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FOREST FIRES IN MISSOURI

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CONTENTS

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Forests occupy more than one-third of Missouri's total land area (Gansner 1963). Most of this 15 million acres is capable of timber production. Missouri's forests also provide wildlife habitat, recreational opportunities, watershed protection, and jobs and economic security for rural residents.

Because wildfires cause degrade and volume loss in timber and impair the attractiveness of the forest for recreation, fire protection is a necessity if forest lands are to serve the people well. But even in 1970, a relatively light fire-year, Missouri had 3,000 fires in protected areas, the second highest of the 20 States in the Eastern Region of the USDA Forest Service. The 45,000 acres burned in Missouri in 1970 was much greater than the acreage burned in any other State in this Region (USDA Forest Service 1971).

Responsive fire management programs are based on accurate reporting and compiling of fire records. It is important, therefore, to make an in-depth examination of Missouri fire business as deduced from these records. This means trying to determine how the information might fit into an overall operational attack upon the problem of protecting the forests from fire.

DATA COLLECTION AND ANALYSIS

Tabulations of State and National Forest fire activity are published annually by the USDA Forest Service. Summary statistics from this source for the 1950 and 1960 decades are given in tables 1 and 2. Although both the State of Missouri and the Forest Service are guided by these data in planning fire prevention and suppression programs, no comparison between agencies is intended. The data in these two tables as well as following fire statistics cover somewhat different periods of time. Also, the problems of protection vary by locality due to dissimilar landownership patterns and activities of the residents. Therefore, it is impossible to make comparisons between State and Federal protection effectiveness from this information.

For the time interval covered in this study, protected State and private forest lands in Missouri ranged from a low of 7 million acres in 1951 to a high of 11 million in 1968. Consequently, the number of fire starts and acreage burned are normalized in table 1 for an average 10-million-acre protection unit. However, because the federally protected area in Missouri has remained fairly stable at about 1.39 million acres since the 1950's (table 2), no correction was necessary.

The State and Federal protection units show many similar trends (tables 1, 2). Both reveal a definite decrease in total number of fires over the two decades. A decided drop in fire numbers (33 percent) occurred on Missouri National Forests. A reduction of the incendiary fire problem during the 1960's was an important factor in that decrease, with acreage burned due to incendiarism down 61 percent within the National Forests. This shows that past prevention programs have been effective, although continued effort is certainly necessary.

A 33-percent reduction in large fires (Class C and larger) is evident on State protection areas, with a corresponding 50-percent drop in total burned acreage.

This background information is important input into the Missouri prevention and suppression programs. There are, however, a number of questions that cannot be answered with these data. For example, "What is the annual profile of fire activity?" "How much of a problem is the multiple-fire day?" "Is incendiarism a seasonal or a continuous year-round problem?" "Does fire actively fluctuate by day of week?" "How do weather elements such as wind affect fire occurrence?"

In an attempt to answer these and other related questions we analyzed data from three fire-protection areas in the major forested area south of the Missouri River. These areas (fig. 1), including both oak-hickory and oak-pine forests, are representative of the overall fire-protection problems in the State (table 3).

1. The Eminence State Protection District, predominantly private land, comprises 1,290,000 acres. Texas County contains more than 400,000 acres of

Table 1 — *Average annual fire activity on Missouri's State and private protected lands*

Item		1951-58	1961-68	Change
				Percent
Average protected acres	Million	8.06	10.60	+32
Number of fires per year	2/	3,567	3,227	-10
Number of Class "C" and larger fires	2/	1,202	801	-33
Number of fires by cause:	2/			
Incendiary		1,280	931	-27
Debris		1,716	1,512	-12
Camper		57	53	-7
Smoker		261	208	-20
Lightning		11	13	+18
Other		242	510	+111
Acres burned	2/	103,033	51,935	-50

1/ Compiled and normalized for a standard, 10-million-acre protection unit (USDA Forest Service).
2/ Per 10 million protected acres.

Table 2. — *Average annual fire activity within Missouri's National Forest protection boundaries*

Item	1950-59	1960-69	Change
			Percent
Number of fires per year	506	341	-33
Number of fires by cause:			
Incendiary	158	126	-21
Debris	68	—	—
Campfires	15	—	—
Smoking	92	45	-51
Lumbering	3	—	—
Railroad	3	—	—
Lightning	8	9	—
Miscellaneous	158	9	-94
Land occupancy	—	69	—
Recreation	—	67	—
Forest utilization	—	4	—
Equipment	—	12	—
All acres burned	6,315	3,596	-43
Acres burned by incendiary fires	3,499	1,354	-61
Acres burned by debris fires	1,101	—	—
Acres burned, land occupancy fires	—	1,157	—

1/ Averages compiled from data of USDA Forest Service--Division of Forest Fire Control.

forest land, and Shannon, with more than 500,000 forested acres, is the State's leading forested county (Gansner 1963). The Current and Jacks Fork Rivers flow through this district. Esthetic quality has been recognized by formation of the Ozark National Scenic Riverways, a popular recreation attraction.

2. The West Plains State Protection District comprises 1,428,000 acres. Although 10 percent larger than the Eminence District, it is less heavily forested and contains a greater area of farmland. The district encompasses portions of several noted Ozark streams, including the scenic Eleven Point River. It includes portions of Norfolk and Bull Shoals Lakes impounded from the White River. These water attractions, as well as the deer and quail populations, draw many recreationists. The district is almost entirely in private ownership.

3. The Rolla-Houston and Salem-Potosi-Centerville Districts of the Clark National Forest include 1,180,000 acres of land. These districts are more than half forested and have many farms; the dominant landownership is Federal.

Weather information used in this study was obtained from two sources: A Forest Service station at Salem, Missouri,[1] and a National Oceanic and Atmospheric Administration (NOAA) National Weather Service cooperative station located in the city of West Plains, headquarters for the West Plains District (fig. 1).

The fire data for the Eminence and West Plains State Districts include number of fires, acres burned, man-hours to control, and fire cause over the period 1961 to 1968. Fire data from the Clark National Forest Districts include number of fires and burned acreage over the years 1952 to 1961, with some supplemental data to 1969. Although these data make possible many statistical comparisons, we have included only those that provide an interpretive base for fire planning.

[1] *In cooperation with the USDC National Oceanic and Atmospheric Administration (NOAA) National Weather Service.*

Table 3 — *Yearly and seasonal averages for several measures of fire activity*

Fire business	Five districts of the Clark National Forest, 1952-1961			Eminence State District, 1961-1968			West Plains State District, 1961-1968		
	Spring season	All other seasons	Annual	Spring season	All other seasons	Annual	Spring season	All other seasons	Annual
Fires (all causes)	82	121	203	154	71	225	423	119	542
Incendiary fires	--	--	--	65	16	81	178	32	210
Debris fires	--	--	--	65	27	92	217	53	270
Class "C" and larger fires	17	11	28	45	18	63	124	26	150
Burned acres	998	832	1,830	2,857	921	3,778	8,498	1,262	9,760
Fire-days	33	63	96	47	43	90	59	60	119
Fires/fire-day	2.5	1.9	2.1	3.2	1.6	2.5	7.1	2.0	4.6
Fire-days as percentage of all days	38	23	26	51	15	25	65	19	33

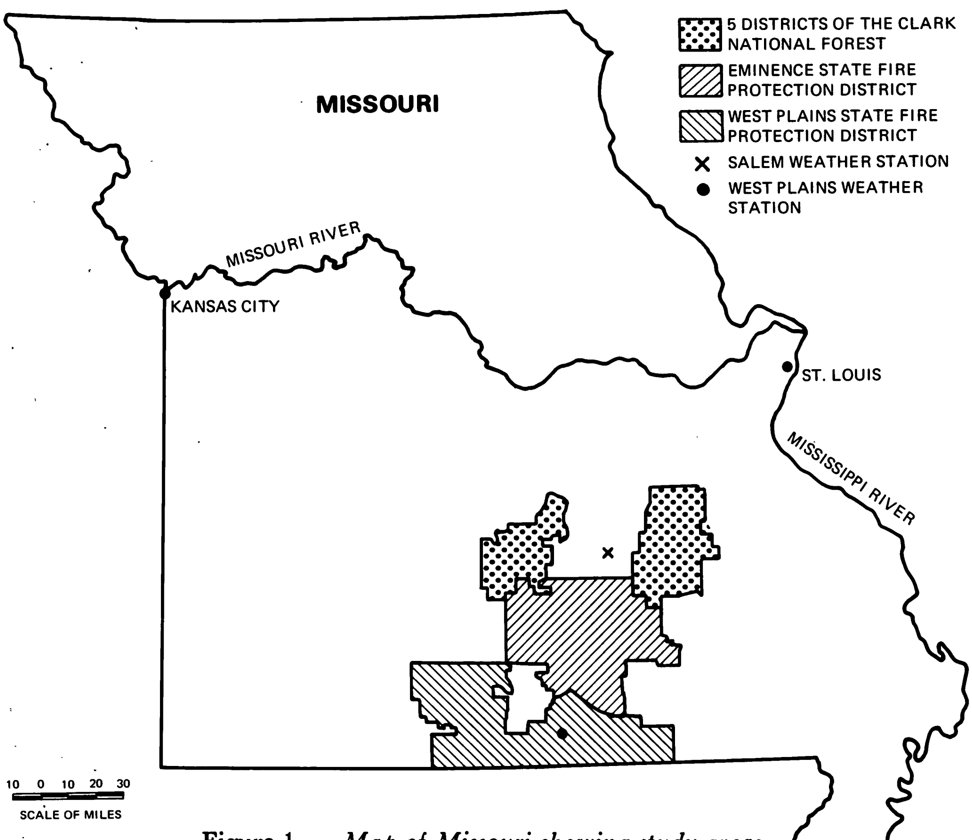

Figure 1. — *Map of Missouri showing study areas.*

THE ANNUAL DISTRIBUTION OF FIRES

Ten years of data from the Clark National Forest show that Missouri's spring fire season begins early in February and slowly increases in intensity to a peak in early April (fig. 2). The decline of fire activity is much more rapid, with the spring fire season ending by early May. A secondary fire season begins in early October and peaks in mid-November. Unlike northern forests where heavy snows end the fall fire season and snowmelt brings a definite spring start, Missouri may have fires throughout the year.

