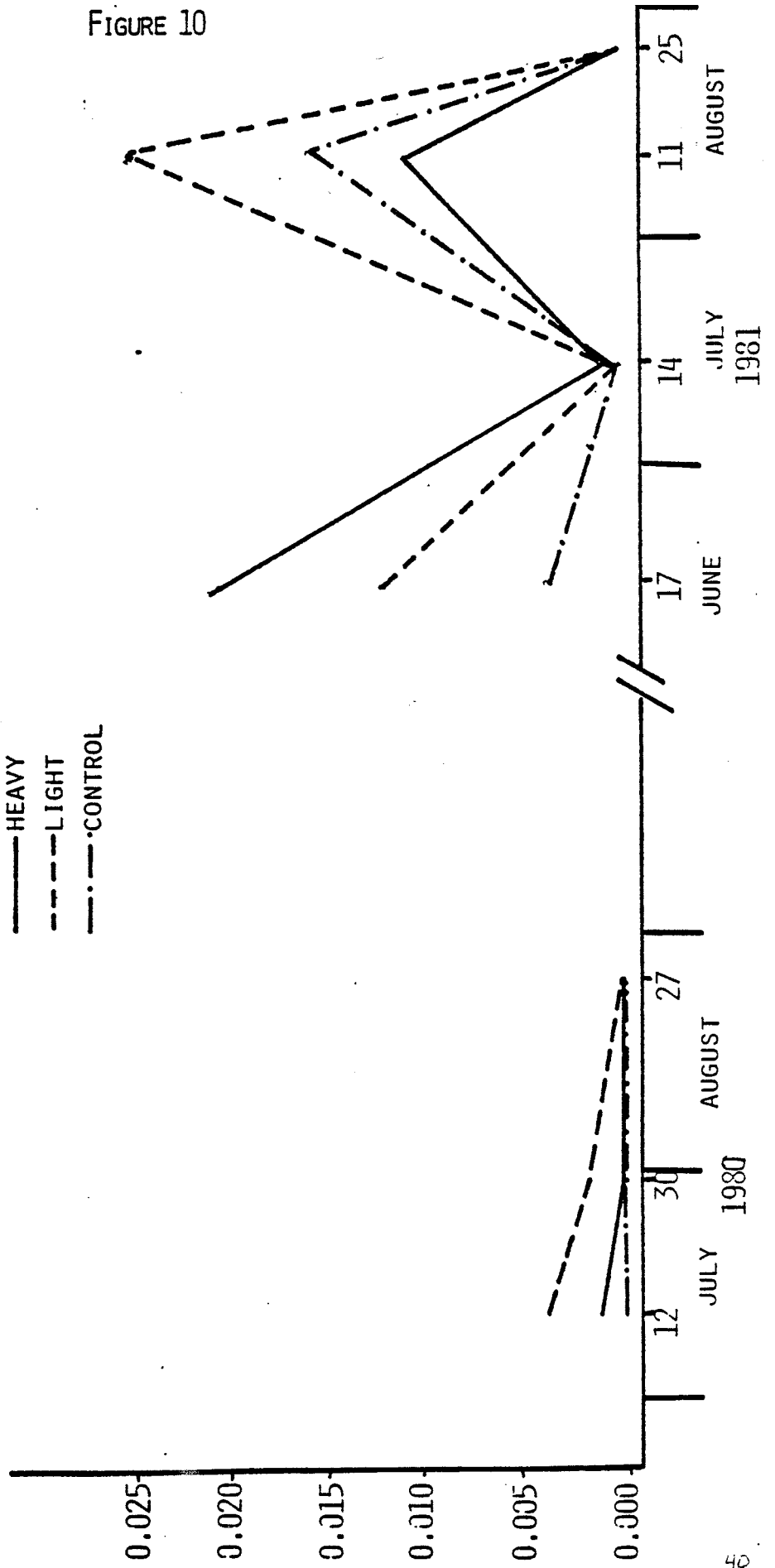