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RESPONSE OF A FOREST ECOTONE TO IONIZING RADIATION

Progress Report

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Abstract

Compositional and structural characteristics of three forest types, including aspen dominated, maple-birch dominated, and an intervening ecotone, were studied before and after irradiation in northern Wisconsin. Preirradiation findings are reported in papers by Murphy and Sharitz (1974) and Murphy, Sharitz, and Murphy (1974).

Irradiation occurred during the summer of 1972. Preliminary data indicate that by the summer of 1973 the density of viable tree seedlings at 10 m from the radiation source was substantially reduced in all three areas relative to the preirradiation densities of 1971. At 20 m and beyond, the density of seedlings in the three areas increased during the period between 1971 and 1973. The overall density of seedlings of *Populus tremuloides* and *Acer rubrum* increased markedly in the three areas and *P. tremuloides* invaded some areas in which it had not been found prior to irradiation. The density of viable trees greater than 2.5 cm d.b.h. decreased sharply at 10 m in the aspen area and ecotone but decreased only slightly in the maple-birch area where all *Acer rubrum* and *Betula papyrifera* in the 10 m transect were still viable in 1973.

Leaf litter production was reduced by up to 94% at 10 m and 64% at 20 m during the period between 1971 and 1973 in the irradiated areas. Leaf litter production was most severely reduced in the aspen area. The overall increase in seedling density at 20 m from the radiation source and beyond may be associated with the opening of the canopy as evidenced by the reduction in leaf litter production. The rate and compositional characteristics of succession in the ecotone relative to aspen and maple-birch forest types is presently under study.

Preface

The investigations described herein and in the two appended reprints were undertaken as a cooperative research effort with the Radiobiology of Northern Forest Communities Project of the Institute of Forest Genetics at Rhinelander, Wisconsin.

Approximately 15% of my time (Principal Investigator) has been devoted to the project since the begining of the current term of the agreement. At least 15% of my time will be devoted to the project during the remainder of the current term. Dr. Rebecca Sharitz (Associate Investigator) has devoted approximately 15% of her time to the project and expects to devote a similar proportion of her time to the project during the remainder of the current term.

Preirradiation Studies

The collection and analysis of preirradiation data as described in the original proposal has been completed. The results of this work are summarized in two papers that were published in the AEC volume entitled The Enterprise, Wisconsin, Radiation Forest (TID-26113). Reprints of the two papers are appended to this report. One of the papers, entitled Properties of the Tree Flora in the Forest Transition from Aspen to Maple-Birch Type, describes in detail the primary accomplishments of the study preceding irradiation as set forth in the original proposal. The paper characterizes the structure and floristic composition of the three forest areas and serves as a baseline for evaluating the effects of radiation along the ecotone. The second paper, entitled Leaf-Litter Production in the Aspen and Maple-Birch Forest Types and the Contribution by Individual Tree Species, summarizes a portion of the ecotone study which developed subsequent to submission of the original proposal.

Oral presentations of preliminary findings were made at two conferences during 1973: the Annual Meeting of the Michigan Academy of Science and the Annual Meeting of the American Institute of Biological Science.

Postirradiation Studies

Using the permanent transects established in the preirradiation study, preliminary data concerning the response of the three forest areas to irradiation were collected during the summer and fall of 1972 and 1973. Two additional sampling trips are scheduled for the present contract period. The collection and analysis of postirradiation data has, therefore, not been completed at this time. The following sections review the preliminary data concerning changes in tree species composition and changes in patterns of leaf litter production subsequent to irradiation.

Tree Species Composition

Figures 1 through 3 show the change in density of viable trees, by size class, in the aspen, ecotone, maple-birch, and control areas from 1971, preceding irradiation, to 1973, nine months following irradiation. Irradiation occurred during the summer of 1972. The data for 1972 were collected while irradiation was still occurring and mortality was not fully expressed at that time.

Aspen Area. In the aspen area at 10 m from the radiation source the density of tree seedlings (less than 30 cm tall) increased from 24/10 m^2 in 1971 to 35/10 m^2 in 1972 and then declined, in response to irradiation, to only 2/10 m^2 nine months later in June of 1973 (Fig. 1-A). The only viable seedlings remaining in 1973 were of the species *Acer rubrum* but even seedlings of that species were reduced in numbers by 88% between 1972 and 1973. The curves in Fig. 1-A show that seedling density at 20 m and beyond increased between 1971 and 1973. At 40 and 50 m from the source, the density of seedlings increased by 130%. Most of this increase was due to an increased abundance of *A. rubrum*, *Acer saccharum*, and *Populus tremuloides*. Between 1971 and 1973 the number of *P. tremuloides* seedlings increased by 850% in the 40 m transect and 53% in the 50 m transect. In the aspen control area the overall seedling density increased from 0.5/10 m^2 in 1971 to 3/10 m^2 in 1973.

