OAK MORTALITY IN THE MISSOURI OZARKS [1/]

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Abstract.--In 1980 and 1983, the Ozark Region of Missouri suffered extreme droughts. Serious mortality has occurred in the red oak group, primarily, scarlet oak (Quercus coccinea Muenchh.) and black oak (Quercus velutina Lam.). Field studies of affected areas on the Mark Twain National Forest revealed most mortality occurred in scarlet oak stands over 60 years old, and greater than 14 inches in diameter. Low level, color infrared aerial photography with 100 acre photo interpreted cells on a systematic sampling design, was used to estimate oak mortality within affected areas. Based on this sample, 180,000 acres of the National Forest are expected to show some signs of oak mortality.

Keywords: forest decline, Mark Twain National Forest, Quercus coccinea Muenchh., Quercus velutina Lam.

INTRODUCTION

The Mark Twain National Forest has been salvaging small amounts of dead and dying scarlet (Q. coccinea Muenchh.) and black oak (Q. velutina Lam.) since 1973. In 1978 sizeable areas of dead and dying oak trees were discovered on the southeastern part of the Mark Twain National Forest. One 28-acre area on the Van Buren Ranger District was part of a timber sale which had been marked for thinning two years earlier. When harvesting began, it was found that most of the scarlet oak and black oak sawtimber trees on the site were either dead or dying.

In 1980, because of the increase in oak mortality, the Forest started an oak salvage sale program. An investigation began to (1) describe the extent of the problem, (2) determine possible causes of the mortality, and (3) determine the effect on the timber resources of the Forest.

During the summer of 1980, the Northeastern Area of State and Private Forestry, Pest Management Group, scheduled an aerial survey of the Forest. This turned out to be an important decision as that summer was unusually dry and hot. The survey was flown during August by pathologists and entomologists with the Northeastern Area. They observed and mapped areas of probable mortality which were later spot checked on the ground. They estimated that 10,000 acres on the National Forest were immediately affected by the drought. Of this area, approximately 4,300 acres were on the 321,000 acre Fristoe Unit of the Mark Twain, a block of land comprised of Doniphan, Van Buren, and Winona Ranger Districts.

The Northeastern Area team highlighted three weather factors that they believed had a major role in causing the oak mortality (Robbins et al. 1980). One was the prolonged high temperatures during the summer of 1980, the two severe winters of 1976-77 and 1978-79, and below normal rainfall during 1976, 1978, and 1980.

This paper is a descriptive report of oak decline on the Mark Twain National Forest. It includes the findings of several field studies initiated by the Forest Service from 1978 through 1985 plus the observations of the authors. Information on the climatic, biotic, and edaphic factors usually associated with oak decline in the East is provided. No conclusions are drawn. It is hoped that the reporting of the decline will stimulate interest in more scientifically based studies of Forest conditions related to oak decline and tree mortality.

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WEATHER CONDITIONS

From 1921 to 1980 10 notable droughts occurred in Southeast Missouri (table 1), the area where most of the Mark Twain's 1.5 million acres of National Forest lands are located. Earlier timber losses on the National Forest related to drought periods have been documented by Forest Service records for the period 1933-1936 and Missouri's most severe drought of 1953-1955 (Fobes-Gordon 1983; USDA-FS 1961).

The drought of 1980 was followed by a drought of less duration in 1983. The 1983 drought was not included in Table 1 because it lasted only 4 months, from June through September, with two of the months classified as extreme (Decker 1986).

Gass and Gum (1983) produced a 1983 drought pattern map based on observations of stress symptoms in the trees by Missouri Department of Conservation foresters in their Districts (fig. 1). The 1983 "high" areas coincided with the area of heavy oak "decline" as mapped during the 1980 aerial survey (Robbins et al. 1980).

Since weather events appeared to be a primary causal agent (Robbins et al. 1980), a further review of weather records from Birch Tree and Van Buren, Missouri, in the most heavily affected areas, was made. The 2 towns are 31 miles apart on a east-west line that crosses National Forest lands where there is a high occurrence of mortality (fig. 1).