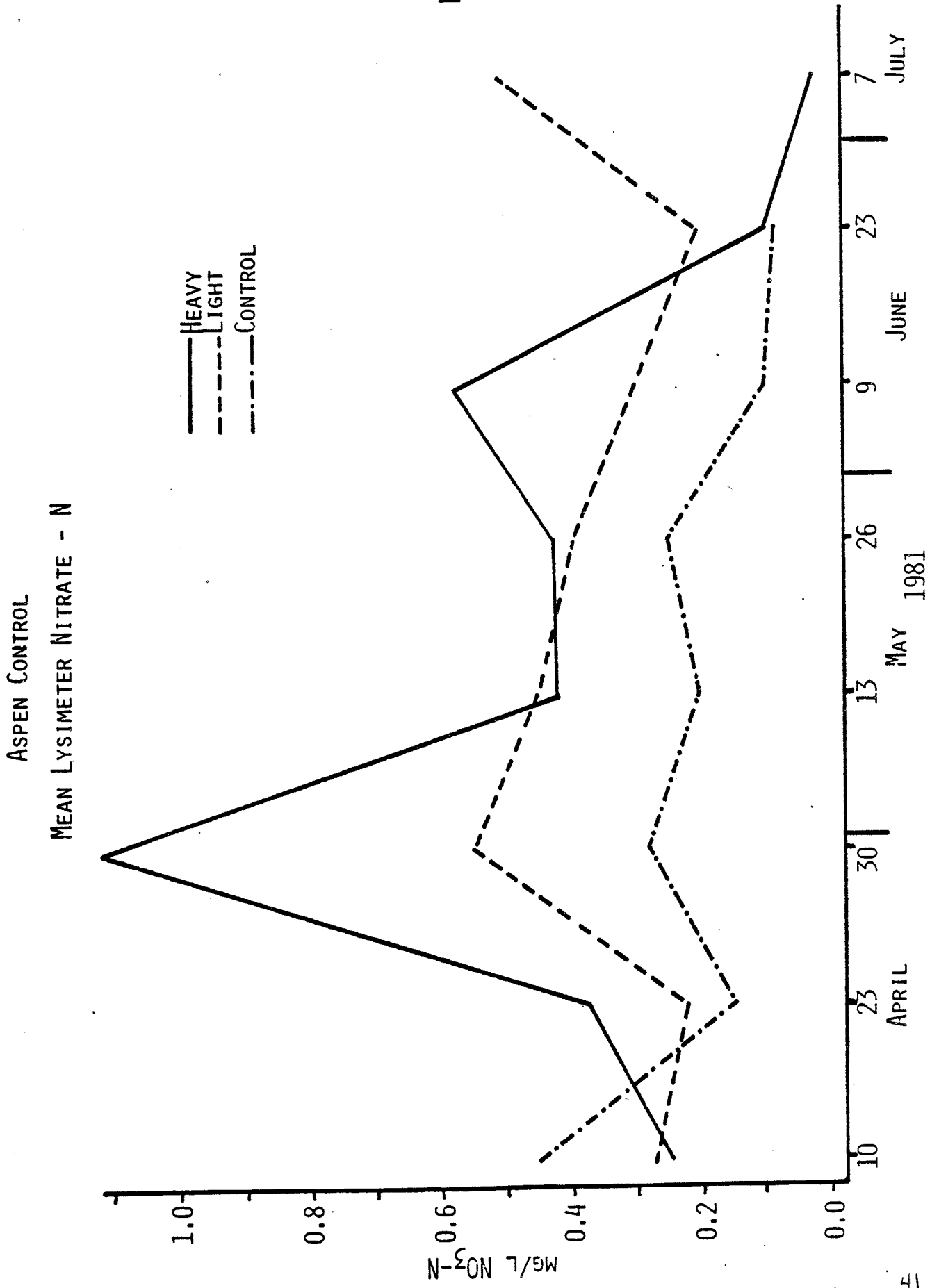
FIGURE 12

