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143

To the Graduate Council:

I am submitting herewith a thesis written by Marvin Dale Strickland entitled "Production of Mast by Selected Species of Oak (Quercus sp.) and Its Use by Wildlife on the Tellico Wildlife Management Area, Monroe County, Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife Management.

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Major Professor

We have read this thesis
and recommend its acceptance:

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PRODUCTION OF MAST BY SELECTED SPECIES OF OAK (*Quercus* sp.) AND ITS USE BY WILDLIFE ON THE TELLICO WILDLIFE MANAGEMENT AREA, MONROE COUNTY, TENNESSEE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Marvin Dale Strickland

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ABSTRACT

This study dealt with the production of mast by white oak (*Quercus alba*, L.) and northern red oak (*Q. rubra*, L.) on the North River watershed of the Tellico Wildlife Management Area, and the relation of mast production and wildlife utilization of acorns to forest regeneration.

Mast production was highly variable between trees within a species and between the two species. Sound acorn production per acre by white oak ranged from a trace by trees 23 and 24 inches dbh to 0.04 pounds (oven dry weight) per acre by trees 11 inches dbh with a total of .17 pounds per acre produced by all diameter classes. Northern red oak production of sound acorns ranged from 0.81 pounds (oven dry weight) per acre by trees 15 and 30 inches dbh to 7.54 pounds per acre by trees 11 inches dbh. Total production of sound northern red oak acorns was 62.9 pounds per acre.

Poor mast production by white oak in 1971 and a general mast failure in 1968 were attributed to temperature trends and late frosts in spring.

The amount of acorns needed by wildlife on the study area was estimated to be 27.1 pounds (air dry weight) per acre for 90 days, 54.3 pounds per acre for 180 days, and 90.5 pounds per acre for 300 days. There was sufficient white oak and northern red oak mast produced in 1971 to support these wildlife populations on the study area for 90 and 180 days but not for 300 days.

The European wild hog appeared to prefer coves to ridges (X^2 = 7.27,* 1 df). However, movement patterns in summer and autumn, 1971 were random and it was concluded that increased use of the ridges was due to an abundance of food, especially acorns, on these sites.

Only 10 mature and germinated white oak acorns remained per acre in spring, 1972. However, there were 1,083 mature northern red oak acorns per acre weighing 6.19 pounds still on the ground in spring. This included 563 sound and germinated, 368 damaged and germinated, and 152 sound, non-germinated acorns.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Acorns are important for forest regeneration as well as food for wildlife. Forest managers are often faced with the responsibility of managing for both oak regeneration and mast consuming wildlife. The importance of acorns requires that information be obtained concerning yields of acorns, factors affecting these yields, and utilization of acorns (Christisen and Korschgen, 1955).

Acorn production is highly variable, and this variability is related to many factors, including species of oak, age of tree, crown vigor, site quality, exposure, and weather (Gysel, 1956). The number of sound acorns is also variable, usually increasing with larger acorn crops (Dalke, 1953; and Christisen, 1955). Attempts have been made to determine the size and characteristics of acorn crops and relate this to carrying capacity in Texas and Louisiana (Reid and Goodrum, 1957; and Goodrum et al., 1971). Knowledge of this nature would be of great value for use in wildlife management of forest areas.

Few mast studies have been conducted in the southern Appalachians. Downs and McQuilkin (1944) and Beck and Olson (1968) reported no consistent relationship existed between tree characteristics and acorn yields in their study of southern Appalachian oaks. In addition, the relations of wildlife to forest communities in the southern Appalachians are poorly known.

The European wild hog (Sus scrofa) is becoming increasingly important as a big game species in the mountains of East Tennessee. However, little is known concerning the relationship of this animal to native flora and fauna present in the mountains. Matschke (1964) noted a strong dependency of wild boar on oak mast in the Tellico Wildlife Management Area. Henry and Conley (1972) suggested that during poor mast years competition between wild boar and other wildlife may be acute.

This study dealt with the production of mast by selected species of oak (Quercus sp.) on the Tellico Wildlife Management Area, and the relation of mast production and wildlife utilization of acorns to forest regeneration. The major objectives of this study were to: (1) measure and evaluate the mast produced by white oak (Quercus alba, L.) and northern red oak (Q. rubra, L.) on the North River watershed of the Tellico Wildlife Management Area; (2) relate acorn requirements of wildlife species on the study area to the amount of mast available; (3) relate the seasonal distribution of European wild hog and other wildlife species to oak mast availability; and (4) determine the availability of acorns in spring and compare this with autumn production estimates.

CHAPTER II

DESCRIPTION OF STUDY AREA

Location and Physiography

The study was conducted on the 80,000 acre Tellico Wildlife Management Area[1] of the Cherokee National Forest in Monroe County, Tennessee. Field investigations were restricted to the North River Watershed, an 11,881 acre drainage in the management area (Figure 1).

The North River Watershed lies within the Unaka Mountain Range of the Blue Ridge Province. It is characterized by uneven mountain peaks, narrow winding ridge crests, steep slopes and narrow valleys dissected by fast flowing streams. Elevations range from a minimum of 1,633 feet at the confluence of North River and Tellico River to a maximum of 5,130 feet at Little Haw Knob.

Soils of the area, typical of mountain soils, were derived from weathering of underlying bedrock. The Ramsey Soil type (Ramsey slates, silt loam, very steep phase), derived from slates and quartzites, makes up over 90 percent of the soil. Ramsey soils are characterized by moderate natural fertility, shallowness (6 to 18 inches), medium to low pH, rapid water percolation, and low water storage capacity (Blackburn, 1962).

[1]Wildlife management is a cooperative endeavor between the U. S. Forest Service and the Tennessee Game and Fish Commission.

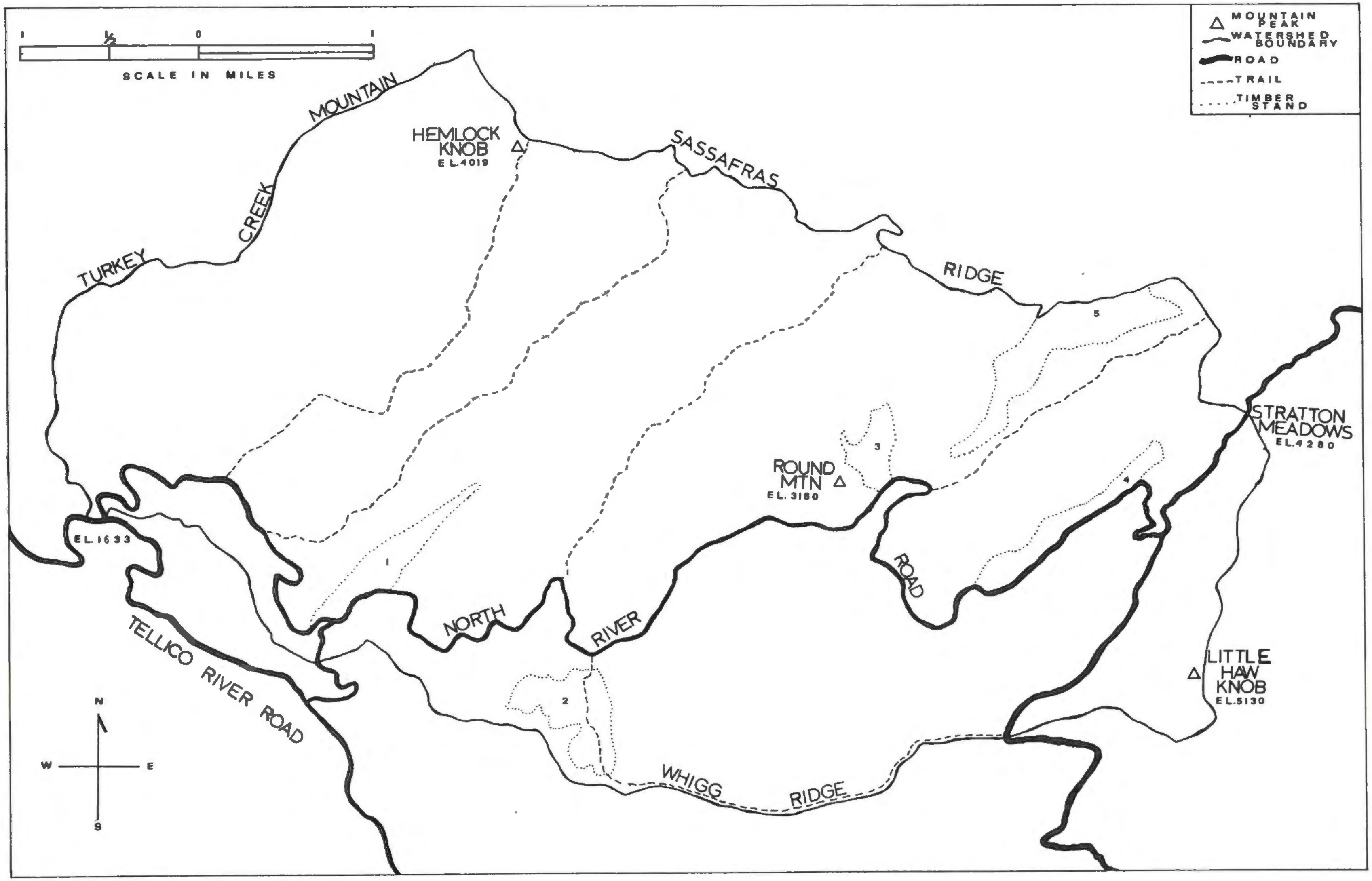

Figure 1. Map of study area, the North River watershed in the Tellico Wildlife Management Area of the Cherokee National Forest, Monroe County, Tennessee.

Climate

The climate of this area is characterized by large amounts of precipitation and moderate temperatures. Both precipitation and temperature vary considerably with changes in elevation. Mean annual precipitation for the study area for the past 10 years (1962 through 1971) was 78.6 inches. The average annual temperature for the same period was 56.3°F; July, the warmest month, averaged 72.7°F and January, the coldest month, averaged 37.1°F. Weather data for 1971 are presented in Table I. Temperature data were recorded at Tapoca, North Carolina, approximately 8.5 miles northeast of the study area. Precipitation data were recorded at Stratton Meadows, North Carolina, approximately 1.5 miles north of the study area.

Logging History and Vegetation

The North River watershed was logged by the Babcock Land and Lumber Company between 1920 and 1925. The entire watershed was a part of a tract of land acquired from Babcock by the U. S. Forest Service in 1925. No logging occurred on the watershed from 1925 to 1957. The Forest Service began a timber sale program for the watershed in 1957 (Blackburn, 1962). From 1957 to 1965 most timber harvests consisted of selection cuttings over approximately 1,138 acres. In 1965 timber management was changed to the even-aged system and clearcutting was established as the primary means of timber harvest. Harvest methods employed during 1920-1925 resulted in even-aged stands of second-growth immature pole and saw timber 50 to 60 years of age with numerous wolf trees interspersed throughout the area.