Class 1 saplings (30-100 cm tall) were eliminated at 10 m but increased in density at greater distances except in the control area

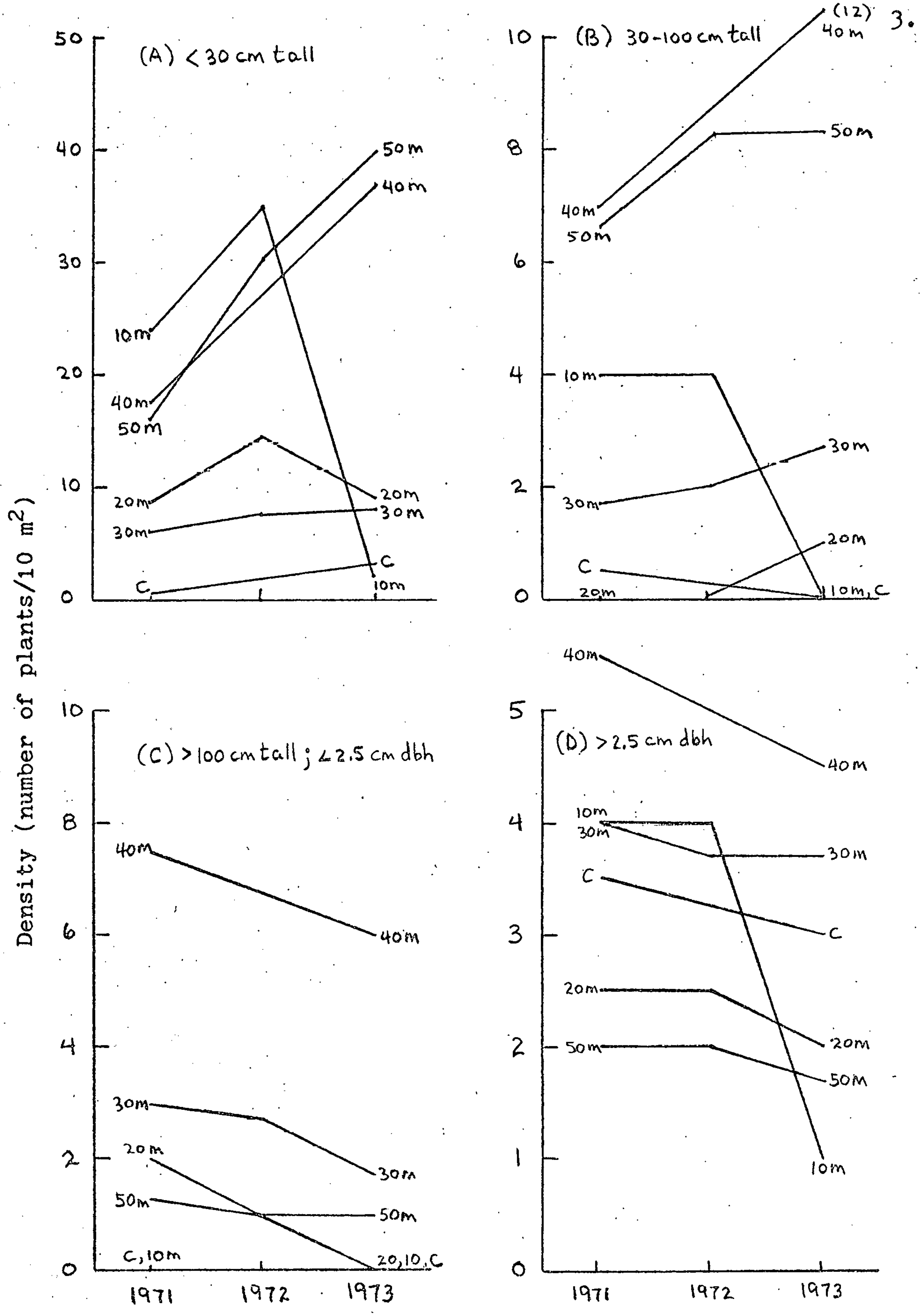

Figure 1. Density of tree species in the irradiated and control aspen areas. Distance from radiation source is indicated in meters (m). C = control.

where the density declined from 0.5/10 m^2 to 0/10 m^2 between 1971 and 1973 (Fig. 1-B). Class 2 saplings (greater than 100 cm tall, less than 2.5 cm d.b.h.) were not present in the 10 m transect but declined in density from 2/10 m^2 to 0/10 m^2 at 20 m during the period between 1971 and 1973. A less pronounced decline was observed in all other transects (Fig. 1-C).

Viable trees (greater than 2.5 cm d.b.h.) declined in density at all distances from the radiation source during the period between 1971 and 1973 (Fig. 1-D). The decline at 10 m was most pronounced (4 trees/10 m^2 in 1971 to 1 tree/10 m^2 in 1973). All these trees were of the species P. tremuloides. The extent of density decline of trees at distances greater than 10 m was less and fairly uniform among transects (Fig. 1-D).

Ecotone. In the ecotone between aspen and maple-birch areas the density of seedlings at 10 m declined sharply from 23/10 m^2 in 1971 to 7/10 m^2 in 1973 (Fig. 2-A). All of the original seedlings at 10 m were killed. The seedlings present in 1973 established themselves subsequent to irradiation. The new seedlings included two species, A. rubrum and P. tremuloides, both of which were absent in 1971. At 20 m and beyond, the density of seedlings increased. The sharp increase at 20 m was due largely to P. tremuloides which attained a density of 16/10 m^2 eventhough it had not been present in 1972. Half of the Abies balsamea seedlings were killed at 20 m.