The peaks and lulls in fire occurrence are highly dependent upon seasonal changes in weather, fuels, and vegetation. Moreover, the life style and traditions

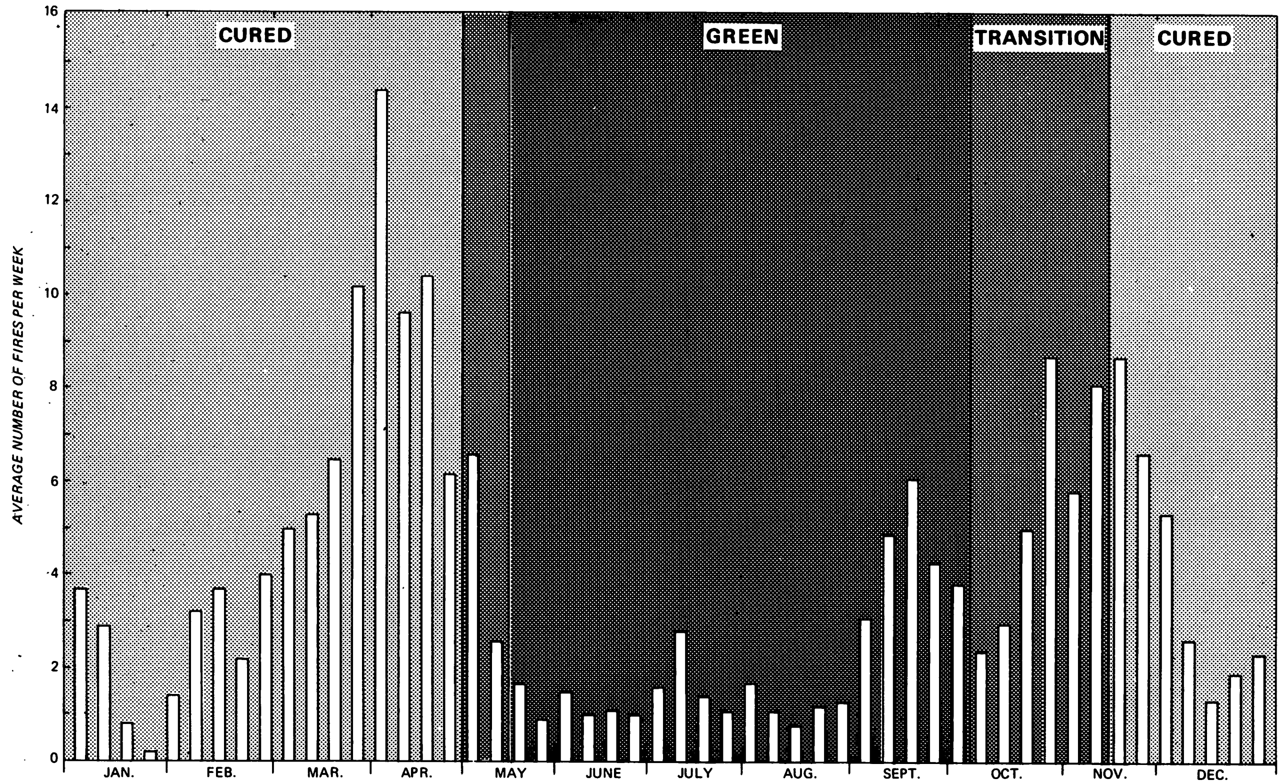

Figure 2. — *Average fires per week on five districts of the Clark National Forest and seasonal vegetative stages.*

of the rural people regarding woods burning affects the annual fire profile. During March and April incoming solar radiation is almost the same as it is during August and September in Missouri. However, because of greater spring cloudiness, measured radiation at the earth's surface is 20 percent less in March and April (Baker and Haines 1969). It might seem that with less available solar radiation in the spring months the forest fire potential would be less than in August and September. But in spring the hardwood forests are devoid of foliage, letting the available solar radiation through to the litter and slash.[2] The quantity of litter fuels is then at a maximum, and the slow shedding of dead foliage by some oaks is completed.

This is the time of year when strong cyclogenesis (low pressure areas) develops over the central United States, producing extended periods of strong winds in Missouri. March and April have low humidities coupled with the strong winds (tables 4, 5, 6, and 7), making this season optimum for fuel drying. In addition, spring is the traditional time for the residents to engage in woods burning. "Spring cleanup" also contributes to the problem.

Early May sees the hardwood forest suddenly turn green with a leafy canopy that greatly reduces solar radiation at the forest floor. The humidity increases and windspeed decreases. The change is especially apparent under the forest canopy. With these conditions litter fuels decay more rapidly, so that by the end of September the weight per acre of surface fuel has reached an annual minimum. Traditionally, cattle were turned into the woods to graze by May and then fire was unwanted. Consequently, in addition to poorer burning conditions during late spring and summer, there was and is less incentive for residents to burn.

[2] *The same conditions might apply in summer or early fall if the forests are seriously defoliated by insects or disease.*

Table 4 — *Frequency of windspeeds, Salem, Missouri, 1300 c.s.t.*
(In percent of days in month)

Month	Windspeed (m.p.h.) ≤5	6-9	10-13	14-19	20-23	24-29	≥30
Jan.	29.7	38.4	20.1	10.1	1.5	0.2	--
Feb.	25.6	38.9	24.8	8.8	1.4	.6	--
March	20.1	32.9	27.2	16.6	2.8	.4	--
April	20.4	36.6	23.2	15.9	3.3	.6	--
May	36.9	37.6	17.8	6.6	.9	.4	--
June	45.8	41.1	9.4	3.6	--	--	--
July	54.8	37.1	7.7	.4	--	--	--
Aug.	57.3	34.2	7.9	.6	--	--	--
Sept.	45.9	38.9	14.1	1.1	.2	--	--
Oct.	39.4	37.4	18.6	4.1	.2	.0	0.2
Nov.	28.8	33.9	23.9	11.3	1.9	.0	.4
Dec.	30.3	36.1	20.9	12.4	.4	--	--

Table 5.—*Frequency of windspeeds, West Plains, Missouri, 1200 c.s.t.*
(In percent of days in month)

Month	Windspeed (m.p.h.) ≤5	5-9	10-14	15-19	20-24	25-29
Jan.	25.2	52.7	16.1	5.2	0.8	--
Feb.	19.5	49.4	24.7	5.5	.6	0.3
March	12.1	47.6	28.8	8.5	2.7	.3
April	14.4	51.6	24.9	7.0	2.0	--
May	24.1	37.3	37.6	1.1	--	--
June	36.4	53.0	9.0	1.5	--	--
July	36.6	52.7	9.9	.5	--	--
Aug.	44.6	48.3	7.0	--	--	--
Sept.	38.2	50.6	10.0	1.2	--	--
Oct.	26.9	57.3	13.4	2.0	--	--
Nov.	21.2	55.4	19.6	3.0	.6	--
Dec.	26.6	45.7	23.7	2.3	1.4	--

As autumn approaches, the green vegetation[3] begins to mature (fig. 2). Following the first hard frost or sometimes even earlier, grasses and other herbaceous vegetation cure rapidly. By early November a large portion of the approximately 2 tons/acre canopy of hardwood leaves and pine needles have become part of the surface fuels. The days are shorter and temperatures lower; therefore, burning periods are normally short and infrequent. Den-tree fires started by hunters and debris-burning fires are occasionally a problem.

Winter, of course, is colder with occasional snow. Surface leaves often dry to low moisture content, but the duff holds moisture, and fires that do start usually do little damage.

The West Plains District averaged less than one fire a week during most of the summer and experienced an insignificant September fire problem during the decade of the 60's (fig. 3). This more southerly district commonly has an earlier and more severe spring fire season than the Clark. The large number of fires shown during September on the Clark (fig. 2) is somewhat misleading, which reflects the hazard of drawing conclusions from relatively short time periods. Unprecedented late-summer droughts in 1952, 1953, and 1954 (fig. 4) caused major fall fire activity to occur much sooner and be stronger than usual (contrast figs. 2 and 3). In the late fall of 1952 a proclamation by the governor, followed by similar Forest Service action, closed all woods and forests in Missouri to the public, the only time this action has been taken. Other fall droughts have occurred, of course (fig. 4), but the 1952 to 1955 period was the worst in the memory of the people living in the eastern Ozarks. Drought can be expected to occur in the future, and prevention action will again have to be stepped up to counteract a potential large-fire disaster. On those occasions some measure of previous drought severity (fig. 4) will be helpful to back up the administrative decisions that officials must make.