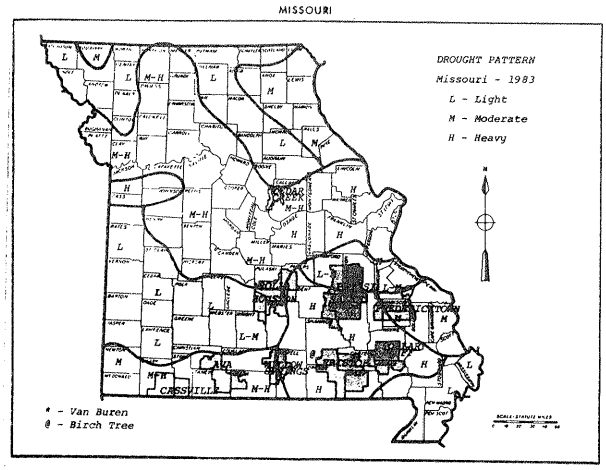


Figure 1.--Drought patterns in Missouri in 1983.

Since Robbins et al. (1980) concluded that more than one single weather element might well be responsible for the decline, departures from long-term norms for annual precipitation, high summer temperatures, severe cold, and late frosts were compared. In order to include all four weather variables for the Birch Tree-Van Buren area, only the records from 1949 to 1984 could be used as some elements were not recorded prior to 1949. The selected 34-year comparison period includes 5 of the 10 most severe droughts for Southeast Missouri including the 1953-55 drought.

Table 1.--Ten notable droughts in Southeast Missouri. 1/

Rank 2/	Drought period		Length of drought: Total	Severe	Extreme	Lowest Palmer index
			- - - - - - Months - - - - - -			
1	July 1953	May 1955	23	6	15	-5.9
2	Oct. 1940	July 1942	22	4	2	-4.1
3	Dec. 1962	June 1964	19	4	5	-5.1
4	Oct. 1935	Dec. 1936	15	5	6	-5.6
5	Apr. 1980	Apr. 1981	13	4	2	-4.0 3/
6	May 1956	May 1957	13	6	0	-3.9
7	Oct. 1924	Sept. 1925	12	6	0	-3.8
8	Aug. 1930	July 1931	12	3	0	-3.8
9	June 1921	Feb. 1922	9	1	0	-3.1
10	Nov. 1971	June 1972	8	0	0	-1.6

1/ Compiled by Department of Atmospheric Science, University of Missouri-Columbia, June 1986. Droughts prior to 1974 are included in "Probability analysis of the PDI and CMI" Abdul Hamidi, M.S. Thesis, University of Missouri-Columbia.

2/ Ranking based on duration of drought.

3/ Exact value of the lowest index for 1980 is not available, but was less than -4.0.

Precipitation

The mean annual precipitation for the Birch Tree-Van Buren area for the 34-year period was 44.45 inches. Annual precipitation was at or below the mean for 5 years between the droughts of 1971-72 and 1980-81. In contrast, from 1949 to 1970, there were only 5 years with precipitation at or below the norm (fig. 2a).

Temperature

Summer temperatures in excess of 90° F. occur on an average of 47 days per year. The temperature exceeded 90° for 93 days in 1980. Temperatures exceeded 90° 29 days in July, and 31 days in August at Van Buren, Missouri. By contrast, 90° days above the norm occurred in 4 of the 5 years of the 1953-1956 drought (fig. 2b).

About 4 days per year of below zero temperatures was the average for the 34-year comparison period. As shown in figure 2b, there was a marked increase in the severity of the winter weather starting in 1977. It is notable that 6 of the 8 years where the cold weather norm was exceeded occurred between 1970 and 1982. By Southeast Missouri standards, the winters of 1977 and 1979 were extremely cold with 16 and 14 days of zero or below temperatures respectively.

Spring Frosts

The occurrence of late spring frosts was also considered to be a weather factor that could contribute to oak decline. Working with white oak in Missouri, Doughtery et al. (1980) found that leaf expansion may begin about April 19, with expansion completed in 25 to 35 days. It is during this period that freezing temperatures can cause defoliation of trees in the Ozarks. The weather records for the Birch Tree-Van Buren area were checked for number of days in which temperatures were below 32° F. during the period of April 15 to May 10.

