A POPULATION STUDY OF THE COTTONTAIL RABBIT IN SOUTHERN MICHIGAN

Thesis for the Degree of Ph. D.

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Aelred Dean Geis

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This is to certify that the

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George A. Petrides
Major professor

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A THESIS

Submitted to the College of Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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Department of Fisheries and Wildlife

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AN ABSTRACT

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Approved George A. Petrides

ABSTRACT

Cottontail rabbit (Sylvilagus floridanus) populations on two 500-acre areas, the Kellogg Bird Sanctuary and Farm, and the Kellogg Forest, were studied between June 1951 and April 1956. The areas are properties of Michigan State University and are located near Battle Creek, Michigan. Major objectives were:

1. Evaluate the accuracy of available census methods.
2. Appraise the effects of factors influencing rabbit abundance, especially hunting.
3. Analyze hunting pressure as it occured on a public area.

Live trapping was conducted almost constantly during the summer of 1951 on the Sanctuary study area. Trapping during the fall was conducted on both areas. At the Sanctuary spring trapping was conducted during 1952-1956. At the Forest, spring trapping took place only in 1955 and 1956. Trapped rabbits were marked with ear tags and in some cases also their tails were dyed yellow. Hunting was the chief means by which rabbits were collected.

An evaluation of census procedures indicated that the Lincoln Index method was reliable where rabbits were trapped and marked and then the marked fraction of the population determined by some other method than retrapping. Either shooting a sample or observing the tail colors was suitable. The De Lury method, based on the decrease in the hunting yield as the population was reduced, could not be applied at the Forest because the rate of kill did not decrease during the season. At the Sanctuary, the rate of kill decreased during the short and intensive

hunting season, but the method consistently gave results that were about 50 percent low.

Several indexes of rabbit abundance were compared to Lincoln Index population estimates. The hunting kill made during a constant effort, and the total hunting kill appeared to be reliable population indexes. The rate of kill based on the total kill and effort was unreliable when hunting effort varied from year to year. Trapping data examined in various ways provided rough indexes of abundance at the Sanctuary, but showed very little relationship to population density at the Forest. Age ratios were reliable fall population indexes only during the few years when spring population levels were constant.

Fall population fluctuations at the Sanctuary between 1932 and 1955 and at the Forest for 1940 and for 1946-1955 were indicated by the hunting kills during fairly constant hunting pressures. No marked change in rabbit productivity has apparently occurred on either area during the periods considered. This is noteworthy since marked changes took place in the vegetation and predator populations on the two study areas.

On both study areas, autumn juvenile: adult ratios were inversely proportional to spring adult population levels. At the Sanctuary, the size of spring populations depended largely on the extent of the previous winter's hunting kill. At the Forest, the hunting kill took fairly constant percentage of the population and the size of the spring population was apparently related to the previous fall's population level.

Wide variation occurred in rates of population increase between spring and fall. High rates seemed to be associated with a better survival of early litters and a higher incidence of breeding among juveniles.

During the warm months an adult mortality of up to about 60 percent occurred. This not only influenced fall population levels but also caused fall age ratios to be exaggerated indexes of breeding success.

At the Forest the hunting bag for the 1951 season was 49 percent of the estimated population. During the other years it varied from 56 to 61 percent. At the Sanctuary the hunting kills ranged from 22 to 66 percent of the estimated fall populations depending upon the hunting pressure exerted. The hunting kill influenced the following spring population levels but apparently had little effect on the following fall populations.

Experiments were conducted to measure the crippling loss. Under experimental hunting conditions at the Sanctuary, it was roughly 10 percent of the recovered kill. With public hunting at the Forest it was about 20 percent.

The non-hunting winter mortality at the Sanctuary was estimated at from 29 to 54 percent of the rabbits not killed by hunting. It appeared to be higher during years which had a low hunting kill. The cause of this mortality was unknown.

The fall age composition at the Sanctuary over a five year period was 82 percent juveniles, 14 percent one and one-half years of age, and only four percent two and one-half or more years old. Heavy hunting

kills apparently decreased the rate of survival indicated by the age composition.

Intensive live trapping was conducted between June 1951 and March 1952 and a life equation was determined for that period.

Because rabbits are a very important game animal the characteristics and effects of heavy public hunting were studied on the Kellogg Forest. Data were gathered when hunters checked out of the area after each hunt. Yearly, monthly, weekly, daily and hourly patterns of hunting effort, kill and rate of kill were determined. Hunting effort was high at the beginning of the season, rapidly tapered off, reached a second peak in early December and dwindled until it was uniformly low during the last four weeks of the season. The extent of the kill followed the trends in effort, except that it was relatively higher during late November and December when the rate of kill was higher. In general, the rate of kill early in the day was slightly higher than that later. Hunting effort was usually greatest about 11:00 A.M.

The entire kill was made by 19.6 percent of the hunters. Six and eight-tenths percent harvested 65.8 percent of the total kill. If there was a uniform probability of success it would be expected that 7.1 percent of the hunters would take 50.4 percent of the total bag. Significant differences were found among hunters in the rate of kill. The distribution of effort among the hunters indicated that 85 percent hunted a total of less than six and one-half hours and 65 percent visited the area only once.

The influence of various weather factors on hunting effort was examined. Clear October days, cool November days, warm December days, calm days every month and November days with snow cover all seemed to induce an increased hunting effort. Rain fall caused a decrease in effort.

Hunters that had had previous experience with the area, who used dogs and/or who hunted on days with snow cover were much more successful than hunters without these benefits. Single hunters had a relatively higher rate of kill than did groups.

Increased hunting success prevailed when there was snow cover, on cool days in October and on warm days in December.

The rate of kill at the Forest did not decrease late in the season due to an increase in effort by experienced hunters, to an increased proportions of hunters that used dogs and a greater number of days with snow cover.

The probable effects of hunting seasons of various lengths were calculated. Lengthening the both ends of the current October 20 to January 31 season apparently would have little effect on hunting effort, kill or success.

Great changes in vegetation and faunas have occurred since Allen (Ecol. Mon., 8:347-436. 1938) studied the Sanctuary area during 1934-1937. These are discussed in detail.

Relative rabbit winter food preferences and availability of the various woody plant species on the area were listed.

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INTRODUCTION

Because of the complexity of the factors affecting a wild animal population, it is difficult to evaluate precisely the relationships of population characteristics during the span of only a few years.

Major objectives of this study of the cottontail rabbit (Sylvilagus floridanus) at the Kellogg Station were threefold:

1. Evaluate the economy of currently available census methods.
2. Appraise the effects of factors influencing rabbit abundance, especially hunting.
3. Analyze hunting pressure as it occurs on a public area.

The investigation of the effect of hunting on rabbit abundance was emphasized because this mortality was most readily controlled. Furthermore the recreational value of rabbits is realized largely from their harvest by hunting and it was desirable to evaluate the influence of this harvest on future abundance. Despite only five years duration, this study has begun to indicate the character of interrelationships between the extent of the hunting kills, spring and fall population densities and fall age ratios.

Description of the Study Areas

Kellogg Bird Sanctuary and Farm

The Kellogg Bird Sanctuary and Farm is a continuous area of 500 acres located in section 8, Ross Township, Kalamazoo County, Michigan.

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The Bird Sanctuary is surrounded on three sides by the Kellogg Farm, Midland Park, a residental area adjoins on the west.

Allen (1938b) described in considerable detail the history, physiography, soils, climate and plant and animal communities of this area.

Some changes have occurred, however, in the vegetation and fauna of the area since Allen's study. The conifer plantations during the time of Allen's work were not over eight feet tall and the trees had branches down to the ground. During the present study, these conifers were 20-40 feet tall and had lost their lower limbs. Consequently, near the ground much less cover currently was afforded by conifer plantations than was the case during 1935 and 1936. In contrast, formerly open grassy fields have now developed considerable shrubby cover.

To obtain a description of current vegetative conditions the Kellogg Sanctuary was cover mapped during the summer of 1951 and the Kellogg Farm during the winter of 1954. Cover types were classified according to the following outline which gives symbols used in Table 1.

OUTLINE OF COVER TYPES AT THE W. K. KELLOGG STATION OF M.S.U.

O Open Land
Herbaceous vegetation, or woody vegetation less than 2 feet high. Woody vegetation over 2 feet high covering not more than 10%. Not cultivated
1. Grass - 70% or more grass
c - scattered conifers
2. Low shrubs - 70% prostrate shrubs
3. Mixtures of 1, 2, and weeds - none over 70% on area of more than 30 yards by 30 yards.

S Over grown land
Open land overgrown with shrubs and young trees on more than 10% of area. No woody clump more than 30 x 30 yards.
1. 10% - 40% covered with woody plants
2. 40% - 90% covered with woody plants
Note: Cover type of open land between woody plants will be found in parenthesis

T Thickets
Dense stands of shrubs or small trees less than 20 feet high covering 90% or more of ground

W Deciduous Woods
1. Young - mostly DBH 12 inches or less - over 20 feet high
2. Old - DBH - over 12 inches

Underbruch density
a. light - 0% - 10% ground covered
b. medium - 10% - 60% ground covered
c. Heavy - 60% - 100% ground covered

C Conifer Plantation
1. Pine
2. Spruce
3. Larch

Accompanying vegetation
a. none, trees closed
b. not closed - per cent not covered and its type noted in parenthesis

A Crop Land

This method of classifying cover is patterned after that used by Bump (1950).

The distribution of cover types on the Kellogg Sanctuary and Farm is indicated in Table 1. Much more woody cover was present on the Sanctuary than was present on the Kellogg Farm. It consisted of well-interspersed conifer plantations, open brushy hillsides and dense lowland thickets. Kellogg Farm vegetation consisted largely of open crops and pastures with woody cover limited to woodlots and scattered

TABLE 1

COVER TYPE COMPOSITION AT THE KELLOGG STATION, HICKORY CORNERS, MICHIGAN

Cover Type	Code	Kellogg Bird Sanctuary Acres	Kellogg Bird Sanctuary Per Cent	Kellogg Farm Acres	Kellogg Farm Per Cent	Total Kellogg Bird Sanctuary and Farm Acres	Total Kellogg Bird Sanctuary and Farm Per Cent	Kellogg Forest Acres	Kellogg Forest Per Cent
Herbaceous, not cultivated	O	11.7	11.3	141.2	35.4	152.9	30.4	61.2	11.9
Herbaceous, scattered conifers	O_{1c}							51.5	10.0
Overgrown land, 10-40% woody cover	S_1	7.6	7.3	7.6	1.9	15.2	3.0	76.7	14.9
Overgrown land, 41-90% woody cover	S_2	16.7	16.1	18.7	4.7	35.4	7.0	35.0	6.8
Overgrown 40-70% sumac, 10-50% spruce	S_3	3.6	3.5			3.6	.7		
Thicket	T	7.2	7.0	6.8	1.7	14.0	2.8	11.3	2.2
Deciduous woods, less than 12" D.B.H. underbrush light	W_{1a}	2.6	2.5	1.1	.3	3.7	.7	8.8	1.7
Deciduous woods less than 12" D.B.H. underbrush medium	W_{1b}	.9	.9	1.0	.3	1.9	.4	14.9	2.9
Deciduous woods less than 12" D.B.H. underbrush heavy	W_{1c}	.3	.3	7.4	1.9	7.7	1.5	5.7	1.1
Deciduous woods more than 12" D.B.H. underbrush light	W_{2a}			6.3	1.6	6.3	1.2	.5	.1
Deciduous woods more than 12" D.B.H. underbrush medium	W_{2b}	3.9	3.8	15.0	3.7	18.9	3.8	13.9	2.7
Deciduous woods more than 12" D.B.H. underbrush heavy	W_{2c}	3.6	3.5			3.6	.7	29.4	5.7
Pine plantation, closed	C_{1a}	10.4	10.1	6.5	1.6	16.9	3.4	11.2	21.6
Pine plantation, open	C_{1b}	.9	.8	1.9	.5	2.8	.6	33.0	6.4
Spruce cedar or fir plantation, closed	C_{2a}	1.0	.9			1.0	.2	1.0	.2
Spruce cedar or fir plantation, open									
Larch, open	C_{2b}								
Cultivated land	A	.2	.2	167.9	42.0	168.1	33.5	25.7	5.0
Open water		31.4	30.3	3.4	.8	34.8	6.9		
Buildings and yards		.4	.4	14.8	3.7	15.2	3.0		
		102.5	99.9	399.6	100.1	502.1	100.0	514.8	100.0

Spruce cedar or fir plantation, open	C_{2b}	1.1	1.0			1.1	.2	30.9	6.0
Larch, open	C_{3b}							4.1	.8
Cultivated land	A	.2	.2	167.9	42.0	168.1	33.5	25.7	5.0
Open water		31.4	30.3	3.4	.8	34.8	6.9		
Buildings and yards		.4	.4	14.8	3.7	15.2	3.0		
		102.5	99.9	399.6	100.1	502.1	100.0	514.8	100.0

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Kellogg Forest

The 515 acre Kellogg Forest, located about two miles southeast of the Sanctuary, was donated to Michigan State University in 1932 by W. K. Kellogg. It has rough topography and sandy soils. The area had been badly eroded. It was Mr. Kellogg's desire that the area be used to illustrate the rehabilitation and use of such land by proper conservation practices.

A wide variety of coniferous and deciduous species have been planted. Many of these are species which commonly are used in wildlife habitat improvement plantings (Gysel and Lemmien, 1955). Because of the variety of plantings and natural vegetation, this area presents considerable difficulty in defining cover types. Table 1 lists the relative amounts of various types of cover found on the area. A cover map of this area is also on file at the Department of Fisheries and Wildlife, Michigan State University.