Class 1 saplings were absent from the 10 m transect over the period observed but their density at all other distances increased between 1971 and 1973 (Fig. 2-B) partly because of the increased density of A. saccharum, P. tremuloides, Amelanchier sp., Fraxinus nigra, Prunus serotina, and Prunus virginiana. Class 2 saplings were

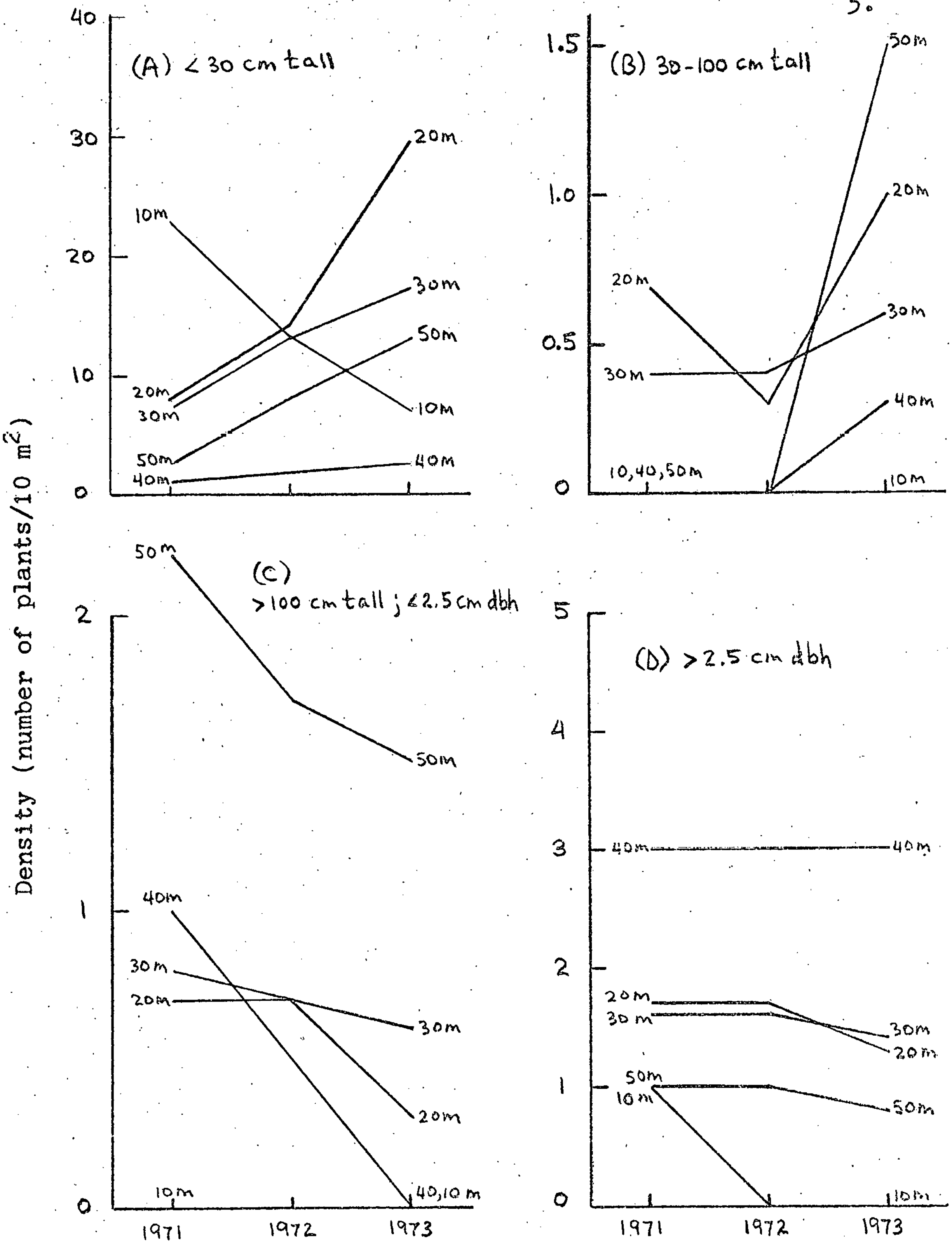

Figure 2. Density of tree species in the ecotone. Distance from radiation source is indicated in meters (m).

absent from the 10 m transect and they declined in density at all other distances (Fig. 2-C). Seven species in this size class showed a decline and only three maintained their original densities. No species in the class 2 sapling category increased in density between 1971 and 1973 in the ecotonal zone.

There was only one tree greater than 2.5 cm d.b.h. at 10 m in the ecotone and it (A. balsamea) was dead by the end of the 1972 growing season. The density of trees at greater distances from the source declined only slightly, due primarily to the loss of some individuals of A. rubrum and P. tremuloides (Fig. 2-D).

Maple-Birch Area. In the maple-birch area the density of tree seedlings at 10 m declined from 7/10 m^2 in 1971 to 1/10 m^2 in 1973 (Fig. 3-A). The only viable seedlings present at 10 m in 1973 were of the species A. rubrum and Quercus rubra. At all other distances the overall number of seedlings increased. The large increase in density at 20 m (240%) was due primarily to A. rubrum, P. tremuloides, Fraxinus americana, and A. saccharum. All of the other species present at 20 m declined in density. With only a few exceptions this pattern was also observed at 30, 40, and 50 m. Many of the species present in the irradiated area were absent from the control area but the overall number of seedlings in the control area did increase, due largely to P. tremuloides, Betula papyrifera and Ostrya virginiana.