[3] *Conditions of vegetation or herbaceous stage have appropriately become an integral part of fire danger rating systems. The method used to describe this state of vegetation is given by Nelson (1964) and identifies three stages of curing condition for vegetation such as grass and forbs.*

Table 6. — *Frequency of relative humidity values, Salem, Missouri, 1300 c.s.t.*
(In percent of days in month)

Month	Percent relative humidity ≤14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-59	60-69	≥70
Jan.	0.2	0.4	1.9	2.7	5.7	4.8	7.8	9.5	15.0	12.2	39.9
Feb.	.4	.8	3.9	4.1	7.9	9.4	8.6	9.8	14.8	11.0	29.1
March	.8	2.0	4.5	8.0	9.9	11.6	8.1	8.7	11.2	9.4	25.8
April	—	3.0	8.0	11.7	10.0	10.2	9.6	7.4	11.7	8.4	20.0
May	—	.2	2.3	5.2	8.1	12.0	11.3	9.0	17.9	14.4	19.5
June	.2	.0	.2	1.3	2.8	6.3	9.1	15.2	30.9	19.1	15.0
July	—	—	.5	1.1	4.5	10.4	13.1	12.5	27.4	18.5	12.1
Aug.	—	.2	1.1	2.3	4.5	10.2	13.3	14.5	28.4	12.9	12.7
Sept.	.4	1.1	2.2	6.7	10.2	8.1	15.2	9.8	17.8	11.3	17.4
Oct.	.4	3.9	6.8	8.2	13.4	9.9	10.9	11.8	12.5	6.1	16.0
Nov.	.8	1.5	3.7	6.1	11.1	7.6	13.3	9.4	13.7	10.8	22.1
Dec.	.2	.7	1.1	2.3	4.3	5.2	8.6	10.1	16.0	14.0	37.6

Table 7. — *Frequency of relative humidity values, West Plains, Missouri, 1200 c.s.t. (In percent of days in month)*

Month	Percent relative humidity										
	≤14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-59	60-69	≥70
Jan.	—	—	1.5	1.8	5.9	8.8	9.7	10.0	21.4	12.1	28.7
Feb.	--	0.3	.9	4.1	6.4	10.8	8.9	8.9	22.3	9.9	27.4
March	—	2.1	4.7	7.6	7.3	9.4	11.1	7.3	14.9	8.2	27.3
April	0.3	1.5	3.9	10.2	13.8	12.9	9.3	6.3	14.5	6.6	20.4
May	--	.2	.9	2.6	4.7	6.2	12.9	12.3	22.9	17.9	19.4
June	—	--	—	—	2.4	3.4	6.1	8.8	37.4	24.3	17.6
July	—	—	--	.5	2.3	3.8	6.6	11.3	34.9	22.5	17.9
Aug.	--	--	.5	1.4	2.3	5.5	6.7	11.3	34.8	20.9	16.3
Sept.	—	—	—	.3	2.6	6.9	8.1	13.4	25.3	20.3	22.9
Oct.	--	.3	3.1	6.3	10.4	11.0	10.1	9.4	17.6	16.4	15.7
Nov.	1.2	.9	4.5	4.8	6.0	6.6	12.1	12.1	15.4	11.4	24.8
Dec.	.5	.3	.8	2.1	4.5	5.6	8.3	11.0	16.4	15.5	34.8

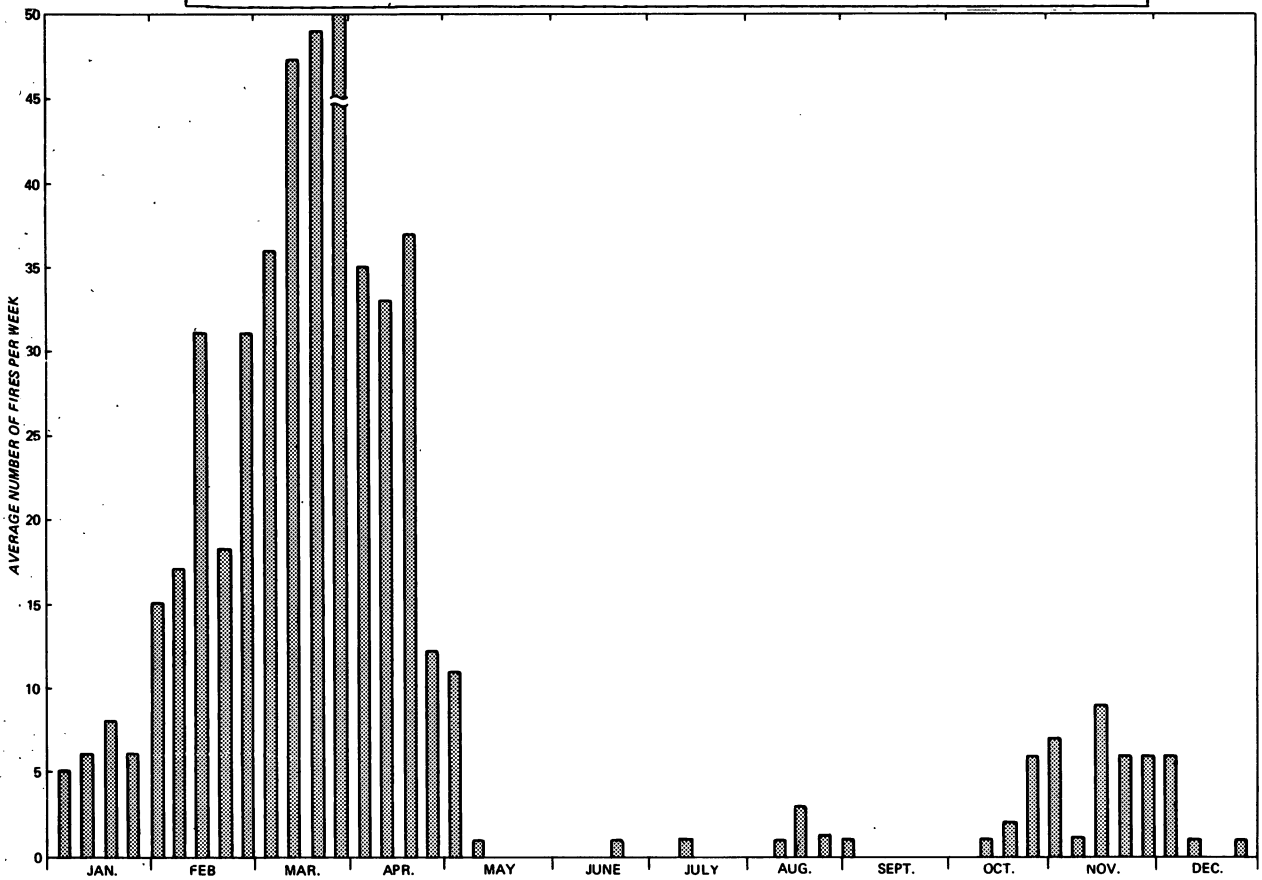

Figure 3. — *Average fires per week on the West Plains District. Weeks averaging less than one fire not indicated.*

THE MULTIPLE-FIRE DAY

In areas where fires are infrequent, fire control planning depends upon predicting days with high probability of a fire. Where fires are numerous, planning depends upon the ability to predict the number of fires that will occur each day. Examining the number of days having at least one fire (fire-days) and the number of fires per fire-day can provide managers with useful predictive information. The three protection areas show large differences in some measures of fire business, but the differences in the average annual number of fire-days are not extreme (table 3).

An indication of the suppression problem on the three areas is easily obtained by dividing the number

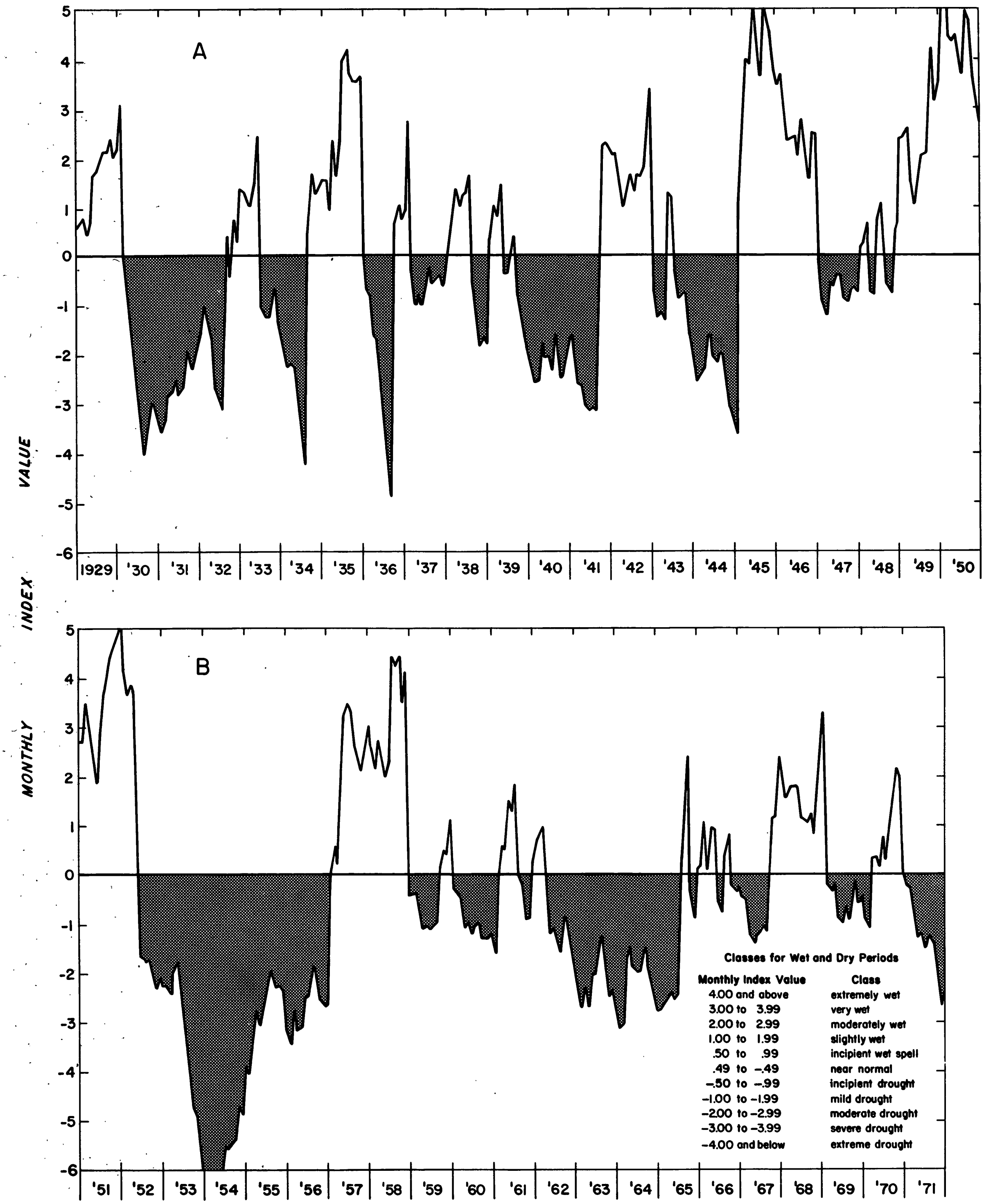

Figure 4. — *Monthly averages of the Palmer Drought Index for the Eastern Ozarks (Palmer 1965). A, 1929-1950; B, 1951-1971.*

of fires per year by the total number of fire-days, thereby finding the average number of fires per fire-day. The combined Clark Districts averaged two fires per fire-day, the Eminence District two and one-half, and the West Plains District more than four. Significantly, these values remain fairly constant year after year (fig. 5); this stability also holds true if only the fires of 10 acres and larger are included.