ASPEN FERTILIZED

MEAN LYSIMETER NITRATE - N

HEAVY
LIGHT
CONTROL

1981

42
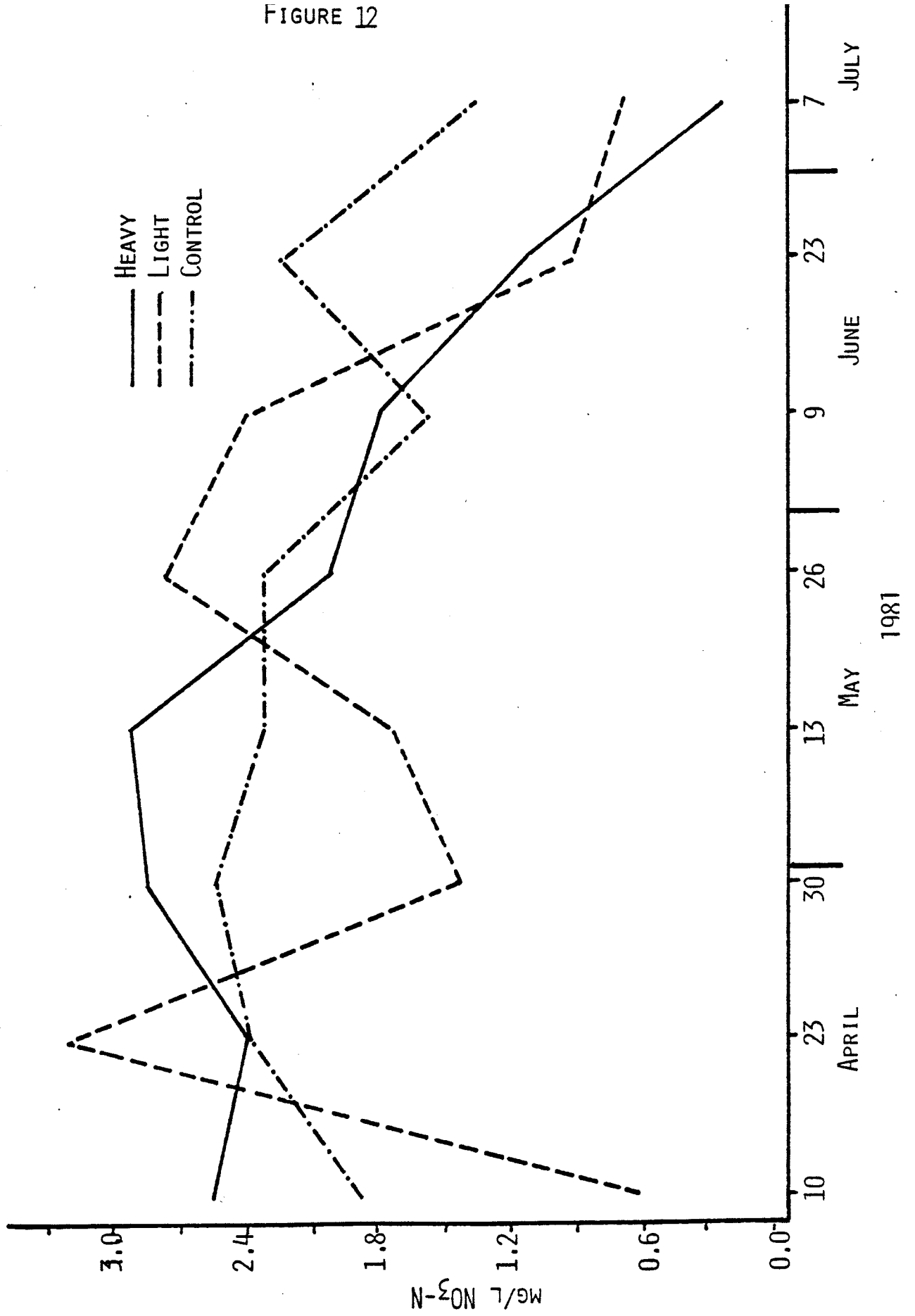
FIGURE 13

ASPEN THINNED

MEAN LYSIMETER NITRATE - N

HEAVY
LIGHT
CONTROL

43

Table 1. Forest floor dry weight (g/m^2) of natural, fertilized, and thinned aspen stands and spruce-fir subjected to different trampling intensities. May and August collections occurred before and after the trampling period, respectively. Means with different superscripts are significantly different (p<.05).

Trampling Intensity

Stand	Heavy				Light				Control			
	80		81		80		81		80		81	
	May	Aug	May	Aug	May	Aug	May	Aug	May	Aug	May	Aug
Fertilized Aspen	8636^a	4827^b	7411^{ab}	7332^{ab}	4786^{ab}	2185^a	5016^{ab}	8629^a	7014^a	7014^a	10790^a	80⋮
Thinned Aspen	4606^a	2768^a	10503^b	4027^a	3874^a	3888^a	10461^b	5514^a	5428^a	4001^a	12362^b	71⋮
Natural Aspen	6806^a	5514^a	10998^b	8175^{ab}	6446^a	6919^a	12569^b	10669^{ab}	6392^a	9024^{ab}	11944^b	115⋮
Spruce-fir	10450^a	8790^a	13430	*	11290^a	6600^b	10830	*	11030^a	7922^a	12460	

*samples lost

Table 2. Relative % cover (standard error) of bare ground overtime in aspen stands subject to different trampling intensities.

