PROGRESS REPORT - BLM-INF PROJECT

#CT 5300-CT2-244 (N)

FIRE EFFECTS STUDY

(Extensive Survey)

Prepared by

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Introduction:

In the early '50's Harold Lutz (Lutz 1956), studied the ecological effects of fire in the Alaskan taiga. For years his work stood alone in this field. In 1973, Les Viereck (Viereck '73), in his paper "Wildfire in the Taiga of Alaska", summarized the present state of knowledge on fire effects. Even though we can outline patterns of forest succession following fire in Alaska, see Fig. 2 in Viereck's paper, we lack the quantitative and qualitative data to support the lines of succession and to describe the various "stages" in the story.

This study was established in 1972 to fill this need. Nonan Noste initiated the project and Joan Foote superseded him in 1973. A third year is planned. A method to survey all strata of vegetation in a stand - moss and lichens, herbs, low shrubs, tall shrubs, and trees - was developed. A series of computer programs was then developed, and is still being developed and/or modified to enable us to describe individual stands, to group most similar stands, and to obtain stand group descriptions. The field and computer methods of Ohmann and Ream were adapted to meet the conditions found in successional stands of interior Alaska.

Methods to survey and analyze forest production, browse utilization, fuel build-up, physical and chemical soil properties, depth to permafrost and age of stand were and are being developed.

Stand Selection:

To qualify, a stand had to be somewhat homogeneous and at least 5 acres in size. The initial plan was to study three stands in each of the following vegetation types and time-since-burn categories: Aspen (Populus tremuloides), Birch (Betula papyrifera), Black Spruce (Picea mariana), White Spruce (Picea glauca), and 1-5, 6-10, 11-15, 16-30, 31-65, 66-130 and over 130 years-since-burn, for a total of 84 stands in four stand types and seven age groups.

Table one shows how the categories are represented after two field seasons.

TABLE ONE

	YEARS-SINCE-BURN							
Stand Type	1-5	6-10	11-15	16-30	31-65	66-130	> 130	TOTAL
ASPEN	4	1		6	5			16
BIRCH	1	1	4	4	5	2		17
BLACK SPRUCE	2			2	11	8	3	26
WHITE SPRUCE		1		4	1	3	2	11
GRASS-SHRUBS (No Tree Reproduction)	3	7	2					12
TOTAL	10	3	6	16	22	13	5	82

(Plus 7 undatable stands)

Forty-two were surveyed in 1972, 40 in 1973 of which 10 stands were resurveys of the permanent Wickersham Dome Fire plots that were established in '71.

These 82 stands represent 28 different fires, 8 research areas and 7 areas where the stands are older than 100 years. The following 14 fires have been dated by BLM records, and conversations with land owners.

Porcupine Fire 1950

Badger Road Fire 1958

Chena Dome Fire 1958

Healy Fire 1958

Hot Springs Road Fire 1957-1958

Murphy Dome Fire 1958

Good Paster Fire 1958-1959

Ester Fire 1959

Goldstream-Standard Fire 1966

Harding Lake Fire 1966

Steese-Hot Springs Road Junction 1968

Manley Fire 1969

Wickersham Dome Fires (2) 1971

With more searching we may be able to date 10 more of the fires. Tree ring counts and post-fire scar-ring counts were used to age the older stands. Growth rings on post-fire trees and/or post-fire rings on fire scarred trees which survived the fire were counted and used to date all fires where the year of the burn was unknown.

Figure 1, shows the geographic range of stands visited. The distribution reflects accessibility - those along roads were the easiest and cheapest to reach, followed by those along the railbelt and the Tanana River. Those on the Porcupine River were the most time consuming and costly, but in terms of information, well worth

the effort. The lack of stands in the older Aspen and Birch groups in Table 1, results from the following facts: 1. Few Aspen stands reach an age of 120 years before they are replaced by Spruce stands, and 2. Heartrot in old birch trunks makes aging difficult. The low density in the early age groups reflect the low frequency with which accessible fires occurred and the difficulty in determining time-since-burn when seedlings and saplings are non-existent.

In the summer of '74 stands which represent gaps in the younger age groups will be surveyed. The Chicken Fire, the McGrath Fire and the Hess Creek Fire are such dated fires. (See Fig. 1) Others will be located.

Field Methods:

A 3-member team was outfitted and trained in the use of equipment and application of the Ohmann and Ream Ecological Inventory Procedures (Ohmann and Ream '71). Within a stand 20 points were located usually in an arrangement of 4 rows, each with 5 points, but variations were common. Using a system of nested plots the following information was collected at each point:

1. Tree data (diameter and density measurements) using a point-quarter method (Cottam and Curtis '56).
2. Tall shrub data (stem count by species and diameter class and % cover by species) in a $4M^2$ circular plot.
3. Seedling data (count by species, % cover by species) in the same $4M^2$ plot.
4. Ground cover, lichens, moss, fungi, herbs and low shrub data (% cover by species) in a square M^2 quadrat located in quadrant one of the tree plot.

Figures 2A and 2B show the arrangement of points and nested plots.