Hereafter the Kellogg Bird Sanctuary and Farm area is referred to merely as the Sanctuary and the Kellogg Forest area merely as the Forest. The several areas together are termed the Kellogg Station.

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GENERAL PROCEDURES

Trapping Periods and Locations

Live trapping played an important part in the investigation. The chief purpose was to enable a portion of the population to be marked for census purposes but, much additional information also was obtained. Traps were placed so as to capture as many rabbits as possible from all parts of the area. They were set in the most likely places and consequently were often unevenly spaced. At the Sanctuary, the bulk of trapping was done on the central part of the area because most of the rabbits were located there. The more even distribution of rabbits at the Forest enabled the traps there to be located throughout the area. Ear corn was used for bait at all times. During 1951 apples were also used in addition to corn but did not seem to increase trap success.

At the Sanctury trapping during 1951 started June 7 and continued almost continuously until August 29. Five trap lines were operated. Dates, numbers, and success of traps are shown in Table 2. Trap locations are shown in Figure 1. That same year two additional trap lines were conducted simultaneously from October 17-29. One was on the Bird Sanctuary and the other was across the north end of the Farm. This was done in order to compare population densities on the two areas and to obtain information on rabbit movements. In 1952 and 1953 the entire central part of the study area was trapped during late August and early September to determine the age composition of juveniles and the incidence of warbles (Cuterebra sp.). Numbers of traps used and other details

TABLE 2

SUMMER 1951 TRAPLINE SUMMARY KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Line Dates	Am May 7, June 7-10, 14, 29, 30	Aw June 10, 14 29, 30			July 31- Aug. 10	Aug. 11-19, 23-29

TABLE 2

SUMMER 1951 TRAPLINE SUMMARY KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Line Dates	Am May 7, June 7-10, 14, 29, 30 July 1-13	Aw June 10, 14 29, 30 July 1-13	July 14-30	July 31- Aug. 10	Aug. 11-19, 23-29
No. nights	21	17	17	10	16
No. traps	19	50	31	66	67
Trap nights	399	850	527	660	1072
No. individual handled	32	7	16	15	27
Current recaps.	39	2	13	1	6
Total captures	71	9	29	16	33
No. marked	32	7	8	11	19
Adult males	7	0	2	1	3
Adult females	10	0	2	1	2
Juvenile males	5	4	3	4	5
Juvenile females	10	3	1	5	9
No. of trap mortalities	1	0	1	1	1

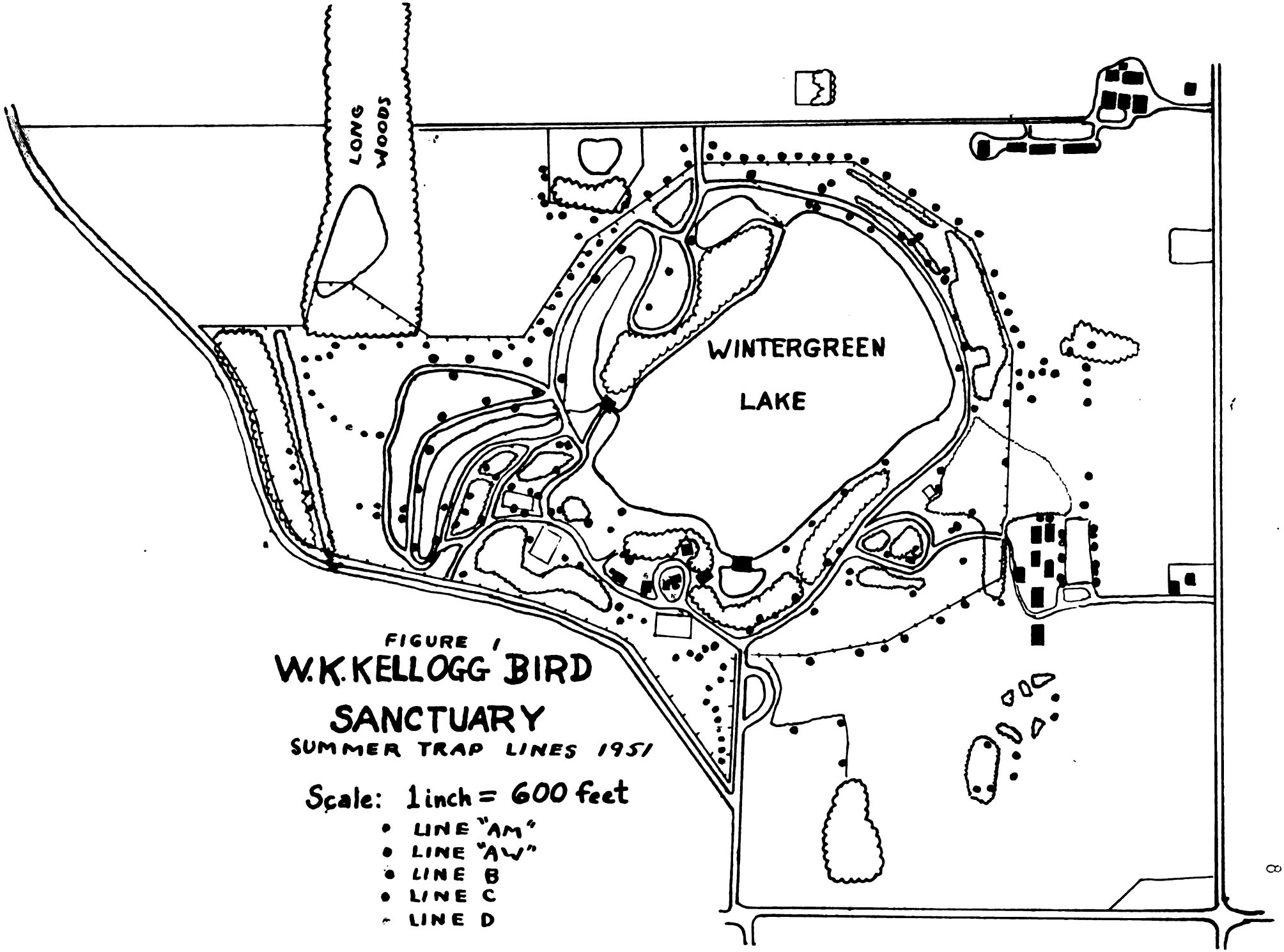


FIGURE 1

W.K. KELLOGG BIRD SANCTUARY

SUMMER TRAP LINES 1951

Scale: 1 inch = 600 feet

- LINE "AM"
- LINE "AW"
- LINE B
- LINE C
- LINE D

are provided in Table 3. The location of these traps was the same as during the spring.

From 1952 through 1955 a ten day trapping period during the last two weeks in March was established as routine. Data concerning these periods are found in Table 4. Trap sites are shown in Figure 2. Each fall live trapping was conducted largely during November. To insure more complete coverage of the better rabbit habitats on the Sanctuary, the trapping was done in two portions. Trap locations used in 1951 are mapped in Figure 3. The distribution of traps was then changed and the same locations used from 1952 through 1955 (see Figure 4). This change involved a reallocation of trap locations between the two trap lines rather than a change in trap locations. The two lines trapped were shaped somewhat like a horseshoe with Wintergreen Lake in the center and the two ends coming together. It was thought that the number of rabbits captured on both lines might indicate the extent of movements during the trapping period. Details of this trapping are given in Table 5.

At the Kellogg Forest trapping was conducted each year from mid-September to mid-October. The area was divided into three portions and each third was trapped about ten days. Details concerning this trapping are listed in Table 6. The trap locations were approximately the same each year. Those used in 1955 are indicated in Figure 5. Varying numbers of traps were located by spacing the traps somewhat closer when larger numbers of traps were available. Because the south trap line was shorter than the others, during years when more than

Time	
Dates	
Number of nights	
Number of traps	
Trap nights	
Number of indiv handled	
Current recapt	
Total captures	
Number marked	
Adult males	
Adult females	
Juvenile males	
Juvenile femal	

TABLE 3

LATE SUMMER AND EARLY FALL TRAPLINE SUMMARIES
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Line	T	F	W.C.	W.C.
	K.B.S.	Farm		
Dates	Oct. 18-25 1951	Oct. 17-29 1951	Aug. 26-Sept. 5 1952	Aug. 15-Sept. 8 1953
Number of nights	12	13	11	24
Number of traps	30	39	57	73
Trap nights	360	507	627	1752
Number of individuals handled	29	11	27	38
Current recaptures	26	4	4	15
Total captures	55	15	31	53
Number marked	24	11	28	36
Adult males	1	3	3	3
Adult females	3	1	4	3
Juvenile males	13	3	11	13
Juvenile females	12	4	9	16

TABLE 4

SPRING TRAP LINE SUMMARY--KELLOGG STATION
HICKORY CORNERS, MICHIGAN

	Kellogg Bird Sanctuary & Farm					Kellogg Forest	
	1952	1953	1954	1955	1956	1955	1956
Dates	Mar. 21-30	Mar. 22-31	Mar. 21-30	Mar. 25-Apr. 3	Mar. 23-31	Mar. 2-13	Apr. 1-10
Number of nights	10	10	10	10	9	11	10
Number of traps	79	79	74	80	80	79	79
Trap nights	790	790	740	800	720	869	790
Number of individuals handled	54	7	4	41	26	20	20
Current recaptures	34	0	0	41	22	15	15
Total captures	88	7	4	82	48	35	35
Number marked	19	4	3	6	9	13	11
Number of males of total handled	25	4	2	20	14	11	12
Number of females	29	3	2	21	12	9	8