TABLE I

TEMPERATURE DATA FROM TAPOCA, NORTH CAROLINA (ELEVATION 1,117 FT.) AND PRECIPITATION DATA FROM STRATTON MEADOWS, NORTH CAROLINA (ELEVATION 4,300 FT.) FOR 1971[a]

Month	Temperature (°F) Av. Mo. Max.	Av. Mo. Min.	Average	No. Frost Days	Precipitation (In.) Total	Department From Mean
Jan.	49.7	28.3	39.0	20	11.98	+4.06
Feb.	53.7	27.1	40.4	22	8.84	+1.19
Mar.	57.4	32.3	44.9	20	7.40	-0.54
Apr.	73.5	41.7	57.6	5	4.26	-2.42
May	76.7	49.4	63.1	1	4.67	-0.81
June	86.2	61.0	73.6	0	4.85	-1.60
July	83.1	63.1	73.1	0	16.32	+8.11
Aug.	84.7	62.0	73.4	0	4.26	-1.85
Sept.	81.4	60.8	71.1	0	5.84	+1.44
Oct.	75.2	52.6	63.9	0	4.46	+0.41
Nov.	60.6	36.7	48.7	10	3.93	-2.06
Dec.	62.3	40.1	51.2	7	8.28	+1.51
Totals and Means	70.4	46.3	56.3	85	85.09	+7.44

[a]From the records of the Tennessee Valley Authority, Hydraulic Data Division.

According to U. S. Forest Service records thirteen major forest cover types occur within the watershed (Table II). Hardwood cover types predominate (82.2 percent of the total acreage) while pine-hardwood (5.4 percent) and pine-hemlock (12.4 percent) cover types also occur. Nonforested areas comprise .4 percent of the total acreage of the watershed.

Land Use and Wildlife

In addition to timber and wildlife management, the U. S. Forest Service allows some grazing of domestic livestock in the North River watershed. Five grazing permittees have all or part of their grazing allotments in the watershed. Cattle are released in the spring and wander over the area until the onset of severe weather the following winter. The cattle usually number around 75 head.

Harvestable populations of wildlife on the study area include European wild hog, white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), eastern wild turkey (*Meleagris gallopavo*), grey squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), and ruffed grouse (*Bonasa umbellus*).

TABLE II

FOREST COMPOSITION OF THE NORTH RIVER WATERSHED AS RECOGNIZED BY THE U. S. FOREST SERVICE[a]

Forest Type	Average Age	Acreage	Percent of Total
Hardwood			
Yellow Poplar-White Oak-Northern Red Oak	50	3345	28.2
White Oak-Red Oak-Hickory	53	3087	26.0
Yellow Poplar	45	1082	9.1
Chestnut Oak	43	1052	8.9
Sugar Maple-Beech-Yellow Birch	52	846	7.1
Scarlet Oak	59	190	1.6
Pine-Hardwood			
Pitch Pine	49	1009	8.5
Pitch Pine-Oak	46	584	4.9
Virginia Pine	45	104	0.9
White Pine-Yellow Poplar	47	37	0.3
Pine-Hemlock			
White Pine	50	150	1.3
White Pine-Hemlock	50	144	1.2
Hemlock	44	40	0.3
Nonforested		211	1.7
Totals and Means	49	11881	100.0

[a]From the records of the Tellico Ranger District, U. S. Forest Service.

CHAPTER III

METHODS

I. MAST PRODUCTION

Sampling Method

Mast from selected white oak and northern red oak was collected with 0.1 milacre traps in fall, 1971. The design for the trap was modified from that described by Klawitter and Stubbs (1961). A total of 30 trees of each species were selected. Two traps were placed beneath each sample tree giving a total of 120 traps. An attempt was made to place a trap beneath the east and west portion of the tree crown. This procedure was not adhered to if there was a possibility of mast falling into the trap from neighboring trees. Large rocks occasionally forced some deviation from standard procedure in trap placement.

Sample Tree Selection

Stands containing one or both species to be sampled were determined from Forest Service records. Stands bordering existing roads were chosen to simplify transporting traps to the sample sites. Sample trees were chosen within each stand by the quarter method (Phillips, 1959). The following items were recorded for each sample tree: diameter at breast height (dbh), crown area, and slope aspect and percent slope. U. S. Forest Service records were consulted for the following information concerning each stand where sample trees were located: forest type, stand condition, age, and elevation.

Mast Collection and Classification

Beginning August 30, each trap was visited at bi-weekly intervals to remove acorns. Acorns collected were then counted, and classified in one of the following categories: (1) immature sound, (2) immature and insect damaged, (3) well formed and sound, (4) well formed but insect damaged, (5) well formed but damaged by arboreal feeders. All acorns appearing sound were cut to check for insect damage. Many seemingly sound acorns were found to contain insect larvae.

Model for Prediction of Total Yield

A timber cruise was completed for the North River watershed using the two-stage sampling method (Freese, 1962) and horizontal point sampling technique (Avery, 1967). A Spiegel relascope and wedge prism were used to select trees to be measured and counted at each point. The cruise data were used to develop a stand table for white oak and northern red oak on the study area.

Increased northern red oak production was related to increased dbh and basal area. Regression analysis was used to develop a prediction equation used in calculating expected acorn yields for each diameter class of northern red oaks. Tests were conducted at the 0.05 level of probability. White oak production was not consistantly correlated with tree or site characteristics; production for each diameter class of white oaks was calculated based on the mean yield per tree. The expected yields were expanded to a per-acre estimate of production based on the stand table.

II. WILDLIFE UTILIZATION

Wildlife Utilization of Forest Communities

Five trails in the North River watershed were selected as index trails to be walked each quarter of the year. The trails ranged in length from 2.4 to 4.5 miles, totaling 17.2 miles. At 1,600-feet intervals along each trail permanent observation points were established. A total of 53 permanent observation points were selected and marked in this manner. Wildlife utilization at these points was noted by recording observations of animals, tracks, feeding signs, and droppings. An attempt was made to distinguish between sign less than one month old and older sign. Sign left by species other than European hog was noted as such and identified to species when possible.

Forest Community Classification

The forest community type was classified at each permanent point according to the dominant species present (Odum, 1959). To facilitate analysis, forest community types were grouped under broad forest cover types occurring on the study area.

Statistical Comparisons

Relationships of all wildlife and of European wild hog along to forest community type, site (classed as ridge or cove), and season were examined by Chi-square tests of independence. All tests were conducted at the 0.05 level of probability.

III. AVAILABILITY OF ACORNS IN SPRING

The availability of acorns in spring, 1972 was examined. Acorns were collected from four 0.1 milacre ground plots beneath each tree sampled with mast traps during autumn, 1971. These samples were taken near the outer edge of the crown along the four cardinal directions, i.e., north, east, south, west. The surface litter was thoroughly examined for acorns. Acorns collected were segregated into one of three categories: (1) Unsound; (2) sound, nongerminated; (3) sound, germinated.

The number of acorns present at each sample point decreased as the percent slope increased; this relationship appeared linear but was not tested. The data were expanded to a per acre estimate which was considered a minimum estimate of the available mast in the spring. The fall and spring estimates were compared to determine the proportion of the fall crop that resulted in germinated acorns and spring food for wildlife.

CHAPTER IV

RESULTS AND DISCUSSION

I. MAST PRODUCTION

Five stands were sampled for northern red oak and white oak (Table III). According to the Forest Service stand typing, two of these stands contained types other than those to be sampled. Stand 1 was typed from aerial photographs as chestnut oak; field reconnaissance indicated the stand was predominantly white oak. Sample site 5 was typed as scarlet oak but provided a sufficient number of white oaks to sample.

Acorn Crop Characteristics

The average white oak sampled in 1971 produced 952 acorns weighing 1.9 pounds (Table IV). Acorn production by white oaks ranged from an average 357 acorns weighing 0.6 pounds produced by trees 12 inches dbh to 4,757 acorns weighing 7.3 pounds by the one tree 20 inches dbh. The average northern red oak produced 4,563 acorns weighing 25.4 pounds. The range of northern red oak production was from no acorns by the one 10 inches dbh tree sampled to 27,965 acorns (155.4 pounds) by the one tree 28 inches dbh.

Variation of acorn production within tree crowns. The average number of acorns caught in mast traps beneath northern red oaks was 16 with a range of 0 to 56. The average number of acorns caught in traps beneath white oaks was 9 with a range of 0 to 80. The number of acorns

TABLE III

FOREST STANDS (TYPED BY THE U. S. FOREST SERVICE) CONTAINING SAMPLE TREES ON THE TELLICO WILDLIFE MANAGEMENT AREA IN 1971

Stand	Stand Type	Condition	Acreage	Percent Watershed In Stand Type	Age	Elevation (ft.)
1	Chestnut Oak	Immature PT[a]	107	8.9	50	1900-2200
2	WO-RO-Hickory[c]	Immature ST[b]	122	26.0	55	2050-2400
3	YP-WO-NRO[d]	Immature ST	55	28.2	33	2800-3200
4	WO-RO-Hickory	Immature ST	92	26.0	62	3600-3800
5	Scarlet	Low Quality PT	190	1.7	57	4400

[a]Pole timber.

[b]Saw timber.

[c]White oak-red oak-hickory forest type.

[d]Yellow poplar-white oak-Northern red oak forest type.

TABLE IV

MEAN NUMBER AND WEIGHT IN POUNDS (OVEN-DRY) OF WHITE OAK AND NORTHERN RED OAK ACORNS BY DIAMETER CLASS PRODUCED ON THE NORTH RIVER WATERSHED, 1971

Diameter Class[a]	White Oak No. Trees	White Oak No. Acorns	White Oak Weight	Northern Red Oak No. Trees	Northern Red Oak No. Acorns	Northern Red Oak Weight
10	5	753	1.2	1	0	0.0
11	5	501	0.8	--	--	--
12	4	357	0.6	2	488	2.7
13	--	--	--	5	2842	15.8
14	7	1379	2.1	1	2432	13.5
15	2	1127	1.7	3	3390	18.8
16	1	1526	2.4	4	1199	6.7
17	3	372	0.6	3	3237	17.9
18	--	--	--	1	1692	9.4
19	--	--	--	3	11360	63.1
20	1	4757	7.3	4	3762	20.9
21	1	657	1.0	1	5418	30.1
24	1	910	1.4	1	11084	61.6
28	--	--	--	1	27965	155.4
Totals and Weighted Means	30	952	1.5	30	4563	25.4

[a]One-inch diameter classes (10-inches class = 9.5 to 10.4 inches).

trapped beneath different portions of the crown was not significantly different when data for both species were analyzed (t = 0.39NS). However, there was significant variation in the number of acorns per trap beneath northern red oaks (t = 2.58*); thus significant variation in the amount of acorns produced within exposed crowns of individual northern red oak trees existed. Gysel (1956) reported similar results for white oak and black oak (Q. velutina, Lam.) in Michigan.