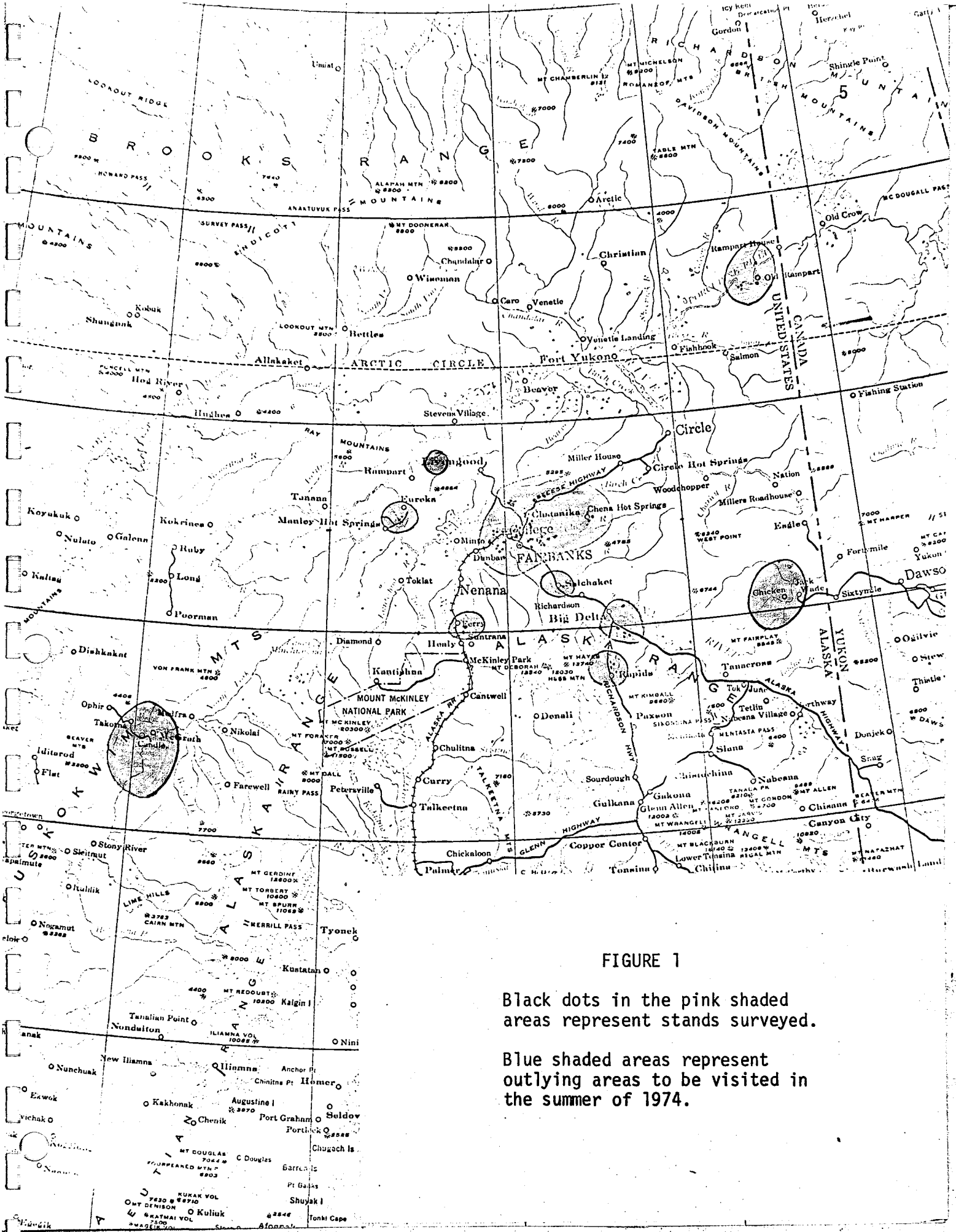


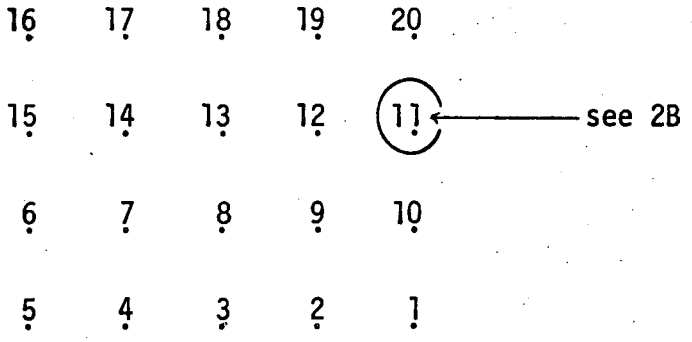
FIGURE 1

Black dots in the pink shaded areas represent stands surveyed.

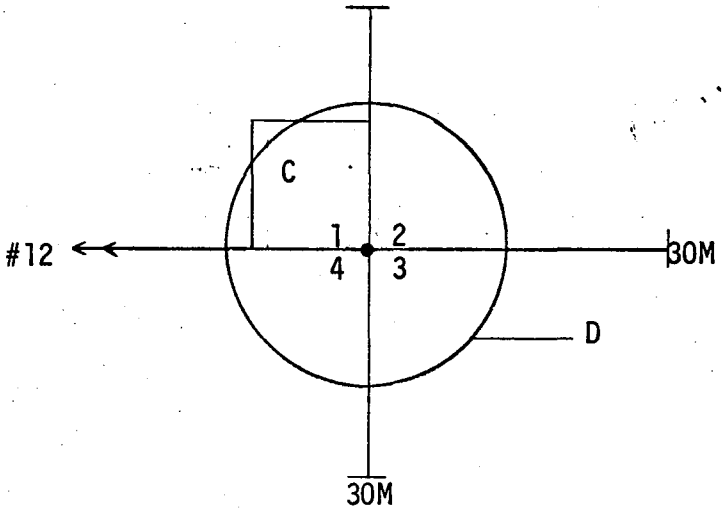
Blue shaded areas represent outlying areas to be visited in the summer of 1974.

FIGURE 2

A - the usual arrangement of points within a stand.



B - nesting of survey plots at each of 20 points.



. - Point (plot) No. 11
←— - Direction to Point No. 12
1-4 - Quadrants in the tree plot. The maximum radius of a tree plot was 30M.
C - $1M^2$ Herb plot.
D - $4M^2$ circular plot for tall shrubs and seedlings. Radius 1.16M

In addition to the Ohmann and Ream EI Procedures, the following information was collected: browse-forage utilization, fuel build-up, depth to mineral soil and permafrost~~depth~~. The stand was photographed, 15 tree cores and 3 soil samples were collected. The browse data was an estimate of the percent of available stems clipped on a height class and species basis within each of the 20-4M^2 circular plots. At four plot-points within a stand the following fuel build-up data was taken:

1. A count of dead stems in each of 4 diameter classes which touched a linear transect both on the ground and in the first two meters above the ground.
2. An estimated distance to the lowest dead branch and the lowest live branch on 5 spruce trees.
3. Depth measurements of the litter and moss layers.

These procedures follow those developed by James Brown of the Northern Forest Fire Lab. A probe was pushed into the ground until frozen ground was reached and the depth was recorded. After the organic and mineral soil samples were removed the distance to the first appearing mineral soil was measured. Five of the largest trees and ten random trees were cored. The latter were taken from the tree in quadrant one of each even-numbered tree plot. Photographs show composition of both the general stand and some of the M^2 quadrats.

Laboratory Analysis:

Where necessary, plant identification was checked. Voucher specimens were identified, mounted, labeled, and will be placed in the University of Alaska Herbarium. Rings on the tree cores were counted to obtain an average age for the oldest trees in the stand and for the stand itself. These cores will be studied to see if we can date release-points that could relate to periods of fire

or other disturbances which occurred in the history of the stand.

Soil samples were dried, sieved, and sent to the Forestry Soils Lab at the University of Alaska and the U.S. Forest Service Laboratory at Corvallis, Oregon, for particle size and nutrient analysis. The field forms for the vegetation data were scrutinized for completeness and readied for the keypunchers.

Computer Analysis:

This involves 8 programs. Using one or more enables us to:

1. Quantitatively and qualitatively describe individual stands or groups of stands.
2. Classify stands into most-similar groupings.
3. Ordinate stands and/or stand groups along vegetational and/or environmental gradients.

The flow diagram in Figure 3 shows how the programs feed into one another.

Stage one - the four initial programs - HERBSUM, SHRUBSUM, SEEDSUM, and TREESUM, summarize respectively the herb, tall shrub, seedling, and tree field data collected for each stand.

Stage two - ORLOCI combines the results of stage one programs, digests the information and then orders the stands into most similar groupings in a cyclical manner. In cycle 1 within ORLOC each stand is grouped with another if there is another one that is still available and is quite similar. Cycle 2 may add a third stand to an existing group, combine two existing stands, or form a new group of two stands, but in all the degree of similarity is less than it was for cycle 1. This goes through n-cycles until all stands are grouped together. (Orloci '67)

