THE VALUE AND PREDICTION OF ACORN CROPS FOR DEER

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THESIS

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ABSTRACT

THE VALUE AND PREDICTION OF ACORN CROPS FOR DEER

By Jerry Paul Duvendeck

In a study conducted from 1952 to 1956 at the Houghton Lake Wildlife Experiment Station in Michigan I investigated the food value of acorns to white-tailed deer (Odocoileus virginanus) by controlled feeding of penned animals. I also investigated the possibility of developing a method of predicting acorn crops for deer. Acorn production on 64 selected oaks was studied intensively. Extensive investigations of acorn production and deer use of acorns were conducted throughout the oak forests of northern Michigan.

Deer will eat approximately 1.5 lb of acorns per day per hundredweight, when they are available. Of deer fed a basic starvation ration of poor browse foods plus acorn supplements only those given a 0.5 lb supplement of acorns per hundredweight would have had a chance of surviving a 90-day winter period with a weight loss less than the critical 30 per cent. White oak acorns are apparently more palatable than red oak acorns, but weight loss was not significantly different between two groups of deer, one receiving white oak acorns, the other red oak acorns, as a supplement to a poor food browse diet. Deer entering a winter in excellent condition may be better able to resist a critical winter weight loss than animals that are in poorer, lighter condition.

There are wide variations in acorn crops produced between years, between different oak stands, and between individual trees in the same year. Several factors may affect the quality and quantity

of acorns available to deer. However, it appears that in years when medium or better acorn crops are produced, and medium or better crops may be expected on the average in two out of five years, adequate quantities of sound acorns may be available to deer through the fall and part or all of the winter.

Counts of oak flowers, frost damage surveys, counts of fertilized flowers, and counts of aborted acorns did not lead to an acorn crop prediction method. Observations of mature oaks, made with the aid of binoculars in late June and early July of the year an acorn crop will mature, to visually estimate the per cent of the crown area of oaks producing acorns, the per cent of twigs within the producing portion of the crown bearing acorns, and the average number of acorns per twig can lead to a general prediction of the number of pounds of sound acorns that will be produced in an oak stand, and a fairly accurate estimate of acorn availability to deer through the fall and winter.

Based on findings in the deer feeding studies and observations of acorn production and deer use of acorns in the oak forests of northern Michigan some suggestions for oak management for deer are made.

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By

Jerry Paul Duvendeck

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Dr. R. A. MacMullan and Dr. Ralph Blouch directly supervised my work while they were Biologists-in-Charge of the Houghton Lake Wildlife Experiment Station. To Dr. L. L. Eberhardt, former Game Division Biometrician, I am deeply indebted for guidance and help on statistical design and analysis. I am also indebted to Dr. Dale Fay and William G. Youatt for analyzing deer blood samples. I thank Dr. C. T. Black for editing the manuscript. I wish to thank my many other Game Division colleagues who assisted throughout the study.

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INTRODUCTION

A drastic reduction in carrying capacity of much of Michigan's winter range for white-tailed deer (Odocoileus virginianus) has resulted in periodic heavy starvation losses (Bartlett, 1951), but in some years deer in heavily overbrowsed areas survive the northern Michigan winter in good condition. Since it is possible that acorns may be a factor affecting the survival of deer, this study was undertaken to determine the value of acorns as food for deer, and to attempt to develop a method of predicting acorn crops. It also led to some suggestions for oak forest management for deer. The study started in 1952 at the Houghton Lake Wildlife Experiment Station of the Michigan Department of Conservation, located in Roscommon County, Michigan.

The presentation is in two parts. The first deals with investigations of the food value of acorns to deer by controlled feeding of penned animals. The development and evaluation of a method of predicting acorn crops are presented in the second part.

THE VALUE OF ACORNS IN THE DIET OF MICHIGAN DEER

In good mast-crop years the acorns produced in the oak forests in the northern half of the Lower Peninsula of Michigan provide a large amount of food for wildlife. Acorns are classed by Forbes et al. (1941) as one of the most important natural deer foods.

I fed penned deer browse food diets supplemented by acorns to investigate: (1) the amount of acorns needed to sustain deer through a winter in poor browse food areas, (2) the relative food value of acorns of the red oak group compared to white oak acorns, and (3) the differences between deer entering a winter in excellent condition compared with deer starting the winter in fair condition (simulating conditions that might be found in years of mast crop abundance as compared with years of crop failure).

GENERAL METHODS

The experimental deer were kept in a battery of 23 pens made of 2 widths of snow fencing, one above the other, supported by cedar posts (Figure 1). Deer were penned individually, with one exception noted later.

All food was weighed fresh (to the nearest 0.1 lb.) as it was put in the pens, and all uneaten material was weighed and removed. Browse foods used in the experiments were cut from the lower limbs of trees that would ordinarily be available to deer. Fresh browse was cut two or three times weekly and never stored more than 2 or 3 days before feeding. Weight changes frequently occurred in browse foods between the time they were placed in the pens and the time the uneaten portions were removed, because of evaporation or absorption of moisture, or coating by snow and ice. Control feed racks were used as an aid in checking this variation and adjusting the computed daily food consumption. Wooden feed racks with chicken wire tops held browse foods fully assessible to the deer. Acorns were put in small wooden boxes (Figure 2).

Loss in deer body weight was used as the main criterion of diminishing physical condition. In controlled-feeding studies at Michigan's Cusino Wildlife Experiment Station during 1936-41, Davenport (1946) found that a body weight loss of around 30 per cent during the winter period was the maximum a deer could sustain. This percentage appears to be supported by recent records (Figure 3) of 60 penned deer dead from malnutrition at the Cusino and Houghton Lake Wildlife Experiment Stations. In my experiments, when a deer

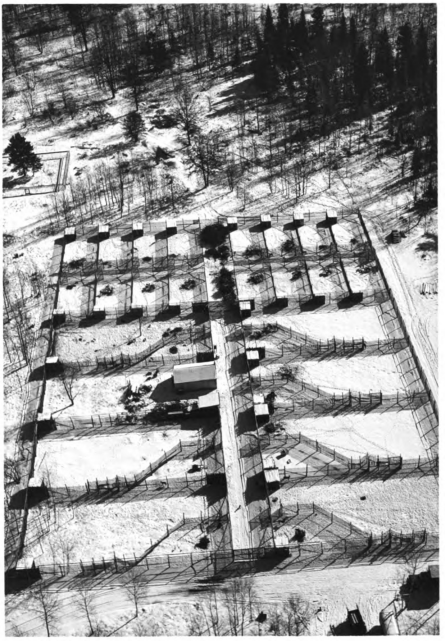


Figure 1. Deer pens at Houghton Lake Wildlife Experiment Station.

Figure 2. Deer feeding rack and acorn feeding box.

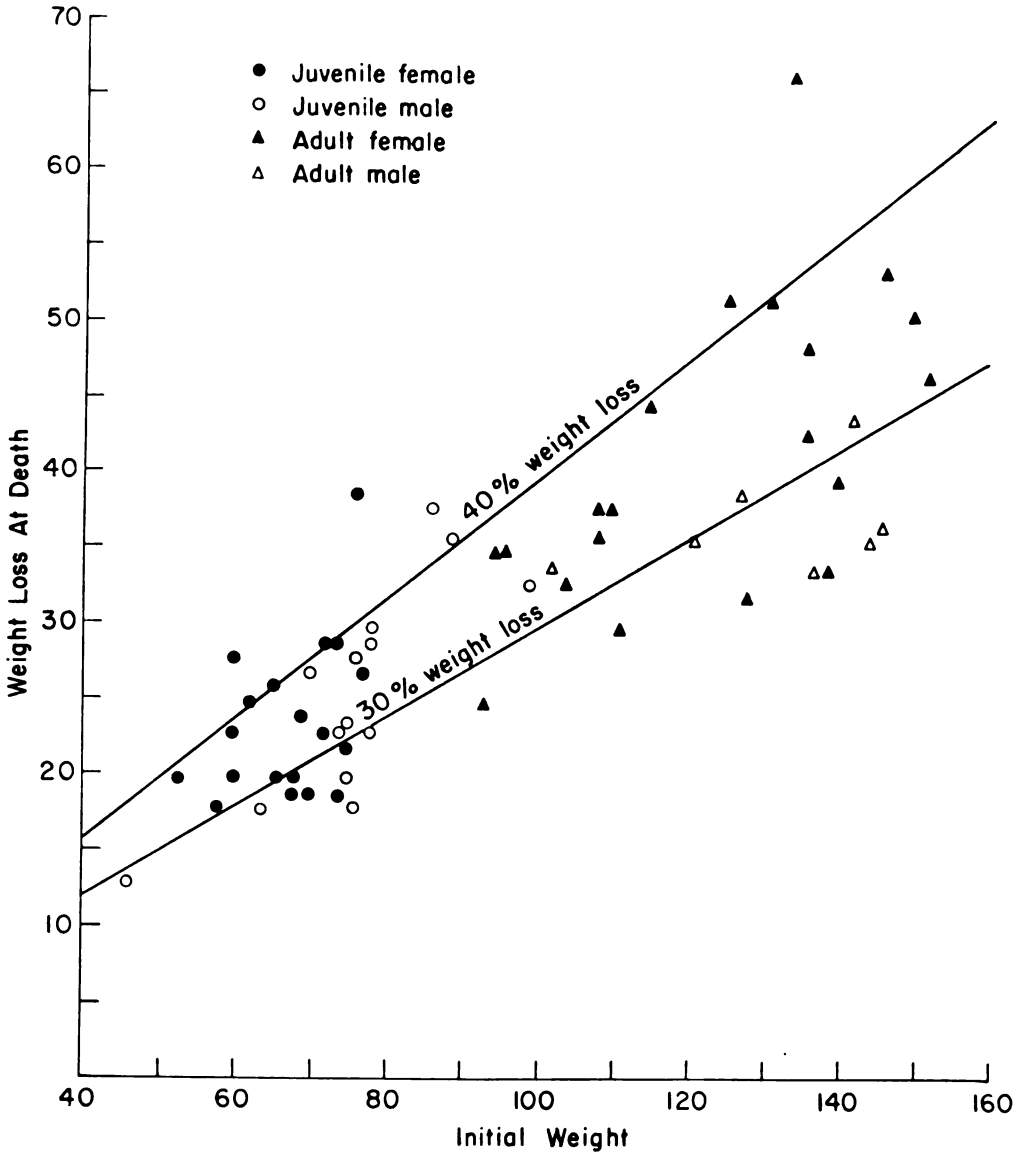


Figure 3. Weight records of 60 deer that died of malnutrition at Cusino and Houghton Lake Wildlife Experiment Stations.

had lost between 25 and 30 per cent of its fall weight, I stopped controlled feeding and put the animal on a good food diet.

Blood samples were taken periodically from deer on my experiments and analyzed for red and white cell counts, hemoglobin content, packed cell volume, non-protein nitrogen, and phosphorus, but no blood factor was discovered that indicated the physical condition of the deer.

Deer used in the experiments were either wild-trapped stock or semitame deer raised from fawns at the Ogemaw State Game Refuge, Ogemaw County, Michigan. Since semitame deer were easier to handle (thus less likely to injure themselves) than wild-trapped deer, and since preliminary experiments revealed no apparent differences in reaction to feeding between the two types of deer, I used semitame animals exclusively in the remainder of my experiments.

The controlled feeding experiments were designed to be conducted for 90 days during winters of 1954, 1955, and 1956. The controlled feedings were designed as separate experiments and analyzed as such. No statistical comparison was attempted between years, as Snedecor (1946) points out difficulties encountered in attempting to compare statistically experiments conducted under different environmental or climatic conditions. In the analysis of results, 60-day, 71-day, and 73-day weights were used in 1954, 1955, and 1956, respectively, because many deer had to be taken off controlled feeding shortly after these periods. The procedures and results of each experiment will be discussed separately.

In the fall of 1952 acorns were abundant. In most oak areas in the northern Lower Peninsula more were available than deer could consume. Nichol (1938) suggested that when acorns are plentiful deer

may eat little else. Davenport (1937) reported that three deer fed balsam (Abies balsamea) and oak (Quercus spp.) browse plus all the acorns they would eat consumed between 1 and 1.5 lb of acorns daily. I examined the rumen contents of 15 wild deer killed during October, 1952 and found that they had eaten approximately 1.5 lb of acorns per 100 lb body weight. Eight penned deer that I fed a mixed browse diet plus a free choice of acorns ate approximately 1.5 lb of acorns per day per 100 lb body weight. My first feeding experiment was designed to determine whether deer could survive a winter on poor quality browse species plus an acorn supplement of less than 1.5 lb per day.