FERTILIZED ASPEN	HEAVY	LIGHT	CONTROL
5/28/80	1.20 (.66)	0.00	0.60 (.60)
6/23/80	2.3 (1.7)	0.6 (0.4)	2.8 (1.1)
7/23/80	2.2 (.8)	0.8 (0.6)	1.3 (0.8)
8/20/80	3.3 (2.1)	1.4 (0.8)	1.5 (0.7)

NATURAL ASPEN			
5/28/80	0.00	1.40 (1.11)	0.00
6/23/80	0.00	1.4 (1.1)	0.00
7/23/80	2.7 (1.1)	2.9 (1.0)	0.00
8/20/80	1.8 (0.9)	2.2 (2.2)	0.00

THINNED ASPEN			
5/28/80	2.20 (2.70)	1.20 (.66)	0.00
6/23/80	2.0 (1.5)	0.6 (0.6)	0.00
7/23/80	1.4 (.8)	1.8 (1.1)	0.00
8/20/80	1.7 (0.8)	2.2 (1.0)	0.3 (0.3)

Table 3. Forest floor organic content (g/m^2) of natural, fertilized, and thinned aspen stands subjected to different trampling intensities. May and August collections occurred before and after the trampling period, respectively. Means with different superscripts are significantly different $(p<.05)$.
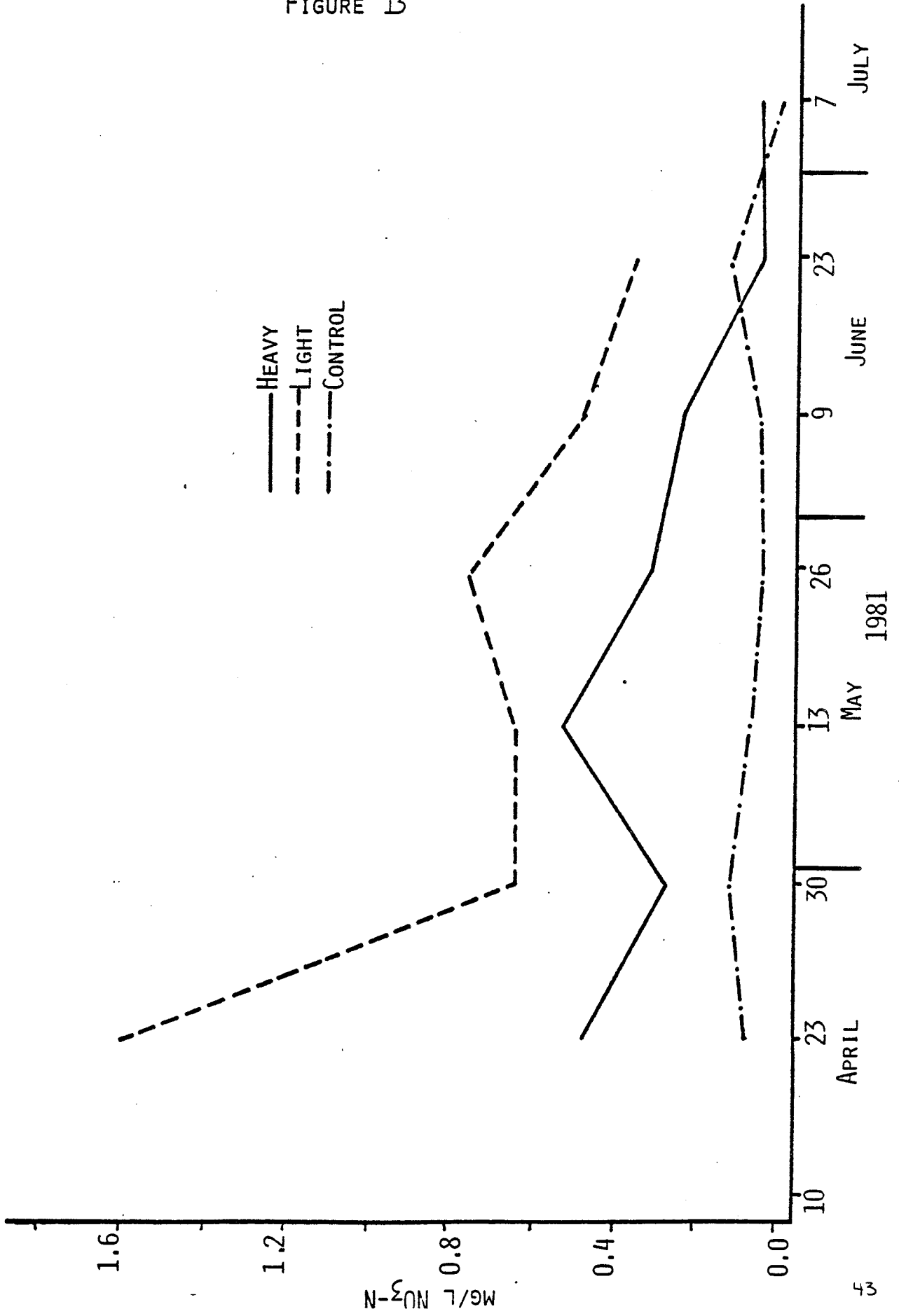
Trampling Intensity