FIGURE 3

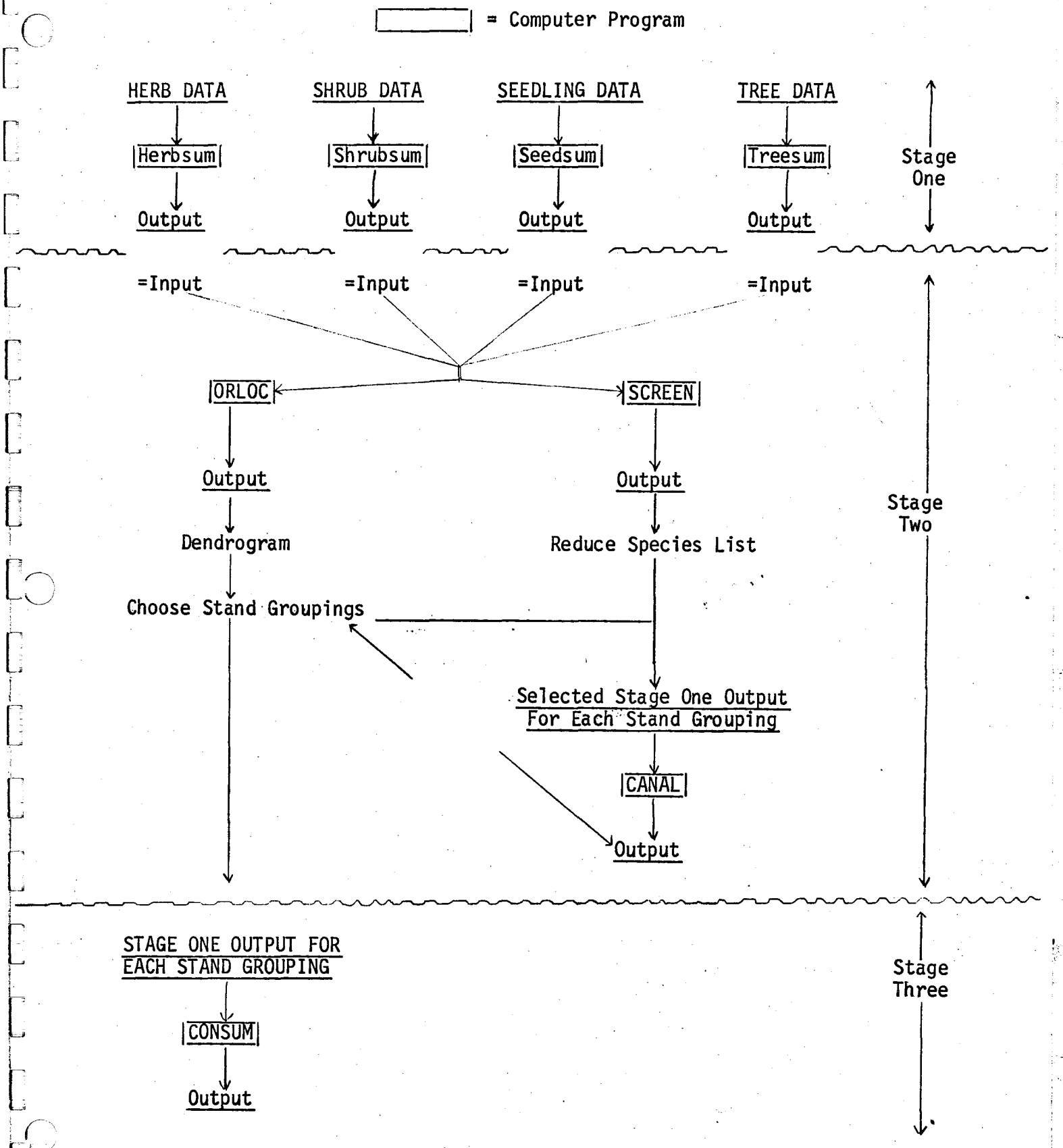

= Computer Program
HERB DATA
SHRUB DATA
SEEDLING DATA
TREE DATA
Herbsum
Shrubsum
Seedsum
Treesum
Output
Output
Output
Output
Stage One
=Input
=Input
=Input
=Input
ORLOC
SCREEN
Output
Output
Dendrogram
Reduce Species List
Choose Stand Groupings
Stage Two
Selected Stage One Output For Each Stand Grouping
CANAL
Output
STAGE ONE OUTPUT FOR EACH STAND GROUPING
CONSUM
Output
Stage Three

Figure 4 is an example of a dendrogram which is used to help visualize the output of the ORLOC Program. The vertical axis is the degree of similarity or dissimilarity. At the extremes a connecting line at 0 means the stands are identical and a line at 100 means they are most dissimilar. The stands lie along the horizontal axis. The lines connecting the stands show relatedness and the degree of the similarity.

There are 32 possible groupings in the dendrogram in Fig. 4. Each group could be labeled, summarized, and could be meaningful, for some purposes. Group "A" uniting all stands at the 100% within group dispersion level could be entitled "Vegetation in the Frost Lake and Cherokee Lake Areas" and the data could be averaged and summarized for this inclusive group or at the other extreme one could take group "B" where two stands are united at the 8% level of dissimilarity. These stands show a high degree of similarity and probably share the same local history.

The aim is to identify types of stand groups that appear to have regional and ecological meaning. In terms of the dendrogram the aim is to determine two points on the vertical axis. The groups above one point are too dissimilar to be useful and the groups below a second point display too much localness to be useful. By eliminating the groupings that fall above or below these points one removes unwanted combinations - those that would least serve our purpose.

This calls for a bit of subjective judgement. As a check on this we run all our groupings through an alternative program - CANAL. (Grigal '71) CANAL ordinates stands along n-axes of variation.

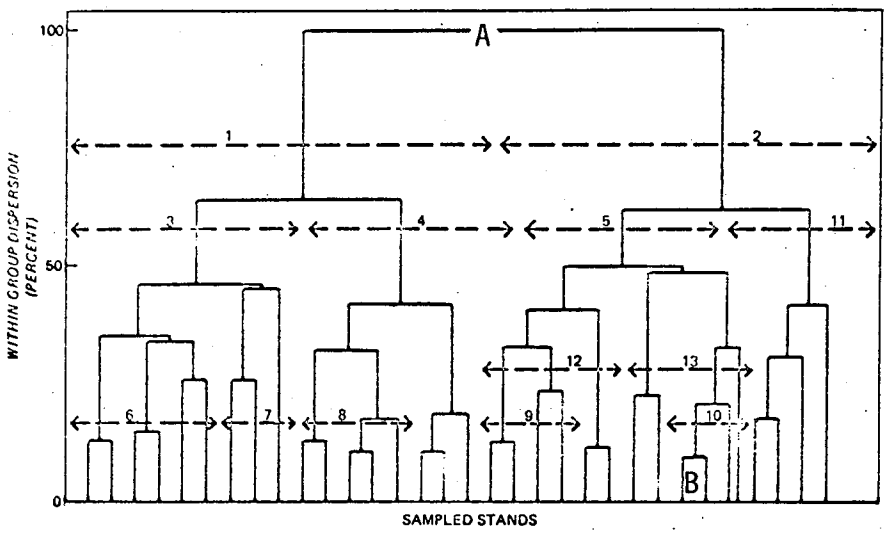


Figure 4 --Dendrogram representing the numerical classification of 33 sampled stands from the Frost Lake and Cherokee Lake wildfire areas. Dashed lines enclose stand groups subjected to canonical ordination. (From Ohmann et al '73)

EXPLANATION OF A & B IN TEXT

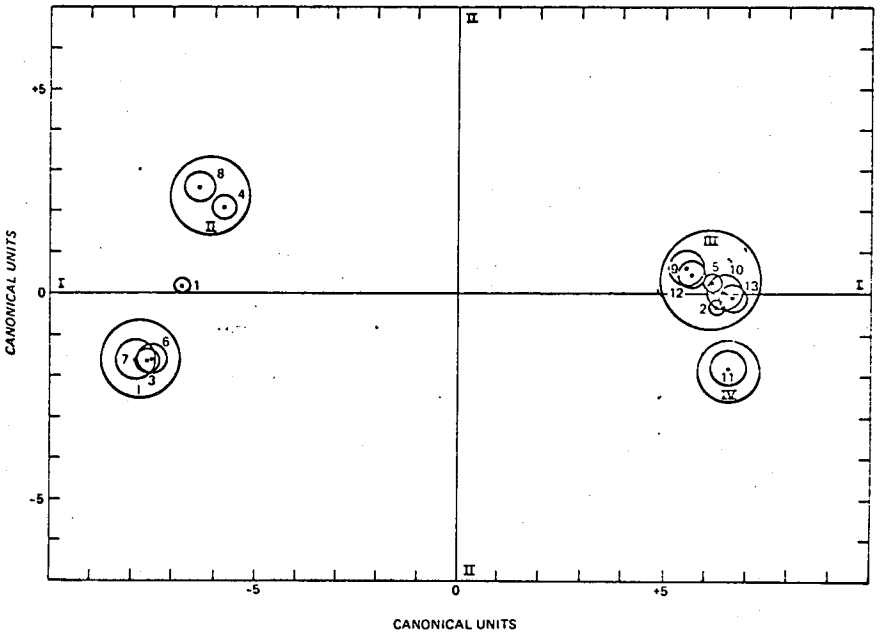


Figure 5 --Position along first two canonical axes of stand groups 1 through 13 from the dendrogram (figure 4 Small circles represent 90 percent confidence intervals around group means. These two axes account for 95 percent of the variation. Large circles surrounding more than one stand group represent regional nodes I, II, III, and IV whose stands held in common were reordinated as new stand groups. (From Ohmann et al '73)

Figure 5 is an example of this alternate method of showing the relationships between stands. By comparing the results from the two methods, strong and weak groupings can be separated more objectively.

The SCREEN PROGRAM takes the output from stage one programs either singularly or together and orders the species in 6 different ways. They are ranked by average frequency of occurrance, average quantity present, predictability, information, contribution to standard distance and lastly, an average of all measures. With this data it is possible to eliminate the least important species until the 50 most informative species are present, and to use only the most important species in running the CANAL Program. This step is necessary because of limitations in the storage capacity in the computer.