RESULTS OF FEEDING EXPERIMENTS

Controlled Feeding--1954

Eighteen deer were split into two similar groups of nine deer each. One of these groups received, as a basic diet, free choice of jack pine (Pinus banksiana) and oak browse. The other group's basic diet included a free choice of balsam fir, plus 10 per cent of the amount of white cedar (Thuja occidentalis) necessary to sustain a deer in good condition (approximately 8 oz per 100 lb body weight per day) as determined by Davenport's (1946) feeding experiments. Each of these two main groups was further divided into three subgroups, each containing an adult doe and two fawns, except one subgroup made up of three fawns. Pairs of subgroups representing both main groups each received a different level of acorn supplement. One pair was given 0.5 lb of acorns per day per 100 lb body weight of deer, the second pair was given 0.25 lb of acorns per day per 100 lb body weight, and the third pair was fed no acorns.

The acorn supplement was fed as a mixture of three species and consisted of approximately 50 per cent Hill's oak (Quercus ellipsoidalis), approximately 42 per cent northern red oak (Quercus rubra), and approximately 8 per cent white oak (Quercus alba).

Maynard, et al. (1935), Davenport (1946), and Dahlberg and Guettinger (1956) demonstrated through controlled feeding that deer will starve on balsam alone. Since oak and jack pine browse are classified as starvation foods by Davenport (1946) and Dahlberg and Guettinger (1956), I believed that my deer would not be sustained on these basic diets, and any differences demonstrated between

groups would be the result of the acorn supplement.

After 60 days on the above diets, half of the 18 deer had lost more than 25 per cent of their original weight (Table 1). Only one of the deer receiving no acorn supplement could be carried beyond this point. After 66 days, only 7 of the original 18 deer could have continued. Five of these were receiving the 0.5-lb acorn supplement.

An analysis of covariance (following Snedecor, 1946) failed to demonstrate significant differences among adjusted mean weight losses in the three acorn-supplement categories (Table 2). However, since the weight-loss classes of groups of deer with different acorn supplements can logically be arranged in a sequence (i.e., 0, 0.25, and 0.5 lb/cwt) without reference to the outcome of the experiment, it seems legitimate to compare the extreme cases (0 and 0.5 lb/cwt) here. A "t" test was used, wherein the difference between adjusted mean weight losses for the groups of deer on the 0- and 0.5-lb acorn supplements (18.3 and 14.0 lb respectively) was compared with a standard error computed in the manner described by Cochran (1957). The computed "t" value (2.44 with 13 degrees of freedom) is significant at the 5-per cent level and falls just short of the 1-per cent level of significance ("one-tailed" test). The covariance adjustment of mean losses (to a common initial weight; 67.9 lb in this experiment) gives percentage losses (last line of Table 3) which differ very little from the unadjusted rates.

On the assumption that the deer body weight loss rates as indicated in Table 3 would continue over an additional 30 days, only those deer receiving 0.5-lb acorn supplement would have a chance of surviving. Therefore, an acorn supplement, of the species tested, less than

Table 1
Weights of Deer and the Food They Consumed on Starvation Browse Diets
Plus Acorn Supplements, January-March, 1954

Diet	Deer No.	Sex	Age	(Weight (lb.) Original	Final	Total Food Consumed (lb.) Jack Pine	Oak	Acorns
Jack pine and oak browse	868	F	Ju	46	34*	106.8	82.8	0
No acorns	871	F	Ju	68	46*	78.3	74.6	0
	866	F	Ju	55	41***	22.1	13.0	0
Jack pine and oak browse plus	869	M	Ju	76	61**	82.1	120.1	11.4
0.25 lb. acorns per day per cwt	819	F	Ju	65	45*	107.1	73.0	4.4
	4951-52	F	Ad	82	66**	71.9	75.6	11.4
Jack pine and oak browse plus 0.5	867	M	Ju	70	58**	79.3	128.9	22.9
lb. acorns per day per cwt	821	F	Ju	61	52**	86.6	107.6	17.1
	856	F	Ad	89	66*	65.6	96.2	26.1
						Balsam	Cedar	Acorns
Balsam and cedar browse	870	F	Ju	60	45**	109.7	43.7	0
No acorns	865	F	Ju	53	40*	112.1	43.5	0
	4907-08	F	Ad	68	47*	167.9	44.4	0
Balsam and cedar browse plus 0.25	864	F	Ju	58	41*	41.7	40.9	7.8
lb. acorns per day per cwt	872	M	Ju	55	40*	98.9	38.8	7.8
	855	F	Ad	97	74**	129.2	46.1	15.5
Balsam and cedar browse plus 0.5	820	M	Ju	62	48**	84.6	37.3	21.3
lb. acorns per day per cwt	818	F	Ju	53	41**	72.4	39.5	16.5
	853	F	Ad	105	84**	87.4	40.4	31.0

* After 60 days on controlled diets.
** After 66 days on controlled diets.
*** After 20 days on controlled diets.

Table 2
Analysis of Covariance of Weight Data from 1954 Deer Feeding Experiment

Source of Variation	Degrees of Freedom	Sums of Squares and Products			Errors of Estimate		
		$S(x-\bar{x})^2$	$S(x-\bar{x})(y-\bar{y})$	$S(y-\bar{y})^2$	Sum of Squares	Degrees of Freedom	Mean Square
Total	17	4,444.94	798.33	316.00	172.616	16	
Acorn supplements	2	835.44	5.67	19.00			
Within lots	15	3,609.50	792.67	297.00	122.926	14	8.78
For test of significance of adjusted mean loss					49.690	2	24.84

Table 3
Body Weight Loss of Deer on 1954 Feeding Experiment[1]

Basic Diets	Acorn Supplements: None — Initial Weight (x)	None — Weight Loss (y)	0.25 lb per cwt — Initial Weight	0.25 lb per cwt — Weight Loss	0.5 lb per cwt — Initial Weight	0.5 lb per cwt — Weight Loss
Jack pine-oak	46	12	76	15	70	12
	68	22	65	20	61	9
	55	14	82	16	89	23
Gross percentage loss		28.4		22.9		20.0
Balsam-cedar	60	15	58	17	62	14
	53	13	55	15	53	12
	68	21	97	23	105	21
Gross percentage loss		27.1		26.2		21.4
Totals	350	97	433	106	440	91
Gross percentage loss		27.7		24.5		20.7
Adjusted percentage loss (see text)		26.9		24.6		20.6

[1] Deer initial weight and weight loss in lb.

0.5 lb per day per 100 lb body weight would not be sufficient to carry deer through a 90-day winter period.

Controlled Feeding--1955

During the winter of 1954-55, a feeding experiment was conducted to investigate nutritional differences between white oak and red oak acorns. Forbes, et al. (1941) analyzed red oak (Quercus rubra) acorns and reported, "The values for composition, digestibility, and digestible nutrients indicate that the acorn is one of the most important of natural deer feeds." It appeared to me that deer in the wild preferred acorns of the white oak group over those from the red oaks. Given a choice, penned deer ate white oak acorns first.

Sixteen deer were divided into four groups each containing an adult buck, an adult doe, a buck fawn, and a doe fawn. Three of the groups received jack pine and oak browse as a basic diet. In addition, one group got 0.5 lb of white oak acorns per day per 100 lb body weight, the second had 0.5 lb per 100 lb body weight of red oak acorns, and the third received no acorns. The fourth group was fed a "good-food" diet consisting of free choice of Kellogg deer pellets (a deer food concentrate produced by The Kellogg Company, Battle Creek, Michigan), shelled corn, apples, cedar, aspen (Populus tremuloides), juneberry (Amalanchier spp.), and cherry browse (Prunus serotina). Table 4 presents deer weight and food consumption data collected in this experiment.

A "t" test does not show evidence of significant differences between mean losses in the groups receiving red and white oak acorn supplements ($t = 1.28$, 10 degrees of freedom). Both types of acorns are apparently good deer foods. An analysis of covariance, including

Table 4
Weights of Deer and Food They Consumed in Feeding Experiment Comparing Food Value of Red and White Oak Acorns, January—March, 1955

Diet	Deer No.	Sex	Age	Weight (lb)		Total Food Consumed (lb)						
				Original	Final[1]	Jack Pine		Oak	White Oak Acorns			
Jack pine and oak browse plus 0.5 lb white oak acorns per day per cwt	820	M	Ad	122	101	172.8		75.4	42.4			
	865	F	Ad	98	83	74.1		123.0	33.8			
	28662	M	Ju	75	58	70.3		98.4	25.8			
	28661	F	Ju	69.5	58	50.8		100.7	25.3			
									Red Oak Acorns			
Jack pine and oak browse plus 0.5 lb red oak acorns per day per cwt	2538	F	Ad	103	85	83.9		177.0	32.4			
	2540	M	Ad	147	115	97.0		52.2	42.4			
	28665	M	Ju	83	65	47.3		114.4	30.9			
	28667	F	Ju	63.5	48	126.0		25.7	20.4			
									No Acorns			
Jack pine and oak browse	856	F	Ad	107	84	115.1		148.4	0			
	829	M	Ad	150.5	116	202.4		194.2	0			
	28657	M	Ju	74	54	124.2		96.3	0			
	2539	F	Ju	53	40	145.9		64.0	0			
						Pellets	Corn	Apples	Cedar	Aspen	Juneberry	Cherry
Good Food	869	M	Ad	148	127	48.5	69.5	7.9	29.2	8.6	1.5	30.4
	864	F	Ad	100	99	72.0	47.5	10.4	22.1	11.1	28.8	3.1
	28656	M	Ju	66	64	78.0	45.5	7.0	5.2	10.0	2.1	2.9
	28653	F	Ju	65.5	74	68.5	62.0	1.9	6.8	0.0	10.1	45.1

[1]After 71 days on controlled diets.

all four groups (Tables 5 and 6), shows highly significant differences among adjusted mean weight losses. Since the mean weight loss of the "good-food" group was so much less than the loss in the other groups, a "t" test was run contrasting the 0.5-lb and no-acorn diets (thus excluding the "good-food" diet). The test falls short of significance at the 5-per cent level (t = 1.69, 10 degrees of freedom; "one-tailed" test). The adjusted percentage losses are again very nearly the same as those obtained from unadjusted data (Table 5).

The deer receiving no acorns lost less weight than a similar group during the previous year's feeding experiment. From general observation of the deer on this experiment as compared to those from the previous year, and because the original weights in 1955 were heavier than those in 1954, I believed that the animals starting the 1955 feeding were in better condition than those starting the 1954 experiment. This probability influenced the design of the 1956 feeding.

Controlled Feeding--1956

During the winter of 1956, a controlled feeding experiment was designed to investigate differences between deer entering a winter period in excellent condition and deer starting the winter in fair condition. To determine whether a deer was in excellent or fair condition, the general appearance of the animal and the weight gain, or the lack of it, through the fall period were used. The terms "excellent" and "fair" are defined as follows:

Excellent--having an excess accumulation of fat.

Fair--only a moderate amount of body fat.

Table 5

Body Weight Loss of Deer in 1955 Feeding Experiment[1]

Basic Diet	Acorn Supplements					
	None		0.5 lb per cwt White Oak Acorns		0.5 lb per cwt Red Oak Acorns	
	Initial Weight (x)	Weight Loss (y)	Initial Weight	Weight Loss	Initial Weight	Weight Loss
Jack pine-oak	107	23	122	21	103	18
	150	34	98	15	147	32
	74	20	75	17	83	18
	53	13	70	12	64	16
Gross percentage loss	23.4		17.8		21.2	
Adjusted percentage loss (see text)	23.4		17.5		21.1	
Special diet	148	21				
	100	1				
	66	2				
	66	-8 (gain)				
Gross percentage loss	4.2					
Adjusted percentage loss (see text)	4.3					

[1]Deer initial weight and weight loss in lb.

Table 6

Analysis of Covariance of Weight Data From 1955 Deer Feeding Experiment

Source of Variation	Degrees of Freedom	Sums of Squares and Products			Errors of Estimate		
		$S(x-\bar{x})^2$	$S(x-\bar{x})(y-\bar{y})$	$S(y-\bar{y})^2$	Sum of Squares	Degrees of Freedom	Mean Square
Total	15	15,573.75	3,444.38	1,726.94	962.708	14	
Acorn supplements	3	130.25	107.62	845.19			
Within lots	12	15,393.50	3,336.75	881.75	158.465	11	14.41
For test of significance of adjusted mean loss					804.243	3	268.08[1]

[1]Significance at 1 per cent level.

This test was designed to simulate conditions that might be found in years of mast crop abundance as compared with years of crop failure. Nichol (1938) reports records of deer going from poor to good condition in 15 days when acorns are abundant in the fall.