Stand	Heavy				Light				Control			
	80		81		80		81		80		81	
	May	Aug	May	Aug	May	Aug	May	Aug	May	Aug	May	
Fertilized	4336[a]	3258[a]	3769[a]	4479[a]	1305[a]	620[b]	806[ab]	1258[a]	4565[a]	3836[a]	5314[a]	4
Thinned	3300[a]	2176[a]	6653[b]	2368[a]	2785[a]	2832[a]	4753[b]	3705[ab]	3427[ab]	2648[a]	5662[b]	5
Natural	4081[a]	3266[a]	5152[a]	5281[a]	4097[a]	4473[a]	5786[a]	6234[a]	4594[a]	6433[a]	7885[a]	7(

Table 4. Forest floor element content (g m^{-2}) of fertilized, thinned, and natural aspen stands subjected to different trampling intensities. May and August collections occurred before and after the trampling period, respectively. Means with different superscripts are significantly different (p<.05).

Trampling Intensity

Stand		Heavy				Light				Control			
		80		81		80		81		80		81	
		May	Aug	May	Aug	May	Aug	May	Aug	May	Aug	May	Aug
Fertilized													
	Ca	143^{a}	95^{a}	112^{a}	107^{a}	130^{b}	62^{a}	81^{ab}	126^{b}	138^{b}	107^{ab}	63^{a}	
	Mg	27^{b}	14^{a}	20^{ab}	16^{a}	23^{b}	8^{a}	18^{ab}	22^{b}	26^{b}	23^{ab}	14^{a}	
	K	20^{b}	11^{a}	15^{ab}	12^{a}	16^{ab}	7^{a}	24^{b}	20^{b}	18^{a}	18^{a}	19^{a}	
	N	61^{a}	82^{ab}	115^{b}	120^{b}	85^{ab}	57^{a}	143^{bc}	153^{c}	101^{a}	98^{a}	110^{a}	
	P	4^{a}	5^{a}	8^{b}	8^{b}	6^{ab}	3^{a}	9^{bc}	10^{c}	7^{a}	6^{a}	7^{a}	
Thinned													
	Ca	95^{b}	71^{ab}	60^{a}	60^{a}	71^{a}	81^{a}	74^{a}	83^{a}	112^{ab}	88^{a}	158^{b}	
	Mg	12^{ab}	8^{a}	13^{b}	9^{ab}	10^{a}	10^{a}	19^{b}	13^{a}	17^{a}	13^{a}	39^{b}	
	K	8^{a}	6^{a}	17^{b}	7^{a}	7^{a}	7^{a}	23^{b}	10^{a}	12^{a}	9^{a}	30^{b}	
	N	78^{b}	46^{a}	104^{b}	47^{a}	54^{a}	65^{a}	122^{b}	74^{a}	86^{a}	72^{a}	173^{b}	
	P	5^{a}	3^{a}	9^{b}	3^{a}	4^{a}	4^{a}	11^{b}	6^{a}	6^{a}	5^{a}	13^{b}	
Natural													
	Ca	135^{a}	105^{a}	115^{a}	117^{a}	134^{ab}	150^{b}	86^{a}	141^{b}	156^{a}	184^{a}	199^{b}	
	Mg	25^{a}	19^{a}	20^{a}	19^{a}	22^{a}	25^{a}	21^{a}	27^{a}	19^{a}	25^{ab}	18^{a}	
	K	20^{a}	15^{a}	18^{a}	15^{a}	16^{a}	21^{ab}	30^{b}	21^{ab}	17^{a}	21^{ab}	26^{b}	
	N	104^{a}	90^{a}	144^{a}	111^{a}	107^{a}	126^{a}	161^{a}	154^{a}	122^{a}	171^{a}	172^{a}	
	P	8^{ab}	6^{a}	12^{b}	8^{ab}	7^{a}	8^{ab}	13^{b}	12^{ab}	8^{a}	11^{ab}	12^{b}	