The lack of variation when all trap pairs were included in the analysis may be due to poor acorn production by the white oaks in stands 1 and 2. Five of the 19 trap pairs located in the above stands failed to capture acorns during the study.

Gysel (1956) stated that "the number of sampling units per tree depends upon the accuracy desired in the study . . . balanced against the time and resources available." It appears that the variability of acorn production within crowns of individual trees warrants a minimum of two sample units per tree.

Chronology of acorn fall. Acorn fall began between August 16 and August 30 (Figure 2 and Figure 3). Most immature acorns of both species fell within the first two weeks. Early fall of immature acorns was also reported by Christisen (1955), Burns et al. (1954), and Beck and Olson (1968). Damaged northern red oak acorns reached their peak fall two weeks prior to the peak fall for sound acorns, as reported by Verme (1953) and Downs and McQuilken (1944). In contrast to northern red oak acorn fall, both sound and damaged white oak acorns fell at the same rate.

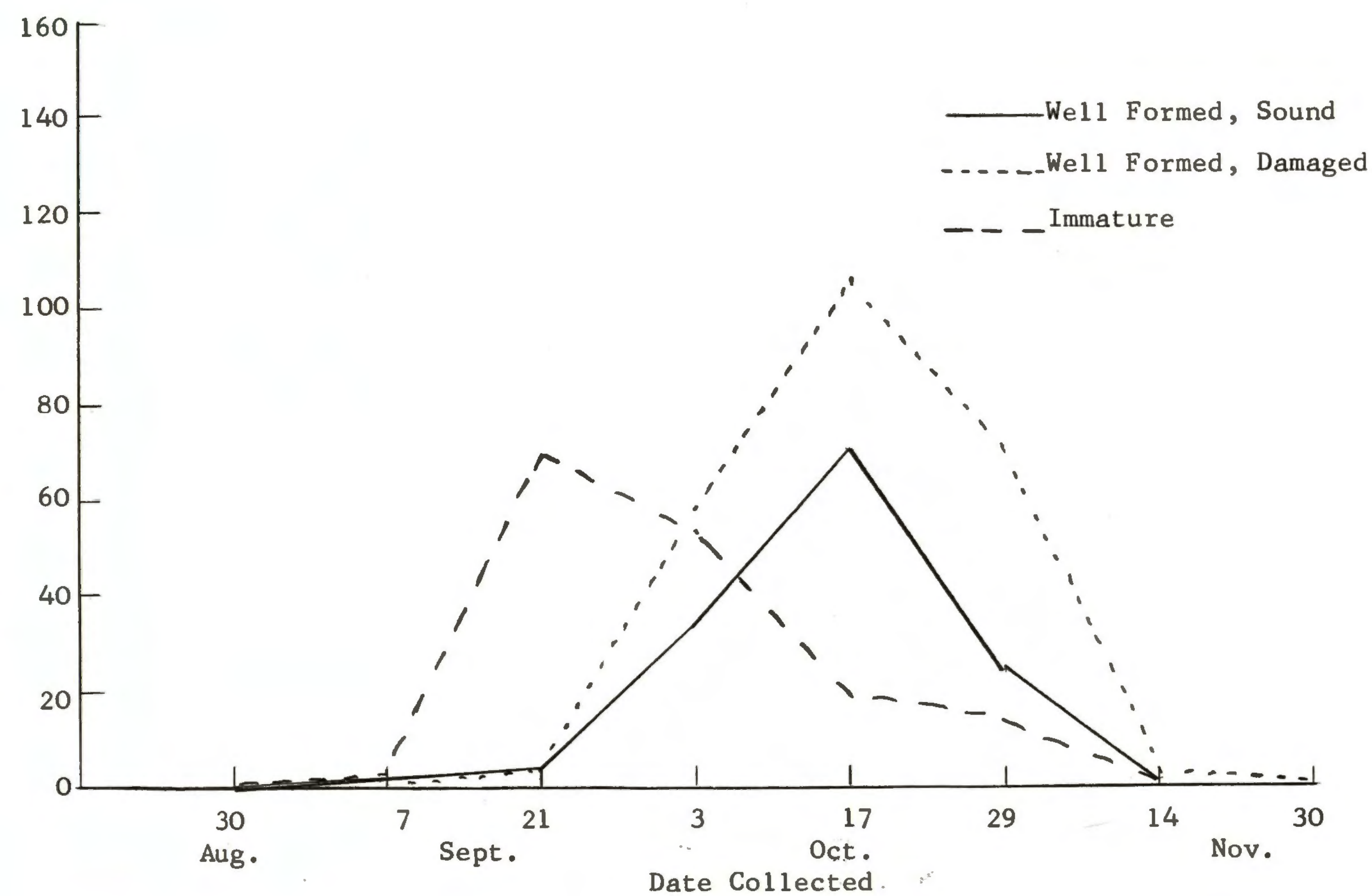

Figure 2. Chronology of acorn fall for white oak collected in seed traps on the Tellico Wildlife Management Area in 1971.

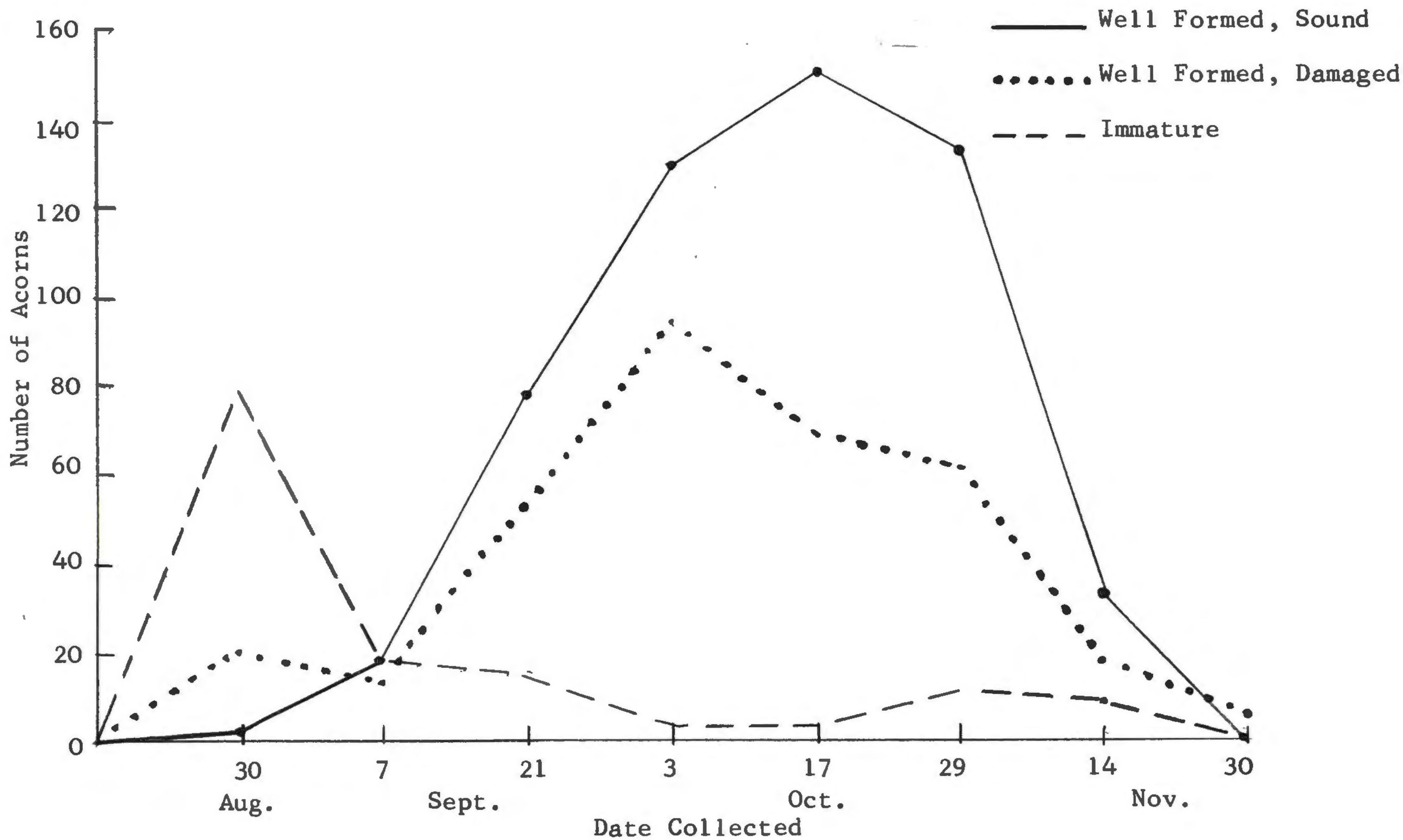

Figure 3. Chronology of acorn fall for northern red oak collected in seed traps on the Tellico Wildlife Management Area in 1971.

Christisen (1955), Verme (1953), and Burns et al. (1954) listed several factors modifying the time of acorn fall. These factors included the date of first killing frosts, wind, insect damage, and animal activity. Killing frosts did not appear to influence acorn fall during this study. The first frost in autumn, 1971 did not occur until early November, approximately one month after peak fall for northern red oak and three weeks after peak fall of white oak. Trees at lower elevations tended to hold their acorns longer, probably reflecting the milder temperatures at these lower elevations (Table III, page 14). Downs and McQuilkin (1944) reported that the species and size of crop may influence the chronology of acorn fall. They reported that the period of drop for well developed acorns increased with larger crops. Beck and Olson (1968) reported that white oak acorns consistently fell earlier than red oaks. No major differences between the two species in the beginning and completion of acorn fall were obvious in this study. Nevertheless, northern red oak produced a larger crop than white oak and exhibited a more evenly distributed fall in 1971.

Weight. Northern red oak acorns were significantly larger and heavier than the white oak acorns (Table V). The number of sound red oak acorns required to weigh a pound averaged 148; the number of sound white oak acorns required to weigh a pound averaged 648. The average weight of the sound white oak acorns was less than that reported by Goodrum et al. (1971) in Texas and Louisiana, Collins (1961) in Louisiana, Downs and McQuilkin (1944) in North Carolina, and Christisen and Korschgen (1955) in Missouri. These authors reported, respectively,

TABLE V

CONDITION AND WEIGHTS OF WHITE OAK AND NORTHERN RED OAK ACORNS COLLECTED FROM 30 TREES OF EACH SPECIES LOCATED ON THE TELLICO WILDLIFE MANAGEMENT AREA IN 1971

	WO		NRO		Number Acorns[a] Per Pound	
Category	No.	Percent	No.	Percent	WO	NRO
Well formed						
Sound	133	25.0	537	51.8	648	148
Insect damaged	213	40.1	330	31.8	744	179
Damaged by arboreal feeders	27	5.1	25	2.4	1055	376
Immature						
Sound	75	14.1	40	3.9		
Insect damaged	83	15.6	105	10.1		
Totals	531	100.0	1037	100.0		

[a]Oven-dry weight.