Three groups of four deer each were used. Each group contained two adult does, a buck fawn, and a doe fawn. In October, the deer of Group 1 were placed on a half-ration diet so that they would not accumulate an excess of fat. The adult deer in this group lost weight between October and January (Table 7). At the same time the other two groups had an unlimited ration of good food. From January 9 through March 23, 1956, all three groups were fed a basic free-choice diet of jack pine and oak browse. Groups 1 and 2 got nothing else, while Group 3 was given an acorn supplement of 0.25 lb of acorns per hundredweight per day. Only those deer receiving an acorn supplement were penned individually. One adult doe in Group 2 was injured at the end of the first week and was removed from the experiment. The four deer in Group 1 were placed together in a pen, as were the deer in Group 2. This grouping of deer was necessary since we were conducting other feeding experiments at the same time and our number of holding pens was limited. Table 7 presents deer weight and food consumption data collected in this experiment.

The results indicated a trend toward differences in weight loss percentages of deer entering a winter period in good condition as compared with deer entering in only fair condition (Table 8), but there is little evidence of significant differences.

Weight loss records of 77 deer on experimental winter diets at Houghton Lake (Figure 4) indicate, in general, that deer in good

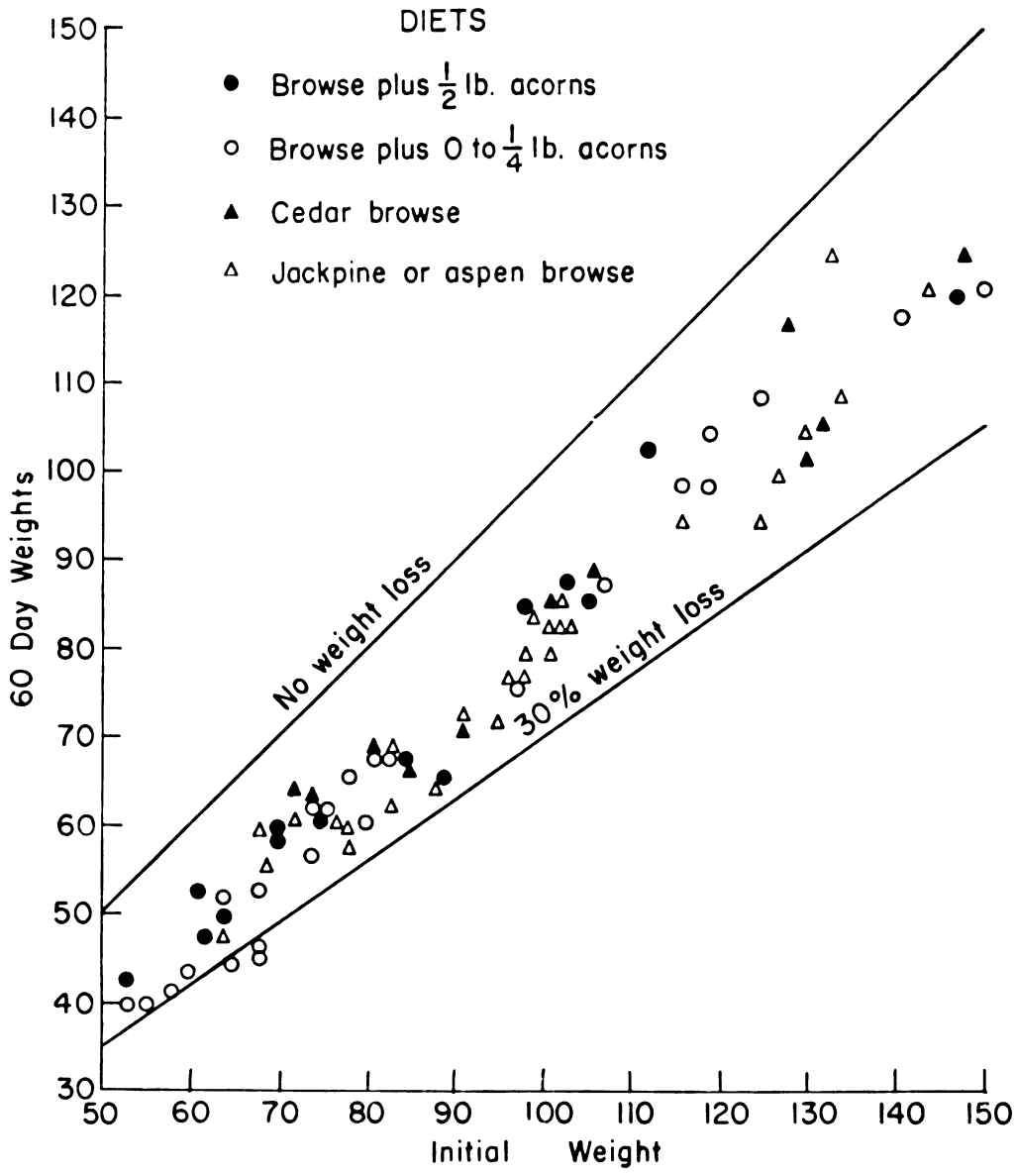


Figure 4. Weight loss of deer, Houghton Lake Wildlife Experiment Station, controlled feeding experiments, 1954-57.

Table 7

Weights of Deer and Food They Consumed in Feeding Experiment Comparing Deer Entering a Winter in Fair and Excellent Condition, January-March, 1956

Diet	Deer No.	Sex	Age	Weight (lb)		Total Food Consumed (lb)		
				Original	Final**	Jack Pine	Oak	Acorns
Jack pine and oak browse. Into winter in fair condition.	865	F	Ad	127/116*	95			0
	864	F	Ad	142/125*	105			0
	2546	M	Ju	66/80*	57	466.2	685.9	0
	874	F	Ju	61/68*	50			0
Jack pine and oak browse. Into winter in excellent condition.	841	F	Ad	141	113			0
	6003	F	Ju	74	60	359.2	487.5	0
	153	M	Ju	78	63			0
	819***	F	Ad	119	--			0
Jack pine and oak browse and 0.25 lb acorns. Into winter in excellent condition.	6010	F	Ad	119	95	194.7	67.4	15.6
	6011	F	Ad	119	102	69.3	199.3	21.4
	6002	F	Ju	64	50	118.7	113.4	9.2
	157	M	Ju	81	65	147.5	90.5	13.3

* Weight when placed on reduced rations 10-17-55.

** After 73 days on controlled diets.

*** Broke lower jaw after 7 days on feeding. Removed from group.

Table 8

Body Weight Loss of Deer on 1956 Feeding Experiment[1]

Initial Condition	Diet	Initial Weight	Weight Loss	Gross percentage Loss
Excellent	Jack pine-oak, 0.25 lb acorns per cwt	119	24	
		119	17	
		64	14	
		81	16	
				18.5
Excellent	Jack pine-oak, no acorns	141	28	
		74	14	
		78	15	
				19.4
Fair	Jack pine-oak, no acorns	116	21	
		125	20	
		80	23	
		68	18	
				21.1

[1]Deer initial weight and weight loss in lb.

condition resist winter weight loss better than deer in fair condition.

Food Preference Observations

Other controlled feeding studies have indicated that deer show marked preferences in their choice of browse species, and that in general preferred foods are the more nutritious foods (Maynard, et al., 1935; Davenport, 1937; Nichol, 1938; and Dahlberg and Guettinger, 1956). Palatability and browse utilization studies have led to lists of seasonal deer food preferences (Nichol, 1938; Petrides, 1941; and Davenport, 1946); but I can find scant reference to indicate that one deer might show a marked preference for a specific browse species that is different from the preference shown by another deer. That such individual variations do exist was demonstrated by the deer I fed basic diets of jack pine and oak. Deer 6010 ate about three times as much jack pine as oak; in contrast deer 6011 ate about three times as much oak as jack pine (Table 7). Tables 1 and 4 show similar differences. As indicated by weight loss of these different animals (Tables 2, 5, and 8), there is little evidence that any one of the various combinations of these two browse species chosen by the deer constitutes a better diet than any other. The four deer fed a good-food diet in 1955 also showed differences in the amount of individual good-food species they ate (Table 4).

In one instance a deer (819, Table 1) refused to eat acorns for over a month; when it did finally start, it would not eat all that were offered. This was the only deer that did not eat all of the sound acorns offered, shells and all. Occasionally insect-infested acorns were inadvertently offered; these the deer would not eat.

The fact that such individual differences did occur in deer choice of both poor and good browse food suggests that in a deer feeding experiment as many animals as possible should be used. Adequate numbers of animals increase the chance of bracketing variations that might lead to erroneous conclusions concerning deer in general.

A SUGGESTED METHOD OF PREDICTING ACORN CROPS FOR DEER

The size of acorn crops interests game managers because acorns are a valuable wildlife food (Martin, et al., 1951). Wildlife managers could use acorn crop predictions as an aid in recommending deer hunting regulations liberal enough to permit harvest of surplus deer that might not survive a winter without the supplemental food provided by an acorn crop (Duvendeck, 1957).

Some Factors Affecting Acorn Crops

A review of some of the factors affecting acorn crop production will aid in understanding some of the difficulties that may be encountered in attempting acorn crop prediction.

Oak trees begin acorn production between 20 and 45 years of age and probably reach a peak between 40 and 80 years (Kittredge and Chittenden, 1929). Downs (1949) states that some oaks are probably good producers, and some poor, due to heredity. He also states that oaks produce good crops of acorns once in 3 or 4 years on the average. Davenport (1946) estimated that in Michigan oaks produced good acorn crops in 2 out of 5 years on the average. Reid and Goodrum (1957) found the black (or red) oak group had a larger percentage of acorn-producing trees than the white oak group. Christisen and Korschgen (1955), Downs and McQuilkin (1944), Gysel (1956), and Kittredge and Chittenden (1929) point out that acorn production may vary widely between years; between oak species; between similar trees of the same species; and between oak stands in the same year. Verme (1953) found that acorn production on trees was greatest in the part of the

crown exposed to sunlight.

From the time oaks blossom until the time the mature crop falls (5 to 6 months for the white oak group and 16 to 18 months for the red, or black oak group) many factors can reduce the potential sound acorn crop size, and the portion of the crop that would become available to deer. Allen (1943) suggests that long wet periods in the spring may curtail fertilization of oak flowers. He also states that in Michigan late spring frosts that kill oak flowers are probably the most important factor reducing potential acorn crop size. Turkel, et al. (1955) describe formation of an abscission layer between the developing ovary and the involucre in white oaks that causes early abortion of immature acorns. Birds and squirrels may eat more than 20 per cent of an acorn crop from oak trees before the crop would normally fall (Christisen and Korschgen, 1955). They also state that in Missouri insects damaged over 80 per cent of post oak (Quercus stellata) acorn crops from 1947 to 1952. Martin, et al. (1951) list 45 species of animals found in Michigan that use acorns for food. I observed porcupines, not listed by them, feeding heavily on acorns in some areas.

The Study Area

The study area included the 1.5 million acres of oak forests in the northern half of the lower peninsula of Michigan for extensive surveys. I used portions of four oak stands, one in Lake County, one in Oscoda County, and two in Roscommon County for intensive studies (Figure 5).

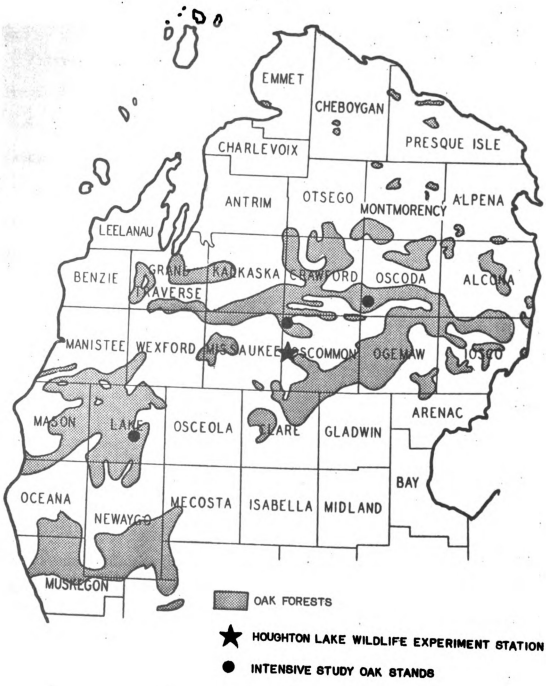


FIGURE 5. OAK FORESTS IN NORTHERN MICHIGAN

Soils

Kittredge and Chittenden (1929) described the soils found throughout the oak forests in northern Michigan as "a group of closely similar upland well-drained soils which may be described in general as sands or light sandy loams to depths of three to five feet or more. They are characterized by a very thin humus layer, low moisture content, low moisture-holding capacity, acid reaction to three feet or more, and low fertility."

The soil type in my Lake County study stand is Roselawn fine sand. In the Oscoda County stand the type is Roselawn sand, and in the two Roscommon County study stands the soil type is Rubicon sand.

Topography

The topography in northern Michigan oak forests ranges from flat to rolling to hilly lands with steep slopes. The Lake and Oscoda County study stands are in rolling areas with moderate slopes. The Roscommon County study stands are in a smooth plane area with slopes less than six per cent.