Once the stand groupings are determined one can move into stage three. Here the program CONSUM gives you a composit quantative and qualitative description of each of the groups or stand types identified. This was one of our initial objectives.

Stand age, stand history, animal activity, permafrost depth, soil characteristics or environmental parameters are other factors to be analyzed. BROWSUM is an additional program that handles animal activity at the stage one level. See Fig. 3. Some of these parameters may be interpreted through the use of the CANAL Program. Some may best be summarized in table form and subjected to regression and/or other statistical tests.

Most of the computer related work has been done through and in conjunction with the Automatic Data Processing Section of the Forest Service, Portland, Oregon.

Manpower problems and numerous communication problems have necessitated three trips to Portland by myself and other INF staff. In June 1974, our permanent staff at Fairbanks will include Robert Woollard, the Computer Technologist who has worked with our data in Portland for the past year. This should greatly reduce problems related to the computer processing of our data.

Results and Discussions:

From Table 1 it can be seen that the desired representation of at least three stands in each category is nearly accomplished. The stands surveyed during the summer of 1974 should finalize that aspect of the study.

Much time has been spent on the computer aspects of the study. To summarize our progress, the stage 1 and stage 3 programs - HERBSUM, SHRUBSUM, SEEDSUM, TREESUM, and CONSUM - are operational. However, several changes need to be made. We are presently working with the ORLOC, SCREEN and CANAL Programs. All aspects of the data and programs have been converted to metric units and to a unique species code-numbering system.

Vegetative data for the 82 stands has been punched and is in stage one input form. The computer work to date has involved only the 42 stands of the 1972 data. We are working on the problems relating to increasing the number of stands. The 1972 data has been run through all the programs except CANAL. It appears there may be about 12 stand groupings.

Once we have the computerized aspects of the system completely working we will use all stands to gain the final stand-type groupings. Any set of groupings reflect the original stand inputs, but the greater the number of stands and the wider spread of variation in species composition in the stands, the more general one can apply the knowledge gained from the stand groups that form during the analysis.

The rest of the stand data is summarized on an individual stand basis for the 42 stands collected in 1972. Some work has been done on how best to summarize it on a stand-group basis. Additional time will be spent on it in the near future. Thereafter, the data from the remaining stands will be incorporated.

The 1950 Porcupine River Fire:

A large area around the Porcupine River burned in 1950. In 1951 and '54 the Cooperative Wildlife Unit at the University of Alaska established some permanent transects and the vegetation was surveyed. In 1957 and '61 the areas were revisited and the transects were resurveyed. Last summer we went to the scene to resurvey the permanent transects. We surveyed the stands using the procedures standard to this study. The advantages of a case study like this are that:

1. You have an actual record of the succession stages that occurred and,
2. You have a time value for the duration of each stage.

The disadvantage of such a case study is that it takes time. Whenever our study can make use of and add to the results of one of these case studies it will be done.

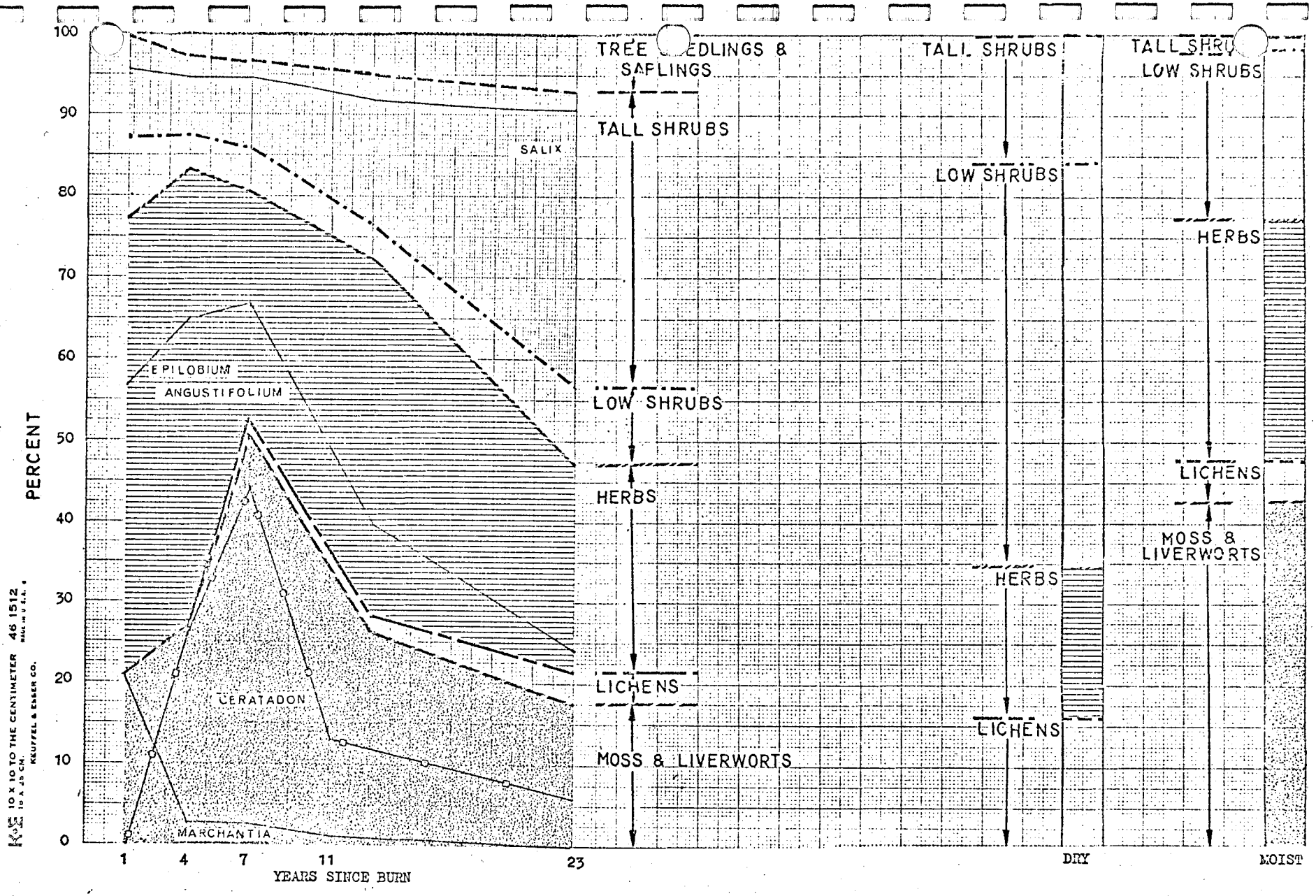
Figure 1 shows the location of the plots and the approximate area of the Porcupine River Burn. In two of the burn stands the original transect points were located. The two remaining burned stands were located with the aid of photographs and written directions, but no transect points were found. The vegetation seemed sufficiently homogenous in each of these areas so that the results would not be rendered invalid by the difference in location, if in fact, it was different. The 5th stand, the unburned control stand, proved to be a different matter.

When the results from the two control stands were compared the one surveyed in 1951 had a 50-50 ratio of white to black spruce while the one surveyed in 1973 had a 5-95 mixture of white to black spruce. The former seemed to be on a fairly dry site while the latter on a more moist one. This variation occurred within a two mile stretch of the unburned forest adjacent to the fire. The two areas wre considered to represent two mature stand types that can be found in the area.

Figure 6 is a composite graph of the vegetation present in the area through time. The vertical axis represents percent of vegetation present, the horizontal axis is time. The species are stacked by type - from lowest to highest on the vertical scale are mosses and liverworts, lichens, herbs, low shrubs, tall shrubs and trees (seedling and sapling stages). A wide vertical spread in the range for a species or vegetation type means it composes a high percentage of the total vegetation at that point in time and a narrow vertical spread in the range for a species or vegetation type means it represents only a small part of the total vegetation at that point in time. Figure 6A treats the first 23 post-fire years and 6B illustrates two unburned control stands. Immediately after the Porcupine Fire a Leafly Liverwort (Marchantia polymorpha) and Fireweed (Epilobium angustifolium) accounted for 55% of the vegetation present. Lichen is the only vegetation type that is not represented at this time.