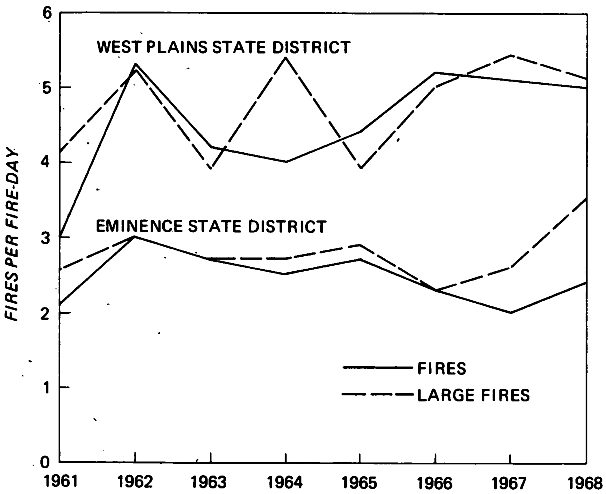

Figure 5. — *Average number of fires per fire-day and average number of 10-acre or larger fires per large fire-day.*

Of more managerial significance, however, is the distribution of fires throughout the year. The annual distribution of fire-days (fig. 6) shows the same pattern as fire numbers (fig. 2), except that the spring and fall seasons have more nearly the same number of fire-days per week.

Computing fire-days as a percent of all days in the year shows that 26 percent of the total were fire-days on the Clark Districts, 25 percent on the Eminence District, and 33 percent on the West Plains District (table 3). But during the spring fire season alone, the Clark National Forest Districts had fires on 38 percent of the days, the Eminence District on 51 percent, and the West Plains District on 65 percent. These percentages are much higher in spring than in the other seasons of the year.

The intensity of seasonal fire business is further indicated by comparing the number of fires per fire-day in spring with the number in all other seasons (table 3). These data again show the concentration of fires during spring. The concentration is most pronounced on the West Plains District, where 2 out of 3 spring days had fires, and fire numbers averaged more than seven per fire-day. This is a heavy suppression load by any standard.

Nevertheless, averages by themselves may be misleading; therefore, the number of fires per fire-day over all seasons should be examined (fig. 7). On the five districts of the Clark National Forest, 50 percent of the fire-days had only one fire. The Rangers in this area could expect to have two fires on about 20 percent of the fire-days. The chance of seven fires per fire-day is less than 1 percent, and 14 was the highest number of fires occurring in a single day on the Clark during the 1950's.

Eminence State District data are similar except that there are a significant number of days within the "10 or more" category. The maximum number of

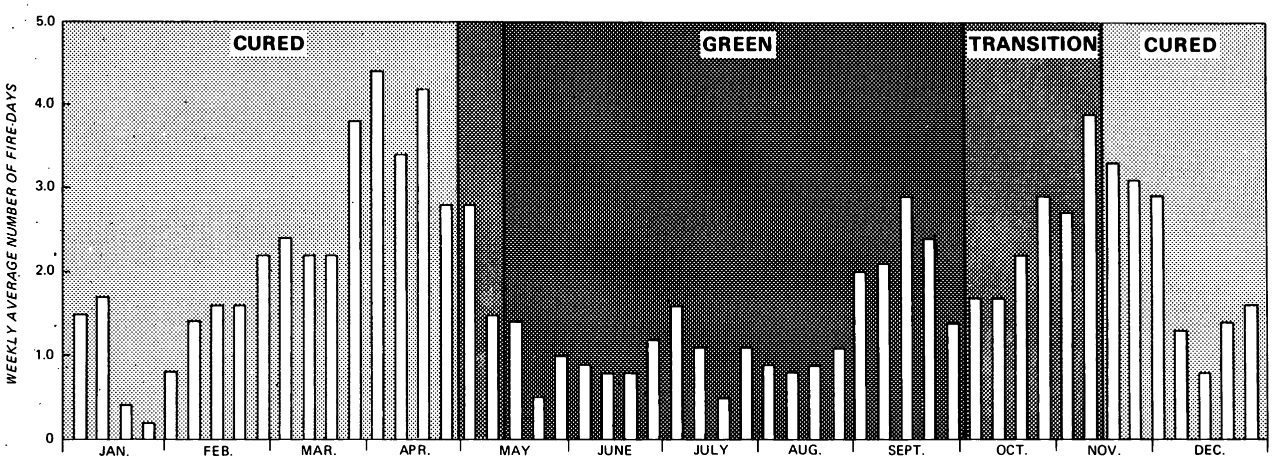

Figure 6. — *Average number of fire-days per week on the five districts of the Clark National Forest and seasonal vegetative stages.*

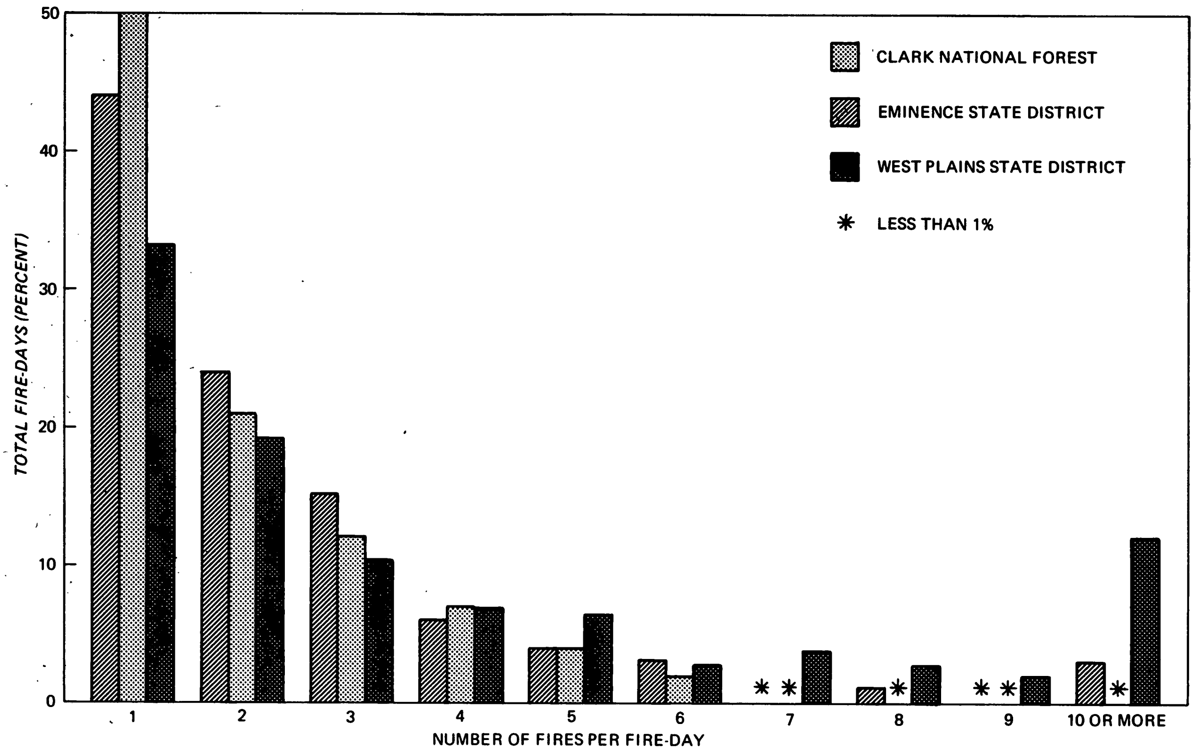

Figure 7. — *Percent of days having a given number of fires per fire-day, averaged for the year.*

fires for any one day on this district was 20 during the years examined.

The West Plains District displays a different pattern. Here only one-third of the fire-days had just one fire and 12 percent of the fire-days had 10 or more fires. The maximum number of fires on any one day, 43, was recorded on February 13, 1962. That day the district fought 21 debris-burning fires. There were 20 incendiary fires with only four set in a single string. Twenty-five of the fires grew to Class C size or larger, while a total of 5,346 acres burned.

Multiple-fire days call for skillful dispatching of men and equipment plus good communications. The decisions involved with the sudden mobilization necessary to fight large numbers of near simultaneous ignitions are vital. The number of men needed is the crux of the decision process. To help solve this problem, the average number of man-hours required to control fires were computed for days having different numbers of fires per fire-day on the West Plains District (fig. 8).

Roughly, 3 to 4 man-hours are required to control the average fire when one to six fires occur on the

Figure 8. — *Average number of man-hours needed to control a fire relative to the number of fires per fire-day, West Plains State District.*

same day. Although the data are somewhat erratic, they show a general increase in manpower necessary for control as the number of fires per fire-day increases. At 15 and 16 fires per fire-day, it takes 7 to 8 man-hours to control each fire. There are probably two reasons for this. First, increased fires per fire-day should reflect increased weather severity, and consequently more control difficulty. Second, manpower resources are not inexhaustible. As the number of fires increases, there are fewer people available to fight each one. Therefore, the insufficient force present at each fire requires a greater total suppression effort. Delays in initial attack contribute to increased control time. Rapid initial attack is often the difference between a small or large fire.