Climate

Climate in the northern half of the Lower Peninsula of Michigan as described by Wills (1941) is of two distinct types. Narrow belts along the great lakes shoreline have a modified marine climate. The interior counties have a climate that alternates between continental and semimarine. When there is little wind there may be pronounced fluctuations in temperature with hot weather in summer and severe cold in winter. A strong wind from the Lakes may immediately

transform the weather into a semimarine type changing the temperature as much as 20 F. Precipitation is fairly well distributed through the year, averaging around 30 inches.

Vegetation

Hill's oak, northern red oak, and white oak are the three oak species most commonly found in the oak forests in northern Michigan. They occur as nearly pure stands of Hill's oak or northern red oak or as varying mixtures of two or all three species. Jack pine, red pine (Pinus resinosa), white pine (Pinus Strobus), red maple (Acer rubrum), trembling aspen (Populus tremuloides) and large-toothed aspen (Populus grandidentata), are the tree species other than oak most frequently found in the oak forests. The shrubs I most commonly found in the oak forest understory are Juneberry (Amelanchier spp.), willows (Salix spp.), hawthorns (Crataegus spp.), dogwoods (Cornus spp.), sumac (Rhus spp.), witch-hazel (Hamamelis virginiana) and hazelnut (Corylus americana). In general the shrub understory in the oak forests is sparce and shrubs are found where openings in the overstory occur. Ground cover plants I found most frequently were bracken fern (Pteridium spp.), sweet fern (Comptonia peregrina), blueberries (Vaccinium spp.) and several species of grasses that I did not identify. Ground cover through the oak forests varies from sparse to dense.

In Roscommon County study stand I there are approximately 16 oaks per acre over 12 inches dbh. Composition by species is approximately 60 per cent Hill's oak, 35 per cent northern red oak, and 5 per cent white oak. In the understory I found some scattered Juneberry and willow. There are also scattered red pine 15 to 20 feet in height.

The dense ground cover consisted principally of sweet-fern and bracken fern.

In Roscommon County study stand II there are approximately 8 oaks per acre over 12 inches dbh. Composition by species is approximately 67 per cent Hill's oak, 31 per cent northern red oak and two per cent white oak. There are a few scattered red maple and aspen in this stand. The shrub understory has willow, juneberry and hawthorne scattered through the stand. Ground cover is relatively dense and consiste principally of sweet-fern and bracken fern.

In the Oscoda County study stand there are approximately 18 oaks per acre over 12 inches dbh. Composition by species is approximately 55 per cent Hill's oak, 25 per cent white oak and 20 per cent northern red oak. A few aspen and red maple are scattered through the stand. Shrubs are scarce. A few witch-hazel were noted. The moderate ground cover found consists principally of sweet-fern, bracken fern, and grasses.

In the Lake County study stand there are approximately 20 oaks per acre over 12 inches dbh. Composition by species is approximately 40 per cent Hill's oak, 35 per cent white oak, and 25 per cent northern red oak. Shrubs are very scarce. Ground cover is moderate and consists principally of bracken fern, grasses and scattered sweet-fern.

REVIEW AND DEVELOPMENT OF ACORN CROP PREDICTION METHODS

To determine the accuracy of an acorn crop prediction method a measurement of the mature crop is desirable, and in attempting to predict acorn crops, all of the factors that can reduce the potential crop size must be considered.

Methods of Measuring Acorn Crops

Various techniques have been used to measure acorn crops on individual trees and in oak stands. Verme (1953) made total counts of the number of nearly mature acorns on individual trees. This method, though very accurate, he states is too time consuming to use over extensive areas. He also found that sample area counts on trees agreed closely with total counts. Petrides, et al. (1953) counted the number of post oak acorns on the first 25 twigs encountered on each tree as an index of year to year acorn abundance in East Texas. This system is suitable to secure state-wide information on acorn crops where oaks have readily accessible branches. Most northern Michigan oaks do not. Allen and McGinley (1947) and Cypert and Webster (1948) used ground counts of acorns falling on triangular shaped plots approximating 10 per cent of the crown area of oaks. Dalke (1953) counted seeds and acorns on mil-acre ground plots spaced at one chain intervals along surveyed lines. Downs and McQuilkin (1944) used box shaped traps with chicken wire tops to sample acorn production of individual trees. Easley and Chaiken (1951) described an inverted pyramid-shaped seed trap made of kraft paperboard mounted on a wooden frame. It samples an area 3.3 feet square. Seeds are held in a wire basket fastened to the open bottom. Though not

completely animal proof I believed (and as explained later found) there would be little loss of acorns caught in this type trap. I used this type trap to sample acorn production of oaks in my four intensive study plots. Gysel (1956) later designed a similarly shaped trap made of waterproofed canvas mounted on a galvanized pipe frame. He covered the top with poultry netting to reduce animal entrance. This type trap is more durable than the paperboard type and more efficient for fewer acorns bounce out.

Gysel (1956) tested both the canvas and paperboard traps by dropping 100 white oak and 100 black oak acorns on the traps from a height of 30 feet. He found that 78 per cent of the white oak and 58 per cent of the black oak acorns were deflected from an uncovered paperboard trap while only 32 and 12 per cent respectively were deflected from an uncovered canvas trap.

Since the mature oaks I studied in northern Michigan are not as tall as those Gysel delt with in southern Michigan, and thus the unobstructed free fall of acorns was less, I tested uncovered paperboard traps from a height of 20 feet. I dropped 250 acorns of each northern red oak, white oak, and Hill's oak, and found that 41, 22, and 18 per cent respectively were deflected. I used these figures to adjust the number of acorns caught in mast traps in my study areas.

I used the following approach to measure acorn production of individual trees. I placed two mast traps under the crown area of each tree samples in three of my study stands, one in Lake County, one in Oscoda County, and in Roscommon County study stand I (Figure 6). Traps were placed in August, 1953 and data collected for the 1953, 1954, and 1955 acorn crops. Sample trees were chosen by entering the stand

Figure 6. Mast traps in oak study stand.

from a road and picking each mature full crowned oak tree encountered that was 12 inches in diameter, or over, at breast height. In Lake County 25 trees (nine white oak), ten Hill's oak, and six northern red oak were sampled. In Roscommon County study stand I 19 trees (one white, 11 Hill's, and seven northern red oak) were sampled. In Oscoda County 20 trees (five white, 11 Hill's, and four northern red oak) were sampled.

Traps were placed under opposite sides of the crown area of the trees to collect acorns from two areas of the crown that appeared to be of average density and crown exposure to sunlight for the particular tree.

In Roscommon County study stand II 50 mast traps were placed at random throughout a 40-acre oak stand. Here I could expand the proportion of the acorn crop caught by the traps directly to the 40-acre area, rather than to individual trees as in the other three study areas. The area was divided into 10.9 square foot blocks (the area of one mast trap). The blocks were numbered consecutively and numbers were drawn from a table of random numbers to determine the location of the 50 traps. The traps were placed in a chosen block only if it occupied an area on which acorns could fall. It was necessary to draw 99 random numbers to have 50 plots under the crown area of oaks. The traps were not set in this stand until 1954. Data was collected here for the 1954 and 1955 acorn crop.

Acorn Crop Measurements

The number of sound acorns caught in mast traps during 1953, 1954, and 1955 are presented in Tables 9, 10, and 11. These data

Table 9

Number of Sound Acorns Caught in Mast Traps
in Roscommon County Study Stand I 1953-1955

White Oak					Hill's Oak					Red Oak				
Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955
2	3.1	3	61	9	1	2.5	0	83	9	13	3.1	1	34	2
					3	3.1	2	24	3	14	2.9	0	51	4
					4	2.7	2	52	5	15	3.3	1	16	3
					5	3.3	0	16	5	16	3.1	2	64	0
					6	3.3	1	45	0	17	2.5	6	118	3
					7	4.4	5	61	3	18	1.9	2	146	3
					8	3.8	6	41	3	19	3.5	0	29	3
					9	1.9	3	168	1					
					10	3.3	2	62	9		Total	12	458	18
					11	3.5	2	34	2					
					12	2.9	0	29	0					
						Total	23	615	40					

Table 10

Number of Sound Acorns Caught in Mast Traps
in Oscoda County Study Stand 1953-1955

White Oak					Hill's Oak					Red Oak				
Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955
1	2.9	24	192	14	2	2.4	2	79	38	5	2.7	1	54	26
3	1.1	152	37	22	6	1.8	0	196	34	11	1.7	0	93	82
4	3.5	8	64	23	7	3.8	34	131	76	16	3.1	0	32	49
12	3.1	15	15	0	8	4.4	7	117	77	20	1.6	6	68	34
13	3.3	8	70	23	9	4.8	0	106	31					
					10	3.5	2	126	42		Total	7	247	191
	Total	207	378	82	14	4.8	2	32	33					
					15	3.5	0	56	32					
					17	3.1	2	105	21					
					18	4.1	3	42	30					
					19	3.3	3	92	39					
						Total	55	1,082	453					

Table 11

Number of Sound Acorns Caught in Mast Traps
in Lake County Study Stand 1953-1955

White Oak					Hill's Oak					Red Oak				
Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955	Tree No.	Percent of Crown Area Sampled	Number of Acorns 1953	1954	1955
5	3.1	1	10	6	1	2.7	0	103	18	13	2.1	0	81	10
8	1.6	4	22	9	2	3.1	0	96	19	16	2.5	0	15	6
11	3.8	4	18	2	3	3.5	0	35	5	20	2.0	0	44	3
12	4.4	1	23	12	4	3.3	0	55	15	21	2.5	0	9	12
15	4.4	0	11	2	6	4.4	2	13	7	22	1.9	0	186	3
18	3.5	5	18	1	7	3.8	0	73	8	25	2.9	0	4	2
19	3.8	0	5	5	9	2.3	0	180	30					
23	4.1	0	3	2	10	3.1	0	142	6		Total	0	339	36
24	6.9	2	5	3	14	4.1	0	127	3					
					17	4.1	0	73	6					
	Total	17	115	42										
						Total	2	897	117					

represent sampling of the mature acorn crop dropping from oaks in the fall. The mature crop usually falls following heavy frosts that occurred during my three years of observations in the last week of September, or the first two weeks of October. I made weekly collections of acorns from mast traps beginning in mid-September and continuing through October. The bulk of the crops had fallen by the end of two weeks following frost.

I checked possible loss of acorns from my mast traps through animal activity by marking 50 acorns and placing five in each of ten traps in Roscommon County study stand I. These acorns were left in the traps throughout the fall collection period in 1953. Only two were lost during the period. I believe that loss of acorns from the mast traps through animal activity is negligible.

Expressing acorn production in numbers of sound acorns produced can be misleading because acorns of different species are not the same size. I believe the number of pounds of acorns produced by individual trees, or in oak stands, lends itself better to interpretation of the value of an acorn crop to animals such as deer. I weighed ten samples of each of the three species of acorns (northern red, Hill's, and white oak) collected for controlled deer feeding experiments in 1952, 1953, 1954, and 1955. The average number of sound acorns per pound as collected was as follows:

Northern red oak	86
Hill's oak	298
White oak	154

Downs and McQuilkin (1944) reported 166 white oak acorns per pound and 90 Eastern red oak acorns per pound. Christisen and

Korschgen (1955) reported 104 and 169 white oak acorns per pound from samples taken in Missouri in two different years. I could find no mention in the literature of weights of Hill's oak acorns.

To estimate the total number and weight of acorns produced by trees in my study plots I computed the ground area covered by the crown area of each study tree by dividing the closed plane curve ground area into 5 foot wide parallel strips and approximating each strip by a rectangle as described by Griffin (1936). I could then compute the proportion of the area sampled by the mast traps. An estimate of the total number of acorns produced by each tree was computed by adjusting the number caught in mast traps, using the figures for per cent caught, and then expanding the adjusted number caught in the area sampled by the traps to the crown area of the tree. Numbers of acorns were then converted to pounds by dividing by the average number of acorns per pound for each species. Tables 12, 13, and 14 present my computed estimates of the number of pounds of acorns produced by the trees I studied in three of the study stands.

The figures certainly concur with previously published reports pointing out that large variations in acorn production occur between species, years, oak stands, and individual trees in the same stand.