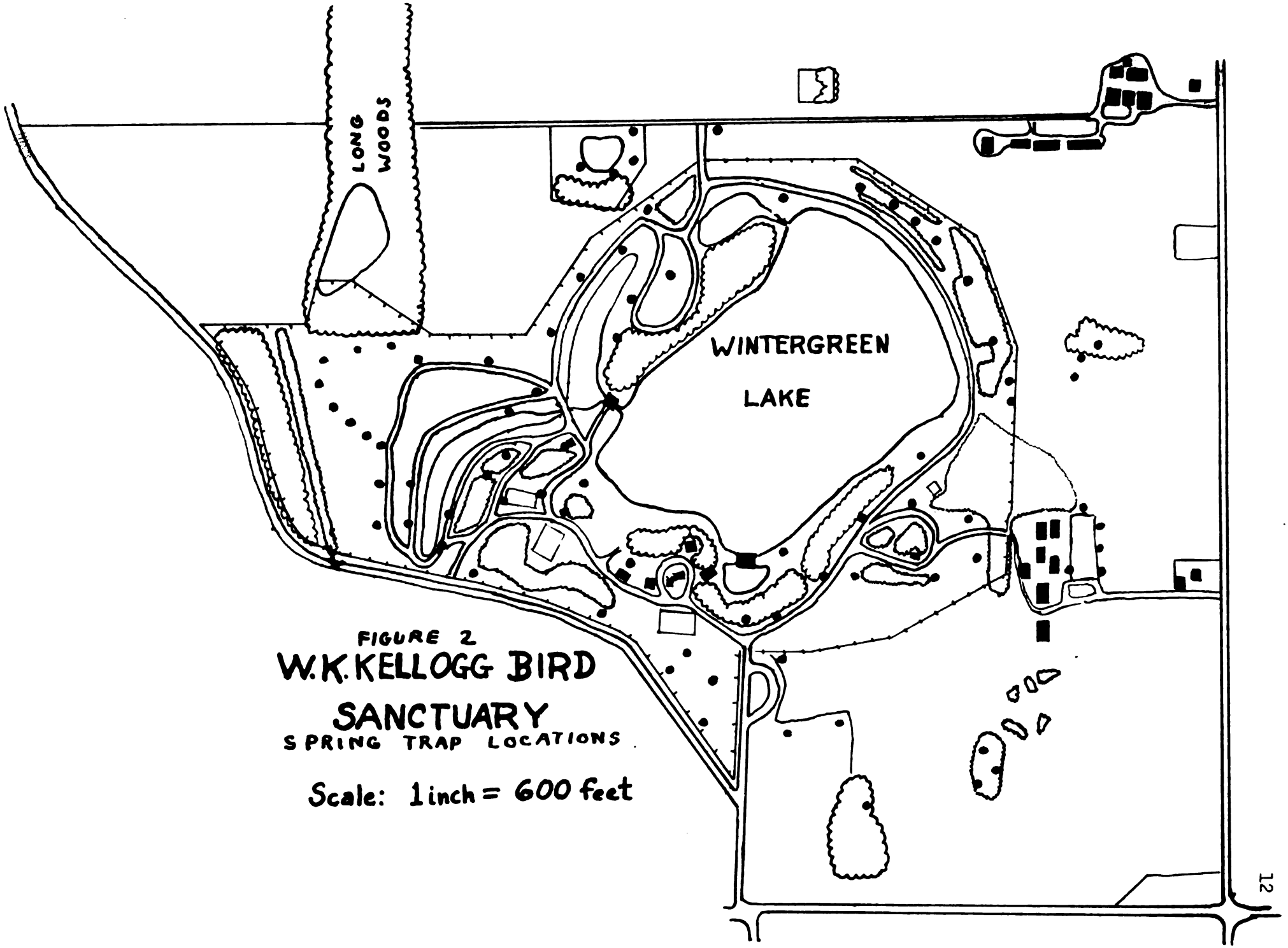


FIGURE 2

W.K. KELLOGG BIRD SANCTUARY

SPRING TRAP LOCATIONS

Scale: 1 inch = 600 feet

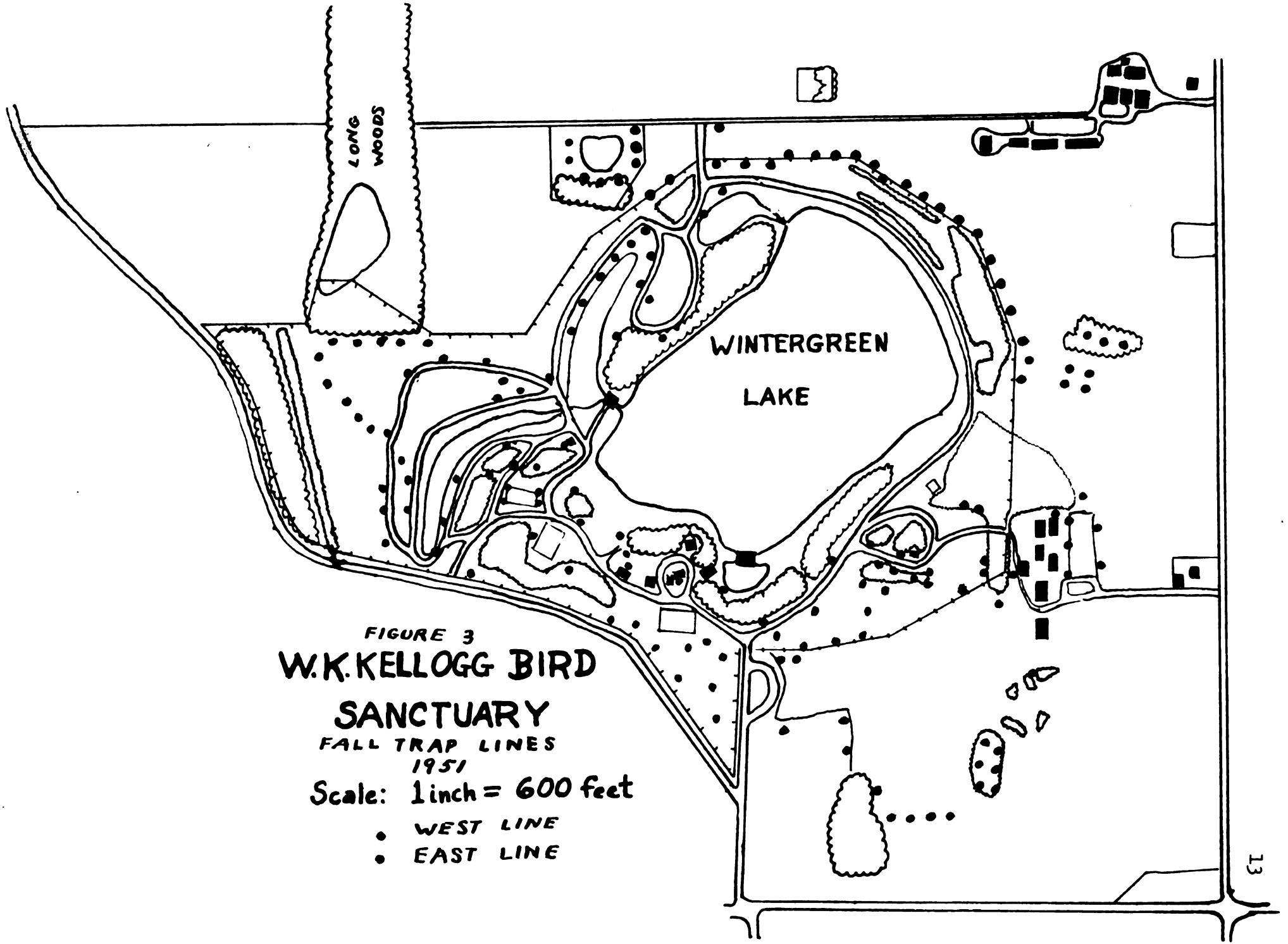


FIGURE 3

W.K. KELLOGG BIRD SANCTUARY

FALL TRAP LINES
1951

Scale: 1 inch = 600 feet

• WEST LINE
• EAST LINE

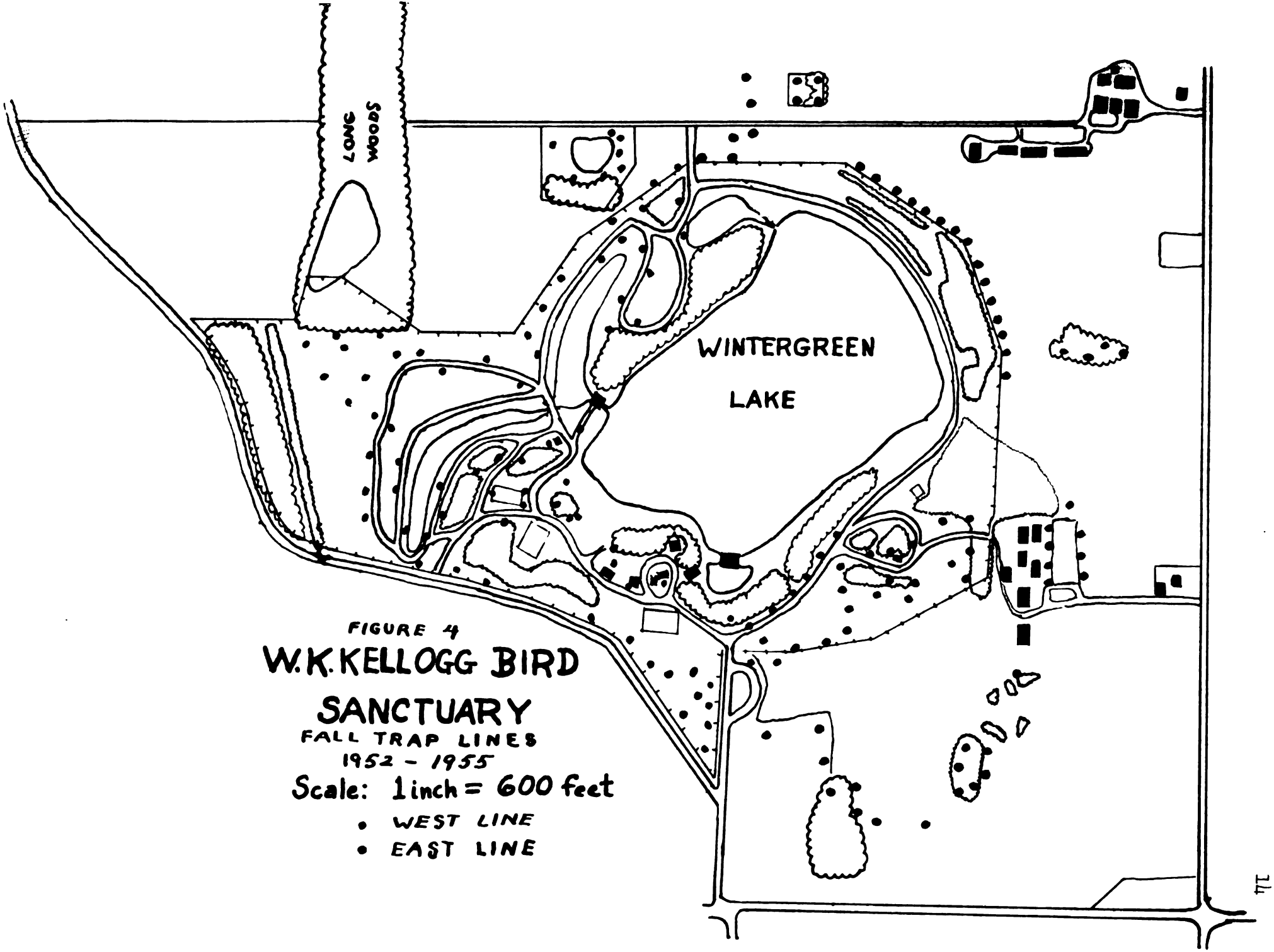


FIGURE 4

W.K. KELLOGG BIRD SANCTUARY

FALL TRAP LINES
1952 - 1955

Scale: 1 inch = 600 feet

- WEST LINE
- EAST LINE

TABLE 5

PREHUNTING SEASON TRAPPING SUMMARY KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

	1951		1952		1953		1954		1955	
	South Nov. 3-15	North Nov. 21-29 Dec. 4-10	East Oct. 24- Nov. 5	West Nov. 6-27	West Nov. 2-17 & Oct. 22	East Nov. 18- Dec. 1	West Nov. 4-18	East Nov. 19-29	West Oct. 25- Nov. 4	East Nov. 5-14
Number of nights	13	11	13	22	16	14	15	11	11	10
Number of traps	76	77	77	77	75	72	76	75	79	81
Number of trap nights	988	847	1001	1694	1200	1008	1140	825	869	810
Number of individuals handled	79	89	55	79	71	58	61	62	50	49
Current recaptures	134	160	23	133	42	42	52	33	26	32
Total handled	213	249	78	212	113	100	113	95	76	81
Number marked	50	67	44	53	37	45	59	57	44	34
Number of adult males	5	6	4	7	6	5	4	3	7	11
Number of adult females	9	15	3	12	5	3	2	11	3	8
Number of juvenile males	28	24	20	20	27	25	25	20	14	12
Number of juvenile females	37	42	28	40	26	20	29	28	26	18

TABLE 6

PREHUNTING SEASON TRAPPING SUMMARY--KELLOGG FOREST
AUGUSTA, MICHIGAN

Year	1951			1952				
Line	West	South	North	North	South	West	North	North
Dates	Sept.7-16	Sept.17-28	Oct.2-12	Sept.17-25	Sept.26-Oct.6	Oct.7-9	Sept.26-Oct.7	Oct.11-19
Number of nights	10	12	11	9	11	13	12	9
Number of traps	63	68	77	75	56	56	19	19
Trap nights	630	816	847	675	616	728	228	171
Number of individuals handled	30	35	65	37	35	35	12	12
Current recaptures	4	17	13	10	12	12	1	1
Total captures	34	52	78	47	47	47	13	13
Number of tagged	30	34	65	37	29	34	8	6
Adult males	5	0	7	0	6	0	1	0
Adult females	4	4	8	4	0	4	2	1
Juvenile males	7	13	20	21	14	17	4	4
Juvenile females	14	18	30	12	15	14	5	7

Year	1953			
Line	North	South	West	North
Dates	Sept.16-27	Sept.28-Oct.8	Oct.9-18	(Gysel's line)
Number of nights	12	11	10	
Number of traps	69	69	72	
Trap nights	828	759	720	
Number of individuals handled	40(38 live)	33	45	7
Current recaptures	10	15	17	1
Total captures	50	38	62	8
Number tagged	40	33	39	6
Number dyed yellow	38	32	40	7
Adult males	3	2	5	0

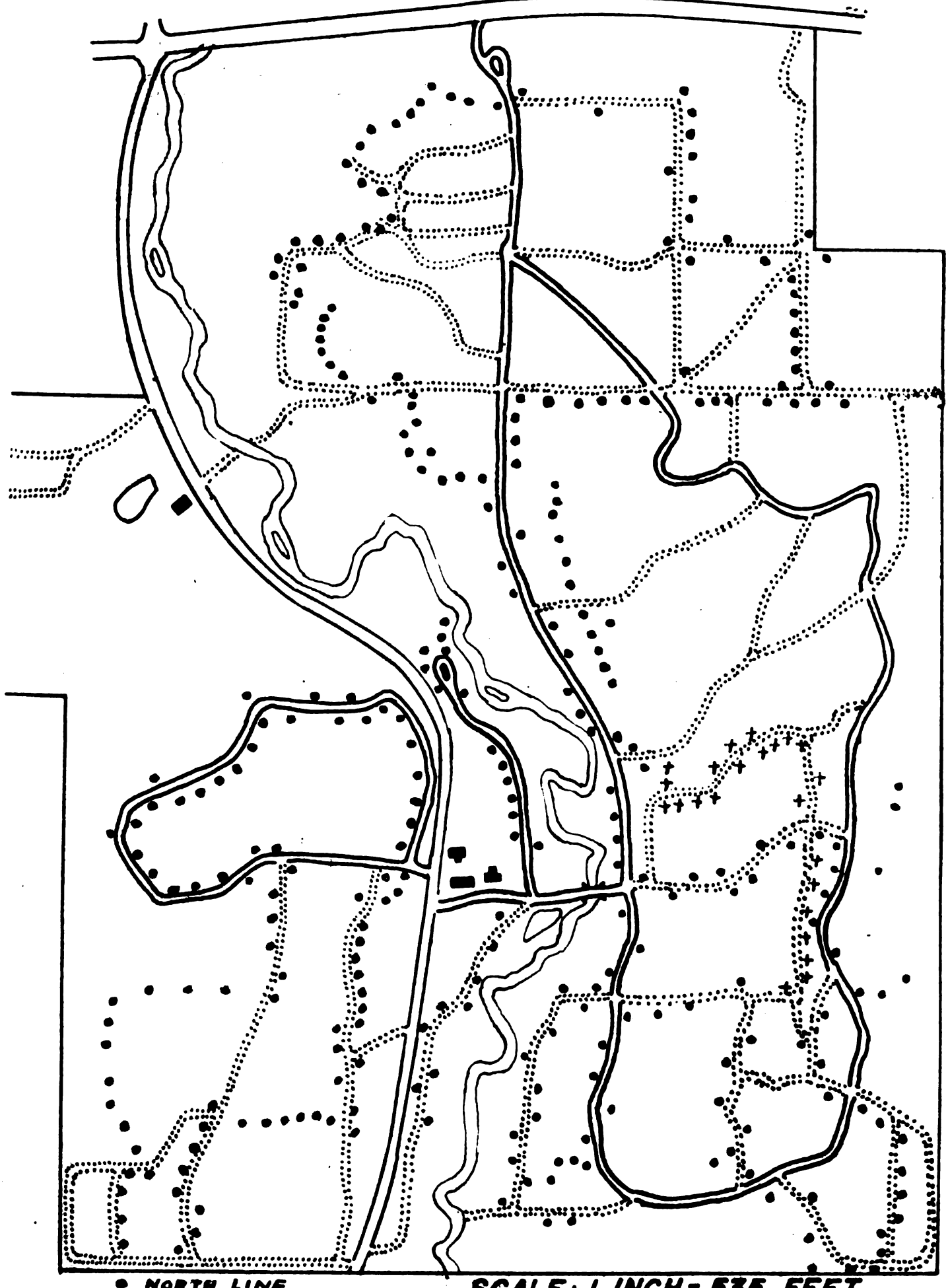
Adult females	5	1	4	1
Juvenile males	20	15	20	3
Juvenile females	12	15	16	3
Unknown				