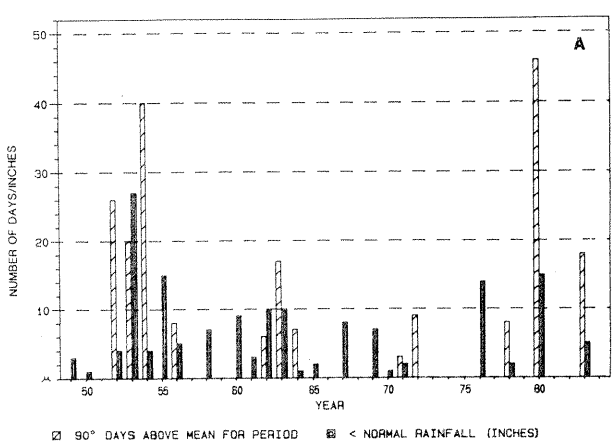
In the 34-year comparison period, incidents of late spring frosts occurred on an average of 3 days a year. That average was exceeded in 4 out of the 5 years just preceding the 1983 drought. Over the entire comparison period, the annual norm for late frost days was only exceeded in 9 of the 34 years (fig. 2b).

Weather Summary

Cold weather, in the form of increased days of late spring frosts, below zero days and an extended period of below normal precipitation, preceded the 1980 and 1983 droughts and seems to distinguish that period from the droughts of the mid-1950's. If all four weather elements, either singly or in combination, are viewed as having the potential to cause tree mortality, then it may be significant that one or more of these elements were in excess of the norm from 1976 through 1983.

FIELD SURVEYS

After the 1980-81 oak salvage operations on the Fristoe Unit, it became obvious that the area with dead and dying oak was extensive. By mid-summer of 1982 District personnel were finding "new" dead and dying oaks in stands where salvage and sanitation operations had taken place the previous season. It appeared that most of the mortality was occurring on broad, flat ridge tops with most of the losses in scarlet and black oak sawtimber stands.



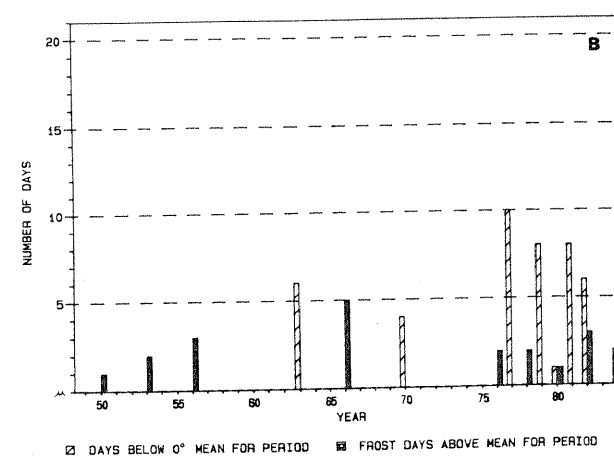


Figure 2.--Departures from means for (A) temperature and precipitation and (B) for days below zero degrees Fahrenheit and frost days for the period 1949 thru 1984. Data is from weather records for Birch Tree and Van Buren, Missouri.

In August of 1982, a special oak mortality survey was started on the Fristoe Unit. The purpose of this survey was to (1) determine the extent of the area where oak mortality was occurring on all three Districts on the Fristoe Unit, (2) determine what common factors (if any) are associated throughout the affected area, (3) determine the severity of the loss, and (4) update the districts' continuous inventory records.

Compartments are the basic timber stand record keeping unit on the Forest and represent areas of land with prominent physical boundaries containing 1,000 acres of National Forest land or less. Ten compartments were sampled on the Winona Distict, ten on the Van Buren District, and six on the Doniphan District.

The survey was biased by the selection of compartments with known or suspected occurrence of oak mortality. No compartments were selected from areas where mortality was not suspected to be occurring. Within each compartment, only sawtimber stands in the oak-pine, black oak-scarlet oak, oak-hickory, post oak-blackjack oak, and mixed oak forest types were sampled.