Four years later the scene is essentially the same except the moss (Ceratadon purpureus) has displaced Marchantia in importance and lichen species are present, but just barely.

In 1957, seven years after the fire, the moss species are at their highest, accounting for almost 50% of the vegetation present. Epilobium is still present but definitely on the decline.



6A—SUCCESSIONAL STANDS

6B—MATURE STANDS

FIGURE 6

Relative cover of vegetation present by type in the first 23 years after fire and in two unburned mature stands. Data obtained from four successional stands and two unburned stands in the Porcupine River Fire area. For more explanation see the text.

Eleven years after the fire, the tall shrubs are showing a definite increase and the trees a smaller increase, while everything else is declining in relative importance. In 1973, 23 years after the fire, the same trend exists. Now the tall shrub species, mainly Willow (Salix), dominate the scene, tree species are on the increase, and all else is on the decrease.

Figures 7 through 12 show the trends and relative amounts of the more dominant species in each type of vegetation. Some species have a short-lasting peak immediately after the fire. Marchantia (Fig. 7) Arctostaphylos and Vaccinimum uliginosum (Fig. 10), and Rosa (Fig. 11) are this type. Epilobium and Equisetum (Fig. 9) also come in strong immediately after the fire but stay strong for four years before they start to decline. Twenty-three years after the fire Marchantia has disappeared, the rest are still present, but just barely.

A second group of species reach their peak 7 to 11 years after the fire. Ceratadon (Fig. 7) and grasses and Carex (Fig. 8) are this type.

A third pattern is represented by those species which from the time of their appearance have a steady increase during the first 23 years following the fire. Sometimes it is a slow steady increase, illustrated by the lichens (Fig. 8), Vaccinium vitis-idaea (Fig. 10) and all the tree species (Fig. 12). Sometimes like with the Salix (Fig. 11) the increase is quite dramatic but occurs only after a period of no change during which the species holds its own, but no more. Aulocomium (Fig. 7) and Empetrum (Fig. 10) are the latest of these species to appear.

It is the additive effect of all these trends within each vegetative type that dictates the overall pattern of each of the vegetative types pictured in Figures

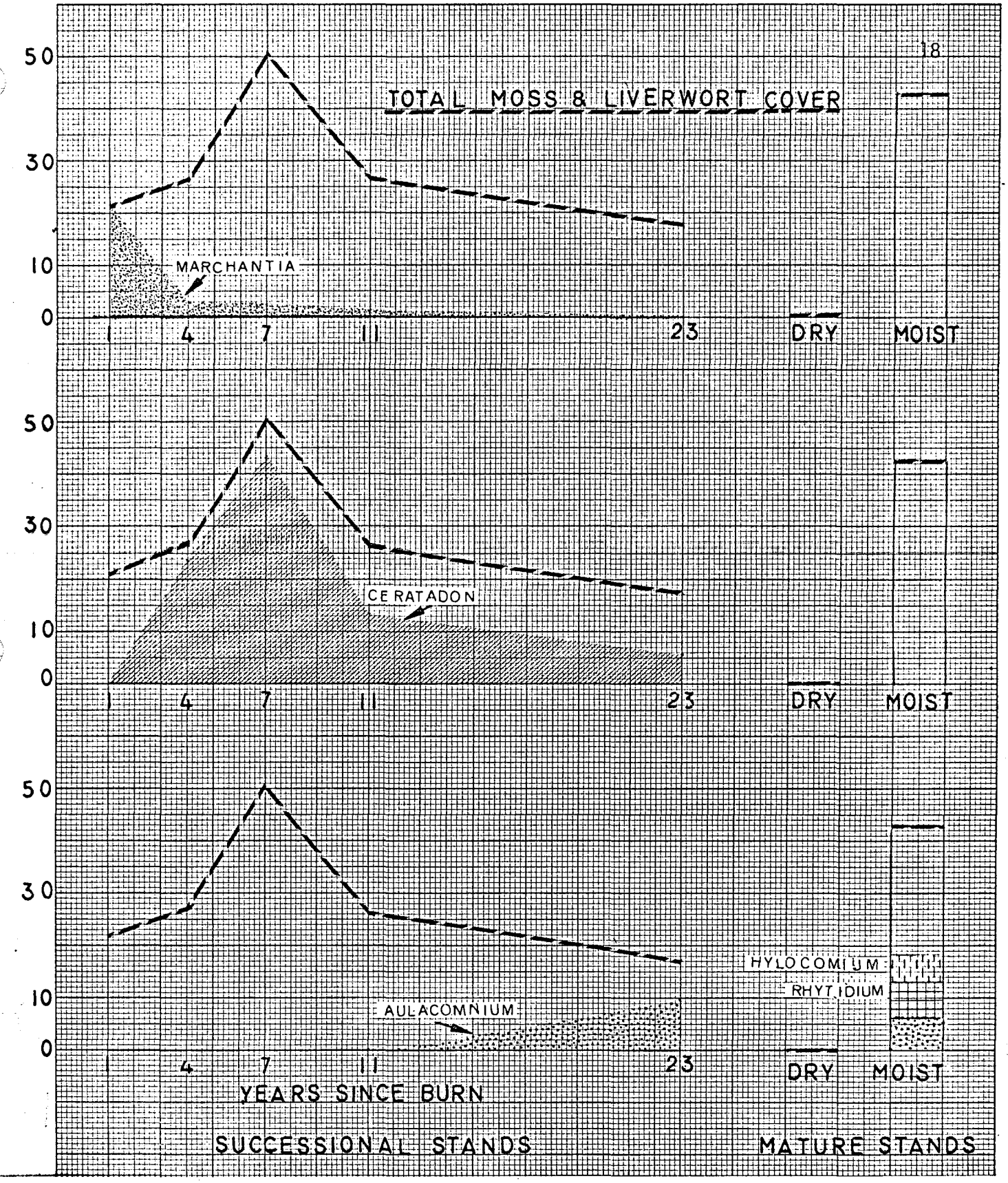


FIGURE 7

Percent relative cover in successional and mature stands showing three trends in species composition of all the mosses and liverworts present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