A notable aspect of the pattern of change in seedling density in the maple-birch area is the appearance of P. tremuloides in 1973 at all distances except 10 m. In 1971 and 1972 P. tremuloides had been entirely absent, as seedlings, in these areas. The greatest influx of P. tremuloides seedlings was at 20 m where the density

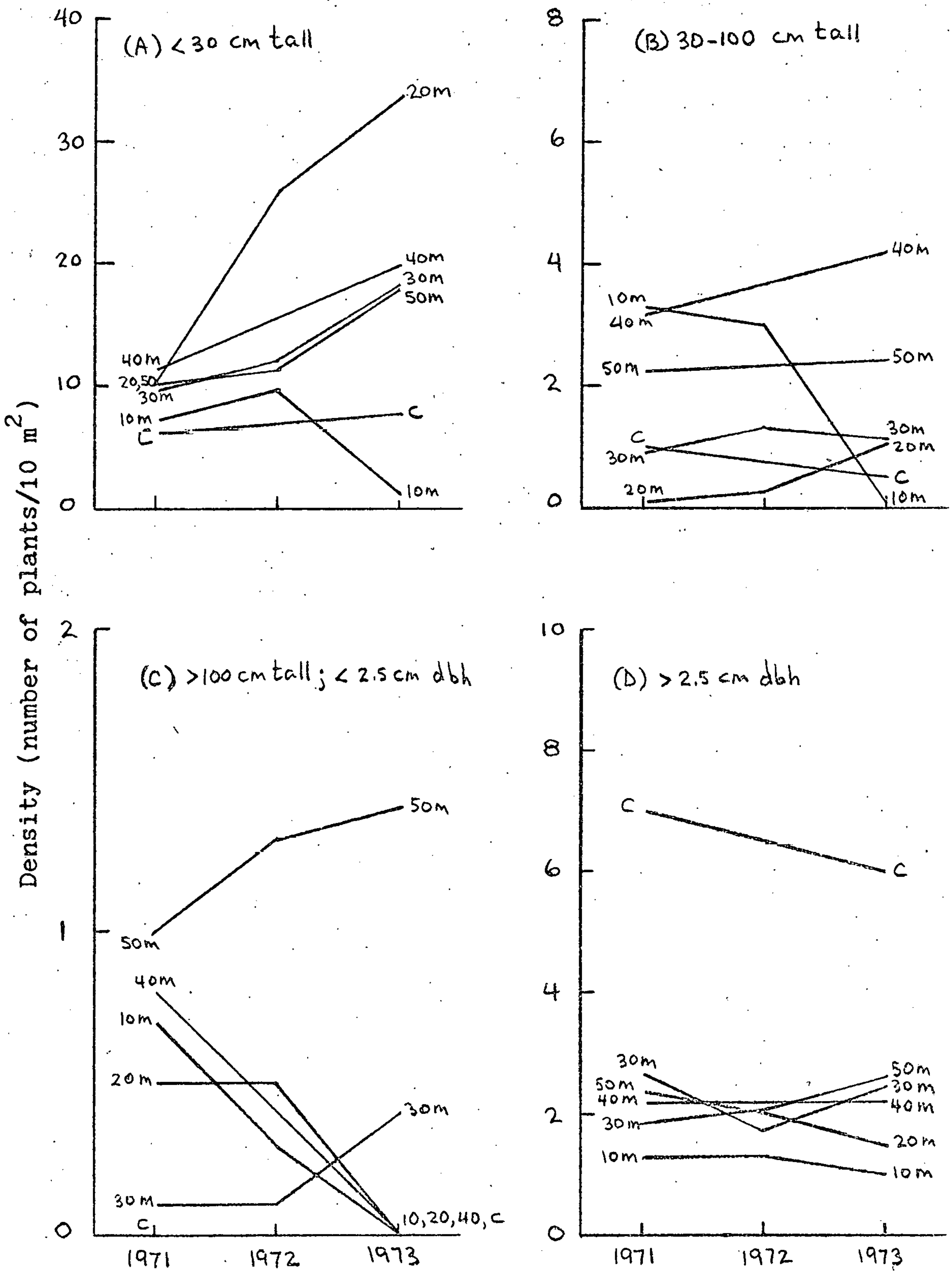

Figure 3. Density of tree species in the irradiated and control maple-birch areas. Distance from radiation source is indicated in meters (m). C = control.

increased from $0/10\ m^2$ in 1971 and 1972 to $24.5/10\ m^2$ in 1973. The extent of P. tremuloides influx diminished with distance from the radiation source. In the control area P. tremuloides increased from $0/10\ m^2$ to $0.5/10\ m^2$ during the same period.

The density of class 1 saplings at 10 m declined from $3.3/10\ m^2$ in 1971 to 0 in 1973. At all other distances in the irradiated maple-birch area the number of class 1 saplings increased slightly during the same period (Fig. 3-B). There was a slight decline in the control area. At 20 and 30 m, class 1 saplings of P. tremuloides appeared in 1973, having been absent prior to that time. Presumably these plants represent fast growing individuals (possibly root suckers) that grew to a height in excess of 30 cm within one year.