Ten factor variable plot cruising was used to collect individual tree and stand information. A minimum of 3 plots were located in stands 0-10 acres in size, 5 plots in stands of 11-20 acres and 1 additional plot was added for each 5 acres in stands larger than 20 acres. Procedures established in the Eastern Region of the Forest Service Handbook for Compartment Prescriptions were used for the field survey procedures (USDA-FS 1978).

The survey was completed on November 15, 1982 (Auerback 1982). The survey sampled 3.2 percent of the sawtimber acreage (excluding shortleaf pine types) on the districts of the Fristoe Unit. Twenty percent of the acreage in the twenty-six sample compartments were visited during the survey. Only 47 percent of the scarlet oak volume (cubic foot) was considered healthy (table 2). Black oak was second with 65 percent classified as healthy. However, 95 percent of the sample volume of the white oak (Q. alba L.), post oak (Q. stellata Wangenh.) shortleaf pine (P. echinata Mill.), and the hickories (Carya spp.) were in healthy trees. A small number of northern red oak (Q. rubra L.) and southern red oaks (Q. falcata Michx.) were recorded (shown as red oak in table 2). Other hardwoods in the table included dogwood (C. florida L.), blackgum (N. sylvatica Marsh.), and sassafras (S. albidum (Nutt.) Nees).

Stand age seemed to have a significant effect on the amount of mortality, although a bias was introduced when the survey was set up to visit only sawtimber stands. However, 75 percent of the forested acreage on the Mark Twain is in stands older than 40 years (USDA-FS 1986a); therefore, there was limited opportunity to sample stands less than 50 years old. We believe that were were not enough sample plots in the 80-year-old and older stands to consider the better health of trees in the older age classes meaningful (table 3).

In a further analysis of the survey data, Johnson (1983) found that in stands composed primarily of scarlet and black oaks, the percent of basal area in healthy trees decreased as d.b.h. increased from 6 to 16 inches (fig. 3). In sawtimber stands, 93 percent of the basal area in 6-inch trees were healthy; whereas only 52 percent of the basal area of 16-inch trees were healthy. The 50 percent break point between healthy and dead and dying trees was 14 inches d.b.h.

An early conclusion from the 1982 survey was that the greatest volume losses were occurring in stands that were predominantly scarlet oak, 60 years old or older, and in trees 14 inches d.b.h. or larger. Volume losses in predominantly black oak stands followed a similar pattern, but to a lesser degree.

The effects of the 1980 drought were found to be different in a survey made by the Southeastern Area S&PF on the Ozark National Forest in Arkansas in 1981. Following a July 1981 aerial detection flight by Southeastern Area pathologists, 43 ground points where mortality was heavy were visited. No significant difference was reported between red and white oak populations or the live and dead populations of those species, (Mistretta et al. 1981). They also saw no significant size difference between the live and dead oaks sampled. The average d.b.h. of the oaks sampled were 9.27 $\pm$ 3.91 inches in live trees and 9.36 $\pm$ 3.77 inches for dead trees.

AERIAL PHOTOGRAPHY, SAMPLE AREAS, AND CORRELATION WITH SOILS, LANDFORM, AND ASPECT

In order to further refine the extent and severity of oak mortality on the Fristoe Unit, 2 flight lines consisting of 130, 9" x 9" color infrared photographs 1:8000 scale, were flown in September 1983 by the Methods Applications Group of the Forest Service State and Private Forestry. An east-west flight line was taken across the approximate center of the unit. The procedure for interpretation of the photographs consisted of sampling a 100-acre cell in the center of alternate photographs. By photo interpretation by A. Steven Munson of NE Area S&PF and the use of soil survey maps, the following information was collected from each cell: (1) number of dead trees, (2) number of stressed trees, (3) affected acreage, (4) landform type, (5) soil series, and (6) aspect.

Areas affected by mortality were delineated within the 100-acre cell. These areas averaged 10 acres in size, and ranged from less than 1 acre to 70 acres. The number of acres in each area was determined by aspect, landform, and soil series.

Table 2.--Volume of trees by species in the sample of the Fristoe Unit in 1982.