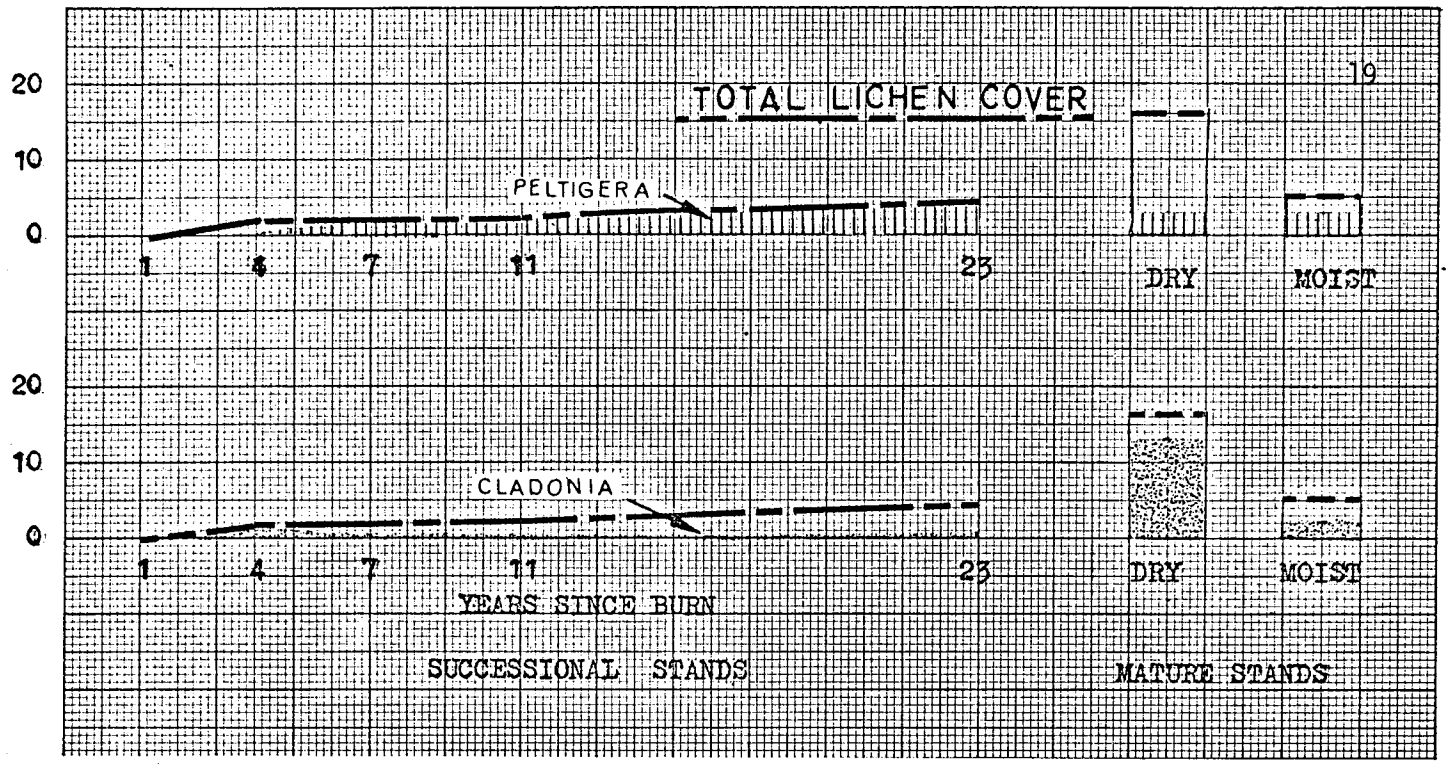


FIGURE 8

Percent relative cover in successional and mature stands showing trends in species composition of all the lichens present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

6 through 12. For example, in Fig. 9 the low point seen seven years after the fire is caused by the fact that the early peaking species have waned, while the species which peak around eleven years post-fire are just starting their rise.

It is also interesting to compare the amounts and relationships of species and types illustrated in Figures 6A through 12 with those of older, unburned stands which occur in the same area. The two columns at the far right (Fig. 6B to 12) illustrate the comparable data for two unburned stands. One of the mature unburnt stands is on a dry site and the other on a more moist site.

At 23 years both the young trees and the tall shrub groups are over represented when compared to those in the older unburned stands (Fig. 6, 11, and 12A). The young trees will become older trees and thus leave the graph. Figure 12B deals with the relative counts of the trees once they have left the graph in Figure 12A. The tall shrubs however, will have to reverse their increasing trend sometime before the mature stage is reached. When and how are unknowns.

The low shrubs (Fig. 6, 10) and lichens (Fig. 6, 8) are under represented at 23 years post-fire when compared to the mature stand. It is interesting to note that by 23 years post-fire all the major shrub species which occur in the mature stand are represented. At this time, both Peltigera and Cladonia lichens are also present, but the species occurring then may not necessarily be the same as those occurring in the mature stand. Perhaps the steadily increasing trend by these two groups will continue until the mature representation is reached.

The herbs (Fig. 6, 9) as a group are not too different in quantity at 23 years post-fire from that in the older areas. However, if one looks at the relative species, Equisetum scirpoides and Carex sp. are out of balance. Carex sp. must

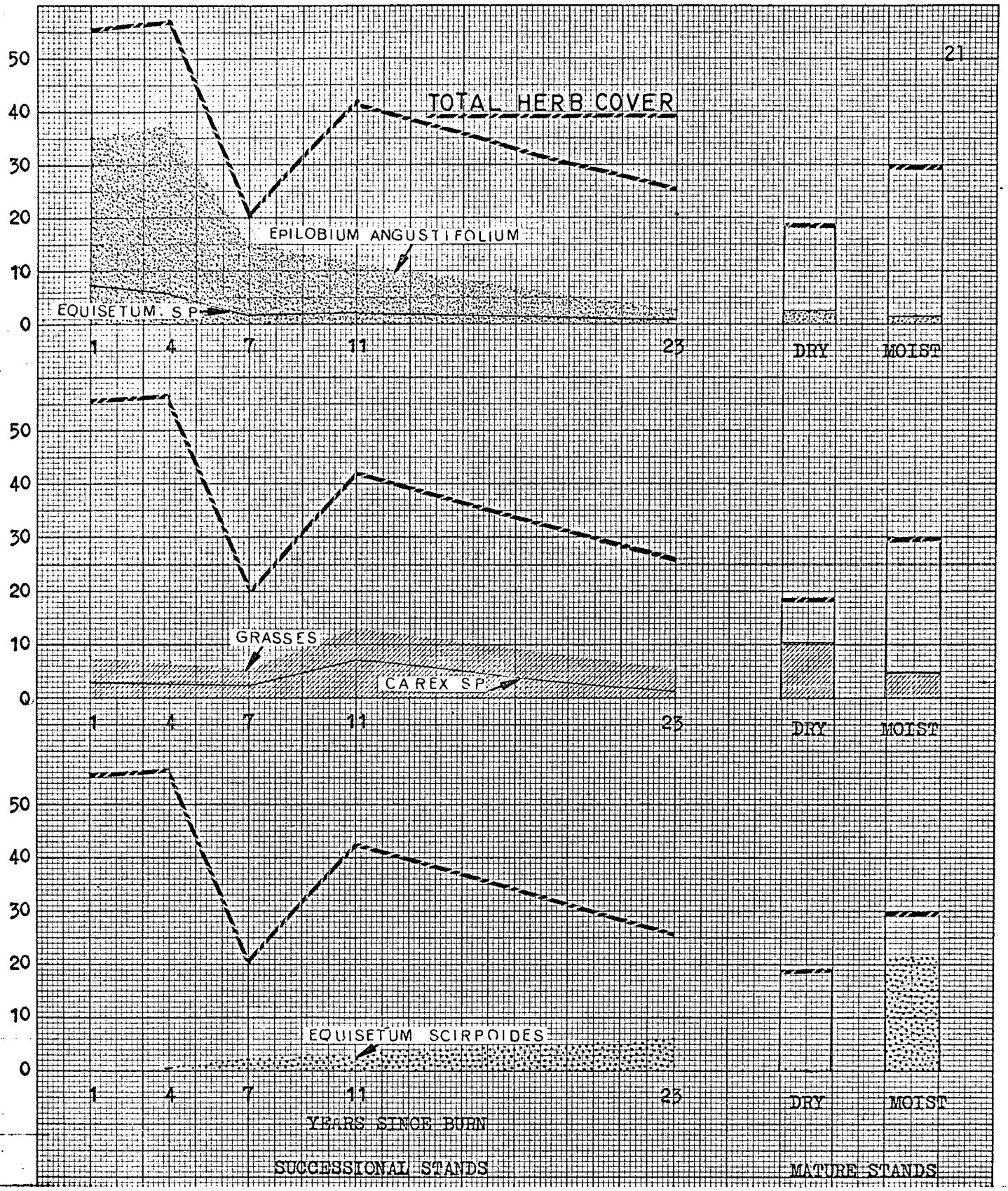


FIGURE 9

Percent relative cover in successional and mature stands showing three trends in species composition of all the herbs present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