In Roscommon County study stand II where 50 mast traps were placed at random, the estimated acorn crop production was 879 lb in 1954 (590 lb northern red oak and 289 lb Hill's oak). In 1955 an estimated 46 lb were produced in this stand (33 lb northern red oak and 13 lb Hill's oak). This represents a production of 22 lb per acre in 1954 and just over one lb per acre in 1955; or an

Table 12

Number of Pounds of Acorns Produced Per Tree in
Roscommon County Study Stand I
1953-1955

White Oak				Hill's Oak				Red Oak			
Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955
2	0.8	15.6	2.3	1	0.0	14.7	1.6	13	0.6	21.6	1.3
				3	0.3	3.4	0.4	14	0.0	34.7	2.7
				4	0.3	8.5	0.8	15	0.6	9.6	1.8
				5	0.0	2.2	0.7	16	1.3	40.7	0.0
				6	0.1	6.1	0.0	17	4.7	93.0	2.4
				7	0.5	6.1	0.3	18	2.1	151.4	3.1
				8	0.7	4.8	0.3	19	0.0	16.3	1.7
				9	0.7	39.2	0.2	Total	9.3	367.3	13.0
				10	0.3	8.3	1.2	Av. Per Tree	1.3	52.5	1.9
				11	0.3	4.3	0.3				
				12	0.0	0.4	0.0				
				Total	3.2	98.0	5.8				
				Av. Per Tree	0.3	8.9	0.5				

Table 13

Number of Pounds of Acorns Produced Per Tree in
Oscoda County Study Stand
1953-1955

White Oak				Hill's Oak				Red Oak			
Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955
1	6.6	52.4	3.8	2	0.4	14.6	7.0	5	0.7	39.4	19.0
3	109.4	26.6	15.8	6	0.0	48.3	8.4	11	0.0	107.8	95.1
4	1.8	14.5	5.2	7	4.0	15.3	8.9	16	0.0	20.3	31.2
12	3.8	3.8	0.0	8	0.7	11.8	7.8	20	7.4	83.7	41.9
13	1.9	16.8	5.5	9	0.0	9.8	2.9	Total	8.1	251.2	187.2
Total	123.5	114.2	30.3	10	0.3	16.0	5.3	Av. Per Tree	2.0	37.8	46.8
Av. Per Tree	24.7	22.8	6.1	14	0.2	3.0	3.0				
				15	0.0	7.1	4.1				
				17	0.3	15.0	3.0				
				18	0.3	4.5	3.2				
				19	0.4	12.4	5.2				
				Total	6.6	157.8	58.8				
				Av. Per Tree	0.6	14.3	5.3				

Table 14

Number of Pounds of Acorns Produced Per Tree in
Lake County Study Stand
1953-1955

White Oak				Hill's Oak				Red Oak			
Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955	Tree No.	Pounds of Acorns 1953	1954	1955
5	0.3	2.6	1.5	1	0.0	16.9	3.0	13	0.0	76.0	9.4
8	2.0	10.9	4.4	2	0.0	13.7	2.7	16	0.0	11.8	4.7
11	0.8	3.8	0.4	3	0.0	4.4	0.6	20	0.0	43.4	3.0
12	0.2	4.1	2.2	4	0.0	7.4	2.0	21	0.0	7.1	9.5
15	0.0	2.0	0.4	6	0.2	1.3	0.7	22	0.0	192.9	3.1
18	1.1	4.1	0.2	7	0.0	8.5	0.9	25	0.0	2.7	1.4
19	0.0	1.0	1.0	9	0.0	34.7	5.8	Total	0.0	333.9	31.1
23	0.0	0.6	0.4	10	0.0	20.3	0.9	Av. Per Tree	0.0	55.7	5.2
24	0.2	0.6	0.3	14	0.0	13.7	0.3				
Total	4.6	29.7	10.8	17	0.0	7.9	0.6				
Av. Per Tree	0.5	3.3	1.2	Total	0.2	128.8	17.5				
				Av. Per Tree	0.02	12.9	1.8				

average production of 2.8 lb per tree in 1954 and 0.13 lb per tree in 1955. These figures are considerably lower than production figures for trees in Roscommon County study stand I which is immediately north of a road bordering the north side of this stand. I feel it is highly probable that 50 traps set at random are not adequate to sample acorn production on 40 acres. Further data would have to be gathered using more mast traps to confirm this probability.

For the data gathered in the three stands where production of individual trees was sampled I added and averaged the production of all of the trees by species (Table 15). It is interesting to note that the average production in pounds per tree for northern red oaks was considerably higher each year than the average production of Hill's oaks, and in two out of the three years higher than white oak production. The differences were greater than could be accounted for by relative weights of the three species of acorns. A greater number of northern red oak acorns per tree was produced. Martin, et al. (1951) lists northern red oak first in mentioning species of oak considered of particular importance to wildlife in the northeast region of the United States. The number of the large northern red oak acorns necessary to provide a given amount of food is less than the numbers needed in other oak species producing smaller acorns. This fact undoubtedly contributes considerably to the importance of northern red oak as a wildlife food producer. It appears that this species may also produce a larger crop more consistently.

Table 15

Average Number of Pounds of Acorns Produced Per Tree in Three Study Stands
1953 - 1955

	White Oak*			Hill's Oak**			Red Oak***		
	1953	1954	1955	1953	1954	1955	1953	1954	1955
Average pounds per tree	8.6	10.6	2.9	0.3	12.0	2.6	1.0	56.0	13.6

* 15 trees
** 32 trees
*** 17 trees

Extent of Damage to Acorn Crops by Various Factors

Several factors can have a marked effect on quantity and quality of acorns available to deer.

Insects

I examined all of the acorns caught in mast traps in my four study areas in 1953, 1954, and 1955 and computed the percentage, by oak species, infested by insects. Table 16 presents these data. I also took samples from acorns that were collected in 1952, 1953, 1954, and 1955, for controlled deer feeding studies and computed the per cent insect infested. Table 17 presents these data. I did not differentiate between acorns completely or only partially damaged by insects because I found in feeding studies that deer would not eat any insect infested acorns.

In the four years for which I have data on the per cent of acorn crops infested by insects, two of the crops were large in northern Michigan (1952 and 1954) and two were small (1953 and 1955). It appears that in years of small crops (Tables 16 and 17) insects may infest a larger percentage of the crop than in years when acorns are more abundant. Based on my samples, insects may be expected on the average to infest 20 per cent or less of a good acorn crop and from 20 to 30 per cent of a poor crop in northern Michigan.

Animal

An accurate estimate of the per cent of an acorn crop taken by birds and arborial animals such as squirrels from oak trees before a crop falls, I believe is next to impossible to obtain. The evidence of damage to acorns by specific animals can sometimes be identified. Figure 7 shows the remains of immature acorns eaten by grey squirrels (Sciurus carolinensis). Figure 8 shows immature acorns eaten by porcupines (Erethizon dorsatum dorsatum). By collecting and counting

Table 16

Insect-Damaged Acorns Caught in Mast Traps 1953-1955

Area	Species	Percent of Acorns Damaged by Insects		
		1953	1954	1955
Roscommon Co. I	Northern red oak	33	13	10
	Hill's oak	67	17	26
	White oak	25	10	10
Roscommon Co. II	Northern red oak	--	14	12
	Hill's oak	--	16	21
Oscoda Co.	Northern red oak	13	17	14
	Hill's oak	37	19	14
	White oak	27	14	10
Lake Co.	Northern red oak	Crop failure	13	18
	Hill's oak	" "	18	28
	White oak	" "	20	22

Table 17

Insect-Damaged Acorns from Samples of Acorns
Collected for Controlled Deer Feeding Studies 1952-1955

	Percent of Acorns Damaged by Insects			
	1952	1953	1954	1955
Northern red oak	6	21	15	18
Hill's oak	10	22	16	20
White oak	12	24	19	28

Figure 7. Immature acorns damaged by squirrels.

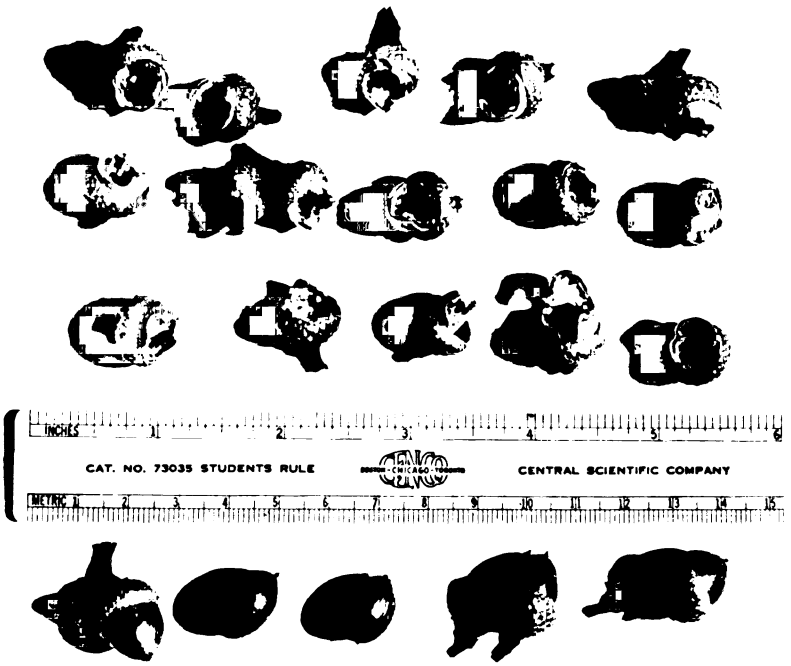


Figure 8. Immature acorns damaged by porcupines.

such acorn remains in mast traps a minimum figure can be computed. This I did from acorn remains collected in mast traps (Table 18). Only a rough estimate can be made however of the total number of acorns eaten whole by ruffed grouse (Bonasa umbellus), or carried away by blue jays (Cyanocitta cristata), grackels (Quiscalus spp.), woodpeckers or other birds, or cashed or burried by squirrels. By watching birds for periods Cypest and Webster (1948) figured they took an estimated 13.8 per cent of a crop. I attempted to count the number of acorns taken by squirrels and birds during 20 minute periods in 1953 in Roscommon County. When a flock of grackles, or even 3 or 4 blue jays are feeding on acorns in an oak, it is impossible to watch all of them at the same time, and therefore I believe impractical to attempt to count in this way the number they are taking. Even when I watched just one squirrel I could not be at all confident that I was getting an accurate count of the acorns it took. I could not keep the animal in view at all times, and when I moved to try and locate it my movement would sometimes send it into hiding.

Animal-damaged acorns caught in mast traps gave some data on the per cent of a crop taken by arborial animals. These figures (Table 18) I believe can only be considered as representing a part of the total taken by arborial animals. I think it is safe to state that, assuming similar arborial animal population levels, in years of poor and good acorn crops the amount of damage to a poor crop can be much greater than that to a good crop.

At times not all of an acorn is eaten by an arborial feeding animal and sound acorn parts are dropped. The amount of food

Table 18

Animal Damaged Acorns Caught in Mast Traps 1953-1955

Area	Percent of Acorns Damaged by Animals		
	1953	1954	1955
Roscommon Co. I	2	2	3
Roscommon Co. II	-	5	7
Oscoda Co.	2	3	5
Lake Co.	-	3	4

available to deer in this form however I believe would be insignificant compared to that provided by the sound acorns that fall.

Disease

Disease, such as fungi or bacteria, can reduce the acorn crop size. The embryo and cotyledon of disease infested acorns may be partially or wholly destroyed. Diseased acorns usually have a foul smell. I do not believe deer use them to any extent. I measured the degree of damage to acorn crops by examining all of the acorns caught in mast traps and counting the number classed as affected by disease. The number of diseased acorns in mast traps was very small. I classified very few as diseased when I examined samples of acorns collected for deer feeding experiments to determine the per cent insect infested. Gysel (1956) pointed out that it is not always possible in the field to tell whether a malformation of the cotyledon or embryo is the result of disease or some other kind of physiological change. Because I found so few acorns that could be classed as diseased, I believe that in northern Michigan disease is not an important descimating factor in acorn crops.

Methods Investigated for Predicting Acorn Crops

Gysel (1958) suggested counting flowers and immature acorns with the aid of a spotting scope to predict the potential size of a crop. He felt later observations and check counts were needed to determine the actual size. Sharp (1958) described a method of estimating acorn crops by counting acorns on terminal branches 24 inches in length and rating the crop as a percentage produced in relation to the potential maximum yield.

To be practical for use by game managers in Michigan, an acorn crop prediction method must be one that does not require too much time or manpower. It must also be a method that will yield a prediction by mid-July,

for recommendations for deer hunting regulations are considered at the August Conservation Commission meeting.

Observation of Oak Flowers

The earliest indication of the potential acorn crop size may come at the time oaks flower in the spring. In 1953 I attempted to count the number of female oak flowers on sample stems of sample trees in three of my study stands to investigate the possibility that oaks produced different numbers of flowers in different years that might lead to an early crop prediction. Gysel (1958) counted flowers and immature acorns on oaks in southern Michigan using a spotting scope with a 30 x eye piece. He found this method time consuming. I tried 7 x 35 binoculars and found them inadequate. I climbed the trees to get close enough to the twigs of annual growth that held the flowers to make my counts.

Counting female oak flowers by climbing trees to get near sample twigs, I feel, is an impractical method of attempting to gather data for acorn crop predictions over large areas. The technique is too time consuming. I also found that flowers were lost as a result of my climbing activity. This would invalidate such counts.