Combining numbers of fires per fire-day with data for average man-hours to control provides some additional information for manpower allocations. For example, at 18 fires per day, the average number of man-hours to control a fire is 10. On that day 180 man-hours will be needed for control action. At 8 work hours per man-day, 23 men are needed. But this is an unrealistically low number of men. The 18 fires may be scattered over three or four counties, requiring travel and search time. Thus, few men spend a full 8 hours controlling fires. The work force, even if optimally used, must be greater than 23 men. The number of men and their locations will probably be decided the previous day or during the morning of the fires. But even before the season starts, the administration must prepare a budget for anticipated suppression costs. The average man-hours for suppression can be estimated from these data for a season.

The concept of the multiple-fire day has other applications. In Missouri in 1970, 30 percent of the fires and 59 percent of the total acreage burned occurred on only 2 percent of the total days (USDA Forest Service 1971). Major fire control activity is usually concentrated within a short time span. Statistics compiled for the average year on the West Plains District bear this out (fig. 9), as follows:

(1) Slightly less than half of all fire-days had two or more fires.

(2) Half of all fires occurred on days when there were eight or more fires.

(3) Half of all large fires occurred on days when there were 11 or more fires.

(4) Half of all man-hours to control were used on days when there were 12 or more fires.

(5) Half of all acreage burned was on days when there were 13 or more fires.

Thus the fire control job is compressed into a relatively small number of days of intense activity, while over the season as a whole the organization handles a much smaller fire load. These data also illustrate the potential of past records as possible predictive tools in fire-control planning.

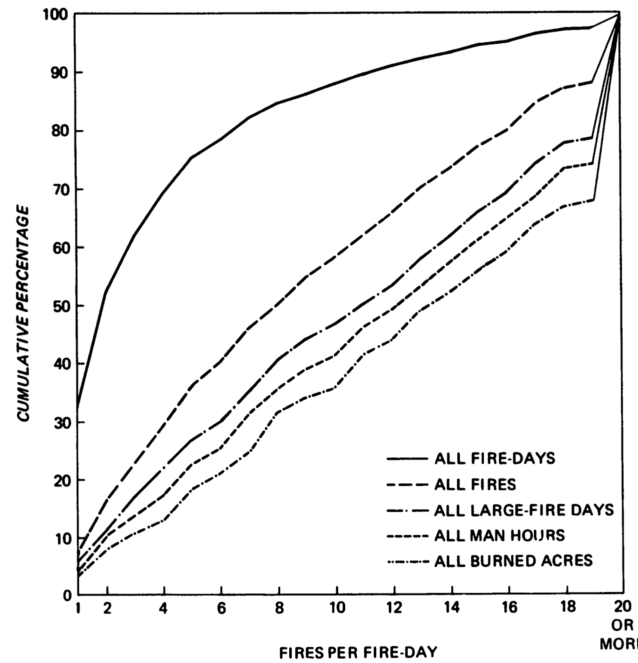

Figure 9.—*Cumulative percent of five measures of fire activity relative to the number of fires per fire-day, West Plains State District.*

One factor is especially important during the time of year when multiple fires are common. Much depends upon speed of control and this in turn is related to rapid initial attack. Men and equipment cannot be tied up on single fires for long periods. Personnel must have enough versatility to handle other fires. Optimum crew size and equipment, consequently, are critical considerations.

FIRE CAUSE

Weather, fuels, and vegetation stage are the factors commonly used to measure fire danger. Fire occurrence in Missouri is also strongly affected by the attitudes and habits of the people. Some residents accept woods burning as a normal practice. Customarily, spring is a favored time for burning; it is rarely done in other seasons. Much of today's wildfire activity stemming from debris burning and incendiarism is basically a carryover from traditional burning practices (Crosby 1960).

To examine the cause factor in more detail, fires were tabulated by cause for the West Plains and Eminence State Districts on an average monthly and yearly basis. Incendiary and debris burning fires accounted for the overwhelming majority of all starts. Consequently, fires originating from these two causes were tabulated separately, and the rest of the causes (lightning, campfire, machinery, smoking, miscellaneous, and unknown) were classified as "other."

Yearly Summaries

The distribution of fires by cause on the West Plains District does not appear to show an increasing or decreasing trend in the year-to-year data (fig. 10). However, there seems to be a falling off of total yearly fire activity on the Eminence District from 1963 through 1968, although there is no clear evidence that it is related to a change in fire cause (table 8). The year-to-year distribution appears random, although there may be a slight increasing trend in "other" starts on the Eminence District, with a corresponding decrease in the incendiary cause category. On the average, the Eminence District records 35 percent of fire causes as incendiary. About 42 percent of the fires are due to debris burning, and 23 percent are started by other causes. On the West Plains District 39 percent of the fires are incendiary starts, 50 percent are due to debris burning, and 11 percent result from other causes.

Table 8. — *Percent of fires and burned area by cause on the two State Districts*

WEST PLAINS STATE DISTRICT

Year	Debris burning: Fires	Debris burning: Burned area	Incendiary: Fires	Incendiary: Burned area	Other: Fires	Other: Burned area
1961	53	57	31	32	16	11
1962	48	58	39	30	13	11
1963	47	41	39	52	14	7
1964	62	52	27	40	11	7
1965	50	52	36	35	14	14
1966	43	48	48	47	10	5
1967	58	47	33	46	9	8
1968	45	51	49	47	6	2
Average	50	51	39	41	11	8
EMINENCE STATE DISTRICT						
1961	48	68	36	22	17	10
1962	39	30	42	54	20	16
1963	35	21	40	62	25	16
1964	54	62	26	19	20	19
1965	37	48	40	36	23	16
1966	31	26	47	58	22	15
1967	47	60	24	29	29	11
1968	44	33	24	28	33	40
Average	42	44	35	39	23	18

Within each of the two State districts, the 8-year average percentages of fire numbers and area burned are almost the same for each fire cause. For example, incendiary starts accounted for an average of 39 percent of the fires and 41 percent of the burned area on the West Plains District. These averages are misleading, however. There are tremendous year-to-year differences in the percentages on both districts. As an example, incendiary starts accounted for about 20 percent of the burned area on the Eminence District in 1961 and 1964, but more than 50 percent of the lost acreage in 1962, 1963, and 1966. These latter 3 years were also the years of greatest area burned on that district (fig. 11), probably reflecting the fact that an active incendiarist can quickly overload the fire-control forces. The highest burned acreage occurred in 1962 on the West Plains District. More than 18,000 acres were consumed, with debris burning accounting for 58 percent of the starts. Surprisingly, even with the tremendous year-to-year variations shown in figure 11, the annual proportion of burned acreage caused by large fires is relatively constant at 80 to 95 percent.

For the most part, the percentage of incendiary starts (table 8) followed the same trend each year on both State districts. When one district showed a change in this cause category, so did the other. Area burned due to incendiarism did not follow this same pattern.

Monthly Averages

Both State districts record a small number of "other" fire causes throughout the year, which peak equally in the spring and fall. Incendiary and debris-burning fires, on the other hand, show a strong maximum in the spring and a weak secondary peak in the fall.

March is by far the worst fire month on the West Plains District, with an average of over 200 fires (fig. 12). On the Eminence District, however, the fire

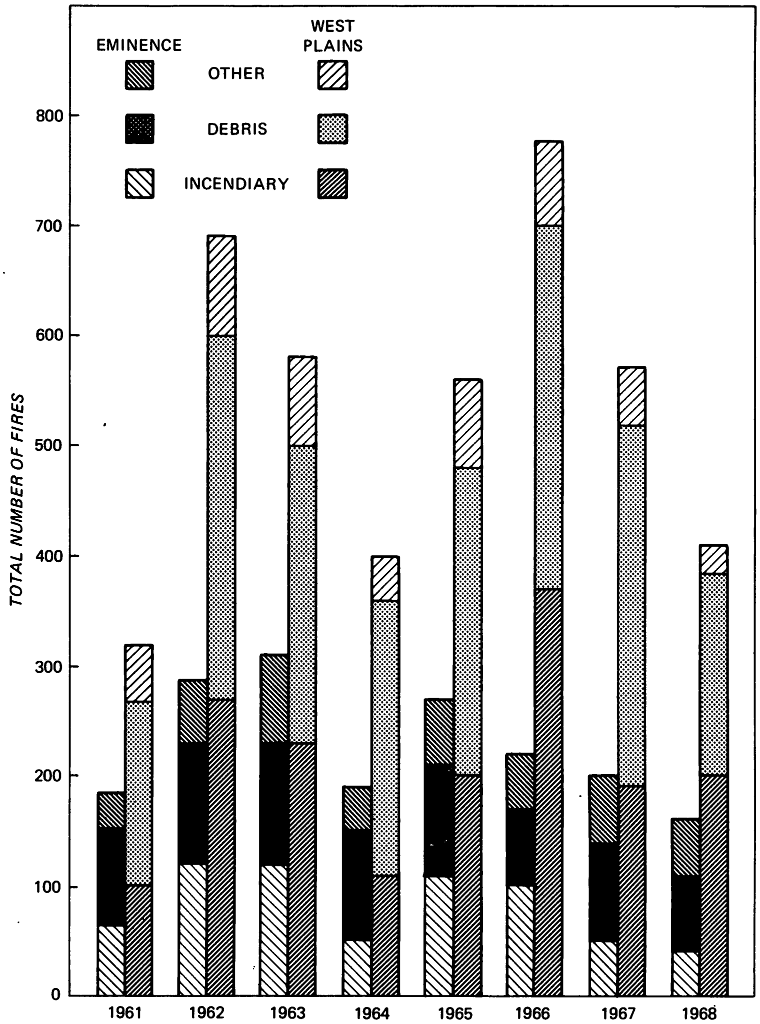

Figure 10. — *Total number of fires on the two State districts by cause.*

starts are almost evenly divided between March and April. If we consider only fires of 10 acres or larger, then April is a worse month on the latter district (fig. 13). It is notable that the large-fire problem in April on the Eminence District is primarily due to incendiarism, which accounts for 53 percent of the starts. When considering large fires this is the only major fire month on either State district when incendiary starts averaged more than one-half of the total.