Table 5. Standing crop (g/m^2 ash free dry wt. $\pm$ 1 standard error) of understory vegetation in
control and treatment plots surrounding the two aspen and conifer study streams at the
end of one season of trampling. Comparisons were made within streams only.

	Stream 1			Stream 2		
	Control		Treatment	Control		Treatment
ASPEN	60.790 $\pm$ 9.436	P<0.05	34.198 $\pm$ 9.382	64.332 $\pm$ 6.324	P<0.005	29.860 $\pm$ 7.60
CONIFER	38.482 $\pm$ 23.354	NS	13.198 $\pm$ 3.758	1.502 $\pm$ 0.704	NS	0.626 $\pm$ 0.380

Table 6. Comparisons of Forest floor (g/m^2 ash free dry wt. $\pm$ 1 standard error) in treatments vs controls before (May, 1981) and after (August-September, 1981) one season of trampling along each study stream. No significant differences were found.

	Before		After	
ASPEN	Control	Treatment	Control	Treatment
Stream 1	3704 $\pm$ 1056 NS	3147 $\pm$ 864	2113 $\pm$ 813 NS	1606 $\pm$ 481
Stream 2	3084 $\pm$ 433 NS	6242 $\pm$ 2118	1059 $\pm$ 153 NS	2319 $\pm$ 814

	Before		After	
CONIFER	Control	Treatment	Control	Treatment
Stream 1	8236 $\pm$ 1580 NS	8501 $\pm$ 1518	3860 $\pm$ 680 NS	6595 $\pm$ 1968
Stream 2	5606 $\pm$ 1367 NS	6205 $\pm$ 832	5024 $\pm$ 1300 NS	2450 $\pm$ 596

Table 7. Litterfall into the two aspen and conifer study streams (g/m^2 ash free dry wt $\pm$ 1 standard error) July-November, 1981. There were no significant differences in litterfall between control and treatment reaches on any of the streams (P > 0.05 Mann-Whitney U, Zar 1974). Comparisons were made within streams only.

| | Stream 1 | | Stream 2 | |
	Control	Treatment	Control	Treatment
ASPEN	196.78 $\pm$ 12.28 NS	216.53 $\pm$ 9.77	105.57 $\pm$ 9.05 NS	120.16 $\pm$ 11.92
CONIFER	48.06 $\pm$ 14.35 NS	144.87 $\pm$ 45.05	70.07 $\pm$ 6.39 NS	54.38 $\pm$ 18.75

Table 8. Downslope transport of particulate organic matter to the two aspen and conifer study streams, July 1981–June 1982. Values are g (ash free dry wt) per m of stream length. Comparisons were made within streams only (Mann–Whitney U, Zar 1984).

| | Stream 1 | | | | Stream 2 | | |
	Control		Treatment		Control		Treatment
ASPEN	61.60 ± 16.62	P<0.05	158.04 ± 37.62		81.39 ± 14.75	NS	128.19 ± 40.87
CONIFER	126.20 ± 53.56	P<0.025	456.00 ± 184.57		179.46 ± 22.76	P<0.05	404.58 ± 54.25

Table 9. Standing stock of fine and coarse particulate organic matter in the two aspen and conifer study streams (g/m^2 ash free dry wt $\pm$ 1 standard error) before (B, July 8, 1981) and after (A, Sept.-December 1, 1981) one season of trampling. Means with different superscripts are significantly different (P < 0.005 Kruskal-Wallis multiple comparison, Zar 1974). Comparisons are within streams only.