Year	1954			1955		
Line	South	North	West	South	North	West
Dates	Sept.20-29	Sept.30-Oct.9	Oct.10-19	Sept.23-Oct.3	Oct.4-12	Oct.13-19
Number of nights	10	10	10	11	9	7
Number of traps	Sept.20-23 - 68 Sept.24-29 - 88	69	91	Sept.23 & 24 - 70 Sept.25-27 - 74 Sept.28-Oct.3 - 104	106	106
Trap nights	800	690	910	986	954	742
Number of individuals handled	39	37	48	33	62	51
Current recaptures	12	11	30	44	35	16
Total captures	51	48	78	77	97	67
Number tagged	36	37	47	33	58	49
Number dyed yellow	38	37	48	32	59	51
Adult males	5	1	1	4	12	3
Adult females	4	3	3	4	11	6
Juvenile males	11	18	21	13	20	21
Juvenile females	15	15	23	11	19	21
Unknown	4			1		

FIGURE 5

KELLOGG FOREST

FALL TRAP LOCATIONS 1951-1955



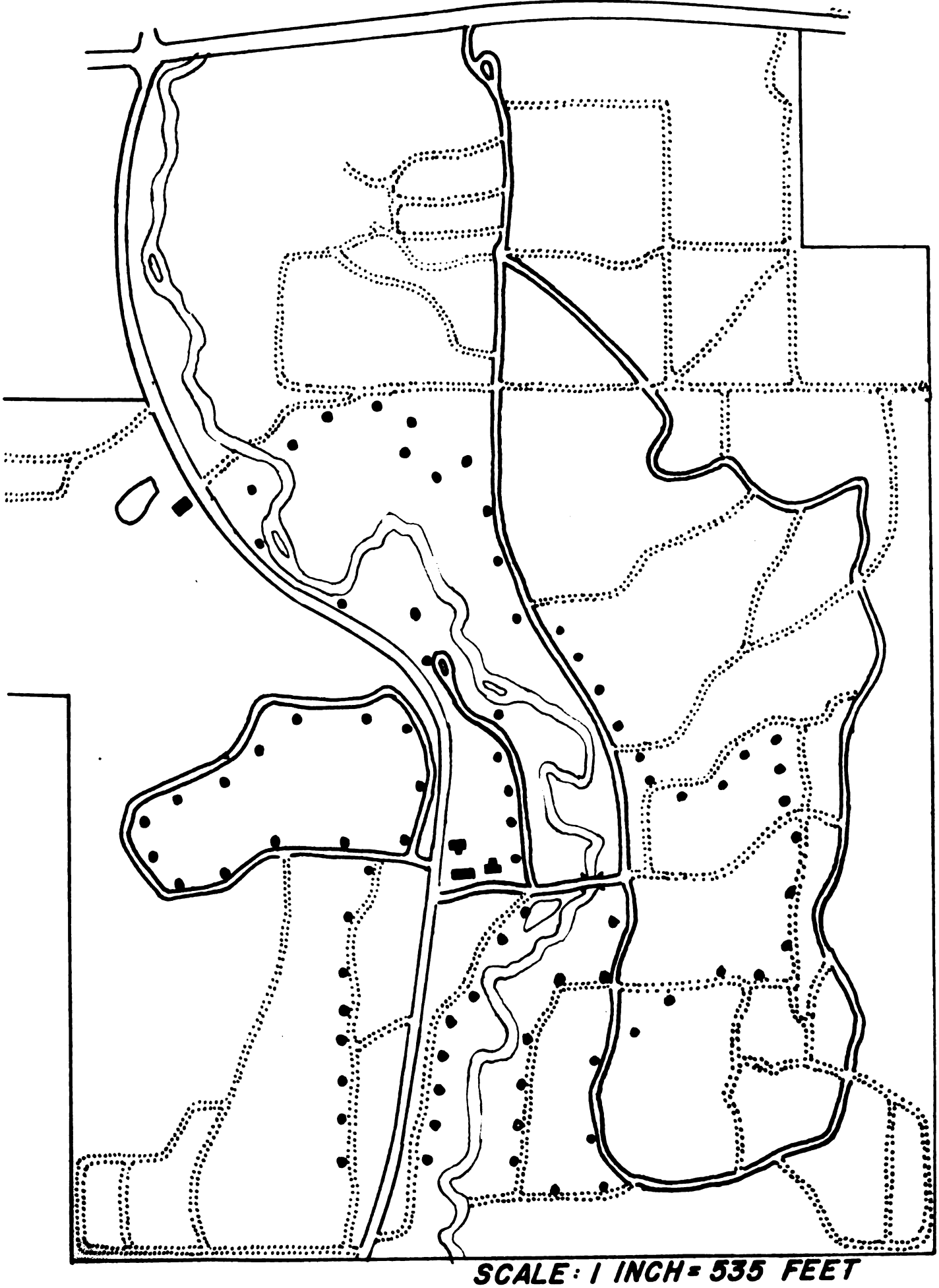
80 traps were available the trap locations indicated by green crosses in Figure 5 were added. In 1952 two additional trap lines consisting of straight intersecting lines of traps were set up to obtain information on movements. During early March 1955 a trap line comparable to that conducted at the Sanctuary was operated. Some details and results of this trapping are given in Table 4. The trap locations are indicated in Figure 6.

Types of Traps

Two types of traps were used. Fifty were unpainted wooden traps (as described by Hickie, 1940) and the remainder were size 3, wire mesh traps manufactured by the National Trap Company, Tomahawk Wisconsin. During the first year, wooden traps were three to five times less effective than the metal traps. However, as the study progressed wooden traps increased in effectiveness while metal traps seemed to become slightly less effective. From 1954 until the end of the study, during September and October, wooden traps were about twice as successful as metal traps, but during March, November, and December the two traps were of equal effectiveness.

The efficiency of wooden traps early in the study apparently was reduced by the odor of "penta" wood preservative with which they had been treated. Cutting three inch holes in the ends of half the wooden traps did not increase their effectiveness. The success with which metal traps took rabbits during warm months was greatly reduced because during the day they often were sprung by red squirrels (Tamias hudsonicus), chipmunks (Tamias striatus) and striped ground

FIGURE 6
KELLOGG FOREST
SPRING TRAP LOCATIONS



squirrels (Citellus tridecemliniatus). Wooden traps took these animals only rarely. Traps were checked during the morning except during the summer of 1951 when they were also checked during the late afternoon to reset sprung traps. The effectiveness of metal traps was somewhat reduced during the study because they became progressively more battered by raccoons and from handling.

Handling Methods

Rabbits were removed from upturned wooden traps by grasping them by the head (as described by Petrides, 1951) and placing them in a cloth bag. This procedure was unsatisfactory for the removal of rabbits from metal traps because they would run up the sides and escape when the trapper opened the door. Rabbits were best removed from metal traps by placing a cloth bag over the open door and frightening the rabbits into it by striking the opposite side of the trap. The date, location, age, sex, weight, breeding condition, and presence of conspicuous parasites were recorded for each rabbit handled. The nose-rump and hind foot lengths of rabbits not fully grown also was recorded.

Sex and Age Determination

Aging and sexing was done by the criteria described by Petrides (1951) except that additionally the epiphyseal cartilage at the distal end of the radius and ulna that mark juvenile, was located by palpation in many live specimens. The bump caused by the epiphyseal cartilage was detected merely by sliding the end of the forefinger along the lateral side of the distal end of the forearm. Because nipple size was

not a reliable age criterian in females (see beyond) and penis length was sometimes a questionable criterion in males, the aging of some live rabbits was uncertain. The writer has the impression, however, that despite some difficulties, very few rabbits were incorrectly aged. No rabbits which were later shot had been incorrectly aged when first trapped during 1951 and 1952. Shot rabbits were aged by the degree of ossification of the epiphyseal cartilage at the proximal end of the humerus, as described by Hale (1949) and Petrides (1951). During the last three years of the study obvious aging errors of live rabbits (especially males) were occasionally made by less experienced men assisting in the trapping. These errors did not effect the results of this study because age ratios were established from the hunting kill which could be accurately aged.

Marking Methods

Almost all rabbits were eartagged in both ears with numbered monel metal finglerling type tags (style 1005, size 3), National Band and Tag Co., Newport, Kentucky). The ear was folded double when the tags were inserted (Haugen, 1942). Thus, the ear was pierced in two places so that when it was unfolded the tag was completely inside. This method was very satisfactory since only one tag was lost. Each year several rabbits had one of their two tags ripped out by shot, but in no known case were both tags lost in this manner. During 1951 and 1952 small juveniles were marked with National Band and Tag Company ear tags. These were numbered metal surfaces with two metal extentions. The

extentions were placed through a small hole punched in the ear, then through a light metal washer placed on the other side and spread open. An ear tag gauge (also obtained from National Band and Tag Company) was placed under the washer before the extentions were opened to avoid cutting off circulation and to provide room for growth. Since only one hole was necessary these tags were better than fingerling-type tags in the rapidly growing ears of very small rabbits.

In 1953 it became desirable to have rabbits marked so that they could be visually identified without retrapping or shooting. Fifty percent alcohol saturated with picric acid was found to dye rabbit tails a bright durable yellow. Rabbits that had their tails dyed yellow in November could still be clearly distinguished as marked rabbits the following June. The mark apparently was lost during the summer following marking.

Shortly after they had been dyed with picric acid during late January, 1953, three rabbits were found dead. This raised a question concerning the toxicity of the dye solution. Cohn and Githers (1928) reported that picric acid is toxic and that the fatal dose by mouth for various species is approximately .5 gm. per kilo (4 grains per pound). Yellow stains around the mouths of recaptured rabbits indicate that they had licked the dyed area. However, calculations indicated that it would be impossible for a cottontail to ingest a fatal amount even if it had been completely covered with 50 percent alcohol saturated with picric acid.

To get some idea if lagomorphs were unusually susceptable to picric acid poisoning, an experiment was conducted with 18 domestic rabbits (Oryctolagus caniculus). Fourteen were administered picric acid in various ways and amounts and four held as controls. Only two rabbits that had received large oral doses died.

G. L. Bowers (personal communication) reported no evident mortality from picric acid among many rabbits marked in summer in Pennsylvania. Later, at the Kellogg Forest up to 60 percent of the rabbits marked with yellow tails were later bagged by hunters. It would have been impossible to harvest such a high percentage of the population if a very high mortality had occurred. These observations indicate that when an alcoholic picric acid solution is applied to the tail and adjacent light colored hair no harm is likely to occur. The three recently-dyed rabbits that were found dead possibly expired due to the chilling effect of having about half their body (tail, sides and belly) soaked with a fifty percent alcohol solution when the air temperature was below freezing. No information is available on the effect that color marking has on rabbit behavior.

Malachite green (blue-green) and Nyanzol A (purple-black) dyes also were tried. Both were reported by Fitzwater (1944) to show promise. Also Flyger (1955) used the later with success in marking grey squirrels. Both of these dyes faded rapidly on rabbits. One animal whose tail was dyed black with Nyanzol A September 23 had its tail color recorded as white when shot by a hunter December 28.

Harvesting Methods

The major method used to collect rabbits was shooting. At the Sanctuary almost all hunting was done under the supervision of the writer. Records were kept of the dates of the hunts, numbers of hunters, areas hunted, numbers of rabbits bagged, kill locations and cripples that escaped. Notes were also made of factors which might have influenced hunting success. Data concerning the hunts are tabulated in Tables 7 to 14. The locations at which marked and unmarked rabbits were bagged are shown in Figures 7 to 11.

During the winters of 1952-53 and 1953-54 some unsupervised hunting was done by Kellogg Farm employees. The kills they recorded are indicated in Tables 8 and 9. These kills are probably minimal since they kept records in a very unsatisfactory manner. Also during those two winters, in order to greatly reduce the rabbit population, live traps and snares were used after hunting was no longer sufficiently productive. During the 1952-53 harvest a ferret also was used. Rabbit removals by these methods also are indicated in Tables 8 and 9. Hunting at the Kellogg Forest was open to the public and is described elsewhere.