Class 2 saplings exhibited an unusual pattern of density change between 1971 and 1973 as shown in Fig. 3-C. Density declined to 0 at 10, 20 and 40 m but increased at 30 and 50 m. No class 2 saplings were present in the control area during the entire period. The increase at 30 m was due to Amalanchier sp. and F. nigra, both of which declined in numbers, as class 2 saplings, at 40 m. The increase in density at 50 m was due largely to an increase in density of O. virginiana.

Between 1971 and 1973 the density of trees (greater than 2.5 cm d.b.h.) declined only slightly at 10, 20 and 30 m, remained the same at 40 m and increased slightly at 50 m (Fig. 3-D). The surviving species at 10 m were A. rubrum and B. papyrifera, both of which remained at their original densities. A. saccharum was eliminated at 10 m. At 20 m A. saccharum, P. tremuloides and B. papyrifera trees remained at their original densities whereas A. rubrum declined by 37.5% and P. grandidentata was eliminated. Trees in the control area declined in density because of the death of several individuals of A. rubrum and P. tremuloides. The density of B. papyrifera in the control area remained unchanged.

Overall Change in the Abundance of Tree Species. In all three areas the total (all distances from the radiation source grouped) density of tree seedlings increased, the total density of class 2 saplings decreased and the total density of trees decreased between 1971 and 1973. The total density of class 1 saplings increased in the aspen and ecotone areas but decreased slightly in the maple-birch area. Considering all size-classes pooled, the aspen, ecotone, and maple-birch areas showed increases in the density of tree species of 14.5%, 46.4%, and 55.6% respectively. In the aspen control area the density of tree species increased by36.4% between 1971 and 1973 and in the maple-birch control area the density remained constant over the same period.

Leaf Litter Production

One of the appended reprints (Murphy et al., 1974) reports on preirradiation rates of leaf litter production in the experimental areas and, more specifically, the contribution by individual tree species to total leaf litter production. We found a direct relation between the relative basal area for a given species and its relative leaf litter production (biomass basis). We also found that it was possible to estimate forest diversity patterns by determining the diversity of leaves produced. We therefore intend to utilize data on leaf litter collected subsequent to irradiation to estimate and interpret changes in the composition of the forest canopy. The data for individual tree species are currently being analyzed. Changes in total leaf litter production in response to irradiation are summarized below.

Figures 4 through 7 show changes in leaf litter production in the control and irradiated areas over the period 1971 to 1973. The plots for the irradiated area show production according to distance from the radiation source.

The curves in Fig. 4 for the control areas indicate that leaf litter production was not constant over the observed period. In all control areas leaf litter production was greater in 1972 than in 1971. In all but two plots leaf litter production declined in 1973. In no plot was there more than a 28% deviation in leaf litter production relative to 1971 and the largest difference between production in 1971 and 1973 was only 12%.

Leaf litter production in the irradiated areas was more erratic over the three year period (Figs. 5-7). Some of the year to year variation may be due to climatic variation (1972 was exceptionally moist) and sampling error but it is clear that leaf litter production was influenced by irradiation, at least to 20 m, in the three forest types observed. The most pronounced reduction in the production of foliage occurred at 10 m . In the aspen, ecotone and maple-birch areas leaf litter production at 10 m was 93.9, 52.6, and 60.2% lower in 1973 than in 1971, respectively. At 20 m foliage production was depressed by 61.9, 29.6, and 24.8% over the same period in the three areas respectively. At 30 m leaf litter production was depressed by 4.1 and 5.3% in the ecotone and maple-birch areas between 1971 and 1973 but increased by 22.0% in the aspen area. At this time it seems safe to conclude that leaf litter production was definitely reduced by irradiation at distances up to 20 m from the radiation source. We intend to analyze the species composition of the leaf