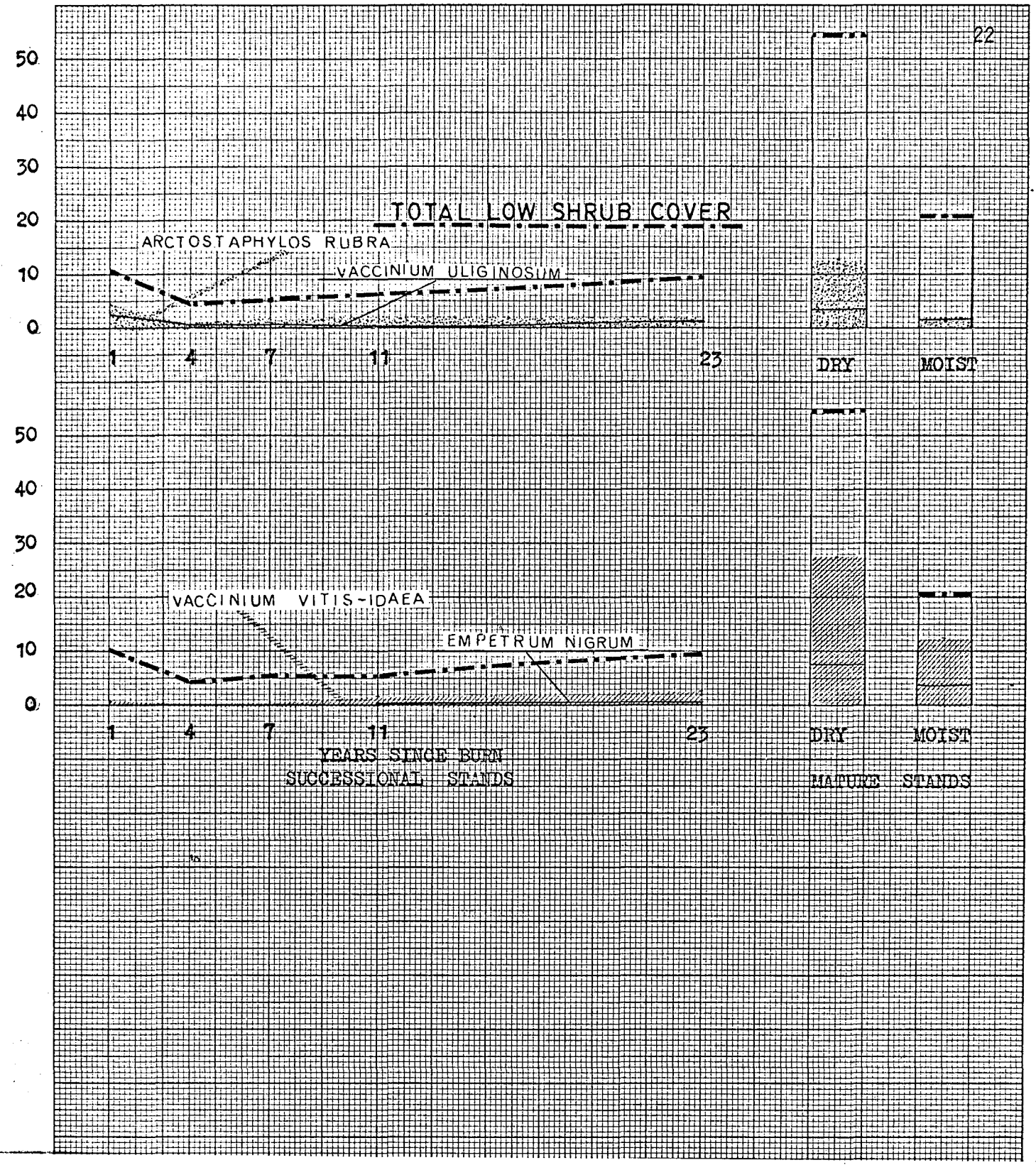


FIGURE 10

Percent relative cover in successional and mature stands showing two trends in species composition of all the low shrubs present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

increase, in order to match the dryer mature stand. Equisetum scirpoides must either disappear to match the dryer mature stand or increase to match the wetter one. The other species must decrease in relative amount.

The last group, the mosses and liverworts (Fig. 6, 7) must also change both in amount and species present. There are few mosses and liverworts present in the dry control, there is a large amount of these groups present in the wetter control. Furthermore, of the species present in the more moist control stand, only Aulocomium is present to any extent 23 years after the fire. Rhytidium and Hylocomium do occur, but only in trace amounts.

In summary, to attain mature stand composition the following must occur:

1. The tall shrubs will have to reverse their trend so they become less important.
2. The young trees will have to mature into older trees.
3. The low shrubs will have to increase in importance.
4. The herbs will stay about the same.
5. In dryer areas lichens will have to increase while in the more moist areas, new moss species must invade.

With time and with the results of our main study the patterns of change between the 23 year post-fire stage and mature stages can be better defined. Through the incorporation of other case studies and the large number of successional stands surveyed in our main study the universality of the trends revealed in the Porcupine River area case study can be tested and modified.

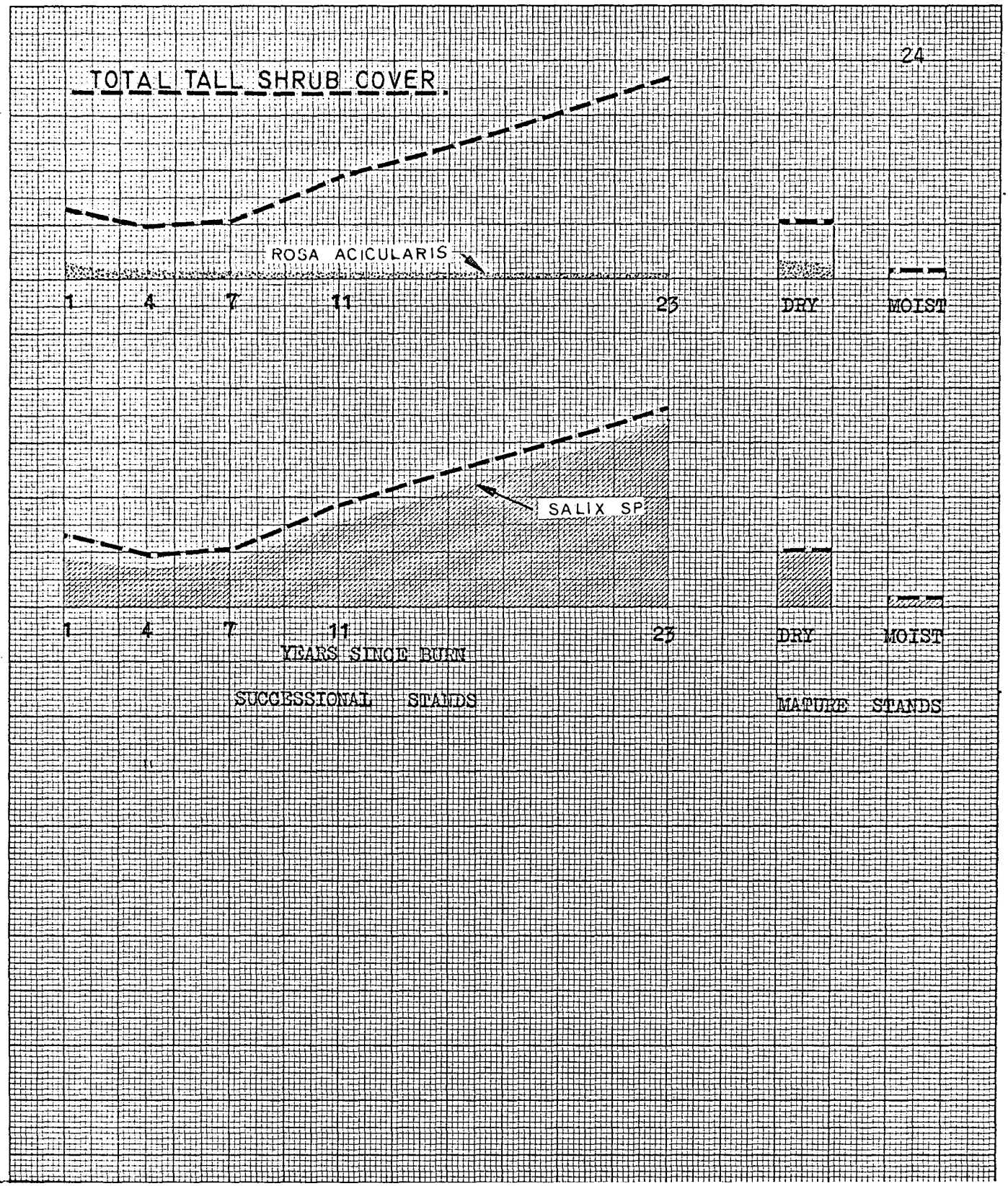


FIGURE 11

Percent relative cover in successional and mature stands showing two trends in species composition of all the tall shrubs present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