Species	Volume - M cubic feet			Percent of volume		
	Healthy	Dying	Dead	Healthy	Dying	Dead
Scarlet oak	670	432	315	47	31	22
Black oak	371	116	86	65	20	15
White oak	469	4	11	97	1	2
Shortleaf pine	415	1	3	99	0	1
Post oak	203	2	4	97	1	2
Hickory species	195	1	2	98	1	1
Northern red oak	38	3	5	83	7	19
Other hardwoods	41	2	5	85	4	11

Table 3.--Volume of trees by age class in the sample of the Fristoe Unit in 1982.

Age class	Volume - M cubic feet			Percent of volume		
	Healthy	Dying	Dead	Healthy	Dying	Dead
0-50	192	20	25	81	8	11
51-60	621	71	52	83	10	7
61-70	820	223	162	68	19	13
71-80	555	239	168	58	24	18
81-90	118	4	8	90	3	7
91-100	23	2	3	80	9	11
> 100	47	9	8	73	14	13

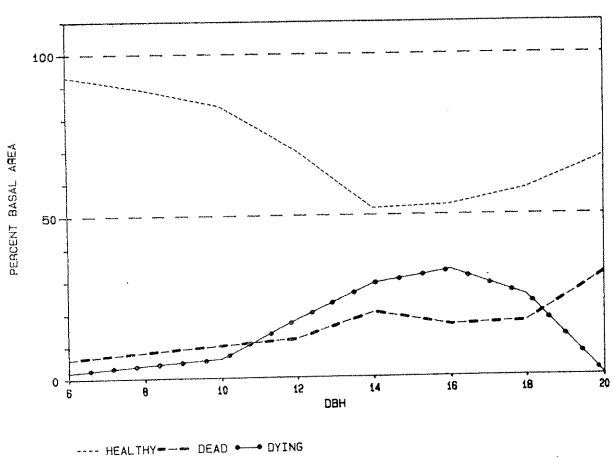


Figure 3.--Relationship of tree health to d.b.h. in 1982

Mortality was found in 48 of the 59 cells which were photo interpreted. Of the 5,900 acres sampled, 918 acres (15.6 percent) had visible signs of tree mortality. Ninety-five areas containing mortality were mapped within the 48 sample cells. There was an average of 60 dead trees and 9 stressed trees per area.

The soil-aspect-landform positions showing the most mortality were Captina soils on broad ridges with neutral or no aspect influence, and Clarksville soils on slopes with south and west aspects (fig. 4, table 4). The Captina, broad ridge, neutral aspect positions are characterized by broad, gently sloping ridgetops and soils with fragipans at depths of 17 to 30 inches. On Clarksville, side slope, south and west aspect positions slopes range from 14 to 60 percent, and soils have chert contents of 30-75 percent. Droughtiness and high summer temperatures are unfavorable conditions associated with both of these sites.

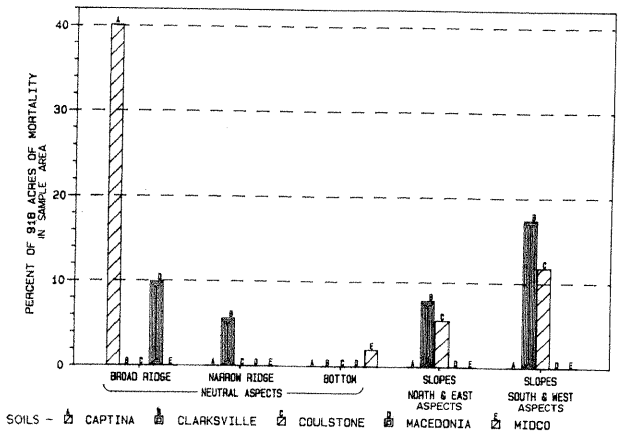


Figure 4.--Soil, landform, and aspect parameters related to oak mortality.

Table 4.--Soil classification of the major soils in the oak mortality area.

Soil	Classification
Captina	Fine-silty, mixed, mesic Typic Fragiudults
Clarksville	Loamy-skeletal, siliceous, mesic Typic Paleudults
Coulstone	Loamy-skeletal, siliceous, mesic Typic Paleudults
Macedonia	Clay, mixed, mesic Typic Paleudults
Midco	Loamy-skeletal, siliceous, non-acid, mesic Typic Udifluvents

VOLUME LOSSES

The drought of 1983 pushed into further decline many of the trees that had been weakened by previous weather events and other causal agents, and mortality in the scarlet and black oaks accelerated. This resulted in increased volumes being offered by the Mark Twain National Forest in salvage sales (fig. 5) (USDA-FS 1986b).