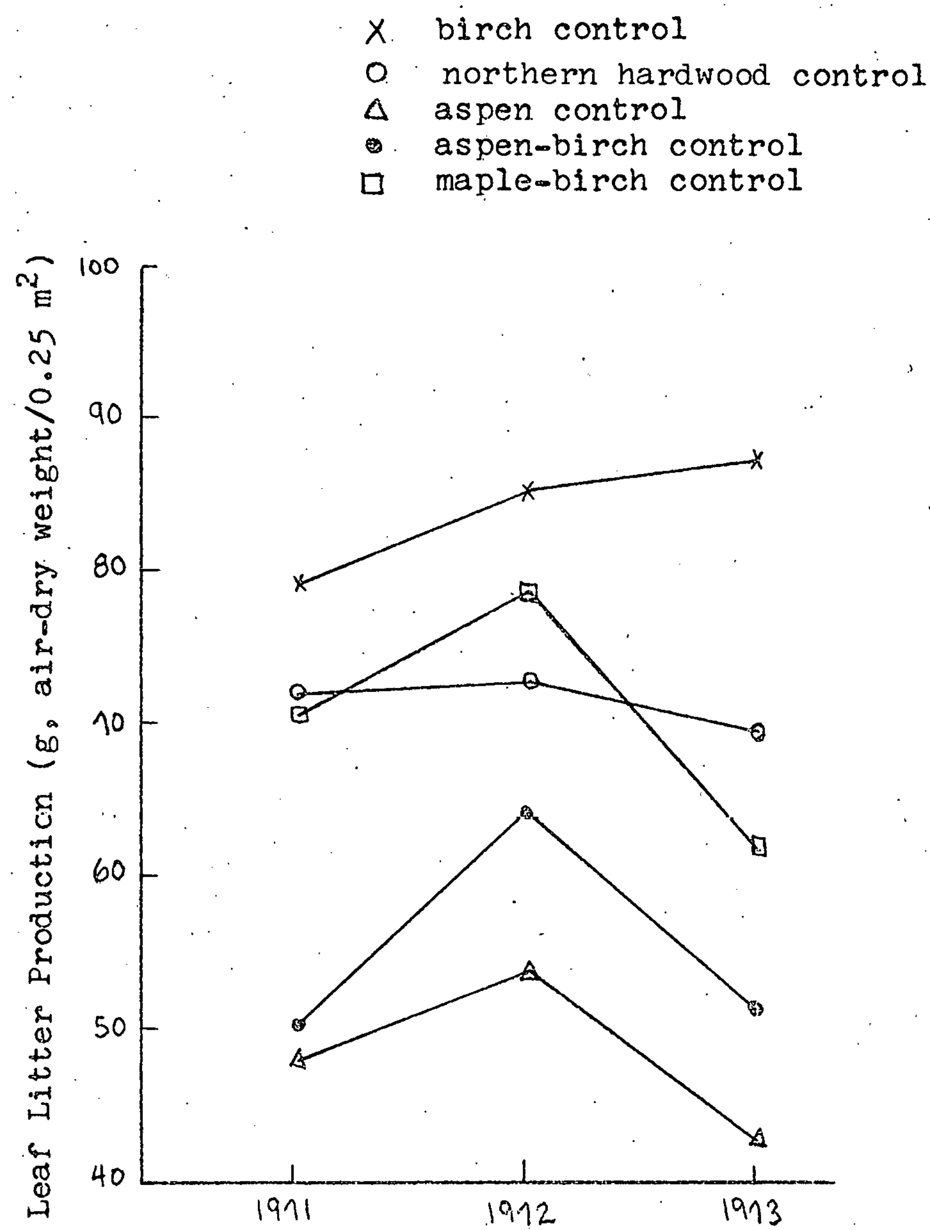

Figure 4. Annual leaf litter production in the control areas.