TABLE 7

SUMMARY OF RABBIT HUNTS KELLOGG BIRD SANCTUARY AND FARM--1951-1952
HICKORY CORNERS, MICHIGAN

Date	Number of Hunters	Starting Time	Finishing Time	Total Gun-Hours	Total Kill	Number tagged Rabbits Killed	Known Cripples That Escaped
Dec. 9	4	3:20 P.M.	5:30 P.M.	8.60	9	3	1
12	3	9:05 A.M.	10:35 A.M.	4.50	5	2	0
12	3	2:00 P.M.	4:15 P.M.	6.75	12	5	1
14	5	1:45 P.M.	3:35 P.M.	9.17	20	11	1
15	4	1:15 P.M.	5:20 P.M.	16.33	14	4	1
16	7	10:15 A.M.	11:45 A.M.	10.5	12	4	2
17	3	3:20 P.M.	4:30 P.M.	3.50	0	0	0
18	4	1:45 P.M.	3.45 P.M.	8.00	8	3	0
19	2	2:30 P.M.	4:00 P.M.	3.00	1	1	0
21	5	1:35 P.M.	2:35 P.M.	5.00	1	0	0
22	2	2:00 P.M.	3:30 P.M.	3.00	3	3	0
30	1	1:30 P.M.	4:30 P.M.	3.00	2	2	0
Jan. 5	5	10:20 A.M.	1:00 P.M.	16.67	8	6	2
6	2	10:00 A.M.	11:30	3.0	2	2	0
12	9*	10:15 A.M.	3:15 P.M.	20.5	11	7	1
13	3*	9:45 A.M.	4:30 P.M.	16.33	10	4	0
19	3*	10:15 A.M.	3:45 P.M.	8.25	4	2	1

*All hunters did not hunt the entire time.

TABLE 8

SUMMARY OF RABBIT HUNTS AT THE KELLOGG BIRD SANCTUARY AND FARM--1952-1953
HICKORY CORNERS, MICHIGAN

Date	Number of Hunters	Starting Time	Finishing Time	Total Gun-Hours	Total Kill	Number Tagged Rabbits Bagged	Number Cripples That Escaped	Number Seen But Not Bagged
Dec. 14	9	9:45 A.M.	11:35 A.M.	16.47	19	9	1	10
14	3	12:30 P.M.	1:15 P.M.	2.25	4	2	0	2
14	1	2:00 P.M.	2:12 P.M.	.20	1	1	0	2
15	3	9:30 A.M.	11.30 A.M.	6.00	1	1	1	7
18	3	1:30 P.M.	3:20 P.M.	5.49	4	1	1	6
21	4	2:00 P.M.	4:10 P.M.	8.68	10	5	1	10
23	5	9:30 A.M.	11:45 A.M.	6.25	5	5	1	7
23	5	1:15 A.M.	3:00 P.M.	8.75	7	5	1	10
24	4	10:55 A.M.	12:00 A.M.	4.32	3	3	0	2
24	4	1:15 A.M.	3:00 P.M.	7.00	5	3	0	2
26	6	10:30 A.M.	11:45 A.M.	7.50	0	0	1	2
26	4*	1:45 P.M.	4:45 P.M.	10.00	11	4	2?	21
27	4	9:45 A.M.	12:45 P.M.	12.00	4	1	1	18
27	1	?	?	1.00	0	0	0	0
28	4*	10:00 A.M.	12:00 A.M.	10.00	3	1	0	2
28	6	12:15 P.M.	3:05 P.M.	16.98	15	7	0	4
29	6	12:10 P.M.	4:15 P.M.	24.48	13	2	2	13
30	8	10:15 A.M.	12:15 P.M.	16.00	3	1	2	12
30	7	1:30 P.M.	3:15 P.M.	12.25	1	0	0	1
31	5	9:50 A.M.	12.10 P.M.	11.65	3	0	1	4
31	5	1:20 P.M.	3:40 P.M.	6.65	1	0	0	2
Jan. 2	4	9:35 A.M.	12:10 P.M.	10.32	1	0	0	0
2	5	1:40 P.M.	4:50 P.M.	15.85	4	1	0	1
3	3	12:15 P.M.	2:45 P.M.	7.50	3	1	0	7
9	4	2:30 P.M.	5:00 P.M.	10.00	3	0	1	1
11	4	2:00 P.M.	5:00 P.M.	12.00	5	4	0	4
15	6	3:25 P.M.	4:20 P.M.	5.52	1	0	0	0
16	3	1:15 P.M.	4:15 P.M.	9.00	0	0	0	2
17	3	11:00 A.M.	12:00 A.M.	3.00	2	2	0	1
17	2	12:00 A.M.	1:00 P.M.	2.00	0	0	0	1

17	6	12:30 P.M.	2:30 P.M.	12.00	3	1	0	3
18	5	10:45 A.M.	12:45 P.M.	10.00	1	1	0	0
24	4*	11:20 A.M.	3:55 P.M.	14.86*	5	5	0	0
25	5	11:45 A.M.	1:00 P.M.					
		1:40 P.M.	2:00 P.M.	7.90	3	2	0	3
31	6	11:00 A.M.	12.00 P.M.	6.00	0	0	0	0
Feb. 1	1	9:00 A.M.	1:50 P.M.	4.83	6	1	0	1
5	2	1:00 P.M.	4:00 P.M.	6.00	1	0	0	0
7	6	8:45 A.M.	11:15 A.M.	15.00	0	0	1	1
15	6	10:00 A.M.	12:10 P.M.					
		12:45 P.M.	2:05 P.M.	21.00	0	0	0	1
17	3	1:45 P.M.	4:45 P.M.	9.00	0	0	0	0
28	3	12:00 A.M.	2:15 P.M.	6.75	0	0	0	1
Nov.30-Jan 11								
Farm Workers		?	?	?	8?	4	?	?
Jan.27-Feb.23								
Trapped		-	-	-	11	5	-	-
Jan.27-Feb.23	shot**	-	-	-	7	1	-	-
Jan.27-Feb.23	snared	-	-	-	3	1	-	-
Jan.27-Feb.23	ferretted	-	-	-	2	2		

*All hunters did not hunt the entire time.

**While checking traps, snares, etc.

TABLE 9

SUMMARY OF RABBIT HUNTS KELLOGG BIRD SANCTUARY AND FARM--1953-1954
HICKORY CORNERS, MICHIGAN

*All hunters did not hunt the entire time.

Date	Number of Hunters	Starting Time	Finishing Time	Total Gun-Hours	Total Kill	Number Tagged Rabbits Bagged	Number Cripples That Escaped	Number Seen But Not Bagged
Dec. 16	3	2:15 P.M.	3:45 P.M.	4.50	4	3	0	5
16	4	1:40 P.M.	3:55 P.M.	5.00	9	8	0	9
18	3	3:35 P.M.	5:45 P.M.	6.51	5	2	3	7
19	5	9:55 A.M.	12:45 P.M.	14.15	7	6	2	3
19	4	2:00 P.M.	5:00 P.M.	12.00	8	3	0	4
19	3	2:15 P.M.	4:30 P.M.	6.75	2	2	0	15
20	3	9:50 A.M.	12:30 P.M.	8.00	3	2	1	4
23	3	1:45 P.M.	3:30 P.M.	6.75	0	0	0	1
30	2	1:45 P.M.	3:00 P.M.	2.50	4	3	0	1
31	4	1:45 P.M.	5:45 P.M.	16.00	3	1	0	1
Jan. 1	1	12:30 P.M.	2:30 P.M.	2.00	0	0	0	1
5	4*	9:30 A.M.	12.15 P.M.	9.25*	1	1	2	3
6	2	1:45 P.M.	3:30 P.M.	3.50	1	1	1	4
7	7	1:30 P.M.	5:30 P.M.	26.00	8	5	1	5
9	4	10:30 A.M.	12:40 P.M.					
		1:30 P.M.	4:00 P.M.	18.66	9	1	0	3
9	4	10:30 A.M.	12:30 P.M.					
		1:45 P.M.	4:30 P.M.	25.00	1	1	0	4
10	7	9:30 A.M.	10:30 A.M.	7.00	1	1	1	1
10	4	10:05 A.M.	12:05 P.M.	8.00	6	0	0	0
10	5	1:30 A.M.	5:15 P.M.	18.75	4	1	0	2
10	4	10:00 A.M.	12:10 P.M.	8.72	2	2	0	0
13	5	1:20 P.M.	5:00 P.M.	18.35	3	3	0	0
14	3	1:30 P.M.	4:40 P.M.	9.54	1	1	0	0
14	4	1:30 P.M.	4:45 P.M.	1.30	4	1	1	3
16	3	10:20 A.M.	12:00 A.M.	5.00	0	0	0	0
16	4	1:15 P.M.	4:05 A.M.	10.52	1	1	0	0
16	3	10.30 A.M.	12:00 A.M.	4.50	0	0	0	1
16	4	1.25 P.M.	4:00 P.M.	10.24	1	1	0	0
17	14	10:45 A.M.	1:00 P.M.	31.50	2	2	1	3
21	5	9:55 A.M.	12:25 P.M.	28.25	0	0	0	3
24	7	10:15 A.M.	12:30 P.M.					
		1:20 P.M.	4:00 P.M.	18.62	3	3	1	6
30	6	9:45 A.M.	11.50 A.M.	12.48	0	1	0	1
Jan. Farm Workers		-	-	-	11	7	?	-
Box Trapped		-	-	-	29	12	-	-
Snared		-	-	-	6	4	-	-
Steel Trapped					0	0		

TABLE 10

SUMMARY OF RABBIT HUNTS AT THE KELLOGG BIRD SANCTUARY AND FARM--1954 AND 1955-56
HICKORY CORNERS, MICHIGAN

Date	Number of Hunters	Starting Time	Finishing Time	Total Gun-Hours	Total Kill	Number Tagged Rabbits Bagged	Number Cripples that Escaped	Number Seen but Not Bagged
Dec. 10-16, 1954	Trapped				13	6	2	
Dec. 28, 1954	7	10:00 A.M.	12:15 P.M.	15.75	19	9	1	10
Dec. 28, 1954	7	1:05 P.M.	4:00 P.M.	20.44	21	11	2	11
Dec. 10, 1955	2-6	7:40 A.M.	5:15 P.M.	39.75	42	24	5+	*
Dec. 16, 1955	2-7	7:45 A.M.	4:25 P.M.	43.00	22	7	1	16
Dec. 19, 1955	5-6	8:25 A.M.	5:25 P.M.	41.41	22	11	0	11

*Not recorded.

TABLE 11

CONDITIONS UNDER WHICH HUNTS WERE CONDUCTED AT KELLOGG BIRD SANCTUARY AND FARM--1951-1952
HICKORY CORNERS, MICHIGAN

Date	Starting Time	Finishing Time	Dog Use	Temperature °F.	Snow Cover	Precipitation During Hunt	Character	Comments
Dec. 9	3:20 P.M.	5:30 P.M.	1 Golden Ret.	35	None	None	Clear	Hunter efficiency poor
12	9:05 A.M.	10:35 A.M.	None	24	2 1/2"	Light snow	Cloudy	Rabbits sitting very tight
12	2:00 P.M.	4:15 P.M.	None	25	3"	Med. hev. snow	Cloudy	Not sitting as tight as in A.M. Hunter efficiency better than on Dec. 9.
14	1:45 P.M.	3:35 P.M.	None	20	6"	Heavy snow	Cloudy	Rabbits concentrated in dense cover. 50-80% of flushed rabbits bagged.
15	1:15 P.M.	5:20 P.M.	None	15	12"	Heavy snow	Cloudy	Hunter efficiency cut down by cold.
16	10:15 A.M.	11:45 A.M.	None	5	14"	None	Partly cloudy	Hunters very elderly.
17	3:20 P.M.	4:30 P.M.	1 Golden Ret.	7	14"	Light snow	Cloudy	
18	1:45 P.M.	3:45 P.M.	1 beagle 1 Golden Ret.	20	15"	None	Clear	
19	2:30 P.M.	4:00 P.M.	1 Golden Ret.	20	15"	None	Cloudy	
21	1:35 P.M.	2:35 P.M.	1 Golden Ret.	17	20"	Mod. snow	Cloudy	
22	2:00 P.M.	3:30 P.M.	1 Golden Ret.	15	20"	None	Clear	
30	1:30 P.M.	4:30 P.M.	1 beagle	32	10"	None	Cloudy	
Jan. 5	10:20 A.M.	1:00 P.M.	1 Golden Ret.	35	5"	None	Cloudy	Hunter efficiency low.
6	10:00 A.M.	11:30	1 Golden Ret.	30	5"	None	Cloudy	
12	10:15 A.M.	3:15 P.M.	1 Golden Ret.	35	10"	None	Clear	
13	9:45 A.M.	4:30 P.M.	1 beagle	38	8"	None	Cloudy	Dog very helpful.
19	10:15 A.M.	3:45 P.M.	None	40	Scattered	Light rain	Cloudy	