Following 1983, salvage sales were started on the Salem-Potosi Ranger Districts which are located north of the Fristoe Unit Districts. Aerial observations made by the authors in August of that year showed that there were more "scorched" crowns appearing in the Salem-Potosi area than on the Fristoe. More black oak volume was being marked in salvage sales in both Forest areas.

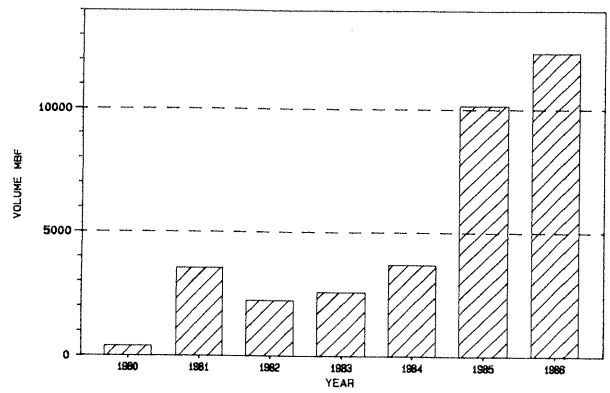


Figure 5.--Oak volume removed in salvage sales.

Limited information exists on the acres where scarlet oak makes up 50 percent or more of a stand's basal area. It is estimated that there are 70,000 acres where scarlet oak is the predominant tree species with 55 percent of the acreage being found on the Fristoe Unit. The Salem-Potosi Districts have approximately 30 percent of the scarlet oak stands. From the Mark Twain record file (USDA-FS 1978) at least 1 merchantable sawtimber scarlet oak per acre is present in 219,728 acres (table 5).

Table 5.--Estimates of acres and volumes of scarlet oak sawtimber in 1983.

Mark Twain units	Scarlet oak 1/	Data source: Mark Twain	Data source: Forest survey
	Acres	M board feet	
Fristoe Unit	95,654	111,571	116,776
All other Districts	124,074	143,926	141,255

1/ Acres with at least 1 sawtimber size scarlet oak per acre.

To determine the standing volume in scarlet oak sawtimber, the Mark Twain stand record file (USDA-FS 1978) and the summaries from the 1977-78 remeasurements of the Forest Survey plots (USDA-FS 1983) were used. There were between 255 and 258 million board feet of scarlet oak sawtimber on the Forest, with about 45 percent being located on the 3 districts of the Fristoe Unit (table 5).

Auerbach (1982) found that the amount of healthy sawtimber volume dropped below 80 percent in stands over 60 years old. In looking at the scarlet oak sawtimber volume in only stands older than 60 years, there could be a potential loss of nearly 28 million board feet on the Fristoe Unit and 45 million feet Forest wide (table 6). This potential loss has to be tempered with the realization that the error of estimate for the smaller amounts of volume on less than Forest size areas could be as much as 50 percent. The error of estimate for the scarlet oak sawtimber on the whole Forest is 15 percent. The low volumes in the stands over 80 years old supports Auerbach's observation that the indicated better health of trees in stands over 80 years old, was likely to be in error due to the sample design.

Table 6.--Age class distribution of scarlet oak sawtimber volume.

Class	Mark Twain units		Total
	Fristoe	All others	
Years	Thousand board feet		
0-50	21,489	42,591	64,080
51-60	67,289	52,995	120,284
61-70	15,560	29,343	44,903
71-80	6,098	11,111	17,209
> 80	6,339	5,212	11,554

To maintain perspective, scarlet oak represents 9 percent of the Forest's total sawtimber inventory and 14 percent of the hardwood group (USDA-FS 1979). About 28 percent of the scarlet oak sawtimber volume is currently in stands greater than 60 years old. No estimates have been made of the potential volume losses in black oak sawtimber. The results of the Statewide Forest Timber Inventory scheduled to start in 1986 will do much in determining what actual changes in volumes and species have occurred.