Estimating Frost Damage to Oak Flowers

When killing frosts occurred after oaks were in blossom (and some did each spring during the study), I surveyed the oak forests to estimate the percentage of trees in the stands and the percentage of the crown areas of the trees that had blossoms killed by the frost. Seven to ten days following a killing frost, damaged portions of oak stands have turned brown, while unaffected portions are pale yellow-green. The percentage of the "potential" crop destroyed can be estimated by such surveys. Because many factors can reduce acorn crop size following blossoming

I believe that the only definite estimate of an acorn crop size resulting from frost damage surveys would be one stating complete crop failure when frost kills all of the flowers.

Counts of Fertilized Female Flowers

In talking with orchard owners in Michigan's Grand Traverse region I learned they predicted cherry crop size by examining flowers and figuring the percentage fertilized. I attempted to count fertilized female red oak flowers on marked sample twigs on sample trees in two of my study plots in 1953, 1954, and 1955. A twig is a single stem of annual growth bearing flowers. These counts were made by climbing five trees in each stand to examine five marked sample twigs on each tree. I thought that the ovary of fertilized flowers would increase in size enough to distinguish them from those not fertilized. My fertilized flower counts were frequently higher than maturing acorn counts made later on the same twigs. This was apparently because I could not distinguish the difference between an oak flower that had been fertilized and one that had not.

Turkel, et al. (1955) state that white oak flowers are pollinated in late May, with fertilization occurring during late June or early July. They also describe abortion of immature acorns caused by formation of an abscission layer between the developing ovary and the involucre. The reason for this abscission layer formation is not known. I believe that this and other mortality factors following fertilization may vary from year to year to such an extent that knowing only the percentage of fertilized oak flowers has little meaning.

Counts of Maturing Acorns on Sample Twigs

Through the summers of 1953, 1954, and 1955, I made counts of maturing acorns on the same selected sample twigs used for fertilized

flower counts in an effort to determine a mortality rate that could be applied to acorn crop prediction. My sample consisted of five twigs on each of ten northern red oak trees. Each twig was a single stem of annual growth that held maturing acorns. I marked each twig so that I could identify it at each count. Periodic counts were made from the time the acorns began development through two growing seasons to maturity. Tables 19, 20, 21, and 22 presents these data. Through the three-year study this method provided data on two different year's northern red oak crops.

Apparently loss of immature red oak acorns from trees over the two-year development period is not similar for different crops or different areas. My counts of maturing acorns on sample twigs indicated a 43.3 per cent loss of the 1954 crop in August, 1953 in Roscommon County study area I, while only 25.7 per cent of the 1954 crop in Oscoda County was lost in the same month. During the 1953 growing season 52.2 per cent of the maturing acorns in Roscommon County study stand I were lost, while only 35.8 per cent of those in Oscoda County disappeared during the same period. For the 1955 crop the percentage loss during the first growing season was nearly reversed for the two areas. In Oscoda County 50 per cent, and in Roscommon County 35.5 per cent were lost.

I found no acorn abortion rate through my counts of maturing acorns on sample stems that could be applied to acorn crop prediction. A larger sample might reveal more consistent figures, but the time involved in obtaining a much larger sample would then become prohibitive.

Table 19

Counts of Maturing Acorns on Sample Twigs on Trees Bearing the 1954 Red Oak Acorn Crop Through Its Two Year Development Period in Roscommon County Study Stand I

Tree No.	Twig No.	Number of Maturing Acorns					
		July 1953	August 1953	September 1953	July 1954	August 1954	September 1954
13	1	4	2	1	1	1	1
	2	4	2	2	2	2	1
	3	3	2	2	1	1	1
	4	5	2	2	2	2	2
	5	1	1	1	1	1	1
14	6	6	5	4	3	3	3
	7	3	0	0	0	0	0
	8	3	3	3	3	2	2
	9	2	2	1	1	1	0
	10	1	1	1	1	1	1
16	11	2	0	0	0	0	0
	12	2	2	2	0	0	0
	13	1	0	0	0	0	0
	14	1	1	1	1	0	0
	15	3	1	1	1	1	1
17	16	3	0	0	0	0	0
	17	5	0	0	0	0	0
	18	7	3	3	2	2	2
	19	5	5	4	4	4	3
	20	6	5	4	1	1	0
18	21	6	4	3	3	3	3
	22	6	4	2	2	1	1
	23	8	4	4	3	2	2
	24	2	2	2	1	1	0
	25	1	0	0	0	0	0
	Total	90	51	43	33	29	24
Percent loss between counts			43.3	8.9	11.1	4.4	5.6
Total percent loss			73.3				

Table 20

Counts of Maturing Acorns on Sample Twigs on Trees Bearing the 1954 Red Oak Acorn Crop Through Its Two Year Development Period in Oscoda County Study Stand

Tree No.	Twig No.	Number of Maturing Acorns					
		July 1953	August 1953	September 1953	July 1954	August 1954	September 1954
5	1	2	2	2	2	2	1
	2	4	2	1	1	1	1
	3	3	2	2	0	0	0
	4	5	5	4	2	2	1
	5	3	2	2	1	1	1
11	6	6	3	3	3	3	3
	7	7	5	4	3	3	2
	8	6	6	6	5	5	4
	9	6	4	4	3	2	2
	10	5	4	3	3	3	3
16	11	5	4	4	2	2	1
	12	5	3	3	1	1	0
	13	5	2	1	1	1	0
	14	4	4	4	1	0	0
	15	4	1	1	1	1	1
20	16	4	3	3	3	3	2
	17	4	4	2	2	2	2
	18	6	6	5	3	3	2
	19	4	4	3	3	3	3
	20	4	2	1	1	1	1
21	21	1	0	0	0	0	0
	22	4	4	3	2	2	1
	23	3	1	1	1	1	0
	24	5	4	4	2	2	2
	25	4	4	4	4	4	3
	Total	109	81	70	50	48	36
Percent loss between counts			25.7	10.1	18.3	1.8	11.0
Total percent loss			66.9				

Table 21

Counts of Maturing Acorns on Sample Twigs on Trees Bearing the 1955 Red Oak Acorn Crop Through Its Two Year Development Period in Roscommon County Study Stand I

Tree No.	Twig No.	Number of Maturing Acorns					
		July 1954	August 1954	September 1954	July 1955	August 1955	September 1955
13	1	1	0	0	0	0	0
	2	1	0	0	0	0	0
	3	2	2	2	0	0	0
	4	1	1	1	1	1	1
	5	1	1	1	1	1	0
14	6	1	0	0	0	0	0
	7	1	0	0	0	0	0
	8	1	0	0	0	0	0
	9	3	2	2	2	1	1
	10	2	1	1	1	1	1
16	11	5	4	4	3	3	3
	12	4	4	3	3	2	2
	13	1	1	1	1	1	0
	14	3	2	2	2	1	1
	15	3	3	3	3	1	1
17	16	2	2	2	1	1	1
	17	2	2	2	1	0	0
	18	1	0	0	0	0	0
	19	2	1	1	0	0	0
	20	2	1	1	1	1	1
18	21	1	0	0	0	0	0
	22	1	0	0	0	0	0
	23	1	0	0	0	0	0
	24	1	1	1	1	1	1
	25	2	2	2	2	2	1
	Total	45	30	29	23	17	14
Percent loss between counts			33.3	2.2	13.3	13.3	6.7
Total percent loss			68.9				

Table 22

Counts of Maturing Acorns on Sample Twigs on Trees Bearing the 1955 Red Oak Acorn Crop Through Its Two Year Development Period in Oscoda County Study Stand

Tree No.	Twig No.	Number of Maturing Acorns					
		July 1954	August 1954	September 1954	July 1955	August 1955	September 1955
5	1	1	1	0	0	0	0
	2	2	2	0	0	0	0
	3	1	1	1	1	1	1
	4	1	1	1	1	1	0
	5	1	1	0	0	0	0
11	6	2	1	0	0	0	0
	7	1	1	0	0	0	0
	8	1	1	0	0	0	0
	9	1	1	1	1	1	1
	10	1	0	0	0	0	0
16	11	1	0	0	0	0	0
	12	1	1	0	0	0	0
	13	1	0	0	0	0	0
	14	2	2	2	0	0	0
	15	1	0	0	0	0	0
20	16	2	2	2	2	1	0
	17	1	1	1	1	1	1
	18	3	2	2	2	1	0
	19	1	1	0	0	0	0
	20	1	1	1	1	1	1
21	21	4	4	4	0	0	0
	22	1	0	0	0	0	0
	23	1	1	1	1	1	1
	24	2	1	1	1	1	1
	25	2	1	1	0	0	0
	Total	36	27	18	11	9	6
Percent loss between counts			25.0	25.0	19.4	5.6	8.3
Total percent loss			83.3				

Collection of Aborting Acorns in Mast Traps

I investigated the possibility of finding an acorn abortion rate by collecting aborting acorns in mast traps throughout their development period. The same traps used to measure acorn production in my four study stands were used for collection of aborting acorns. Periodic collections from the mast traps gave data on the periods and degree of acorn mortality caused by abortion. Table 23 presents these data.

Aborted acorns collected in mast traps gave data for the complete two-year development period of the 1955 red oak crop, and for the 1954 and 1955 white oak crops. If the data for these three crops are typical it appears that a high per cent of acorns that abort do so early in their development period. I do not feel a definite conclusion should be reached on the basis of one red oak and two white oak acorn crops, however. The number of aborted red oak acorns of the 1954 acorn crop caught in mast traps in July and August, 1954 (a total of 664 in the four study stands) is more than three times the number of aborted acorns of the 1955 crop caught in its same development period. This could be the result either of the fact that the 1954 crop was larger than the 1955 crop, or it might represent a higher per cent of acorns aborting late in the development period of the 1954 crop. Though I made no mast trap collections in 1956 I did observe a large number of acorns on the ground in June and July that had aborted from the 1956 red oak crop in Roscommon County.

I believe that loss of acorns through abortion may vary enough from year to year to prevent any one abortion rate from being applicable to acorn crop prediction.

Table 23

Aborted Acorns Caught in Mast Traps 1953-1955 by Month[1]

	1954 Acorn Crop					1955 Acorn Crop							1956 Acorn Crop				
	Percent of Total Aborted Acorns					Percent of Total Aborted Acorns							Percent of Total Aborted Acorns				
	Sept 1953	Oct 1953	July 1954	Aug 1954	Total Aborted Acorns	July 1954	Aug 1954	Sept 1954	Oct 1954	July 1955	Aug 1955	Total Aborted Acorns	July 1955	Aug 1955	Sept 1955	Oct 1955	Total Aborted Acorns
Roscommon Co. I	1.7	2.1	59.6	36.6	287	72.0	10.6	1.3	0.0	8.9	7.2	236	22.6	74.1	2.2	1.1	274
Roscommon Co. II	- No data -					63.5	20.5	4.3	0.0	2.5	9.2	400	9.9	85.6	4.5	0.0	223
Oscoda Co.	17.1	20.0	20.0	42.9	70	8.7	76.7	1.1	0.6	3.3	9.6	645	34.8	61.7	2.8	0.7	141
Lake Co.	0.0	1.2	74.1	24.7	85	18.8	67.8	0.0	0.0	4.0	9.4	276	40.9	56.4	2.7	0.0	188
Total Red oak	3.8	4.8	56.1	35.3	442	34.2	50.7	1.7	0.3	4.0	9.1	1557	25.4	71.1	3.0	0.5	826
Total White oak			85.0	15.0	60					85.1	14.9	74					

[1]Figures for the four areas are for red oak. For white oak acorns only totals are given.

Acorn Crop Prediction Through Visual Estimates

In 1952 and 1953 I looked at many oak stands throughout northern Michigan to determine the extent of the oak forests, and to pick those stands I used for intensive study. Observations I made during this time led to my attempt to predict acorn crops through visual estimates. I noted that acorns of a given year's crop were large enough by late June of that year to be easily seen with the aid of 7 x 35 binoculars. In 1952 when there was a bumper acorn crop in northern Michigan most of the mature oaks I looked at produced acorns over a large part of their crown area. The per cent of twigs bearing acorns within the producing portion of the crown was also high, and the number of acorns per twig was frequently five or more. A picture of a defoliated northern red oak taken in 1952 (Figure 9) shows acorn production as it appeared on many of the mature trees I looked at that year. During the fall and throughout the winter of 1952-53 more sound acorns were available than were used by all mast eaters. Many acorns were still available in the spring. In 1953 the acorn crop was poor. In this year only a small part of the crown area of mature oaks produced acorns. The per cent of twigs bearing acorns within the producing portion of the crown was small, and the number of acorns per twig was rarely more than one. In 1953 acorns were eaten shortly after they dropped and none were left by winter. Based on these observations I felt it might be possible to predict an acorn crop in terms of availability of acorns to deer by looking at oaks in June and observing the per cent of crown area producing acorns, the per cent of twigs within the producing portion bearing acorns, and the average number of acorns per twig.