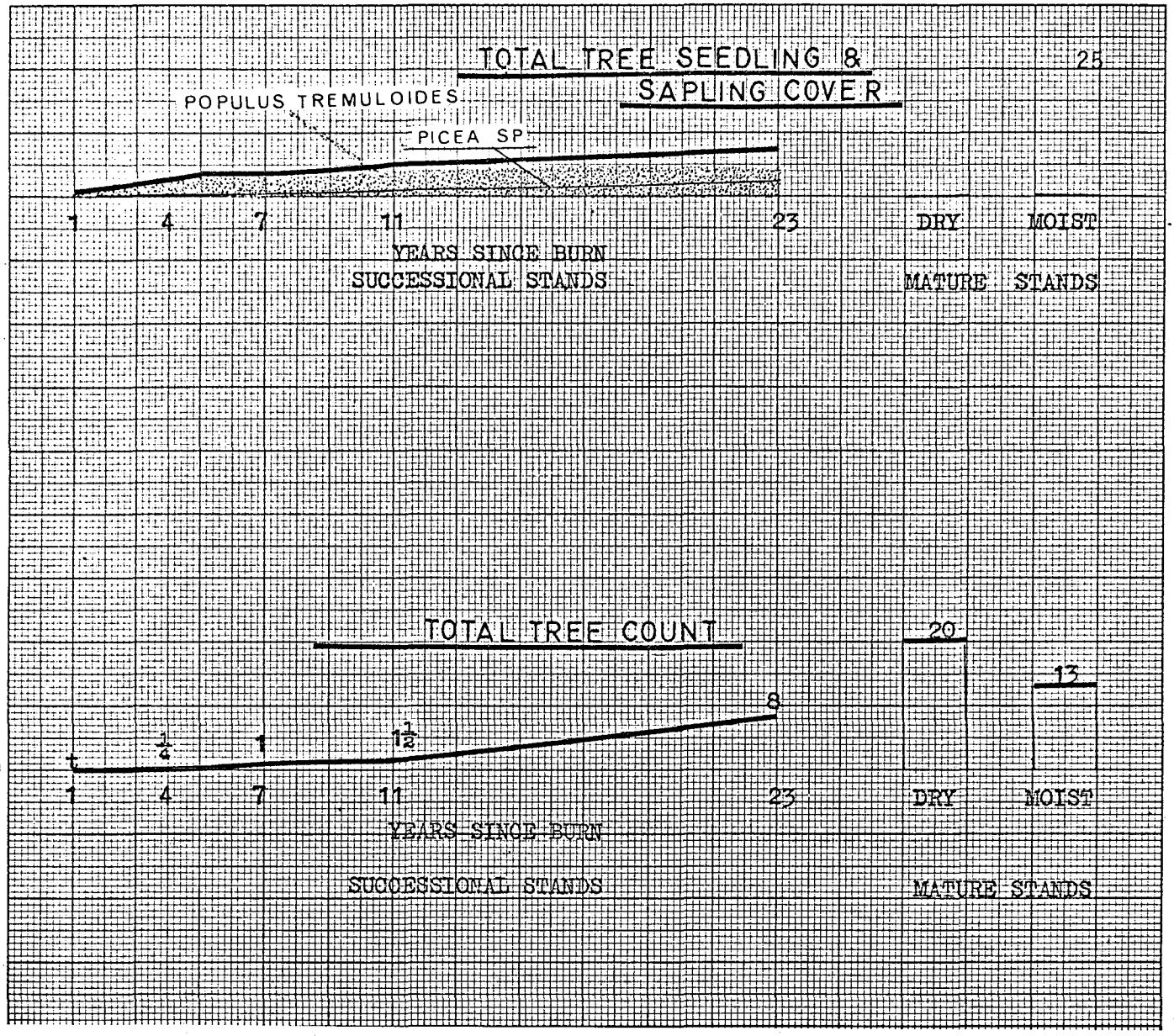


FIGURE 12A

Percent relative cover in successional and mature stands showing trends in the species composition of all the tree seedlings and tree saplings present. Data from four successional and two mature stands in the Porcupine River Fire area. See text for more explanation.

FIGURE 12B

A count of the number of live tree trunks which touch a line transect that runs for 1,000 feet through each stand. The data is for the same stands mentioned in 12A. A tree is considered any Betula, Picea, or Populus species whose trunk attains a diameter at breast height of at least 1cm.

The Future:

The study has come along well. The field work, especially that dealing with the Porcupine Fire, has proved itself important and fruitful. The following list of summer field plans is aimed toward filling in gaps in the existing field data while adding the maximum amount of information to the data. The 1974 summer field plans are to:

1. Visit and survey two recent burns, the Chicken Fire and the McGrath Fire, where permanent plots were established and surveyed soon after the respective fires. Les Viereck, Jerry Wickstrom and group established the plots in the Chicken Fire area. Dick Bishop of the Alaska Department of Fish and Game, Fairbanks office, established and has been following plots in the McGrath area.
2. Visit and survey other recent burns where the year of the fire is known. The Hess Creek Fire, and three stands in the Fairbanks area have been located and dated.
3. Visit the proposed Washington Creek Fire Ecology Area to establish permanent plots in order to obtain pre-burn data.
4. Resurvey the permanent plots in the Wickersham Dome Fire research area.

The computer and statistical aspects of the study are progressing slowly. Our greatest efforts must be expanded on this portion of the study. The plans for FY-1975, in addition to the above field work, are to:

1. Finalize the computer and statistical portions of the study.
2. Attempt to adapt the programs used in this study for use on the computers that exist at the University of Alaska.

The following budget should carry the project through FY-1975.

FY-1975 BUDGET -- (July 1, 1974 - June 30, 1975)

CONTRACT	$11,000.00
Less indirect cost (10%)	1,100.00
Balance	$ 9,900.00
Salary - Temporary Personnel	
One GS-4 (6 pay periods)	2,150.00
One GS-5 (6 pay periods)	2,436.00
Per Diem (20 days X 2 people @ $12.00 per day)	480.00
Total	$5,066.00
Travel	
Carry-all (2 months @ $75/mo)	150.00
1,000 miles @.110	110.00
Aircraft - 185 (5 hrs @ $80/hr) *	400.00
Bel 206 (6 hrs @ $275/hr)	1,674.00
Total	$2,334.00
Equipment	500.00
Lab Analysis	1,000.00
Computer Processing and Time	1,000.00
Total	$2,500.00
GRAND TOTAL	$9,900.00

* This amount does not include the flying time in the McGrath and Chicken Fire areas where BLM helicopters must be used if the areas are to be visited and studied.

REFERENCES CITED

Cottam, Grant and Curtis, J. T. 1956.

The use of distance measures in phytosociological sampling. Ecology 37(3):451-4[illegible]

Grigal, D. F. and Goldstein, R. A. 1971.

An integrated ordination-classification analysis of an intensively sampled oak-hickory forest. J. Ecology 59:481-492.

Brown, James

Unpublished.

Lutz, H. F. 1956.

Ecological effects of forest fires in the interior of Alaska. USDA Technical Bulletin 1133. 121 pp.

Ohmann, Lewis F. and Ream, Robert R. 1971.

Wilderness ecology: A method of sampling and summarizing data for plant community classification. USDA Forest Service Research Paper NC 49, 14 pp.

Ohmann, Lewis F., Cushwa, Charles T., Lake, Roger E., Beer, James R. and Brander, Robert B. 1973.

Wilderness ecology: The upland plant communities, woody browse production, and small mammals of two adjacent 33-year-old wildfire areas of Northeastern Minnesota. North Central Experiment Station, USDA Forest Service, Gen. Tech. Rep. NC 7 30 pp.

Orloci, L. 1967.

An agglomerative method for classification of plant communities. J. Ecology 55:193-206

Viereck, Leslie A. 1973.

Wildfire in the Taiga of Alaska. Quaternary Research 3:465-495.