INSECTS AND DISEASE

A field survey that followed the aerial survey of oak decline in 1980 identified two general classes of damage symptoms. The first was the progressive dieback of the upper branches followed by invasion by secondary organisms such as the two-lined chestnut borer (Argilus bilineatus (Weber)), the oak borer (Cerambycidae), and the stem canker fungus (Hypoxylon atropunctatum).

The second type of damage symptom was characterized by leaf scorch and premature defoliation. Few oaks with this symptom were observed to have been invaded by borers or fungi during field checks in the Fall of 1980.

The primary diseases found on the Fristoe Unit were hypoxylon canker and oak wilt (Auerbach 1982). Several visits to the area by pathologists from the Missouri Department of Conservation and the Forest Service Pest Management Group of State and Private Forestry failed to confirm that oak wilt (Ceratocystis fagacearum) was playing any significant role in the oak decline. An evaluation of the oak mortality on the Ozark National Forest by pathologists of the Southeastern Area of State and Private Forestry in 1981, lead to the conclusion that oak wilt did not cause the symptoms or mortality which were observed (Mistretta et all 1981).

Auerbach (1982) observed the rapid development (over three months) of what he called "mortality pockets" where trees showed wilting leaves followed by complete defoliation. He related this to attacks by the two-lined chestnut borer and the presence of oak wilt. Possibly, the black shoestring rot (Armillaria mellea Vahl.), which he also found, hypoxylon canker, and the two-lined chestnut borer accelerated mortality, thus causing the development of "pockets". Futhermore, as individual trees die, more crown area of bordering trees is exposed to direct sunlight and high temperatures. This could be a contributing factor in the development of "mortality pockets".

The continuing presence of the two-lined chestnut borer, the shoestring root rot and hypoxylon canker were also found following the 1983 drought (Gass et al. 1983). They stated that if a tree was healthy and not stressed none of the organisms would be present.

The relationship of hypoxylon canker to oak mortality has been the subject of a series of studies dating back to 1980. On the Ozark National Forest, pathologists concluded that hypoxylon canker was not the primary cause of mortality, as more than half of the dead trees were uncankered (Mistretta et al. 1981). A girdling experiment involving healthy black, red, and white oaks showed there was a natural occurrence of hypoxylon within the branches (57 percent) and the trunks (11 percent) of the trees (Bassett et al. 1984). They believed the latent colonization of tissues of healthy oaks by hypoxylon prior to any known stress could explain how the fungus is capable of rapid increases following drought.

In a survey of living and dead oak in Arkansas following the 1980 drought, hypoxylon was found to occur twice as frequently on black and blackjack oaks than on white and post oaks (Bassett et al. 1982). Based on their girdling studies they believed that it is not a matter of hypoxylon being able to survive in the two oak species but, rather the greater ability of white oak to avoid and tolerate drought stress.

The Southeastern Area State and Private Forestry evaluation of oak mortality in the Ozark National Forest concluded that no disease or insect was observed causing oak mortality on that Forest (Mistretta et al. 1981).

Two of the primary hardwood defoliators in the Ozark Region are species that belong to the "looper complex" which defoliates trees in the spring and, the variable oak leaf caterpillar (Heterocampa manteo) which feeds on hardwood foliage in the late summer. Moderate to heavy populations of those two groups of insects develped during the years 1969 through 1972, and again in 1978 through 1981 (fig. 6) (Gass 1985). It is not known what additive effect the defoliations have had on the severity of the mortality. However, a reduced period of phothosynthesis and the drain on starch reserves for refoliation probably increased stress levels in trees already weakened by adverse climate.

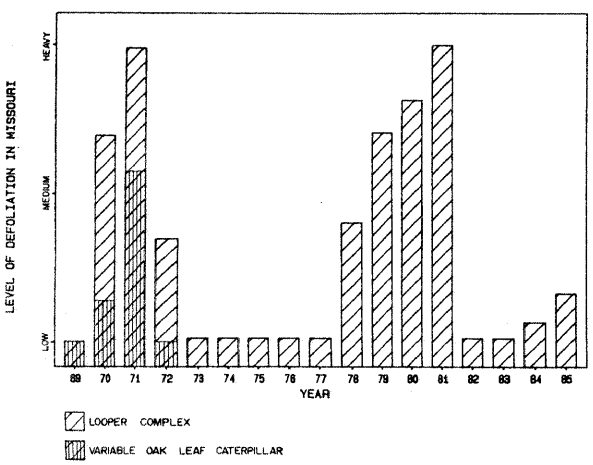


Figure 6.--Levels of defoliation by the looper complex and the variable oak leaf caterpillar.