196 (oven dry), 225 (air dry), 169 (fresh), and 104 (fresh) white oak acorns per pound.

Seed production is an energy requiring process. Verme (1953) found small sized acorns accompanied crop failure. He suggested that the factors decreasing acorn production also decreased the amount of energy available to the acorns that did develop.

Although few white oak acorns were collected in the stands at the lower elevations, the number of acorns collected in the highest stand did not indicate a crop failure for these trees. Therefore, the diminutive size of the acorns collected in the upper stand cannot be attributed to acute factors causing a crop failure. It seems likely that the small acorns may have resulted from poor site quality, a genetic characteristic of the trees in the stand, or combination of these two factors.

Korstian (1927) found that heavy acorns possessed greater germinating capacity and seedling survival. The small size of the acorns produced by the white oaks may indicate a decrease in their germinating potential and ability to survive following germination. This could also apply to the larger northern red oak acorns with partially destroyed cotyledons.

<u>Soundness of acorns</u>. Only one-fourth of the white oak acorns collected were sound compared to more than one-half of northern red oak acorns (Table V). Christisen (1955), Beck and Olson (1968), Downs and McQuilkin (1944), and Dalke (1953) reported that a proportionately larger number of sound acorns occurred with larger acorn crops. The northern red oaks produced many more acorns than the white oaks; the smaller

white oak crop may account for the greater amount of damage to white oak acorns.

Insect damage. Insects accounted for the greatest amount of damage to both species of acorns (Table V, page 20). Korstian (1927) listed at least three groups of insects: (1) nut weevils, *Curculio* sp.; (2) moth larvae, *Valentinia glandullella* and *Melissopus latifureanus*; and (3) gall forming cynipids, *Callirhytis fructuosa* and *C. lapillula*; that feed as larvae on acorns.

The larvae of the nut weavil (*Curculio* sp.) was by far the most frequently encountered insect in the study. Other insect larvae found included the weevil (*Conotrachelus* sp.), a Dipteran (*Dasineura* sp.), and a moth (*Valentinia glanulella*). Brezner (1960) stated that the moth and weevil listed above are secondary foragers of the acorn and gain entrance after the *Curculio* leaves. He stated that *Curculio* larvae remain in the acorn from three to four weeks and leave shortly after the acorn drops to the ground. Korstian (1927) suggested that acorns suffering from insect infestation are also subject to more rapid decay than uninfested ones. Acorns infested by the nut weevil larvae ranged from slightly damaged to almost entirely destroyed.

Acorns damaged by arboreal feeders. Well formed acorns found in the traps that were damaged while still in the tree amounted to only 2.8 percent of the northern red oaks and 7.2 percent of the white oaks (Table V, page 20). These figures give little indication of the total percent of the acorn crop lost to squirrels and birds in the tree. Many acorns consumed or damaged by these animals obviously were not sampled by the mast traps.

Downs and McQuilkin (1944) reported the average loss of sound acorns on the tree to wildlife as 24 percent for a seven year period. Christisen and Korschgen (1955) estimated that an average of 13.6 percent of the white oak crop in their five year study was removed by arboreal species. Cypert and Webster (1948) estimated that birds removed 13 percent of acorns produced by water oak (Q. nigra, L.) and willow oak (Q. phellos, L.) before they fell from the tree. These authors indicated that the percent of the crop damaged by arboreal feeders would be greater in years of poor production than in years of abundant production.

Immature acorns. Immature acorns comprised 29.7 percent by number of the white oaks and 14.0 percent of the northern red oaks by number (Table 5, page 20). Many of the immature acorns appeared sound and therefore would not be expected to fall prematurely. It is possible that arboreal feeders may have knocked the acorns from the tree before damaging them.

Other authors have also noted a large number of undeveloped acorns in their samples (Downs and McQuilkin, 1944; Dalke, 1953; and Kautz and Liming, 1939). Beck and Olson (1968) classified these undeveloped acorns as aborted and noted that 26.7 percent of their sample was in this condition.

Acorn crop evaluation. Korstian (1927) stated that the percentage of insect damaged acorns developing into normal seedlings was negligible. Christisen and Korschgen (1955) stated that "the number of sound acorns for wildlife and reforestation could often be doubled if acorns were free of insect attacks." Yet, Barrett (1931) found that chestnut oak acorns infested with nut weevils could still produce healthy seedlings. Likewise, Collins (1961) stated that "although sound acorns are preferred by wildlife . . . some acorns that contain an egg or a small larvae and appear sound will be readily utilized as food for a short period after they reach the ground."

If the above considerations prevail then the following assumptions may be made concerning the acorn sample collected during this study: (1) the sound portion of the acorn crop can be used to estimate mast available for wildlife food and forest regeneration; (2) the damaged portion of the sample may contribute to the food supply for wildlife a short time in the fall and a minimal amount of seed for forest regeneration; (3) the immature acorns contribute little for wildlife food and forest regeneration.

Factors Affecting Acorn Yield

The number and weight of well formed acorns produced by sample trees were utilized for evaluating the white oak and northern red oak acorn crop in 1971. The results of this analysis are presented in Table VI.

Tree characteristics. The number of acorns produced by individual white oaks was highly variable; no relationship existed between yield and tree diameter. However, acorn yields of northern red oak trees showed a general trend of increasing with increased diameter. The distribution of white oak sample trees was skewed toward the pole timber stage; most of the large trees sampled were short in stature

TABLE VI

RELATIONSHIP OF TREE AND SITE CHARACTERISTICS TO ACORN PRODUCTION BASED ON MEAN SQUARES FROM REGRESSION ANALYSIS[a]

Species	Source	Degrees of Freedom	Number Well Formed	Number Sound	Weight Well Formed	Weight Sound	Weight Damaged
White Oak	Regression	3	59.84*	13.94*	22.50*	5.47*	5.80
	Elevation	1	53.69*	12.66*	20.36*	4.88*	5.31*
	Percent Slope	1	2.14	0.30	2.13	0.59	0.48
	DBH[b]	1	4.00	0.99	0.02	0.00	0.02
	Residual	26	176.49	20.55	51.01	9.03	20.80
Northern Red Oak	Regression	3	2054.99*	970.02*	13135.24*	6092.24*	1407.32*
	Elevation	1	434.33*	158.68	2043.56	651.42	387.42*
	Percent Slope	1	73.10	47.97	508.11	391.30	60.89
	DBH[b]	1	1693.37*	763.37*	10583.57*	5049.52*	1012.29*
	Residual	26	2395.49	1157.42	14312.39	7236.89	

[a]The symbol (*) indicates that a statistical relationship is significant at the 0.05 level of probability.

[b]One-inch diameter breast height classes (10-inches class = 9.5 to 10.4 inches).

with thin poorly formed crowns. The distribution of northern red oaks in the sample stands was more normal with the majority of the trees occurring in the 13 to 20 inches diameter classes.

Downs and McQuilkin (1944), in their study of southern Appalachian white oak and northern red oak, reported little correlation between acorn production and diameter at breast height. In a random sampling of stands in the Appalachians, Beck and Olson (1968) found no correlation between the amount of acorns produced and residual basal area of these stands. Likewise, Burns _et al_. (1954) in Missouri stated that variability in the number of acorns produced by individual trees was not consistently correlated to tree characteristics. Goodrum _et al_. (1971) and Petrides _et al_. (1953) in Texas, Christisen and Korschgen (1955) in Missouri, and Collins (1961) in Louisiana found that mast yields generally increased as the diameter of the tree increased.

A number of reasons have been given for variability in seed production by individual oaks. Wood (1934), Downs and McQuilkin (1944), Burns _et al_. (1954), Collins (1961), Christisen and Korschgen (1955), and Goodrum _et al_. (1971) recognized variability in an individual tree's ability to produce acorns. These authors suggested that individual trees are consistently good or poor producers due to innate characteristics.

In addition, Sharp (1958) found red oaks to be more consistent acorn producers than white oaks; only 30 percent of white oaks produced seed during a good white oak mast year while most red oaks produced acorns in a good red oak year. Wood (1934) reported that 40 percent of chestnut oak trees in his study in New Jersey failed to produce acorns. However, trees not producing acorns in the New Jersey study ranged in dbh from 3.2 to 9.1 inches and at least some of them were probably too small to produce seed.

Sample site and stand location. Gysel and Arend (1953) and Gysel and Lemmien (1964) stated that site quality affected acorn production. Site quality may have influenced white oak production in this study although no correlation existed between percent slope and yield. Percent slope was the only component of site quality that was examined in this study.

Elevation. White oak production was significantly different at different elevations on the study area. Some white oak acorns were produced above 3,500 feet; few were produced by white oaks growing at an elevation less than 3,500 feet. A late freeze occurred on the night of May 4, 1971. White oaks below 3,500 feet were flowering at this time and many of the blooms were damaged by the frost (Dick Conley, personal communication, 1971). Williamson (1966) suggested that most of the potential white oak acorn crop was lost to premature abscission during the early fruiting stage due to a lack of fertilization. He stated that abscission occurred similarly for all trees in his study. Many more undeveloped cupules were produced by white oaks growing below 3,500 feet than by trees above 4,000 feet. Therefore, some environmental factor, probably the late freeze, likely increased the number of unfertilized pistilate flowers on trees growing at the lower elevations. As two years are required for red oak seed maturation, the effect of the 1971 frost on the northern red oak acorn crop below 3,500 feet should become apparent in 1972.

The yield of northern red oak acorns was slightly greater at high than at low elevations. However, this probably was due to the fact that the high elevation stand contained most of the largest and most productive trees.

Temperature. It has been suggested that temperature is the primary environmental factor contributing to good and poor acorn years in the white oak (Sharp and Chisman, 1961; Sharp and Sprague, 1967). Uhlig and Wilson (1952), Reid and Goodrum (1957), and Goodrum et al. (1971) reported poor mast crops due to late spring frosts. Collins (1961) suggested a late freeze may decrease white oak acorn production markedly the same year it occurs and decrease red oak production the following year.