Figure 9. Maturing acorns on a defoliated northern red oak in 1952.

Based on my observations of one excellent and one poor acorn crop I set up a five category classification of mast crop size in terms of availability of acorns to deer by arbitrarily adding three intermediate crop classes. It facilitates understanding of the terms I use to describe the quality of the crop and is as follows:

Quality of crop	Availability to deer
Poor	Few acorns early in the fall; none thereafter.
Fair	Acorns available in the fall; few or none throughout the winter.
Medium	Acorns in the fall and through part of the winter; none left by spring breakup.
Good	Acorns in the fall and winter; some left in spring.
Excellent	More acorns throughout the fall, winter, and spring than all mast eaters combined, at high population levels, can consume.

To convert observations of the per cent of the crown area of trees producing acorns, the per cent of twigs bearing acorns, and the average number of acorns per twig to acorn crop quality I set up the following formula.

Criterion	Numerical value 0	1	2	3
Per cent of crown producing acorns.	0-4	5-33	34-66	67-100
Per cent of twigs bearing acorns.	0-4	5-33	34-66	67-100
Average number of acorns per twig.	Less than one	1-2	3-4	5-6

When the numerical values for each of the three criteria are added the quality of the acorn crop is rated as follows: poor 0-2, fair 3-4, medium 5-6, good 7-8, excellent 9.

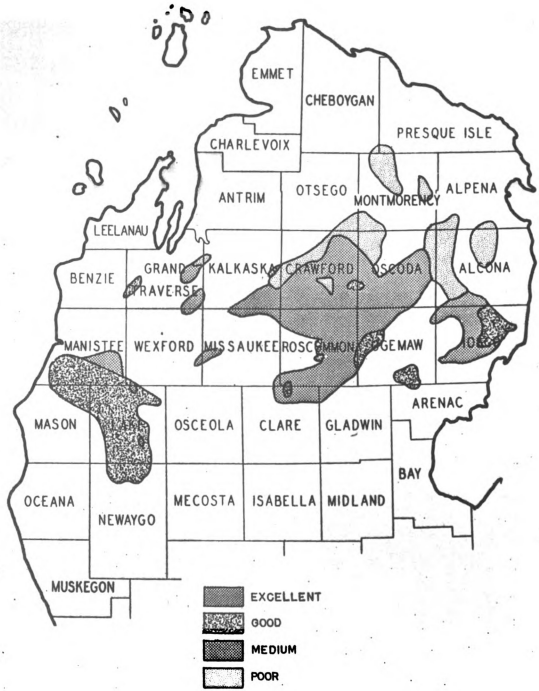
The formula is based on my observations of the excellent 1952 acorn crop when all three criteria on oaks I looked at would receive a numerical value of 3, and the poor 1953 acorn crop when the numerical value for the oaks observed was zero for per cent of crown producing acorns and average number of acorns per twig, and one for per cent of twigs bearing acorns. It seemed logical that when the criteria were classed between these extremes acorn crop production would have to be in one of the three intermediate categories.

In 1954, 1955, and 1956, I attempted to predict the size of the subsequent fall's acorn crop by spot checking the oak forests throughout northern Michigan in late June and early July and applying my formula to observations. In each stand checked I looked at at least 20 mature trees 12 inches or over dbh that appeared to represent a cross-section of the mature portion of the stand. On each tree I counted the number of acorns per twig on at least 15 twigs scattered throughout the producing portion of the crown. I made predictions for the red and white

oak groups, not for oak species. The predictions for 1954 are given in figures 10 and 11. The white oak and red oak acorn crop predictions differed in many areas. Acorn crop prediction for both red and white oak groups was similar throughout the oak forests in 1955 (Figure 12). In 1956 the prediction was for a poor crop for both groups throughout the oak forests with the exception of a few scattered areas too small to be indicated on a map.

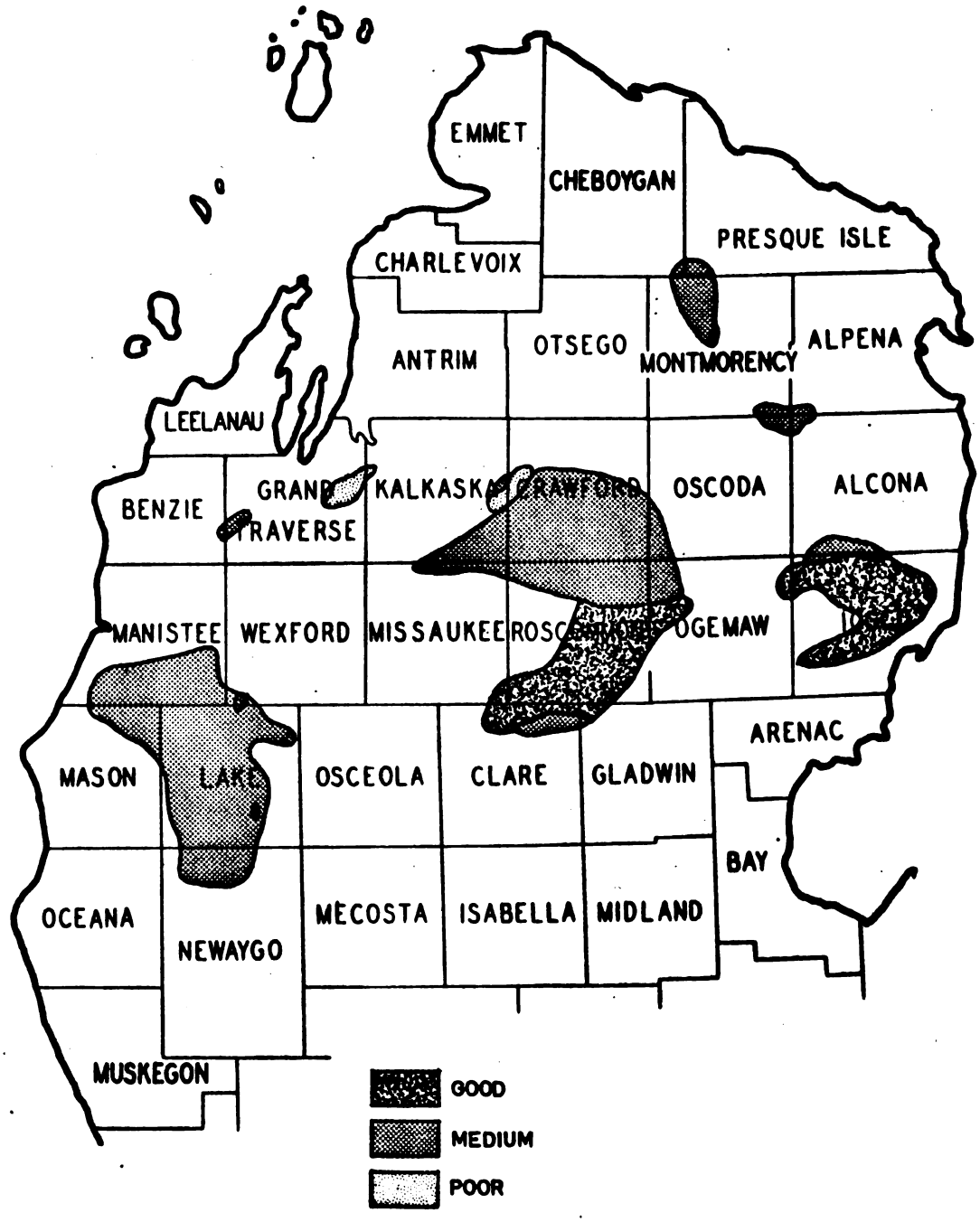
Each year that I predicted a crop I checked areas throughout the oak forests periodically through the following fall, winter and spring to check the accuracy of my estimates. Before snowfall, and after the spring thaw, an estimate of acorn availability was obtained by walking through portions of oak stands and looking for acorns on the ground. During the winter when snow covered the ground deer would paw through as much as 16 inches of snow in areas where acorns were available to feed on them. I also found that squirrels digging in the snow indicated that acorns were available. When digging activity of deer and squirrels ceases I believe very few acorns are left. I checked this by clearing the snow from several four to five foot square areas under oaks in stands where acorns had been available and looked for acorns in the cleared areas. I found acorns that had been insect infested, but no sound acorns in these cleared areas. Subsequent checks of these oak stands following the spring thaw indicated that no acorns were available then.

In 1954 and 1955 I used the visual estimate technique on trees in the four study stands to compare the predictions with the average number of pounds of acorns produced by the trees as computed from mast trap collections. Table 24 presents this comparison. I also



This represents the bulk of the oak areas in the northern half of the Lower Peninsula.

FIGURE 10. ESTIMATE OF THE 1954 RED OAK ACORN CROP - AUGUST 1954



This represents the bulk of the oak areas in the northern half of the Lower Peninsula.

FIGURE 11. ESTIMATE OF THE 1954 WHITE OAK ACORN CROP - AUGUST 1954

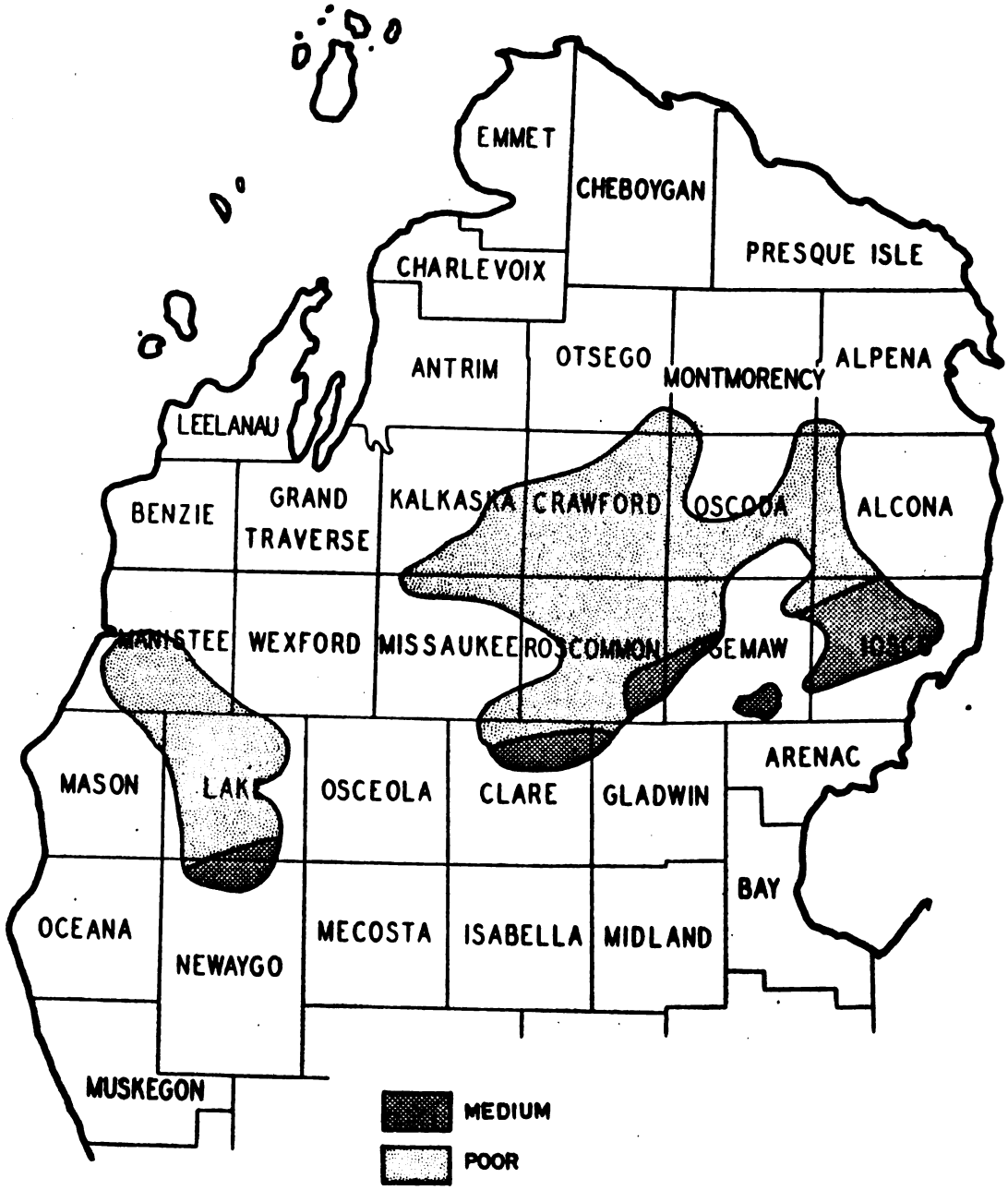


FIGURE 12. ESTIMATE OF THE 1955 ACORN CROP - AUGUST 1955

Table 24

Comparison of Prediction of Acorn Crop with Pounds of Acorns Produced on Trees in Four Study Stands in 1954 and 1955

	Prediction for Acorn Crop 1954		Average Pounds Per Tree 1954		Prediction for Acorn Crop 1955		Average Pounds per Tree 1955	
Study Stand	White Oak	Red Oak	White Oak	Red Oak	White Oak	Red Oak	White Oak	Red Oak
Roscommon County I	Medium	Good	15.6	25.9	Poor	Poor	2.3	1.0
Roscommon County II	--	Medium	--	2.8	--	Poor	--	0.1
Oscoda County	Good	Good	22.8	30.0	Fair	Poor	6.1	1.6
Lake County	Fair	Good	3.3	28.9	Poor	Poor	1.2	3.0

used the technique on each individual tree in each of the three study stands where individual tree production was measured. I used these observations, and the pounds of acorns produced per tree to add a figure for average number of pounds of acorns produced per tree to my classification of acorn crop size. It thus becomes:

Quality of crop	Average no. of pounds of acorns per tree	Availability to deer
Poor	0-5	Few acorns early in the fall; none thereafter.
Fair	6-10	Acorns in the fall; few or none throughout the winter.
Medium	11-20	Acorns through the fall and part of the winter. None left by spring breakup.
Good	21-30	Acorns through the fall and winter; some left in the spring.
Excellent	Over 30	More acorns throughout the fall, winter and spring than all mast eaters combined, at high population levels can consume.