OBSERVATIONS AND OPPORTUNITIES FOR FURTHER STUDY

Oak decline is not unique to the Mark Twain National Forest. Oak mortality in the Eastern States has been mentioned in numerous publications as far back as 1902 (Henken et al. 1983). All of the stress agents that have been identified as causing or contributing to oak mortality in other states and areas, and at other times can be associated with the decline and mortality in the red oak group on the Mark Twain National Forest. Our observations indicate that it was not the 1980 drought that triggered the decline and increased rate of mortality, because there were obvious signs that some scarlet and black oak stands were in trouble as early as 1978.

We are finding healthy scarlet oak in excess of 60 years old on Macedonia soils where there is no fragipan. Our data are too limited at this time to say that longer rotations for scarlet oak on this soil would be recommended. We continue to believe that soils and slope position contribute, along with other factors, to decline in the red oak group during periods of droughts. Auerbach observed that fewer scarlet and black oaks were showing signs of stress, and fewer dead trees were found as he moved down slope. He saw most of the severe mortality occurring on the broad flat ridges and on the upper one third of the slope.

Topography appears to interact with temperature in some situations. Studies have shown that there can be as much as a 15° F. difference in crown temperatures between flat areas and adjoining slopes (Spurr et al. 1973). The crowns of trees in openings are exposed on all sides to high thermal temperatures as compared to those in closed stands where the direct exposure is to the upper crown only. For example, in 1983 flights, "commercial" clearcuts on private lands could be easily identified from the air because most of the crowns of the scattered residual trees were badly scorched and totally brown. If there is a "heat effect", thinnings late in the rotation in scarlet oak stands may increase the rate of mortality if drought conditions develop before the scheduled final harvest.

In recent years, periods of extreme cold have occurred when soil moisture was very low. The effects of cold, dry periods on tree roots warrants more consideration in the study of causal agents related to oak mortality.

The role played by insects and disease during drought periods still seems unclear. Is it a coincidence that the populations of insects in the looper complex and the variable oak leaf roller increased during the 1971-72 and 1980-83 droughts? There remains a question as to how much stress must take place before hypoxylon canker begins to play its part in the decline and death of a tree.

IN SUMMARY

By September 30, 1986, 35 million board feet of dead and dying scarlet oak and black oak sawtimber had been harvested through salvage sales on the Mark Twain National Forest. Additional volumes of dead and dying oaks have also been removed in affected areas by firewood permits, and as a part of regularly scheduled timber sales. Based on comparison of mortality areas mapped through the use of color infrared aerial photography and Forest records and maps, approximately 180,000 acres will show some visible signs of the effects of oak mortality.

A 29-acre area on the Winona Ranger District of predominately scarlet oak sawtimber size trees has been left uncut. Permanent plots for the study of the continuing decline of the overstory and successional changes were established in 1984 (Johnson 1984).

History suggests that, in many upland areas where mortality is occurring, shortleaf pine was once the dominant species of the presettlement forest. Steyermark (1940) identified an oak-pine association as one of 5 edaphic climaxes occurring in the Ozarks. He did not see shortleaf pine developing as a fire subclimax in the Missouri Ozarks. He saw the oaks penetrating into the pine forest rather than vice versa. Based on events in recent years, we can speculate that the oaks may gain in abundance during the wet cycles and decline during periods of drought in areas where the oak-pine association normally occurs.

Some work has been done in recreating the composition of the presettlement forests in Missouri(Schroeder 1981), but there is little information on the amount of scarlet and black oak that was present and where it was located on the landscape. Perhaps, through man's manipulation and abuse of the forest, these species have obtained a greater abundance than nature usually allows. In this current decline of the red oaks, we may be seeing the ecology of the Ozarks at work.

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