Sharp and Chisman (1961) found that flowering white oaks in Pennsylvania were not visibly damaged by either light frosts (32°-29°F) or heavy frosts (29°-25°F); only killing frosts (below 25°F) were obviously detrimental to new leaves, shoots, and flowers. They reported that, over a 12 year period, only one extensive freeze and one localized freeze occurred; during this same period good to heavy yields of white oak mast occurred in only five of the years. Sharp and Sprague (1967) reported that temperature trends during the period of flowering and fruit set in white oaks affected acorn yields (Figure 4). They reported that "typical good white oak years resulted when rapid temperature increases occurred in April and were followed by sharp declines with much cooler night temperatures from May 1 to May 19." The early warm period increased development of viable pollen and advanced catkin

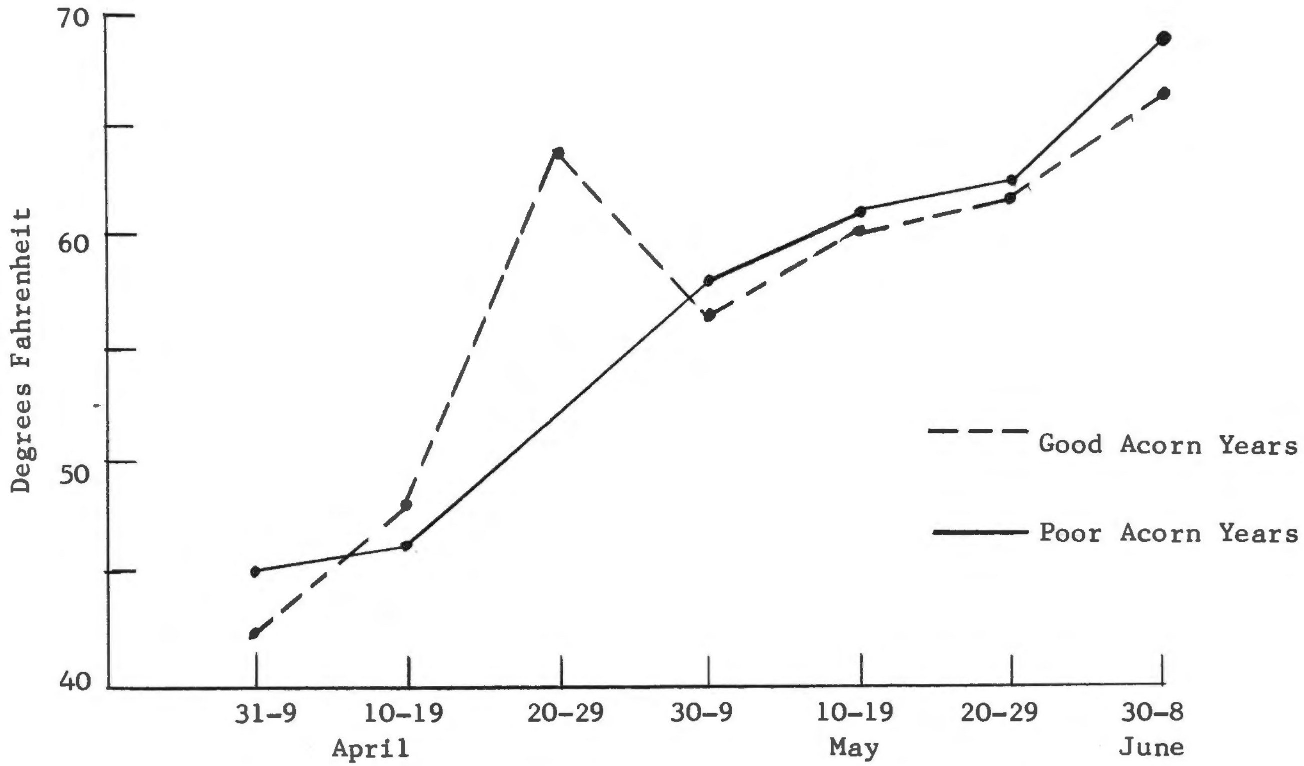

Figure 4. Mean daily temperatures of five good acorn years and seven poor years 1949-1962. Averages are of 10-day periods March 31 through June 8.

emergence and shoot and leaf development. The following cool period delayed pollination and enhanced ovary development thus increasing the chance for successful fertilization. However, heavy frosts during this period resulted in flower damage and reduced acorn production. Poor acorn years were associated with gradual increased in night temperatures from early April through May which apparently hindered production of viable pollen.

A widespread mast failure occurred in eastern Tennessee and western North Carolina in 1968. Both red and white oaks produced poor mast crops. In 1970 Tennessee Game and Fish personnel reported a fair white oak mast crop on the Tellico Wildlife Management Area (Conley, 1970). In 1971 the white oak crop was poor and the northern red oak crop was excellent on the study area. The mean daily temperatures in 1967, 1968, 1970, and 1971 for the period from March 31 to June 8 are illustrated in Figures 5 and 6. The 1968 temperatures, affecting the 1968 white oak crop (Figure 6), followed trends similar to that for poor acorn years presented by Sharp and Sprague (Figure 4). Temperatures during April, 1967 (Figure 6), affecting the northern red oak crop of 1968, resembled the trend for good acorn years. However, a wide spread frost occurred April 28, 1967. The 1970 temperature (Figure 5), affecting the 1971 red oak crop, was remarkably similar to that described for good acorn years. Finally, the temperature trend for 1971, affecting the 1971 white oak crop (Figure 5), was almost identical to the trend for poor acorn years. In addition, late frosts occurred in 1967 and 1971.

It appears that the severe mast shortage in 1968 was the result of a combination of adverse environmental factors. These factors

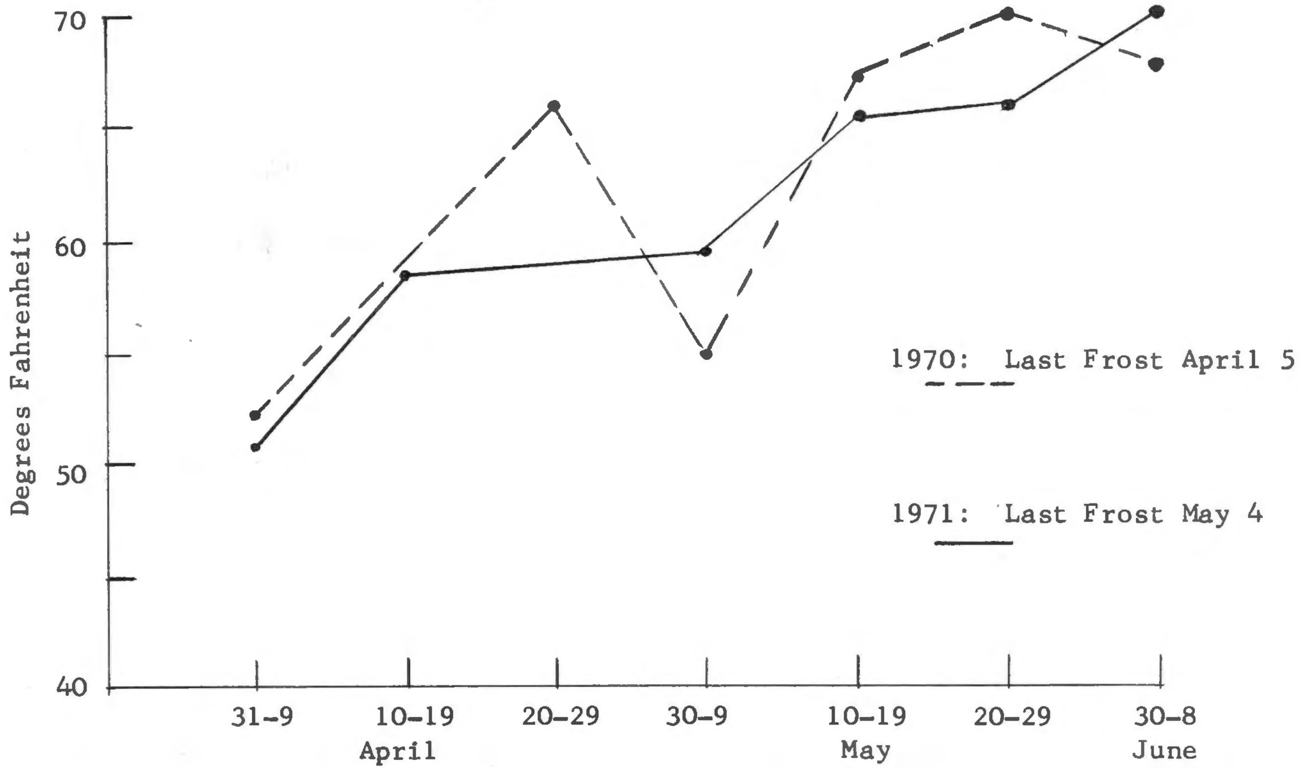

Figure 5. Mean daily temperatures May 31 through June 8 and date of last frost on the North River watershed in 1970 and 1971.

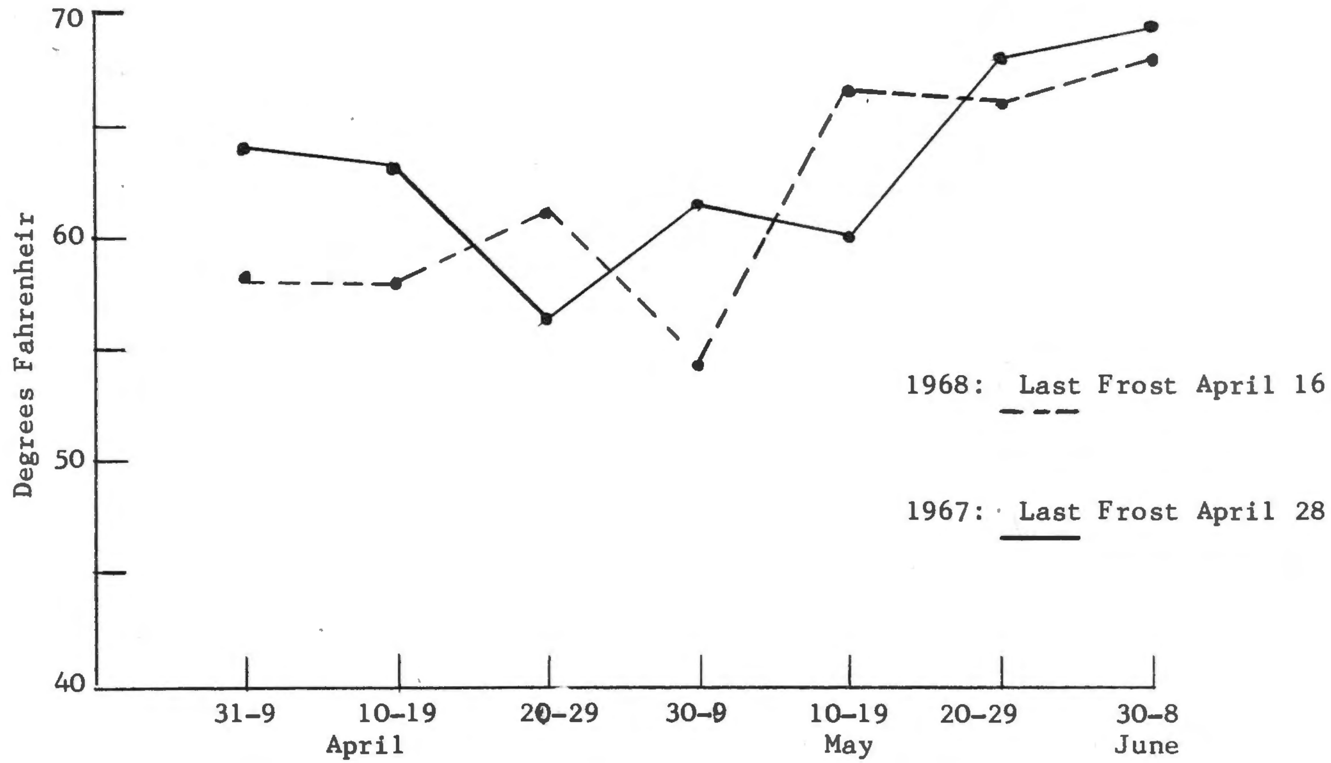

Figure 6. Mean daily temperatures May 31 through June 8 and date of last frost on the North River watershed in 1967 and 1968.