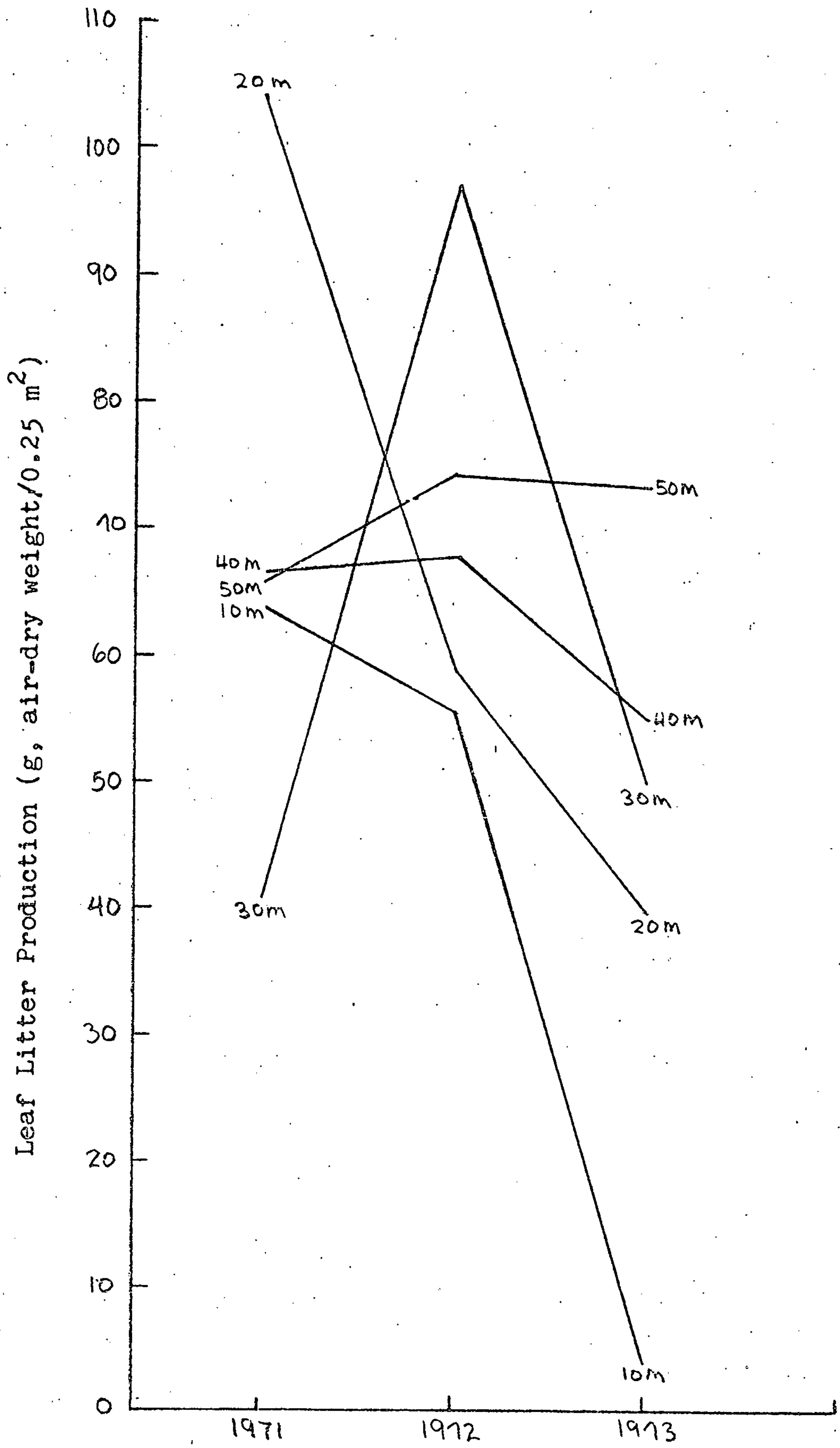

Figure 5. Annual leaf litter production in the aspen area. Distance from radiation source is indicated in meters (m).

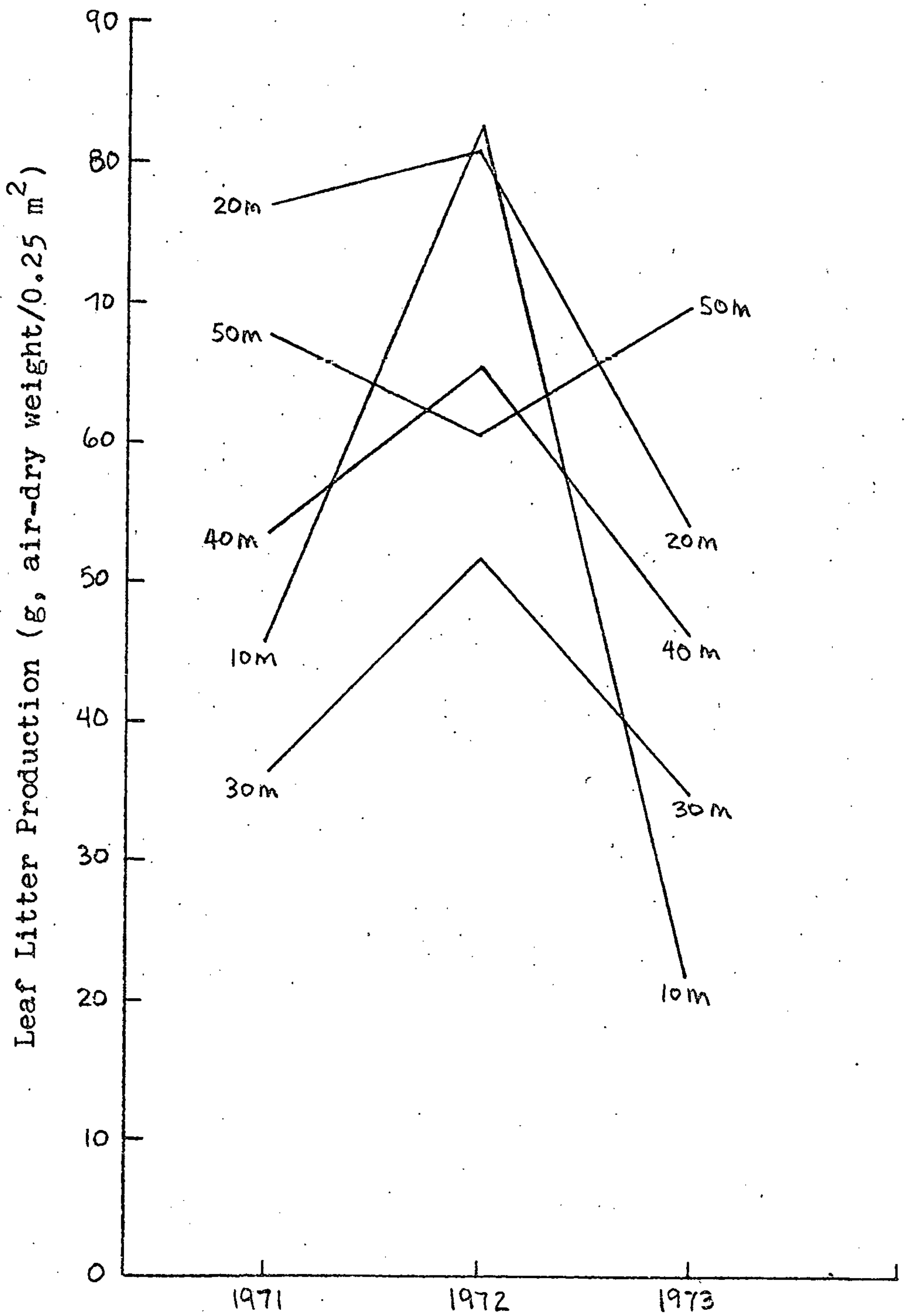

Figure 6. Annual leaf litter production in the ecotone. Distance from radiation source is indicated in meters (m).