FIRE ACTIVITY BY DAY OF WEEK

Many managers feel that day of the week is an important factor to consider in fire-control planning, because of social patterns that increase fire starts. Weekends, holidays, sale days, election days, and other special occasions all produce broad similarities in local social response, which may be related to variations in fire occurrence. As an example, on weekends more visitors are in the forests and parks, and large numbers of rural residents who work in the cities are home. One might argue that more people create a greater risk potential, therefore more fires.

Tabulation of day-of-week data in the northeastern United States is not often done. A 5-year summary of number of fires compiled by the Wisconsin Department of Natural Resources (1970) shows a small but

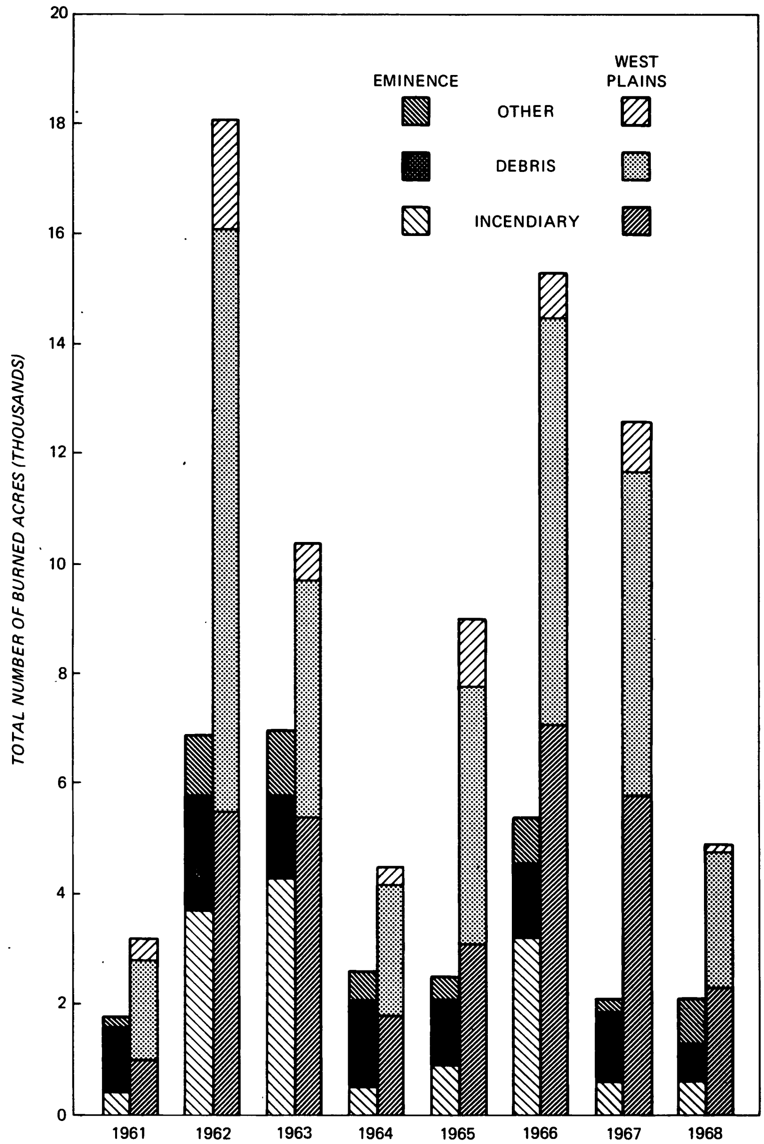

Figure 11.—*Number of acres burned by cause on the two State districts.*

fairly consistent year-to-year bias for Saturday fires. State of Pennsylvania data indicate a decided preference for weekend fires.[4] To test the hypothesis for Missouri, we tabulated available measures of fire activity by day-of-week. The tabulations were done as yearly averages for a given day of the week over the period of record. National Forest data were also compiled by individual years and seasons. Information for the two State districts was broken down still further into cause classification.

Few clear patterns emerged from this analysis. In terms of average acreage burned and man-hours to control, the only interesting feature occurred on the Eminence District. There the greatest acreage burned on Thursdays with 65 percent of the loss due to incendiarism. Correspondingly, the greatest amount of manpower was used on that day. On the average, 340 man-hours per year were used for fire control on

[4] *Personal correspondence with Mr. E. F. McNamara, Pennsylvania Department of Environmental Resources, 1972.*

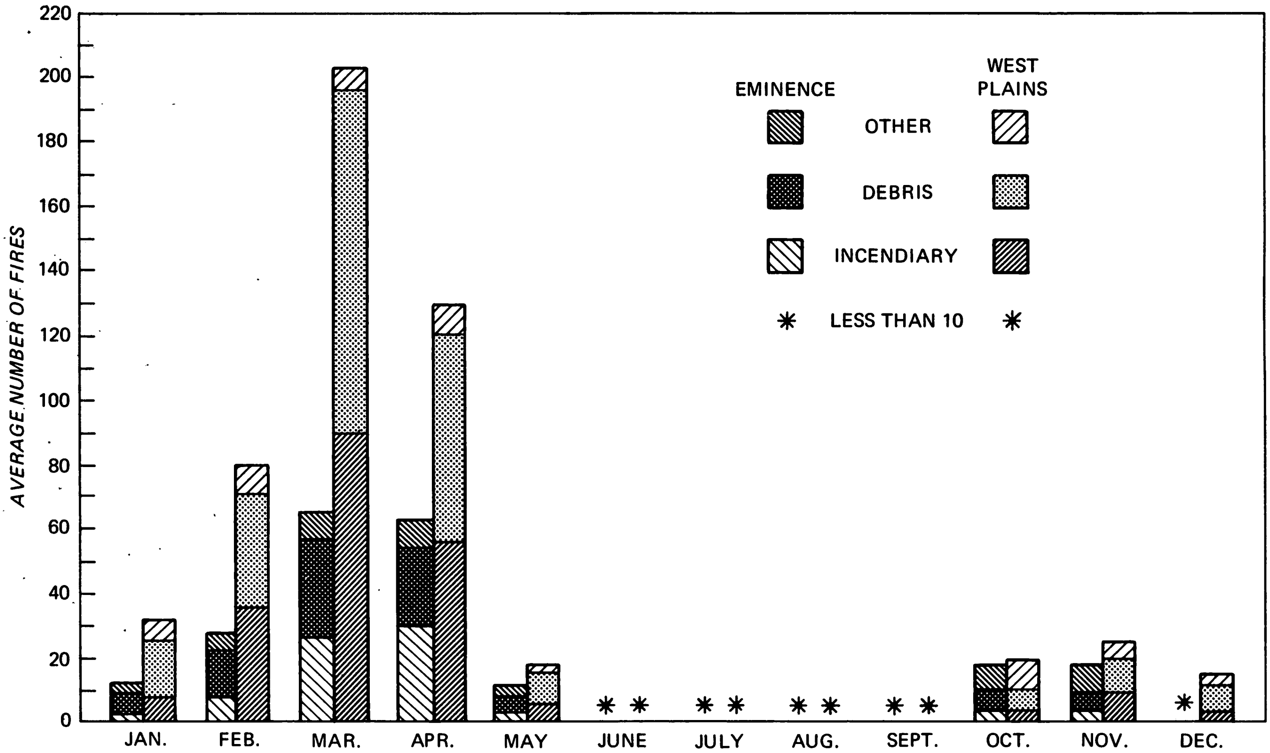

Figure 12. — *Average number of fires per month by cause groups on the two State districts.*

Thursdays at Eminence, more than one-half again as many hours as on the next worst day of the week. This certainly reflects the management problems inherent in dealing with incendiarism.

No obvious day-of-week trend is apparent in large-fire starts. The Eminence District had the greatest number of large fires on Saturday, while the West Plains District had the fewest number of large fires on that day.

Only when we examine average number of fires do some interesting weekend data emerge. This measure of fire activity shows that there are more fires on Saturday on the two State districts than on other days, although the difference is relatively small. The second greatest number of fires occurs on Tuesday on the West Plains District and Thursday on the Eminence District. These cause data do not appear to indicate a meaningful day-of-week pattern.

There is, however, an increasing trend in total fires through the weekend on the Clark. This may reflect a much higher weekend usage of Missouri's National Forests in comparison with State and private forest lands. To test this trend further, supplemental data from the Clark for the period 1960-1969 were also sorted by day of week. This showed by far the greatest number of fires occurring on Sunday, with Saturday fires not as prominent as they were during the 1950's. Fire-days occurred most often on Sundays with Saturdays second in this measure of fire activity.

No generalizations can be made from this analysis that would have meaning outside of the examined areas. It is apparent, however, that day of week can be a local factor affecting fire starts. It also may be only a coincident factor. The fire control manager should be alert to any day-of-week pattern that may be evidenced on his district. An analysis could well provide the basis for further investigation of both cause and characteristics of people responsible. This then would be an aid in fire prevention as well as in planning presuppression and suppression activities.

FIRE WEATHER

The climatic patterns that prevail in Missouri have been well described by Miller and Decker (1957), Decker (1963), and McQuigg and Decker (1963).