included warm temperatures in early April accompanied by a late frost April 28, 1967, and cool temperatures throughout April, 1968. The excellent northern red oak mast crop in 1971 was associated with temperatures in spring, 1970; rapidly rising temperatures in early and mid-April were followed by a cooling trend in late April and early May (Figure 5, page 31). The poor white oak mast year in 1971 was associated with lower April temperatures and a late frost, May 4 (Figure 5). The temperature trend in 1971 may effect a poor red oak mast crop in 1972.

Prediction of Acorn Crop

Prediction model. As stated previously, the yield of northern red oak acorns increased with increased diameter at breast height. It was found that yields also increased linearly with increased basal area (approximated by squaring diameter). A prediction equation using diameter and diameter squared was utilized to calculate the expected yields for each diameter class of northern red oak occurring on the study area. This prediction model accounted for from 58 to 64 percent of the variability in production by this species. These data were expanded to a per acre estimate of mast production by northern red oak using the number of trees per acre in each diameter class from a cruise of the study area. Expected yields by 1-inch diameter classes are presented in Table VII.

White oak acorn production was not correlated with diameter or diameter squared. Even in the stand at the higher elevation, where a fair amount of mast was produced, no correlation existed. It was therefore determined that the mean number of acorns produced per tree for white oaks would be the best estimate of production for this species.

TABLE VII

EXPECTED YIELD OF WELL-FORMED NORTHERN RED OAK ACORNS
BY 1-INCH DIAMETER CLASSES

Diameter Class[a]	Number Trees Per Acre	Number Sound Per Tree	Per Acre Number Sound	Per Acre Weight[b] Sound	Per Acre Weight[b] Damaged
10	0.524	1547.98	810.52	4.57	2.86
11	1.086	1139.88	1237.79	7.54	4.67
12	0.774	872.26	675.30	4.55	2.73
13	0.739	745.12	550.94	4.08	2.31
14	0.402	758.46	305.05	2.36	1.25
15	0.117	912.28	106.83	0.81	0.40
16	0.308	1206.58	371.39	2.69	1.28
17	0.136	1641.36	223.72	1.53	0.72
18	0.101	2216.62	224.54	1.47	0.68
19	0.146	2932.36	427.25	2.68	1.25
20	0.247	3788.58	934.26	5.69	2.67
21	0.059	4785.28	283.29	1.68	0.79
22	0.081	5922.46	479.72	2.80	1.33
23	0.062	7200.12	445.69	2.56	1.22
24	0.034	8618.25	293.02	1.66	0.80
25	0.063	10176.87	639.11	3.59	1.73
26	0.039	11875.97	463.16	2.58	1.25
27	0.009	13715.55	122.07	0.67	0.33
28	0.008	15695.60	131.84	0.72	0.35
30	0.007	20077.15	148.57	0.81	0.40
31	0.007	22478.65	152.85	0.83	0.41
32	0.006	25020.62	160.13	0.86	0.43
33	0.012	27703.08	335.21	1.80	0.89
34	0.006	30526.01	170.95	0.92	0.46
40	0.004	50413.69	206.70	1.09	0.55
44	0.007	66481.74	452.08	2.38	1.20
			Σ10351.98	Σ62.90	Σ32.60
Reg. Intercept[c]		(1)	(1)	(2)	(3)
r^2[d]		0.606	0.606	0.588	0.821
SE[e]		5.58	5.58	14.28	6.08

[a]One-inch diameter breast height classes (10-inches class = 9.5 to 10.4 inches).

[b]Weight in pounds oven-dry.

[c](1) $Y = 29.38-4.14\ dbh + 0.15\ dbh^2$; (2) $Y = 66.06-9.31\ dbh + 0.36\ dbh^2$; (3) $Y = 37.64-5.10\ DBH + 0.19\ dbh^2$.

[d]Coefficient of determination. [e]Standard error of regression.

Estimated yields for white oaks utilizing this mean value multiplied by the number of trees in each diameter class per acre are presented in Table VIII.

The yield estimates are presented in three categories. These categories include: (1) the number of sound acorns, (2) the weight of the sound acorns, and (3) the weight of the damaged acorns. The number of sound acorns produced is considered an estimate of the acorns available for germination; the weight of the sound acorns represents the amount of mast available as food for wildlife, at least through the winter; and the weight of damaged acorns represents food available to wildlife during and immediately after acorn fall.

Most mast studies do not consider damaged acorns when reporting acorn yields. However, these acorns could be a food source of considerable importance to species that uitlize mast for food prior to hibernation. Beeman (1971) found that 41 percent of the black bears diet in the late fall in the Great Smoky Mountains, Tennessee, consisted of acorns. He concluded that most of the fat reserves of the bears were added during the fall when acorns are the important food. The amount of acorns available may also affect bear reproduction. Matschke (1964) stated that acorns, when available in large quantities, probably stimulate reproductive activity in the European wild hog. He further stated that the productivity of this animal in the fall months is dependent upon the availability of acorns.

Predicted acorn yields. White oaks in the North River watershed produced very little mast in 1971. The number of sound white oak acorns

TABLE VIII

EXPECTED YIELD OF WELL-FORMED WHITE OAK ACORNS BY 1-INCH DIAMETER CLASSES[a]

Diameter Class[b]	Number Trees Per Acre	Number Sound	Weight Sound	Weight Damaged
10	0.066	15.62	0.02	0.04
11	0.109	25.61	0.04	0.06
12	0.092	21.68	0.03	0.05
13	0.039	9.25	0.01	0.02
15	0.029	6.94	0.01	0.02
16	0.051	12.11	0.02	0.03
17	0.023	5.40	0.01	0.01
18	0.020	4.74	0.01	0.01
20	0.017	3.89	0.01	0.01
21	0.015	3.54	0.01	0.01
23	0.012	2.90	0.00	0.01
24	0.012	2.71	0.00	0.01
		Σ 114.40	Σ .17	Σ .28

[a]Calculated using the mean number of acorns produced per tree multiplied by the number of trees per acre for each diameter class.

[b]One inch diameter breast height class (10 inches class = 9.5 to 10.4 inches).

was 114.4 per acre. The amount of well formed acorns available was 0.45 pounds per acre, including 0.17 pounds of sound acorns and 0.28 pounds of damaged acorns.

Northern red oaks produced a much larger crop than white oaks. The number of sound acorns per acre was 10,352. The total weight of well formed acorns was 95.5 pounds per acre. This yield included 62.9 pounds of sound acorns and 32.6 pounds of damaged acorns.

The yield of sound white oak acorns in this study was considerably less than that reported in other studies. Dalke (1953) reported a yield of 2.9 and 6.6 pounds of sound white oak acorns per acre in a two year study in southcentral Missouri. Gysel (1957) reported a mean annual yield of 144 pounds per acre over a four year period in southern Michigan. However, this was probably an over-estimate of the true productivity of the area since only mature trees with well formed boles and crowns were sampled and per acre estimates were based on the ratio of these trees' crown area to an acre. Downs (1944) reported an average annual white oak acorn crop of 21.1 pounds per acre for 2,100 acres in the mountains of western North Carolina. He noted, however, that during years of crop failure, very few well developed acorns were produced. This study reported yields of trees growing in a narrow range of elevations, 2,200 to 2,700 feet.

The northern red oak yield in this study was less than that reported by Dalke (1953) for 1938 (136 pounds per acre) but greater than the yield he reported for 1939 (no sound acorns). Gysel (1957) reported only 21 pounds per acre of northern red oak acorns in his study. The yield was also greater than the 22.1 pounds per acre reported by Downs (1944).

All the above authors noted the amount of variability in year to year mast yields. A comparison of the productive potential of these areas with the North River watershed could not be made.

Data in Table VII, page 34, indicate that most of the northern red oak mast on the study area was produced by trees less than 20 inches in diameter. Yet the amount of mast produced per tree is much greater for trees larger than 20 inches. The bulk of the white oak mast was produced by trees 16 inches in diameter or less (Table VIII, page 36). Therefore, as these species continue to grow and mature the potential for mast production on the area should increase considerably.

Wildlife Requirements for Acorns

Acorns are the most widely available and most commonly eaten wildlife food (Martin *et al*., 1951). VanDersal (1940) reported that 186 different kinds of birds and mammals feed on oak products; acorns were recognized as an important source of food for many of these animals. High and low levels in populations of squirrels (Burns *et al*., 1954), turkey (Uhlig and Wilson, 1952; Holbrook and Lewis, 1967), deer (Reid and Goodrum, 1957), and European wild hog (Matschke, 1964) were attributed to high and low mast yields. Acorns are relatively high in fat and carbohydrates and contain important vitamins and minerals. Foods high in these energy nutrients are important in conditioning animals during the reproductive season; good condition during the reproductive period is conducive to a high rate of productivity and survival of young (Reid and Goodrum, 1957).

Acorn requirements of several species have been combined and expressed in pounds per acre. Goodrum et al. (1971) and Reid and Goodrum (1957) estimated that 24.18 pounds of sound fallen air-dry acorns per acre were needed to supply the needs of five species of wildlife in Missouri for 180 days. Shaw (1971), reviewing the above studies plus work in the Missouri Ozarks by Evans (1968) and Virginia by Giles and Powell (no date), concluded that the figures given by the above authors failed to include the needs of grouse, black bear, and non-game species and should be increased by approximately 15 percent.