TABLE 12

CONDITIONS UNDER WHICH HUNTS WERE CONDUCTED AT KELLOGG BIRD SANCTUARY AND FARM--1952-1953
HICKORY CORNERS, MICHIGAN

Date	Starting Time	Finishing Time	Dog Use	Temperature °F.	Snow Cover	Precipitation During Hunt	Cloud Cover	Comments
Dec. 14	9:45 A.M.	11:35 A.M.	None	28	2"	Light snow	Cloudy	
14	12:30 P.M.	1:15 P.M.	None	28	2"	Light snow	Cloudy	
14	2:00 P.M.	2:12 P.M.	None	28	2"	None	Cloudy	
15	9:30 A.M.	11:30 A.M.	2 Golden Ret.	33	2"	None	Cloudy	
18	1:30 P.M.	3:20 P.M.	1 Golden Ret.	38	Patches	None	Clear	
21	2:00 P.M.	4:10 P.M.	None	40	None	Rain	Cloudy	
23	9:30 A.M.	11:45 A.M.	None	45	None	Light rain	Cloudy	
23	1:15 P.M.	3:00 P.M.	1 Golden Ret.	45	None	Light rain	Cloudy	
24	10:55 A.M.	12:00 A.M.	1 beagle	35	None	None	Cloudy	
24	1:15 A.M.	3:00 P.M.	1 beagle	36	None	Scattered showers	Cloudy	
26	10:30 A.M.	11:45 A.M.	2 Golden Ret. 1 beagle	30	Scattered	None	Cloudy	
26	1:45 P.M.	4:45 P.M.	1 Golden Ret.	29	Scattered	None	Cloudy	
27	9:45 A.M.	12:45 P.M.	1 Golden Ret.	25	Scattered	None	Partly cloudy	
27	?	?	None	25	Scattered	None	Clear	
28	10:00 A.M.	12:00 A.M.	1 terrior	25	Scattered	None	Clear	
28	12:15 P.M.	3:05 P.M.	1 beagle 1 terrior	28	None	None	Partly cloudy	
29	12:10 P.M.	4:15 P.M.	None	35	None	None	Cloudy	
30	10:15 A.M.	12:15 P.M.	None	35	None	None	Cloudy	
30	1:30 P.M.	3:15 P.M.	None	37	None	None	Cloudy	
31	9:50 A.M.	12:10 P.M.	None	30	None	None	Cloudy	
31	1:20 P.M.	3:40 P.M.	3 beagles	37	None	None	Cloudy	
Jan. 2	9:35 A.M.	12:10 P.M.	2 beagles	34	None	None	Cloudy	
2	1:40 P.M.	4:50 P.M.	2 beagles	38	None	None	Cloudy	
3	12:15 P.M.	2:45 P.M.	2 beagles	35	Scattered	None	Cloudy	
9	2:30 P.M.	5:00 P.M.	1 Golden Ret. 1 cocker span.	32	3"	None	Cloudy	
11	2:00 P.M.	5:00 P.M.	1 beagle	34	2 1/2"	None	Cloudy	

	15	3:25 P.M.	4:20 P.M.	1 beagle	55	None	Light rain	Cloudy	
	16	1:15 P.M.	4:15 P.M.	1 beagle 1 Golden Ret.	25	None	None	Cloudy	
	17	11:00 A.M.	12:00 A.M.	1 Golden Ret.	30	Trace	None	Clear	
	17	12:00 A.M.	1:00 P.M.	1 Golden Ret.	30	Trace	None	Cloudy	
	17	12:30 P.M.	2:30 P.M.	None	30	Trace	None	Cloudy	
	18	10:45 A.M.	12:45 P.M.	3 beagles	32	.2 ice	None	Cloudy	
	24	11:20 A.M.	3:55 P.M.	1 terrier	35	.8"	Some snow	Cloudy	
	25	11:45 A.M.	1:00 P.M.						
		1:40 P.M.	2:00 P.M.	4 beagles	28	1"	None	Cloudy	
	31	11:00 A.M.	12:00 P.M.	None	40	None	None	Clear	
Feb.	1	9:00 A.M.	1:50 P.M.	None	22	1"	Snow	Clear	Shot while checking traps. Conditions ideal.
	5	1:00 P.M.	4:00 P.M.	1 beagle	40	None	None	Cloudy	
	7	8:45 A.M.	11.15 A.M.	None	40	None	None	Cloudy	
	15	10:00 A.M.	12:10 P.M.						
		12:45 A.M.	2:05 P.M.	None	40	None	None	Clear	Ferret used.
	17	1:45 P.M.	4:45 P.M.	None	20	Trace	Snow	Partly cloudy	Ferret used.
	28	12:00 A.M.	2:15 P.M.	None	40	Trace	Snow	Partly cloudy	Ferret used.

TABLE 13

CONDITIONS UNDER WHICH HUNTS WERE CONDUCTED AT KELLOGG BIRD SANCTUARY AND FARM--1953-1954
HICKORY CORNERS, MICHIGAN

Date	Starting Time	Finishing Time	Dog Use	Temperature °F.	Snow Cover	Precipitation During Hunt	Percent Cloud Cover
Dec. 16	2:15 P.M.	3:45 P.M.	None	20	.5"	None	0
16	1:40 P.M.	3:55 P.M.	None	20	.5"	None	0
18	3:35 P.M.	5:45 P.M.	None	25	?	Snow cover	100
19	9:55 A.M.	12:45 P.M.	None	30	.8"	None	5
19	2:00 P.M.	5:00 P.M.	1 beagle	30	.8"	None	5
19	2:15 P.M.	4:30 P.M.	1 Golden Ret.	35	.8"	None	5
20	9:50 A.M.	12:30 P.M.	None	40	.3"	Snow	100
23	1:45 P.M.	3:30 P.M.	None	25	2.0"	None	100
30	1:45 P.M.	3:00 P.M.	2 Golden Ret.	30	2.0"	None	5
31	1:45 P.M.	5:45 P.M.	1 beagle	25	2.0"	Snow	100
Jan. 1	12:30 P.M.	2:30 P.M.	1 beagle	30	2.0"	Snow	75
5	9:30 A.M.	12:15 P.M.	2 beagles	35	2.5"	Fine snow	100
6	1.45 P.M.	3:30 P.M.	None	32	3.5"	None	100
7	1:30 P.M.	5:30 P.M.	4 beagles	35	3.5"	None	100
9	10:30 A.M.	12:40 P.M.					
	1:30 P.M.	4:00 P.M.	2 beagles	30	3.0"	None	100
9	10:30 A.M.	12:30 P.M.	1 beagle,				
	1:45 P.M.	4:30 P.M.	1 terrior	30	3.0"	None	100
10	9:30 A.M.	10:30 A.M.	None	20	3.0"	None	100
10	10:05 A.M.	12:05 P.M.	1 beagle,				
			1 terrier	20	3.0"	None	80
10	1:30 A.M.	5:15 P.M.	1 terrier				
			1 beagle	20	3.0"	None	10
10	10:00 A.M.	12.10 P.M.	1 beagle	20	3.0"	None	80
13	1:20 P.M.	5:00 P.M.	1 beagle	15	4.5"	None	90
14	1:30 P.M.	4:40 P.M.	2 beagles	30	5.0"	Light snow	100
14	1:30 P.M.	4:45 P.M.	2 beagles	30	5. "	Light snow	100
16	10:20 A.M.	12:00 A.M.	2 beagles	28	6. "	Snow	100
16	1:15 P.M.	4.05 A.M.	2 beagles	28	6. "	Snow	100
16	10:30 A.M.	12:00 A.M.	None	28	6. "	Snow	100
16	1:25 P.M.	4:00 P.M.	1 beagle	28	6. "	Snow	100
17	10:45 A.M.	1:00 P.M.	None	15	3.5"	None	0
21	9:55 A.M.	12:25 P.M.	4 beagles	18	1.0"	None	0
24	10:15 A.M.	12:30 P.M.					
	1:20 P.M.	4:00 P.M.	2 beagles	34	Trade	Light rain	100
30	9:45 A.M.	11:50 A.M.	3 beagles	26	3.00	Slight snow	75

TABLE 14

CONDITIONS UNDER WHICH HUNTS WERE CONDUCTED AT KELLOGG BIRD SANCTUARY AND FARM--1954 AND 1955-56
HICKORY CORNERS, MICHIGAN

Date	Starting Time	Finishing Time	Dog Use	Temperature °F.	Snow Cover	Precipitation During Hunt	Percent Cloud Cover
Dec. 28, 1954	10:00 A.M.	12:15 P.M.	None	30	Trace	None	
Dec. 28, 1954	1:05 P.M.	4:00 P.M.	None	30	Trace	Light snow	
Dec. 10, 1955	7:40 A.M.	5:15 P.M.	None	30	.5-1"	Snow	95
Dec. 16, 1955	7:45 A.M.	4:25 P.M.	None	20	2-3"	None	50
Dec. 19, 1955	8:25 A.M.	5:25 P.M.	2-4 beagles	15	4-6"	None	0-50