ASPEN

Stream 1

	Control		Treatment	
	B	A	B	A
FPOM	47.20 $\pm$ 18.20[a]	33.50 $\pm$ 12.30[a]	23.20 $\pm$ 9.50[a]	20.00 $\pm$ 7.70[a]
CPOM	203.60 $\pm$ 40.80[a]	271.90 $\pm$ 105.90[a]	102.10 $\pm$ 48.00[b]	527.10 $\pm$ 127.40[a]

Stream 2

	Control		Treatment	
	B	A	B	A
FPOM	9.50 $\pm$ 5.10[a]	0.50 $\pm$ 0.30[b]	19.10 $\pm$ 14.30[a]	1.60 $\pm$ 0.60[c]
CPOM	33.20 $\pm$ 20.10[a]	150.10 $\pm$ 62.50[b]	81.60 $\pm$ 34.20[b]	328.00 $\pm$ 142.90[c]

CONIFER

Stream 1

	Control		Treatment	
	B	A	B	A
FPOM	51.30 $\pm$ 17.80[a]	12.60 $\pm$ 4.20[a]	18.10 $\pm$ 4.40[a]	21.40 $\pm$ 8.00[a]
CPOM	316.30 $\pm$ 126.10[a]	441.80 $\pm$ 130.60[a]	820.50 $\pm$ 270.50[a]	1469.20 $\pm$ 554.50[a]

Stream 2

	Control		Treatment	
	B	A	B	A
FPOM	116.60 $\pm$ 23.30[a]	67.30 $\pm$ 14.10[b]	100.90 $\pm$ 22.00[a]	157.90 $\pm$ 37.00[c]
CPOM	3122.90 $\pm$ 579.30[a]	2496.00 $\pm$ 373.90[b]	3089.00 $\pm$ 506.80[b]	4052.60 $\pm$ 496.20[c]

Table 10. Dissolved organic compounds expressed as peak area counts in aspen streamwater between non-trampled (control) and trampled sites.

| Date | Treatment | Fraction | |
		Neutral (x ± SD)	Acid (x ± SD)
July, 1981	C	43.7 ± 15.2	3.0 ± 1.4
	T	88.1 ± 32.0	5.1 ± 1.6
August, 1981	C	140.6 ± 170.9	4.1 ± 0.6
	T	66.9 ± 24.3	3.3 ± 2.2
June, 1982	C	319.1 ± 225.8	4.3 ± 1.3
	T	506.9 ± 1.5	3.6 ± 0.1
July, 1982	C	148.1 ± 23.7	2.4 ± 0.8
	T	145.7 ± 38.9	2.3 ± 1.0

Table 11. ANOVA of the neutal dissolved organic content of aspen streamwater.

Effect	F	P
(Streams)	0.02	0.90
Treatment (Trampling)	0.78	0.39
Season	6.64	0.02*
Year	19.75	0.0002*
Treatment x Season	4.79	0.04*
Treatment x Year	2.11	0.16
Season x Year	14.46	0.0011*

* = significant at $\leq$ 0.05

Table 12. Dissolved organic compounds expressed as peak area counts, in spruce-fir streamwater between non-trampled (control) and trampled sites.[*]

Dates	Treatment	Neutral Fraction ($\lambda \pm$ SD)	Acid Fraction ($\lambda \pm$ SD)
July, 1981	C	44.3 ± 22.1	3.0 ± 0.5
	T	69.8 ± ----	0.2 ± ---
August, 1981	C	48.1 ± 5.4	1.9 ± 2.4
	T	---- ---	--- ---
July, 1982	C	155.0 ± 6.1	4.4 ± 0.6
	T	127.3 ± ---	5.9 ± ---

Table 13. Dissolved organic compounds expressed as peak area counts in aspen lysimeter water between non-trampled (control) and trampled sites.

	Neutrals				Acids		
Season		Treatment		Season		Treatment	
Early	535.2 ± 348	Control	997.3 ± 945*	Early	27.9 ± 23	Control	68.7 ± 123
Late	896.2 ± 961	Trampled	390.9 ± 121	Late	74.0 ± 121	Trampled	35.4 ± 24

*Vertical means significant at 0.05 or less

Table 14. Dissolved organic compounds expressed as peak
area counts from lysimeter collections in
spruce-fir between non-trampled (control) and
trampled sites.

| Season | Treatment | Fraction | |
		Neutral	Acid
7/81	C	1979.0 ± 1201.3*	89.9 ± 138.7
	T	521.8 ± 223.3	43.0 ± 47.8
8/81	C	2044.0 ± 2333.5*	40.1 ± 33.6
	T	520.0 ± 212.1	41.7 ± 53.4

* = $p < 0.0003$

One Way Anova