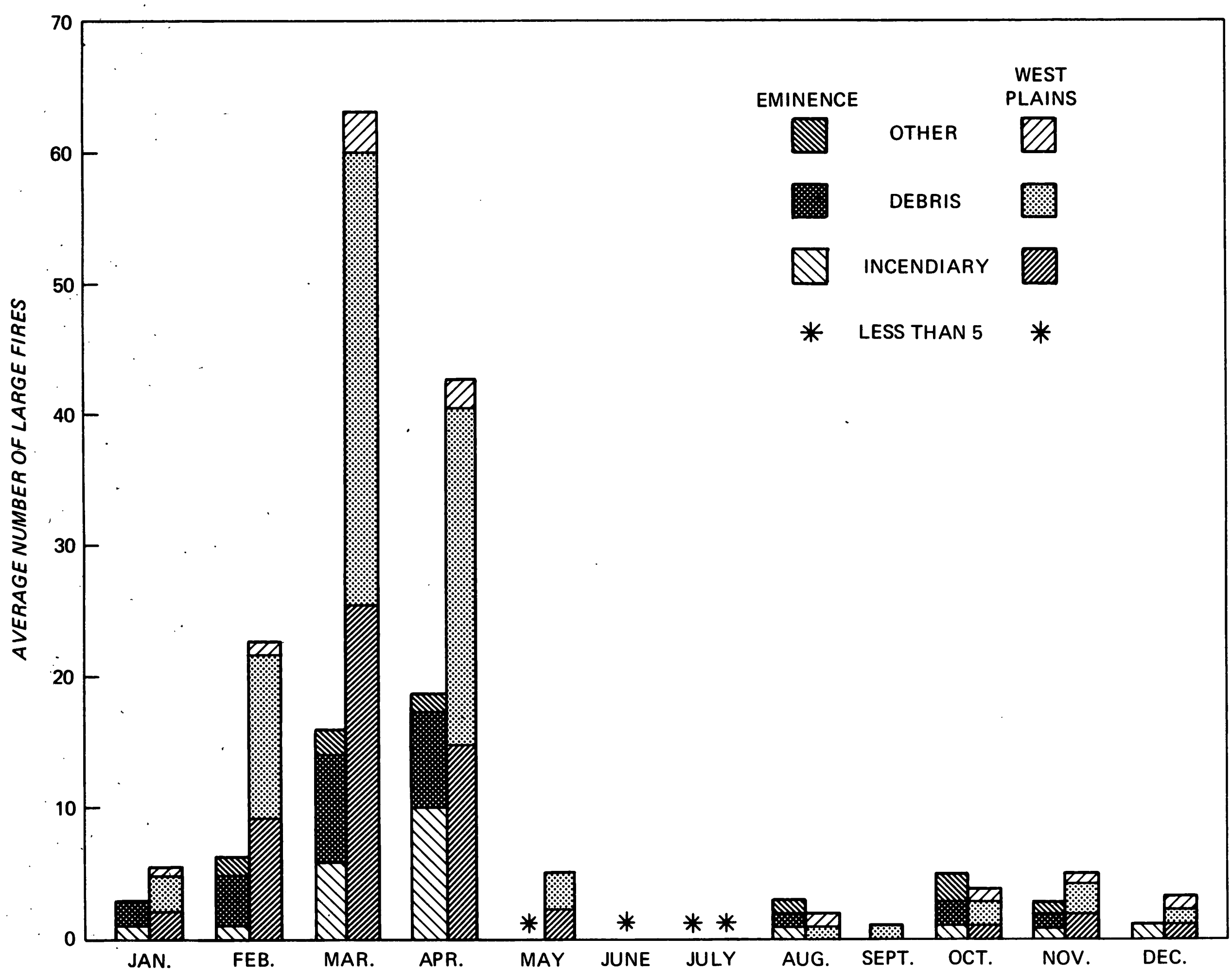

Figure 13. — *Average number of large fires per month by cause on the two State districts.*

Yearly precipitation varies from less than 34 inches in the extreme northwest to over 50 inches in the southeastern lowlands. During the height of the spring fire season (figs. 2 and 3), weekly precipitation normals vary from 0.6 inch in the northwest to 1.2 inches in the extreme south and southeast. During this same period, afternoon maximum temperatures average 60° F. in the north to 68° F. in the extreme southeast.

In Missouri the probability of a fire-day is usually a function of season, fuel availability, fine fuel moisture, windspeed, and human activity. The first four variables are relatively easy to measure; the fifth is more complex. Haines, Main, and Johnson (1970) found the Fine Fuel Spread Index in the 1964 version of the National Fire Danger Rating System (Nelson 1964) to be a surprisingly good predictor of the probability of a fire-day. This index assumes uniform fuel availability and essentially assigns a constant value to human activity. It is fundamentally a weighted composite of the fine fuel moisture (which is responsive to atmospheric temperature and relative humidity) and windspeed.

The index was computed for the spring season using the weather records at Salem, Missouri. By comparing this index with the fire activity on the five districts of the Clark National Forest it is possible to show both the probability of a fire-day and a large-fire day (fig. 14). Computations were done by using mean values over two-unit index increments. The coefficient of determination value (R^2) is high (fig. 14), but this is not unexpected. Like most fire danger rating systems, this index sorts days into classes with general levels of fuel moisture.

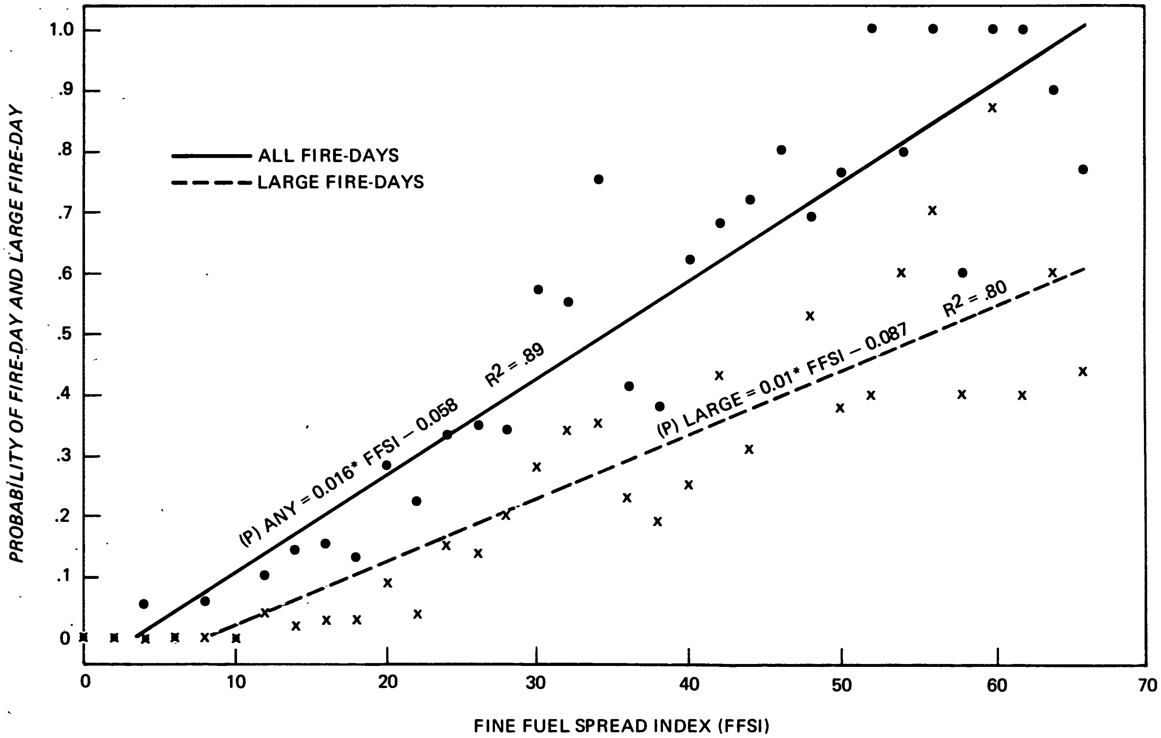

Figure 14. — *The relation between the Fine Fuel Spread Index and both the probability of a fire-day and the probability of a large-fire day. Clark National Forest, spring season.*

A knowledge of fuel moisture will provide information on expected rates of spread and energy release as well as the ignition potential. The ignition factor, by itself, answers the question, "Will it burn?" In level terrain the fire may need wind to act as a spread agent or it will go out. If the fire goes out quickly, there will have been a fire start, but not necessarily a *reportable* fire. Debris-burning fires offer a good example. If a firebrand from a trash burner ignites dry grass on a Missouri oak-hickory litter area during a calm afternoon, the fire should spread slowly and may be suppressed by the person maintaining the burner. On a windy day, however, the fire may escape and the operator will have to call for the assistance of a fire suppression unit.

We calculated the wind's effect in determining the probability of a fire-day (fig. 15). Spring days were divided into two categories for the Clark National Forest: those with winds above 5 m.p.h. and those with winds at or below this velocity. The fine fuel moistures in each group were then plotted against the probability of a fire-day. Even with this rather rough breakdown, the importance of wind as a factor in the computations is convincing. At low fine-fuel moisture the chance of a fire-day increased 25 percent with windspeeds over 5 m.p.h.

We also tabulated the frequencies of occurrence of various relative humidity, temperature, and windspeed categories for early afternoon, when fire danger observations are usually taken (tables 4-7 and 9-10). During March, the most severe fire month (fig. 13), wind velocity is at or above 5 m.p.h. 88 percent of the time at West Plains (table 5). At Salem it is above 5 m.p.h. 80 percent of the time during March (table 4). In late summer the same breakdown of wind puts the frequency nearer the 50 percent mark. Wind velocity is one of the reasons for the intense spring fire season in Missouri.

Fine fuel moisture values are usually calculated from atmospheric temperature and relative humidity readings. The included tables for these two meteorological variables give frequency of occurrence, and therefore indirectly describe the probable ignition features of this fuel.