Estimates of the needs of the wildlife species occurring in the North River Watershed are presented in Table IX. Also included in the table are estimates of available northern red and white oak mast for 90, 180, and 300 days. Damaged acorns were considered available the first 90 days only. The amounts of food required daily by white-tailed deer (3 pounds air-dried per 100 pounds body weight), grey squirrel (.2 pounds per animal per day), and turkey (.7 pounds per animal per day) were obtained from the data presented by Reid and Goodrum (1957). An estimate for the daily requirements of the European wild hog was based on daily requirements reported for a young domestic boar, 110-180 pound class (5.5 pounds per animal per day) by the National Academy of Science (1968). Food requirements for cattle that graze on the study area were also included. The daily requirements of a 660 pound yearling steer (3.14 pounds) were used for the calculations (National Academy of Science, 1970). As was suggested by Shaw (1971), 15 percent was added to the per acre total to compensate for species not included in the table. These estimates were made on the assumption

TABLE IX

FOOD REQUIREMENTS OF MAST CONSUMING SPECIES AND AVAILABILITY OF WHITE OAK AND NORTHERN RED OAK ACORNS ON THE NORTH RIVER WATERSHED, 1971

Dietary Needs	Species and Population of Animals (Acres Per Animal)					
	White-tailed Deer (20)	Gray Squirrel (2)	Turkey (50)	Wild Hog (50)	Domestic Cow (158)	Total
Pounds of food required per animal per day	3.0	0.2	0.7	5.5	6.9	
Pounds of acorns required						
90 days	135.0[a]	10.8[b]	45.0[b]	371.7[b]	491.4[a]	1053.9
180 days	270.0[a]	21.6[b]	90.0[b]	743.4[b]	982.8[a]	2107.8
300 days	450.0[a]	36.0[b]	150.0[b]	1239.0[b]	1638.0[a]	3513.0
Pounds of acorns per acre required						
90 days	6.8[a]	5.4[b]	0.9[b]	7.4[b]	3.1[a]	27.1[c]
180 days	13.6[a]	10.8[b]	1.8[b]	14.8[b]	6.2[a]	54.3[c]
300 days	22.5[a]	18.0[b]	3.0[b]	24.8[b]	10.4[a]	90.5[c]
Availability of white oak and northern red oak acorns						Pounds per acre
90 days						110.4
180 days						81.8
300 days						74.2

[a]For 50 percent of diet.

[b]For 75 percent of diet.

[c]Corrected total for species not included in table.

that acorns constitute about half the diet of deer and cattle and about three-fourths the diet of gray squirrels, turkey, and European wild hog.

Approximately 27.1 pounds per acre would be required by the animals considered for 90 days. These same populations would require 54.3 and 90.5 pounds per acre for a period of 180 and 300 days, respectively. Based on the mast yields estimated for northern red and white oak, enough mast was produced on the area to support these animals for 90 and 180 days but not for 300 days. Thus, in a year with an abundant crop of northern red oak acorns, mast should be available to ground feeding animals all winter. The 180 days with mast available would extend from October to April, a critical period for many species of wildlife. It is apparent from Table IX that European wild hogs and domestic cattle require almost as much mast as the other species combined. Henry and Conley (1972) suggested that during poor mast years these exotic species would be in direct competition with native wildlife for the available acorns.

With additional information this technique could be a valuable tool in measuring the carrying capacity of an area during a time of critical food supply. More information is needed concerning the amount of mast consumed by non-game species and their population densities, especially small mammals. For example, Verme (1953) found that chipmunks will eat as much as 0.05 pounds of acorns per day. Hamilton (1941) reported that adult deer mice required approximately 0.01 pounds per day. Consumption of mast by non-game species may account for more than the 15 percent attributed to them in Table IX. In addition, this study measured mast production by only two of the five major oak species on the study area, and this for only one year. Similar information for all oak species for several years could be used to construct an expected yield table indicating the average acorn yield for the area. With this information and with a knowledge of the needs of wildlife for acorns, a determination of how much area should be maintained in mast producing species could be made.

Application

A number of tools are available for the wildlife biologist to use in determining the mast production potential of an area. The following steps are suggested for utilizing mast production data when intensive wildlife management is a major goal.

1. Gather quantitative data (utilizing seed traps) on the mast production by all major species for several years, and determine the distribution and diameters for these species.
2. Utilizing these data, construct an expected mean yield table by diameter classes with the yields expressed in pounds per acre.
3. Collect daily temperature data each year for the period from April to June.
4. Develop a technique for establishing an acorn production index, to be used exclusively after quantitative data have been gathered.

5. Construct a table of acorn requirements for all major mast eating species occurring on a given area.

The index and the weather data could be utilized in the prediction of the relative abundance of mast each year. The expected yield table could be used to estimate pounds produced by oaks during a particular year based on the index. The table could also be used in conjunction with the table of acorn requirements of wildlife to aid in planning timber harvests.

II. SEASONAL DISTRIBUTION OF WILDLIFE

The relationships between European wild hog and the forest community are poorly understood. One objective of this study was to determine the seasonal distribution of this animal and other wildlife and relate their seasonal movements to mast availability. To accomplish the above objective five trails in the North River Watershed were walked once each season during 1971 and winter, 1972. Sign present at permanent observation points was noted and identified to species when possible.

Trail Description

Three trails began at the head of large coves and followed a stream for most of their length. Two trails followed narrow ridges for approximately two-thirds of their length before dropping off the ridges into coves. Thirty percent of the observation points occurred on a ridge and 70 percent occurred in coves.

Hardwood forest community types were found at 84.9 percent of the points while pine and pine-hardwood types occurred at 15.1 percent of the points (Table X). These frequencies are similar to the distribution of hardwood and pine and pine-hardwood forest types recognized by the U.S.F.S. in the North River drainage (82.2 percent and 17.8 percent, respectively).

Each trail was walked in winter, spring, summer, and fall, 1971, and winter, 1972. A total of 254 points were sampled during these five seasons.

Wildlife Sign

Wildlife sign was present in 65 percent (165) of the point samples. Species leaving sign included white-tailed deer, European wild hog, wild turkey, ruffed grouse, raccoon, bobcat (*Lynx rufus*), fox (*Urocyon cinereoargentias* and/or *Vulpes fulva*), skunk (*Mephitis mephitis* and/or *Spilogale putoris*), and rabbit (*Sylvilagus floridanus* and/or *S. transitionalis*). Sign left by predators were not included in the analysis since their use of an area was probably a function of the abundance of prey species and influenced only indirectly by habitat.

The occurrence of wildlife was examined with respect to forest community type. The occurrence of wildlife sign was apparently influenced by the forest community type (X^2 = 13.18,* 5df). This non-random occurrence of sign resulted from the disproportionate use of two community types, yellow poplar-white oak-northern red oak and yellow poplar. Sign occurred 17 percent more often in the yellow poplar-white oak-northern red oak type and 33 percent more often in the yellow poplar type than would be expected with random range utilization.

TABLE X

FOREST COMMUNITY TYPES IDENTIFIED AT OBSERVATION POINTS ESTABLISHED ON INDEX TRAILS IN THE TELLICO WILDLIFE MANAGEMENT AREA IN 1971

Forest Community Type	Number of Points	Percent of Total
Hardwood		
White Oak-Red Oak-Hickory	16	30.2
Yellow Poplar	14	26.4
Yellow Poplar-White Oak-Northern Red Oak	12	22.6
Yellow Poplar-Hemlock	3	5.7
Pine-Pine:Hardwood		
Shortleaf Pine-Virginia Pine	6	11.3
Pitch Pine-Oak	2	3.8
Totals	53	100.0

The results of the above tests were probably influenced by the prevalence of European wild hog sign. Sign made by this animal was the most abundant sign observed, occurring in 62 percent of the point samples. White-tailed deer sign was second in frequency of occurrence yet was observed in only 9 percent of the point samples. Wildlife sign was present in only 7 percent of the point samples containing no European wild hog sign.

European Wild Hog Distribution and Movements

There is a paucity of knowledge concerning relationships between European wild hog and the forest community. Matschke (1964) noted a strong dependency of this animal on oak mast in the Tellico Wildlife Management Area. Matschke and Hardister (1966) and Shaw (1941) reported availability of mast as one of the principal factors influencing European wild hog movements. Stegeman (1938) suggested that this animal shifted its feeding area with the changing supply of food. This same behavior was reported for feral swine by Kurz (1971) on the Savannah River Plant, South Carolina. On that area hogs inhabited hardwood bottoms until a depletion of the mast crop occurred, at which time they moved into an adjacent pine plantation.

Influence of Forest Community and Season

During the five seasons of this study, European wild hog distribution did not appear to be influenced by season and forest community type (X^2 = 47.02NS, 49 df). However, for one season (winter, 1971), distribution was influenced by forest community type (X^2 = 12.09,* 5 df); these animals exhibited a preference for yellow poplar and yellow poplar-white oak-northern red oak communities.

Influence of Site and Season

To analyze the effect of site on European wild hog distribution, sample points were grouped as to their occurrence in a cove or ridge situation. Thirty percent of the points occurred on or near ridge crests while 70 percent of the points occurred in a cove or lower slope situation.

The non-random distribution of European wild hog sign was not due to seasonal differences in distribution (X^2 = 4.11NS, 4 df) but to a preference for coves (X^2 = 7.27,* 1 df). Sign by this animal was found in coves 17 percent more often than would have been expected with random range utilization. This preference for coves occurred in winter, 1971 (X^2= 10.12,* 1 df) and spring, 1971 (X^2 = 9.93,* 1 df). Random range utilization occurred the remainder of the seasons in 1971 and in winter, 1972.

The streams bisecting the mountain coves appear very attractive to the European wild hog. Sign was found in and around most streams of any size in every season trails were walked. Much of this sign was wallowing, both in the upper ends of the higher coves and in the lower and more level wet areas. Stegeman (1938) stated that wild hog wallowing occurred throughout the year.

It is likely that the home range of most European wild hogs includes both ridge and cove sites. Lewis (1966) reported a range of 3,850 acres (2.3 miles wide by 3.2 miles long) and 4,700 acres (3.6 miles wide by 4 miles long) for two young European wild hogs released on Catoosa Wildlife Management Area in East Tennessee. A range of these proportions could easily include a ridge and a cove in the North River drainage. However, no seasonal migration pattern was obvious in this study.

In general, European wild hogs appeared to prefer coves. This was obvious in the winter and spring of 1971. These animals appraently used the streams and seeps for wallowing and fed in the damp areas and on lower slopes. Henry and Conley (1972) found that invertebrates ranked third in volume and second in frequency of occurrence and roots ranked fifth in volume and third in frequency of occurrence for European wild hogs on the Tellico Wildlife Management Area during fall. While these foods did not appear to be significant in late fall when mast comprised 82.2 percent of the total food consumed, they may be a much more important food source in other seasons. This may help to explain the abundance of sign in the coves where roots, tubers, and invertebrates are more plentiful (Whittaker, 1952; and 1956) and the moist soil is more easily rooted.