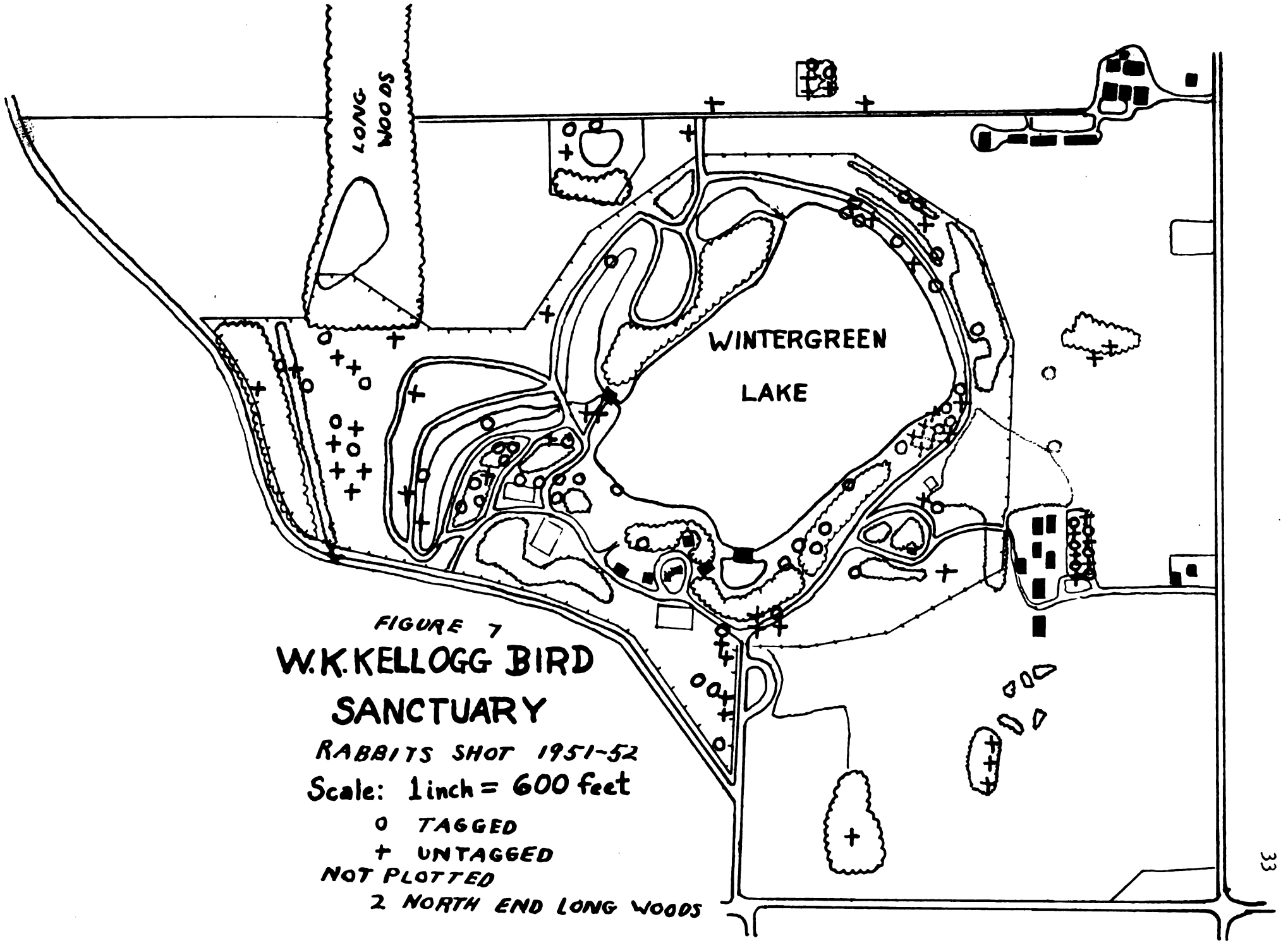


FIGURE 7

W.K. KELLOGG BIRD SANCTUARY

RABBITS SHOT 1951-52

Scale: 1 inch = 600 feet

0 TAGGED

+ UNTAGGED

NOT PLOTTED

2 NORTH END LONG WOODS

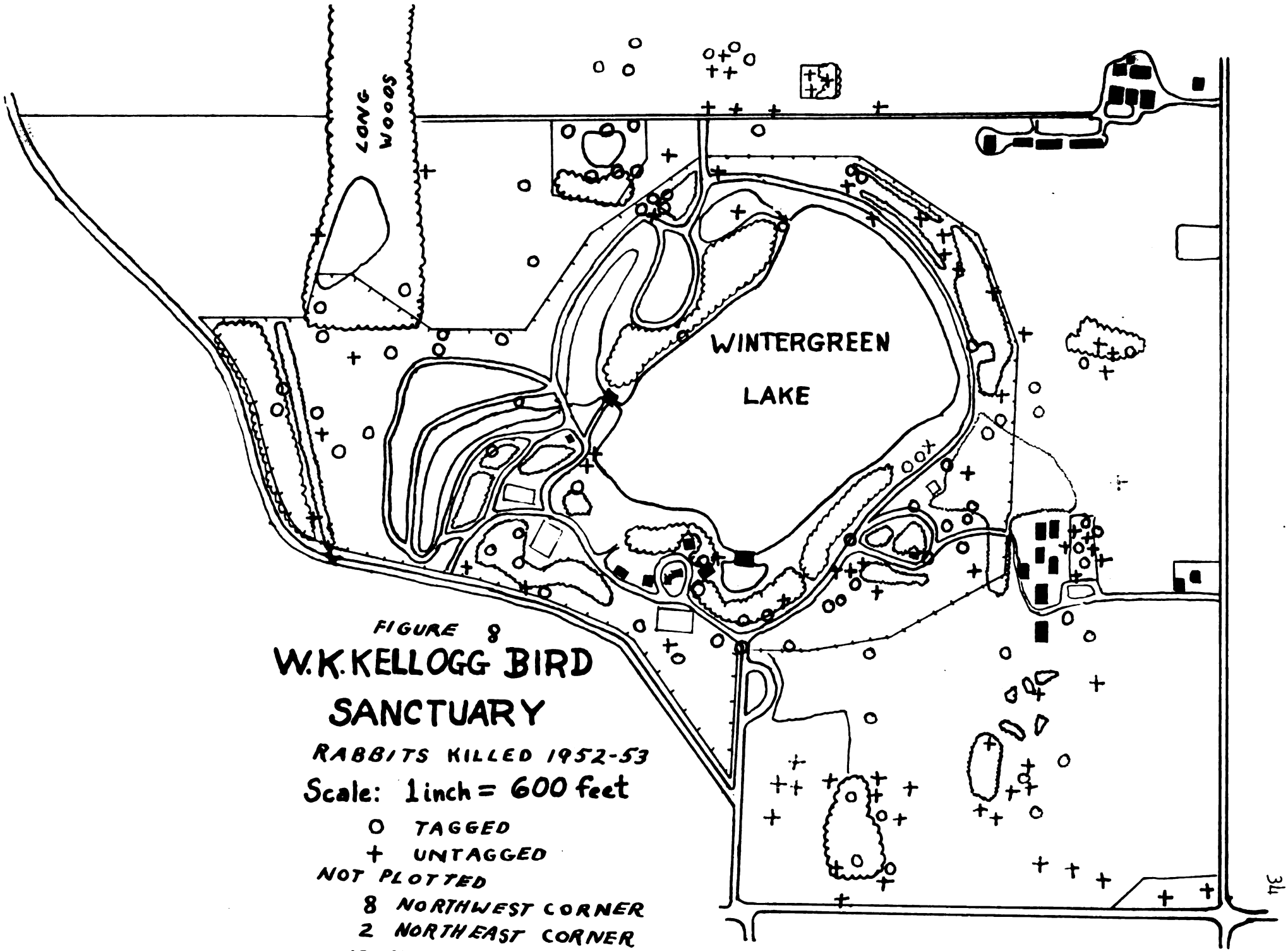


FIGURE 8

W.K. KELLOGG BIRD SANCTUARY

RABBITS KILLED 1952-53

Scale: 1 inch = 600 feet

O TAGGED

+ UNTAGGED

NOT PLOTTED

8 NORTHWEST CORNER

2 NORTHEAST CORNER

10 NORTH END LONG WOODS

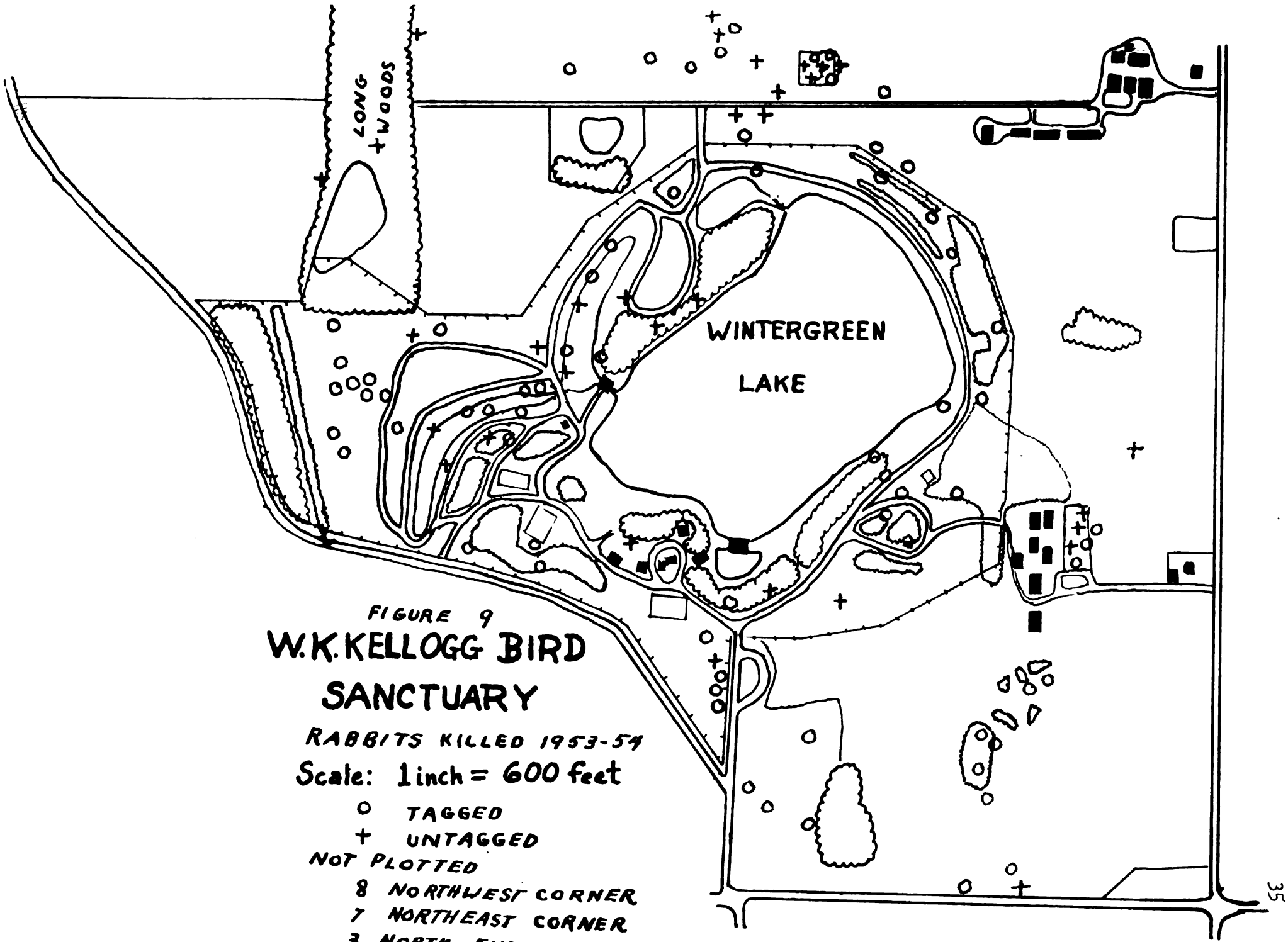


FIGURE 9

W.K. KELLOGG BIRD SANCTUARY

RABBITS KILLED 1953-54

Scale: 1 inch = 600 feet

o TAGGED

\+ UNTAGGED

NOT PLOTTED

8 NORTHWEST CORNER

7 NORTHEAST CORNER

3 NORTH END LONG WOODS

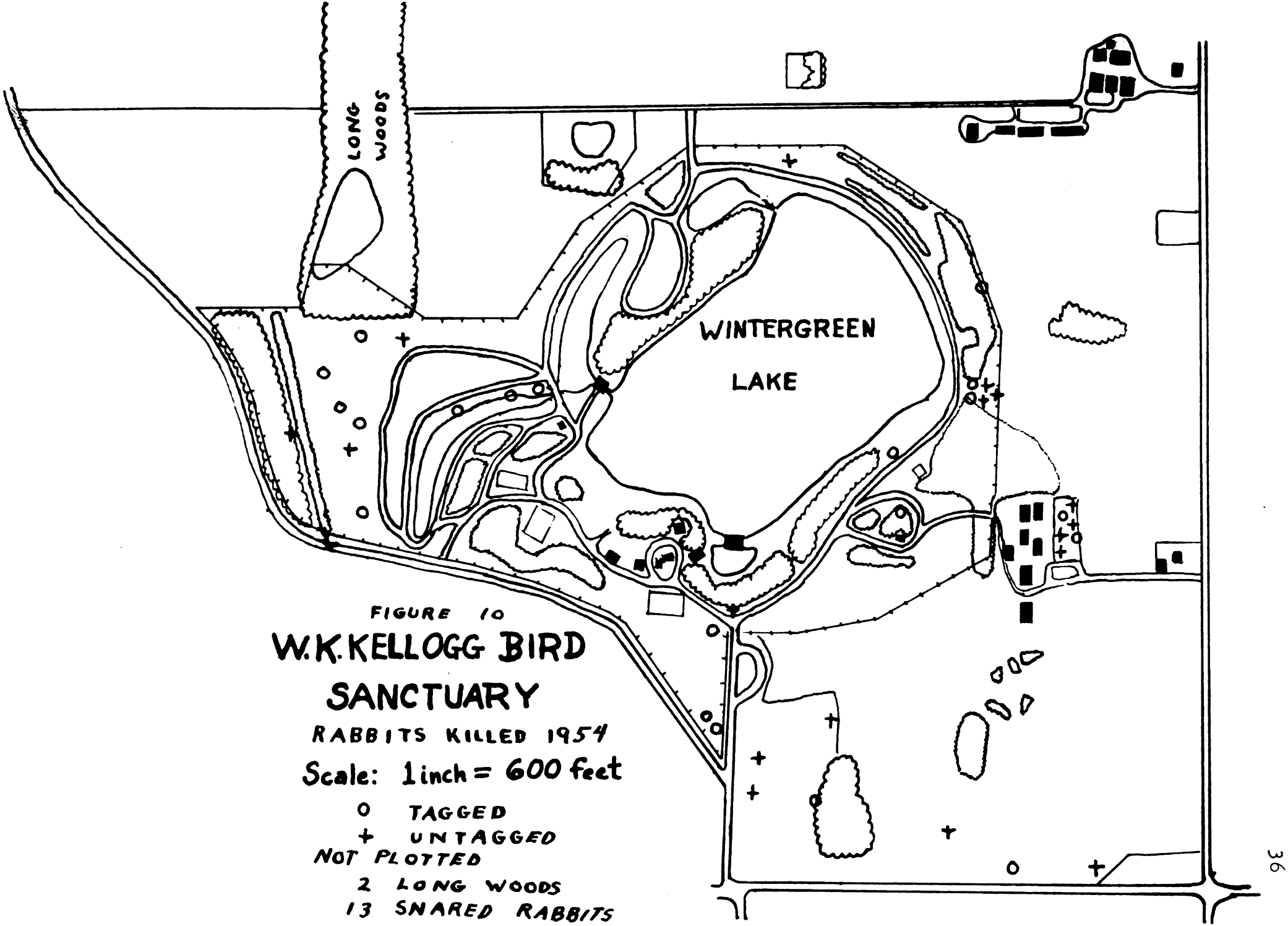


FIGURE 10

W.K. KELLOGG BIRD SANCTUARY

RABBITS KILLED 1954

Scale: 1 inch = 600 feet

o TAGGED

\+ UNTAGGED

NOT PLOTTED

2 LONG WOODS

13 SNARED RABBITS

POPULATION DYNAMICS

Population Measurements

Accurate population estimates, particularly of pre-hunting season populations were essential to the study. Population estimates and indexes were obtained by various methods. The results of these have been compared and evaluated.

Tagged: Untagged Ratio Estimates (Lincoln Index)

This census method was first used by Allen (1938b) to estimate the rabbit population on the Kellogg Bird Sanctuary and Farm. It involved live trapping and marking a portion of the population, then determining from the hunting kill the fraction of the population which had been marked. The population estimate (B) was obtained from the relationship:

$$\frac{\text{Number of Rabbits marked (A)}}{\text{Total population (B)}} = \frac{\text{Number of marked rabbits in sample (C)}}{\text{Total rabbits in sample (D)}}$$

Since three of the four quantities are known, the fourth (total population) is readily calculated. It may be noted that the values for C and D merely indicate the fraction of the population that was marked when the known number A was handled, consequently, actual values for C and D are important only in that sample size influences the reliability of the population estimate. The accuracy of this census method depends upon how closely the marked-unmarked ratio in the sample reflects that which actually existed in the population at the end of the marking period.

In order for the marked-unmarked ratio to be reliable the following conditions must be met:

1. Both marked and unmarked animals are equally likely to be sampled.
2. The mortality rate is the same in marked and unmarked animals between the time of marking and sampling.
3. Either sampling or marking is conducted uniformly throughout the study area.
4. Movements of animals out of or into the study area do not occur or do not change the marked-unmarked ratio that existed at the time of marking.

The number of marked animals in the population (A) applies to the time the marking was done, and the population estimate refers also to that time. This method does not measure the population size existing at the time the sampling was conducted. Because this is true, it was possible to mark rabbits at several times during the year and to obtain population estimates for those times from the segregated marked-unmarked ratios in the hunting kill. Details concerning estimates of this sort are tabulated in Table 15.

Theoretically, the marked-unmarked ratio could be determined by three types of sampling, (1) shooting, (2) sight observations of tail colors, and (3) live trapping. Geis (1955) showed that shooting provided apparently reliable and unbiased population samples, but that a uniform probability of capture by live traps did not occur. The third method of sampling therefore was ruled out.