EVALUATION OF PREDICTION METHODS

Counts of Oak Flowers

As I pointed out previously I believe attempts to count female oak flowers to gather data for acorn crop predictions over large areas is impractical for the technique requires too much time to use over extensive areas.

Frost Damage Surveys

Surveys of oak stands following frost can lead to an estimate of the per cent of the potential crop destroyed. Because other factors following flowering in oaks can reduce acorn crop size the only definite acorn crop prediction based on frost damage surveys would be one of complete crop failure when all oak flowers are killed.

Fertilized Flower Counts

I found no way to tell the difference between an oak flower that had been fertilized and one that had not. Even if this were possible the technique of counting fertilized flowers to find a percentage to use in acorn crop predictions would be impractical because it would require too much time to be used over extensive areas, and I could find no rate of loss of acorns caused by factors following fertilization that would apply to all years.

Counts of Maturing Acorns on Sample Twigs and Collection of Aborting Acorns in Mast Traps

Loss of acorns caused by abortion apparently is not similar for different crops or different areas. My counts of maturing acorns

on sample twigs and collection of aborting acorns in mast traps did not lead to an acorn abortion rate that could be used for early acorn crop prediction. From the data I collected it appears that a high per cent of the acorns that do abort may do so early in the development period. The data also indicate that the number of acorns that abort may be quite high compared to the sound acorns that mature (Tables 9, 10, 11, and 23). It also appears that in the two or three months immediately preceding the drop of a mature acorn crop few acorns abort. Observations of maturing acorn crops made in late June and early July might therefore agree closely with the actual crop that matures. It should also be pointed out that sound acorns that abort in August and September of the year of a crop are developed to a point where they are half to three-fourths the size of mature acorns and would therefore provide considerably more food than acorns aborting earlier.

Acorn Crop Prediction Through Visual Estimates

In 1954 and 1955 when I used the visual estimate technique to predict acorn crops in oak stands where I had subsequent measurements of the crop my predictions of the quality of the crop and the average number of pounds of round acorns produced per tree agreed with my classification of acorn crop size in 12 out of 14 instances. I believe that in Roscommon County study stand II the disagreement could be due to the previously mentioned probability that 50 mast traps placed at random were not enough to accurately sample, and thus compute, acorn production on 40 acres. Deer did frequent and dig for acorns in this stand through February, 1955, a fact that supports the prediction of a medium crop in this area.

I cannot explain the prediction for a fair white oak acorn crop in the Lake County stand in 1954 and the computed production of 3.3 pounds per tree which would place the crop in the poor classification.

Following my predictions of the 1954, 1955, and 1956 acorn crops I checked oak stands throughout the oak forests in the fall and winter to see if my prediction of crop quality agreed with the availability to deer part of my classification of acorn crop size. In all oak stands I checked where my prediction was for a poor acorn crop I found that acorns were gone before snowfall. None were apparently left by winter. In areas I checked where I predicted a fair acorn crop I usually found a few sould acorns left by snowfall, but I saw very little digging through the snow by deer and squirrels in these areas during the winter. In oak stands where my predictions were for medium crops I found plenty of sound acorns available through the fall for deer use. In these areas in winter deer did dig for acorns well into the winter when snow depths and snow crust conditions did not become severe enough to make deer stay in winter yards. In areas of predicted good acorn crops I found an abundance of acorns available throughout the fall and it appeared that a lot were left for winter use. When snow conditions did not prevent it deer dug for acorns in these areas throughout the winter, and I usually found some sound acorns still available in the spring. The only difference I could see between areas where predictions were for good and excellent crops was that in the latter areas there appeared to be quite a few more sound acorns left in the spring.

In all of the stands I checked my prediction of the quality of the crop apparently agreed with the classification of the crop in

terms of availability of acorns to deer.

Since my acorn crop predictions in areas where I had subsequent measurements of the crop agreed with the amount produced in most instances I believe that this technique, when used in an area where the number of mature oaks is known, can provide a general estimate of the number of pounds of sound acorns that will be produced in the area. It will also, I believe, provide a fairly accurate estimate of the length of time through the fall and winter that sound acorns might be available to deer.

The visual estimate technique of predicting acorn crops has been used by game managers in Michigan, with apparent success, since my study ended, and it has been accepted as a useful game management tool.

SUMMARY AND RECOMMENDATIONS

Summary of Field Studies

A study of the value of acorns as a winter food for deer was conducted over a three-year period at the Houghton Lake Wildlife Experiment Station in Michigan by controlled feeding of penned deer. The daily food intake of deer receiving a diet of good food was approximately 4 lb fresh weight per hundredweight. Deer ate approximately 1.5 lb of acorns per day per hundredweight, when they were available. Of deer fed a basic starvation ration of jack pine and oak browse, or balsam plus a small amount of cedar, only those given a 0.5-lb supplement of acorns per hundredweight would have had a chance of surviving a 90-day winter period with a weight loss less than the critical 30 per cent. White oak acorns were apparently more palatable than red oak acorns, but weight loss was not significantly different between two groups of deer, one receiving white oak acorns, the other red oak acorns, as a supplement to a poor food browse diet. Deer entering a winter in excellent condition may be better able to resist a critical winter weight loss than animals that are in poorer, lighter condition.

Acorn production of the oak forests in northern Michigan was studied from 1952 to 1956 in an attempt to find a practical method of predicting acorn crops for deer. Measurements of acorn production on individual trees using mast traps to collect samples revealed wide variations in acorn crops produced between years, between different oak stands, and between individual trees in the same year.

Investigations of factors that can reduce acorn crop size, quality, and availability to deer revealed that insects may be expected to infest from 20 to 30 per cent of small acorn crops, and 20 per cent or less of larger acorn crops in northern Michigan. Frost usually reduces the potential acorn crop size by killing some oak flowers. It may in some years greatly reduce the potential acorn crop size. Abortion of immature acorns early in their development period may considerably reduce the potential acorn crop size. The per cent of the sound acorn crop taken by various animals is extremely difficult to accurately estimate, but it appears that in years of medium or better acorn crop production sound acorns may be available to deer through the fall and part or all of the winter. Disease is apparently not an important descimating factor in acorn crops in northern Michigan.

Evaluation of methods investigated for predicting acorn crops led to these conclusions. Climbing trees and using a spotting scope to count oak flowers to get an early indication of acorn crop size is too time consuming to be used over extensive areas. Frost damage surveys can lead to an early estimate of the per cent of the potential acorn crop destroyed. Attempts to count fertilized oak flowers to determine a per cent of the number of female flowers fertilized as an early indication of acorn crop size is impractical because of the difficulty in distinguishing between flowers that are fertilized and those that are not. None of the three above mentioned techniques would lead to an accurate early acorn crop prediction because factors reducing acorn crop size, such as acorn abortion, that follow these observations apparently vary from year to year. I found this apparently true in my attempts to figure an acorn abortion rate by counting maturing acorns on sample

twigs, and collecting aborting acorns in mast traps. Observations of mature oaks, made with the aid of binoculars in late June and early July of the year an acorn crop will mature, to visually estimate the per cent of the crown area of oaks producing acorns, the per cent of twigs within the producing portion of the crown bearing acorns, and the average number of acorns per twig can lead, I believe, to a general prediction of the number of pounds of acorns that will be produced in an oak stand, and a fairly accurate estimate of acorn availability to deer through the fall and winter. This visual estimate technique of predicting acorn crops has been used with success by game managers in Michigan and it has been accepted as a useful game management tool.

Recommendations for Oak Management for Deer

Based on my study and observations, and published reports of other workers, previously cited, I compiled some recommendations for cutting practices in oak forests that would leave oaks to produce adequate quantities of acorns for deer in years of medium or better acorn crop production.

Good acorn crops may be produced in northern Michigan in two out of five years on the average. In a good mast crop year one mature oak may produce over 100 pounds of sound acorns but the average sound acorn production per tree that reaches the ground is probably closer to 20 pounds. Only mature full-crowned oaks over 12 inches dbh and 40 years of age may be expected to produce this much.

To determine the number of oak trees necessary to produce enough acorns for deer use through the fall and winter, the amount a deer

will eat, the portion of the crop that might be available to deer, and the number of deer using the area should be known.

I found in controlled feeding experiments that deer will eat approximately one and one-half pounds of acorns daily when they are available. At this rate one deer would eat approximately 200 pounds of acorns between the middle of October when the bulk of an acorn crop has fallen and the end of February. My feeding studies indicated that a deer could survive a winter when it had one-half pound of acorns daily as a supplement to poor browse foods, so I believe it is reasonable to assume that a deer getting three times that much through February would come through the winter in fairly good condition.

Only a part of the sound acorn crop that falls is available to deer. Other mast eaters take some. Based on my observations of the amount of acorns on the ground during autumn periods when acorn production per tree averaged approximately 20 pounds, I believe it is safe to assume that at least half the crop and possibly more is available to deer. But if only half this crop were available 400 pounds of acorns would have to be produced to provide 200 pounds for one deer to use in fall and winter. Thus at an average production of 20 pounds per tree 20 mature oaks would be needed for each deer.

Estimates of deer population are made each year by the Michigan Department of Conservation. The average number per square mile in the fall has fluctuated around 20 in the northern half of the Lower Peninsula. In areas with 20 deer per square mile it would take 400 oaks producing an average of 20 pounds of acorns per tree to provide an adequate amount of acorns for deer use in fall and winter.

There is no way of being sure acorns will be available through

a winter, for weather conditions may become severe enough so deer will yard in conifer swamps. I observed deer in winter leaving deer yards and frequently traveling a half mile to dig through as much as 16 inches of snow for acorns. Leaving oaks within a half mile of deer yards will better insure acorn availability. Deer start feeding on acorns as soon as they drop in the fall, and during this period deer are scattered through their summer range. Leaving oaks in summer range further than a half mile from deer yards may tend to distribute use of acorns and thus possibly prevent heavy use in the fall in areas adjacent to yards that might reduce the amount left there for winter use.

Frost, by killing blossoms in the spring, often reduces the potential acorn crop size in northern Michigan, particularly in low areas. In areas where oaks are to be cut, leaving trees in higher elevations will better insure that there could be good acorn production. A mixture of red and white oak groups will better insure a crop each year for one spring frost will not affect the same year's crop on both oak groups.

Deer prefer white oak acorns over those of the red oak group and will eat them first. White oak acorns usually sprout shortly after they drop in the fall and thus are less available through the winter than red oak acorns that do not sprout until the following spring. By leaving a higher ratio of white oaks to red oaks more than a half mile from deer yards, than in areas near yards, it is possible that deer might tend to use the acorns away from wintering areas first and thus better insure that acorns might be left in areas where they could be available in the winter.

A summary of my suggestions for management of oak for deer in areas where oak is to be cut follows:

Leave a total of 20 mature full-crowned oaks over 40 years of age and 12 inches dbh for each deer using the area. Leave ten of the oaks within one-half mile of deer yards and ten in summer deer range further than a half-mile from deer yards. Leave oaks at a rate of three red to one white oak near yards and two red to one white oak away from winter range. When there are variations in elevations in an area where oak is to be cut, leave the oaks in higher elevations.

I believe that in years of good mast crop production in areas where there are as many oaks as I recommend, enough acorns should be produced to provide deer with acorns as food through the fall and most of the winter.

My recommendations have been incorporated into the policy of the Game Division of the Michigan Conservation Department on timber cutting practices. They have been accepted and are being followed by State and Federal Foresters in Michigan.

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