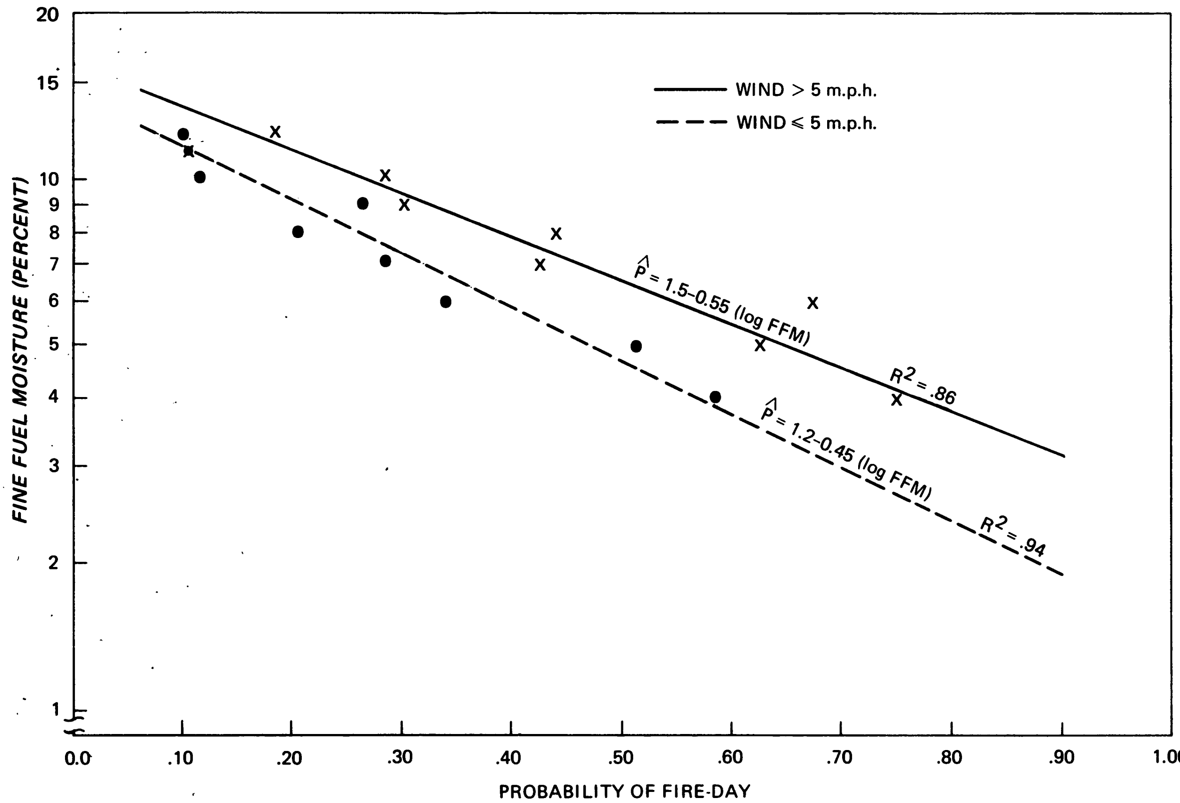

Figure 15. — *The relation between the Fine Fuel Moisture and the probability of a fire-day, with windspeeds at or below 5 m.p.h. and above 5 m.p.h. (for the Clark National Forest).*

Table 9. — *Frequency of temperature values, Salem, Missouri, 1300 c.s.t.*
(In percent of days in month)

Month	Temperature (°F.)									
	≤39	40-49	50-59	60-69	70-79	80-84	85-89	90-94	95-99	≥100
Jan.	59.1	20.6	14.6	5.3	0.4	--	--	--	--	--
Feb.	45.8	27.9	17.9	7.1	1.2	0.2	--	--	--	--
March	27.7	24.5	22.2	17.3	7.6	.7	--	--	--	--
April	2.2	12.6	21.9	27.6	28.2	5.9	1.5	--	--	--
May	--	1.5	10.1	25.7	35.8	20.6	5.9	0.4	--	--
June	--	--	1.7	6.5	31.1	24.1	27.4	6.1	3.1	--
July	--	--	.2	.7	18.8	27.4	30.6	16.7	5.4	0.2
Aug.	--	--	--	2.7	22.5	28.1	30.8	12.9	2.9	.1
Sept.	--	.2	1.8	17.7	40.6	18.7	14.4	4.6	1.8	.2
Oct.	.6	4.8	20.6	31.0	31.0	9.3	2.3	.4	--	--
Nov.	16.7	25.4	25.7	24.3	8.0	--	--	--	--	--
Dec.	49.8	25.0	18.8	6.3	.2	--	--	--	--	--

SUMMARY

Fire protection is critical in Missouri because of the large forest acreage. A tabulation of records on three fire protection areas shows that in much of the State the major fire season begins in early February. Activity peaks in early April and is over by early May. There is a second fire season in the fall with maximum activity in mid-November, but it is less severe than the spring season. There are also more multiple-fire days in the spring than in the fall.

The multiple-fire day is highly indicative of the problem that protection units face. The average number of fires per fire-day changes dramatically from district to district within Missouri, but stays fairly constant from year-to-year within a given area. This area stability is also evident when the measure is

Table 10 — *Frequency of temperature values, West Plains, Missouri, 1200 c.s.t.*
(In percent of days in month)

Month	<39	40-49	50-59	60-69	70-79	80-84	85-89	90-94	95-99	100-104
	Temperature (°F.)									
Jan.	43.7	24.3	18.8	12.0	1.2	—	—	—	—	—
Feb.	31.1	28.7	22.6	12.9	4.2	--	0.3	—	—	—
March	10.4	22.1	24.2	23.6	16.4	2.4	.8	—	—	—
April	--	2.7	15.1	27.6	36.1	14.2	3.3	0.9	—	—
May	--	--	2.3	15.0	33.2	27.6	20.3	1.5	--	--
June	--	--	--	3.7	17.0	24.8	37.2	15.2	1.8	--
July	--	--	--	.2	3.2	17.1	33.1	31.4	11.5	3.2
Aug.	--	--	--	.6	10.6	14.4	30.7	33.9	7.4	2.3
Sept.	—	—	.8	7.8	34.7	24.2	20.6	8.7	2.9	--
Oct.	—	.5	8.8	29.9	35.1	16.7	7.3	1.4	—	--
Nov.	5.1	17.5	27.8	31.1	18.1	.3	--	--	—	--
Dec.	36.1	25.7	21.2	14.9	2.1	—	—	—	—	--

number of large fires per large-fire day, or the ratio of acreage burned by large fires to total acreage burned.

Incendiarism and debris burning are by far the most important causes of fire starts. These two factors account for 77 percent of the total fire starts on the Eminence District and 89 percent on the West Plains District. Incendiarism becomes an even greater concern if acreage burned and multiple-fire starts are used as the measure of fire activity.

Grouping the fire activity data by day of week does not produce many obvious patterns. Even average number of fires shows no discernible trend by day of week on the two State districts. On the five districts of the Clark National Forest, however, there is an increased number of total fires on weekends. This might reflect the high usage of the National Forests during these days.

Determining the probability of a fire-day in a protection area in Missouri can be done quite easily by combining the fine fuel moisture with the windspeed. The combination produces a good indication of fire potential, even though occurrence is also dependent upon the number of firebrands in an area.

LITERATURE CITED

Baker, D. G., and D. A. Haines. 1969. Solar radiation and sunshine duration relationships in the North-Central Region and Alaska. Minn. Agric. Exp. Stn. Tech. Bull. 262, 372 p., illus. (also North Cent. Reg. Res. Publ. 195).

Crosby, J. S. 1960. Forest and range fire problems of the Missouri Ozarks. USDA For. Serv. Misc. Rep. CS-32, 53 p. Cent. States For. Exp. Stn., Columbus, Ohio.

Decker, W. L. 1963. The march of the seasons through Missouri. Univ. Mo. Agric. Exp. Stn. Bull. 791, 51 p.

Gansner, D. A. 1963. Forest area in Missouri counties. USDA For. Serv. Res. Note CS-4, 4 p. Cent. States For. Exp. Stn., Columbus, Ohio.

Haines, D. A., W. A. Main, and V. J. Johnson. 1970. Relation between the national fire danger spread component and fire activity in the Lake States. USDA For. Serv. Res. Pap. NC-41, 8 p. North Cent. For. Exp. Stn., St. Paul, Minn.

McQuigg, J. D., and W. L. Decker. 1963. Climate of the southeast lowlands of Missouri. Univ. Mo. Agric. Exp. Stn. Bull. 794, 46 p.

Miller, M. F., and W. L. Decker. 1957. Let's look at the weather. Univ. Mo. Agric. Exp. Stn. Bull. 678, 31 p.

Nelson, R. M. 1964. The National Fire Danger Rating System. USDA Forest Serv. Res. Pap. SE-13, 44 p. Southeast. For. Exp. Stn., Asheville, N.C.

Palmer, W. C. 1965. Meteorological drought. U.S. Weather Bur. Res. Pap. 45, 58 p.

USDA Forest Service. 1971. Wildfire statistics, 1970. Div. Coop. For. Fire Control, Washington, D.C., 59 p.

USDA Forest Service. 1960-69. Wildfire statistics. Until 1968 called Forest Fire Statistics Annual Publ. by Div. Coop. For. Fire Control, Washington, D.C.

USDA Forest Service. 1950-59. National Forest Fire Report. Div. Fire Control Annual Publ., Washington, D.C.

Wisconsin Department of Natural Resources. 1970. Annual forest fire report for 1969. Bur. Fire Control, Madison, Wis., 23 p.

☆U.S. Government Printing Office: 1972 — 761-530

SOME RECENT PUBLICATIONS OF THE NORTH CENTRAL FOREST EXPERIMENT STATION

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Canadian Forest Products Shipped Into the North-Central Region, by Eugene M. Carpenter. USDA For. Serv. Res. Pap. NC-83, 22 p., illus. 1972.

Aspen: Symposium Proceedings. USDA For. Serv. Gen. Tech. Rep. NC-1, 154 p., illus. 1972.

A Method of Evaluating Crown Fuels in Forest Stands, by Rodney W. Sando and Charles H. Wick. USDA For. Serv. Res. Pap. NC-84, 10 p., illus. 1972.