Range utilization was random in summer and fall, 1971 and winter, 1972. Only a fair mast crop was reported in 1970 (Conley, 1970). As a result mast may have been lacking on the ridges in the winter months of 1971 and failed to attract European wild hogs to ridges during their daily movements. Shaw (1941) indicated that the availability of berries in summer and acorns in the fall affected the distribution of this animal. Fruit and berry production on the management area was good in 1971. Acorn production was reported as medium (Conley, 1971). A plentiful supply of food probably resulted in the random range utilization in summer and fall, 1971 and winter, 1972.

During seasons when fruits, berries, and mast were available the European wild hog exhibited random range utilization. In seasons when these foods were not available these animals preferred cove sites. The European wild hogs utilization of the cove throughout the year was probably influenced by their penchant for wallowing in the spring seeps and wet areas as well as the availability of food.

III. AVAILABILITY OF ACORNS IN SPRING

Acorns were collected in spring, 1972 beneath trees sampled with mast traps the previous fall. Acorns were examined to determine the number of germinated seedlings and sound acorns were weighed to determine the amount of mast available as food for wildlife in spring; these data were compared to the mast production estimates of fall, 1971. Acorns were found beneath all northern red oak sample trees. Germinated or sound non-germinated acorns were found beneath 53 percent of these trees. Acorns were found beneath 67 percent of white oaks sampled; germinated acorns were found beneath only 43 percent.

Description of Spring Mast

Most of the acorns collected beneath both species were severely damaged, with little more than a hollow pericarp remaining (Table XI). Most of the germinated white oak acorns were damaged, primarily by insects. Only a small proportion of the white oak acorns were sound and germinated. There were more germinated northern red oaks than germinated white oaks and a greater proportion of the germinated red oak acorns

TABLE XI

COMPOSITION OF THE MAST SAMPLE COLLECTED IN THE SPRING OF 1972 ON THE TELLICO WILDLIFE MANAGEMENT AREA

Category	White Oak Number	White Oak Percent of Total	Northern Red Oak Number	Northern Red Oak Percent of Total
Damaged and Non-germinated	67.73	77.60	1045.09	82.30
Damaged and Germinated	18.56	21.20	73.96	5.85
Sound and Germinated	1.02	1.20	112.99	8.95
Sound and Non-germinated	0.00	0.00	30.53	2.40
Totals	87.31	100.00	1262.57	100.00

were sound. In addition, a few red oak acorns were sound yet had not germinated.

There were 1,083 well-formed northern red oak acorns per acre on the study area in spring, 1972 (Table XII). This included 563 sound and germinated, 368 damaged and germinated, and 152 sound, non-germinated acorns. White oaks averaged only 10 well formed acorns per acre, 9 damaged, germinated and 1 sound, germinated. This represented 5.5 percent of the well-formed northern red acorns and 2.5 percent of the well-formed white oak acorns that fell in autumn, 1971. The sampling technique failed to account for the effect of slope at sampling sites. For this reason the amounts given for each species probably represent a minimum estimate of acorns remaining on the ground in the spring.

Destruction of Acorns

Damage to sound acorns after they reach the ground is due primarily to animals other than insects. Korstian (1927) indicated that 90 to 100 percent of the acorn crop, especially in years of limited seed production, may be consumed or destroyed by mammals. Gysel (1957) reported that following a poor seed production year no sound acorns remained by November. Downs and McQuilkin (1944) suggested that open quadrat studies in the Southern Appalachians indicated that consumption of acorns by animals and insects left few acorns for forest regeneration. Beck and Olson (1968) stated that in their study few acorns were left to develop except in bumper years. Christisen and Korschgen (1955) concluded that wildlife consumption of mast was probably a factor limiting regeneration of oaks in poor seed years, yet had little effect in

TABLE XII

NUMBER OF ACORNS PER ACRE PRESENT IN SPRING, 1972 BY DIAMETER CLASSES OF WHITE OAK AND NORTHERN RED OAK[a]

Diameter[b] Class	Northern Red Oak			White Oak	
	Damaged Germinated	Sound Germinated	Sound Non-Germinated	Damaged Germinated	Sound Germinated
10	38.73	59.17	15.99	1.23	0.07
11	80.31	122.70	33.15	2.01	0.11
12	57.26	87.48	23.64	1.71	0.09
13	54.69	83.54	22.57	0.73	0.04
14	29.75	45.44	12.28	--	--
15	8.66	13.23	3.58	0.55	0.03
16	22.76	34.78	9.40	0.95	0.05
17	9.73	15.40	4.16	0.43	0.02
18	7.49	11.45	3.09	0.37	0.02
19	10.78	16.46	4.45	--	--
20	18.24	27.86	7.53	0.31	0.02
21	4.38	6.69	1.81	0.28	0.02
22	5.99	9.15	2.47	--	--
23	4.58	6.99	1.89	0.23	0.01
24	2.51	3.84	1.04	0.21	0.01
25	4.64	7.10	1.92	--	--
26	2.88	4.41	1.19	--	--
27	0.66	1.01	0.30	--	--
28	0.62	0.95	0.26	--	--
30	0.55	0.84	0.23	--	--
31	0.50	0.77	0.21	--	--
32	0.47	0.72	0.20	--	--
33	0.89	1.37	0.37	--	--
34	0.41	0.63	0.17	--	--

TABLE XII (continued)

Diameter Class[b]	Northern Red Oak Damaged Germinated	Northern Red Oak Sound Germinated	Northern Red Oak Sound Non-Germinated	White Oak Damaged Germinated	White Oak Sound Germinated
40	0.30	0.46	0.13	--	--
44	0.50	0.77	0.21	--	--
	Σ 368.28	Σ 563.21	152.24	Σ 9.01	Σ 2.49

[a]Calculated using the mean number of acorns present per tree multiplied by the number of trees per acre in each diameter class from cruise of study area.

[b]One-inch diameter breast height classes (10 inches class = 9.5 to 10.4 inches).

years of good mast production. Nevertheless, Klugh (1927) and Mellanby (1968) stressed the benefits of acorn-feeding mammals, especially small rodents.

Germination of Insect Damaged Acorns

According to Korstian (1927), a very small percentage of acorns containing weevils will produce normal seedlings. Nonetheless, some damaged acorns will germinate if the embryo is not damaged (USDA Forest Service, 1965).

Most of the germinated white oak acorns in the spring were so severely damaged that seedling survival is doubtful. However, a few white oak acorns and several red oak acorns were only slightly damaged and could survive.

Site Factors Affecting Germination of Acorns

Korstian (1927) and Barrett (1931) noted the importance of moisture to germinating acorns. Both authors indicated that litter or soil cover was very important in preventing moisture loss from acorns on the ground. Olson and Boyce (1971) stated that the percent of acorns capable of germination and the number of new seedlings were directly related to the size of the acorn crop. However, Tryon and Carvell (1962) found little difference between sites of dense and sparse oak reproduction in: (1) total seed production, (2) number of sound acorns produced, (3) damage to acorns by insects, and (4) damage to and loss of acorns by animals. They further stated that "the ability of oak regeneration to persist on a specific site is more closely related to environmental conditions than is its ability to become established."

All germinated acorns were collected in similar circumstances. All were located beneath a deep litter layer in a very moist situation. In addition, 77 percent of the fall crop of white oak mast was collected above 3,500 feet yet approximately 42 percent of the germinated white oak acorns were collected at the lower elevations. This seems to indicate that the number of acorns germinating in a single season may be more closely related to site factors rather than the size of acorn crop.

Judging from the amount of sound and germinated seeds left following a good red oak seed year and the number of germinated acorns resulting from the poor white oak seed year, it is unlikely that wildlife utilization of acorns on the study area will significantly decrease the amount of advanced oak regeneration needed for reforestation. However, adjustment of the conditions on the forest floor as described by Tryon and Carvell (1962) may be in order prior to harvesting oak stands to insure this advanced regeneration of oak seedlings.

Acorns Available for Wildlife Utilization

The white oak crop of 1971 was relatively light, especially below 3,500 feet. The amount of white oak mast remaining in the spring of 1972 was minimal averaging .0082 pounds per acre (2 percent of the autumn crop). In contrast, the amount of sound or slightly damaged red oak mast was substantial averaging 6.19 pounds per acre (15.6 percent of the fall crop). Thus the northern red oak mast crop of 1971 provided a food source for the entire winter and at least some food for wildlife in the following spring.

CHAPTER V

SUMMARY

The study area was an 11,881 acre watershed in the Tellico Wildlife Management Area of the Cherokee National Forest in Monroe County, Tennessee. Elevations on the study area ranged from 1,633 feet to 5,130 feet.

Acorns produced by 30 white oak and 30 northern red oak in 1971 were collected with 0.1 milacre seed traps. Northern red oak produced many more acorns than white oak.

Acorns of both species began falling between August 16 and August 30. Immature and damaged acorns began falling first followed by mature sound acorns.

The larger northern red oak acorn weighed more (148 per pound) than the smaller white oak acorn (648 per pound). Sound acorns weighed more than damaged acorns.

Only one-fourth of the white oak acorns collected were sound compared to more than one-half of northern red oak acorns. Nut weevils (Curculio sp.) accounted for most of the damage. A few acorns were damaged by birds and small mammals while still in the tree.

Production was not affected by percent slope at the sample sites. Acorn production in 1971 and 1968 were correlated with temperature trends during June and late spring frosts.

The amount of northern red oak seed produced was related to diameter at breast height and basal area of individual trees. Production increased as dbh and basal area increased. Expected yields of sound and damaged northern red oak acorns by diameter class were calculated and expanded to a per acre estimate of mast production based on a stand table developed for the area. The amount of white oak mast produced was not consistently related to tree characteristics and production estimates were based on the mean yield per tree expanded on the basis of a stand table. White oak produced 114.4 sound acorns per acre (0.17 pounds) while northern red oak produced 10,352 sound acorns per acre (62.9 pounds).

An estimate was made of the pounds of acorns required by five species occurring on the study area. It was determined that the European wild hog and domestic cattle have acorn requirements approaching that for all other species combined on the study area.

From observations of wildlife sign it was determined that the movements of wildlife, particularly European wild hog, were influenced by the availability of food. The European wild hog exhibited a preference for coves except in seasons when mast and berries were available in quantity on the ridges, at which time this animal moved randomly over the study area.

The amount of sound and germinated seeds present in spring following a good red oak seed year and a poor white oak seed year indicated that wildlife utilization of acorns on the study area will not decrease the potential for seedling regeneration. Collections in spring also indicated that a considerable amount of northern red oak mast remained on the study area while little white oak mast persisted.

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