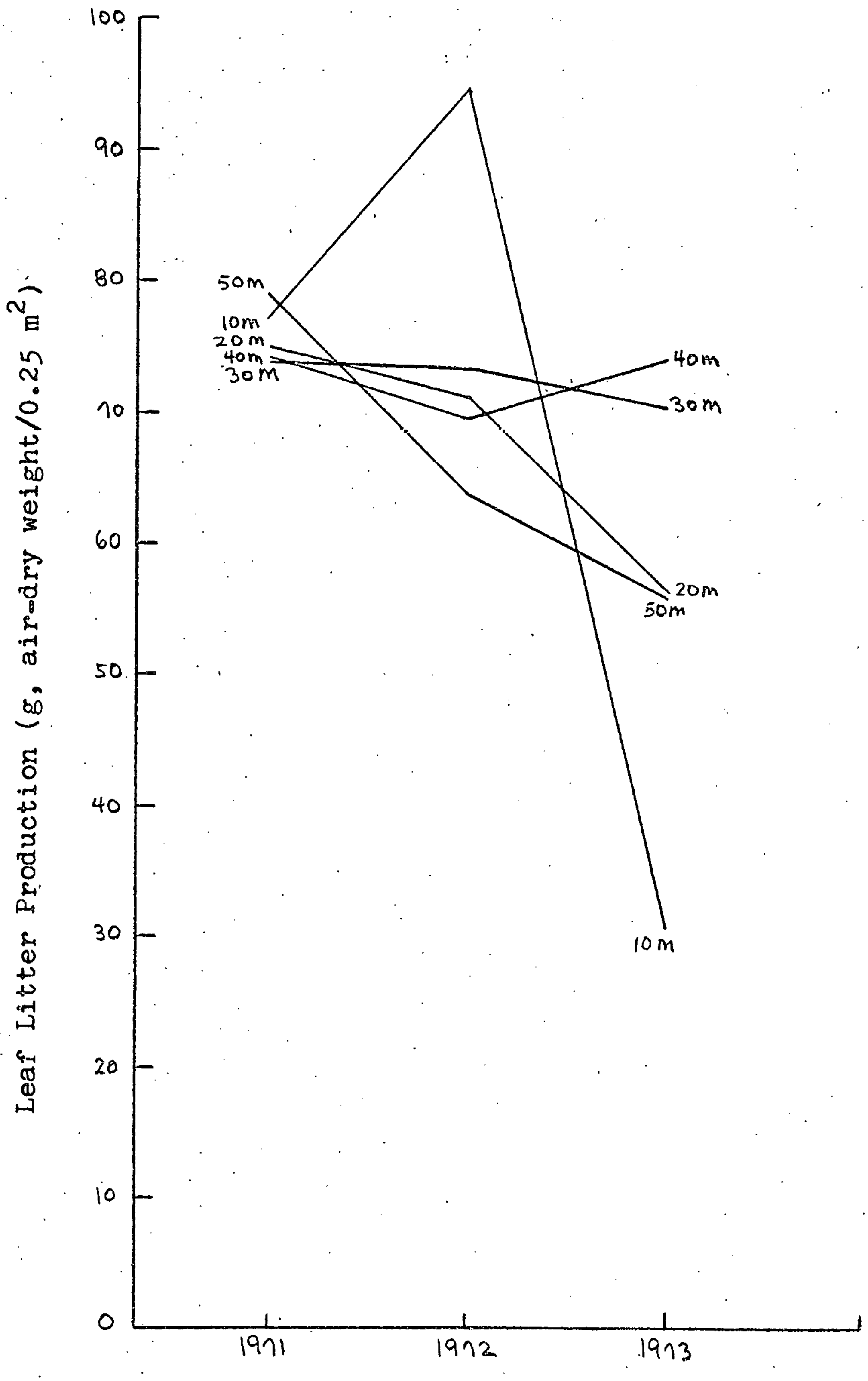

Figure 7. Annual leaf litter production in the maple-birch area. Distance from radiation source is indicated in meters (m).

litter to determine if certain species were particularly influential in causing the observed increases or decreases in litter production and whether the response of each species to radiation was dependent upon the forest type in which it occurred.

From the data summarized above, it is apparent that the foliage production was depressed most severely in the aspen area. The difference in depression between the ecotone and maple-birch areas was not great and the extent of depression was less than in the aspen area. In one of the appended reprints (Murphy and Sharitz, 1974) we predicted the aspen area would be more extensively modified by radiation than either of the other two areas and leaf litter production patterns appear to reflect this.

Future Sampling

As previously indicated, two additional sampling trips are scheduled for 1974. We are interested in determining the influence of the opened canopy on the rate and compositional characteristics of succession. We also wish to determine the rate at which leaf litter production returns to original preirradiation levels. We hope to continue these observations over a period of several years. The overall impact of radiation stress will obviously depend upon the rate at which forest succession proceeds in the damaged areas. Information on succession in disturbed northern forest types is extremely scarce.

References

Murphy, P.G. and R.R. Sharitz. 1974. Properties of the tree flora in the forest transition from aspen to maple-birch type, p. 97-104. In The Enterprise, Wisconsin, Radiation Forest: Preirradiation Ecological Studies, T.D. Rudolph (ed.). USAEC, TID-26113.

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Removed reprints