TABLE 15

SUMMARY OF 1951-1952 LINCOLN INDEX DATA--KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Date Handled	Age	Number Marked	Number Marked Which Were Shot	Total Number Shot	Population Estimate
June	Adult	28	7	27	108
August	2 1/4 mo.	52	14	94	349
November	Adult	35	13	27	73
November	Juveniles	126	38	96	318
November	All ages	161	51	123	388
March	Adult	54	20	52	140

In 1953, in order to test the degree of agreement between the marked fraction in a shot sample and one based on sight observations of dyed tails, hunters were asked to report the number of rabbits seen but not bagged that had tails which were (1) white, (2) yellow or (3) not clearly seen. The agreement between population estimates obtained by the two methods was extremely close (Tables 16 and 17). On both study areas in 1953 the two population estimates differed by less than one rabbit. During 1954, both methods again were compared. At the Sanctuary the two estimates were 249.2 and 248.6. At the Forest the estimates were 395.9 and 413.8. In 1955 the agreement was again very close at the Kellogg Forest with the two estimates being 310.7 and 303.9. At the Sanctuary only 27 sight observations were made; consequently, the lack of agreement shown is not surprising. Thus in a total of five valid comparisons the total difference between estimates based on the two sampling methods was only 26 rabbits. This very close agreement indicates that both sampling procedures yield comparable results. Therefore, the yellow-tailed:white-tailed ratio from sight observations can be added to the tagged-untagged ratio in the hunting kill to increase the sample size upon which the marked fraction is based and thus increase the reliability of the population estimate. By dying tails at the same time that tagging is done, more efficient results are obtained with little increased labor.

When Lincoln Index population estimates are based on samples obtained by shooting or visual observation, several types of evidence that might indicate whether or not sources of error are being

TABLE 17

DATA USED TO ESTIMATE THE PRESEASON POPULATIONS--KELLOGG FOREST HICKORY CORNERS, MICHIGAN

Year	1951	1952	1953	1954	1955
Number bagged	267	196	245	206	176
Number recently marked rabbits bagged	66	67	72	64	81
Number tagged preseason	130	118	118	123	143
Number clearly seen but not bagged					
White			234	232	149
Yellow			96	97	129
Total			200	120	98
Number dyed preseason	0	0	117	122	141
Population estimate based on tagged-untagged ratio	526.0	345.2	401.5	395.9	310.7
Population estimate based on sight observation			402.2	413.8	303.9

encountered. One would be whether or not a change took place in the marked-unmarked ratio during the sampling period. If the marked fraction remained constant, it would seem likely that during that period (1) both marked and unmarked animals were equally sampled, (2) movement of animals to and from the study area did not cause a change in the marked-unmarked ratio, and (3) mortality was the same for both marked and unmarked animals. Data from the Kellogg Forest indicated especially well whether or not a change in the marked-unmarked ratio was likely to occur during the sampling period. This seemed true because:

1. Sampling was conducted over a long time (October 20 to January 31) and started the day after marking. Thus time was allowed for a differential movement or mortality between untagged and tagged animals to take place if it was going to do so.
2. Rabbit habitat was fairly uniformly distributed over the area, thus creating a situation more favorable for rabbit movements into or out of the study area than existed at the Sanctuary study area where the excellent rabbit habitat in the center of the area was largely surrounded by more open farm land.
3. More than half of the population was bagged by hunters each year. Therefore, if marked or unmarked rabbits were more likely to be collected a change in the marked fraction would certainly be evident during the hunting season.

Table 18 gives the marked-unmarked ratios observed during the 1953, 1954 and 1955 hunting seasons at the Kellogg Forest. They are tabulated here by three week intervals, except for the last six weeks which are combined because of the small numbers of observations late in the season. Neither the tagged-untagged ratio in the kill nor the yellow-tailed:white-tailed ratio among rabbits clearly seen but not bagged showed a consistent change during the season. It had been thought that a gradual decrease in the marked fraction might occur due to interchange of marked and unmarked animals around the edges of the area. No statistically significant tendency for this to take place was evident. Even the greatest drop in the marked fraction observed between the beginning and end of the season was not significantly different from that at the beginning. These data indicate that if such movement occurred it involved too few animals for the marked fraction to be seriously affected. It also seemed evident that marked animals did not differ from unmarked animals in their probabilities of being seen or shot or of dying naturally.

A second type of evidence concerning the reliability of Lincoln Index population estimates based on a shot sample has previously been published (Geis, 1955). In that study the known number of rabbits shot on two areas also was estimated from the rabbits' trapping records by the method described by Hayne (1949). Due to a non-uniform trap response these estimates were 45 and 43 percent of the population values known to be correct. The total population estimates obtained in the same way for the two areas were 40 and 47 percent of the total

TABLE 18

SUMMARY OF MARKED-UNMARKED RATIO CHANGES DURING THE 1953-1955 HUNTING SEASONS--KELLOGG FOREST AUGUSTA, MICHIGAN

Time Interval		Oct. 20-Nov. 9	Nov. 10-Nov. 30	Dec. 1-21	Dec. 22-Jan. 31
1953-54					
Kill	(Tagged	26	8	13	22
	(Total killed	82	46	35	70
	(Percent tagged	32	17	37	31
Seen	(Yellow tail	49	12	19	16
	(Total seen clearly	133	65	54	78
	(Percent marked	37	18	35	20
1954-55					
Kill	(Tagged	23	18	16	7
	(Total killed	75	49	55	20
	(Percent tagged	31	37	29	35
Seen	(Yellow tail	39	21	26	11
	(Total seen clearly	141	57	91	40
	(Percent marked	28	37	28	28
1955-56					
Kill	(Tagged	34	23	17	8
	(Total killed	73	43	33	23
	(Percent tagged	46	53	53	35
Seen	(Yellow tail	87	16	19	7
	(Total seen clearly	180	44	36	20
	(Percent marked	48	36	53	35

population estimates based on the tagged-untagged ratio in the hunting kill. Thus, there was relatively close agreement in the degree of error (1) when estimating the known number of rabbits shot from the trapping records of that partial population and (2) when estimating the total number present from all trapping records in comparison to the number estimated by means of the ratio of marked rabbits among the shot animals. If the trap response of shot rabbits is representative of that of the total population, then this consistency of underestimation indicates that the total population estimates based on the tagged-untagged ratio in the hunting kill were accurate.

A third type of evidence concerning the accuracy of this census method was obtained by estimating the pre- and post-hunting season populations and determining that the difference between them approximately equaled the known hunting kill. During the fall of 1954, 96 rabbits were marked on Kellogg Bird Sanctuary proper. Sight observations made before shooting indicated that 56% of 113 observations were of yellow-tailed rabbits which yielded a pre-hunting season population estimate of 172 for that area. Fifty-three rabbits then were bagged or trapped of which 29 or 55% had yellow tails. Therefore, the number of yellow-tailed rabbits remaining in late December was about 67. During the following May and June, 62 or 58% of 107 observations made on Kellogg Bird Sanctuary were of yellow cottontails. This led to a post-hunting season population estimate of 116 or 56 less than the pre-hunt estimate. The agreement of the known kill (53) is regarded as evidence supporting the accuracy of this method. The agreement of

the marked fraction in December observations (56%) with those in the shot sample (55%) and those five to six months later in May and June (58%) is another way of expressing these constant results.

All evidence gathered in this study indicated that population estimates made by the Lincoln Index method in which rabbits are live trapped, marked, released, and then sampled either by shooting or by making tail color observations, were reliable within the limits of sampling variation. Not only did quantitative evidence indicate the accuracy of this method but also its application yields logical results which were in harmony with field observations.

Hunting Results

DeLury (1941, 1951) presented methods for estimating the size of an animal population from the decrease in yield per unit effort that occurs as the population is harvested. His methods are based on the assumptions that:

1. Harvestibility remains constant.
2. The population is closed, i.e., natural mortality, recruitment and the like are insignificant.

Rabbit hunting data would seem to satisfy these assumptions if these largely interrelated circumstances prevailed:

1. Hunting conditions that influence success are fairly constant.
2. Hunting pressure is heavy over a short season.
3. The fraction of the population harvested is large.
4. Movements during the season has no influence on hunting success.
5. Unknown natural mortality is insignificant.

Rabbit hunting seasons in Michigan, however, are long and occur under widely varied conditions. Often hunting success is better at the end of the season than at the beginning. Consequently, the DeLury method under most circumstances could not be used to estimate rabbit numbers here.

At the Sanctuary study area, however, hunting was conducted in an atypical manner. Hunting did not start until December but then was intense. A pronounced drop occurred in the rate of kill as the harvest progressed which indicated that the DeLury census method might logically be applied. For the 1951, 1952, 1953 and 1955 hunting seasons, hunting effort data were divided into groups of approximately 25 gun-hours and the rate of kill calculated for each interval. Preseason population estimates were obtained graphically by plotting the rate of kill on the abscissa against the number of rabbits known to have been removed on the ordinate. At the point where the line fitted to these points crossed the ordinate the entire population theoretically would have been harvested, and therefore that point indicated the pre-hunting season population level. Figures 12 and 13 show both the kill per 100 gun-hours and rabbits seen per 100 gun-hours plotted against the number of rabbits previously removed during the 1952 and 1953 harvests. Both indexes of abundance yielded about the same population estimates. In 1951 and 1955, less hunting took place and only the kill per 100 gun-hours was used as an index of abundance. Observations for these years are plotted in Figure 14. In 1954 only one hunt took place and consequently this census method could not be applied.

FIGURE 12

FALL POPULATION ESTIMATES BY DE LURY METHOD

KELLOGG BIRD SANCTUARY AND FARM 1952

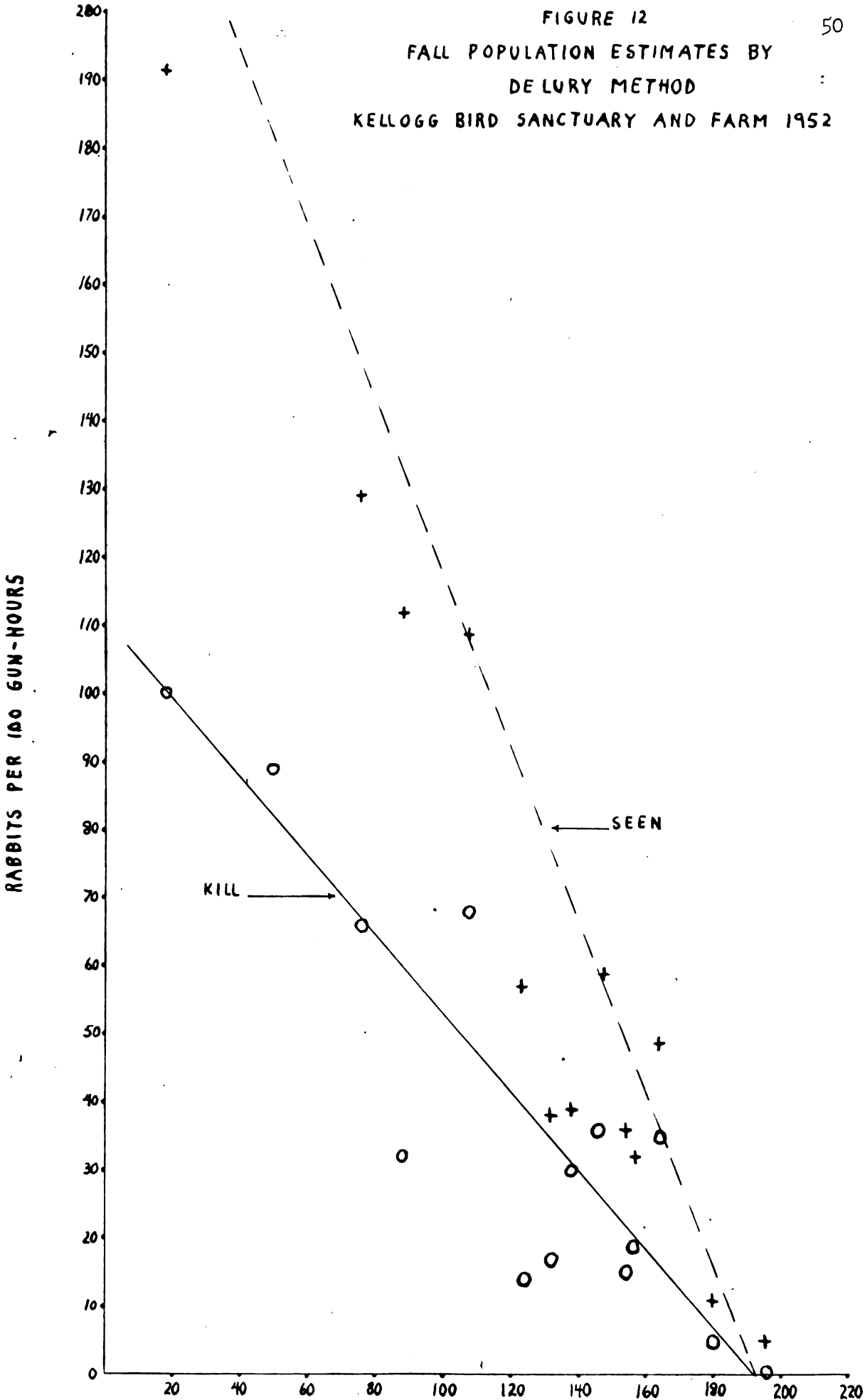


FIGURE 13

FALL POPULATION ESTIMATES BY

DE LURY METHOD

KELLOGG BIRD SANCTUARY AND FARM 1953

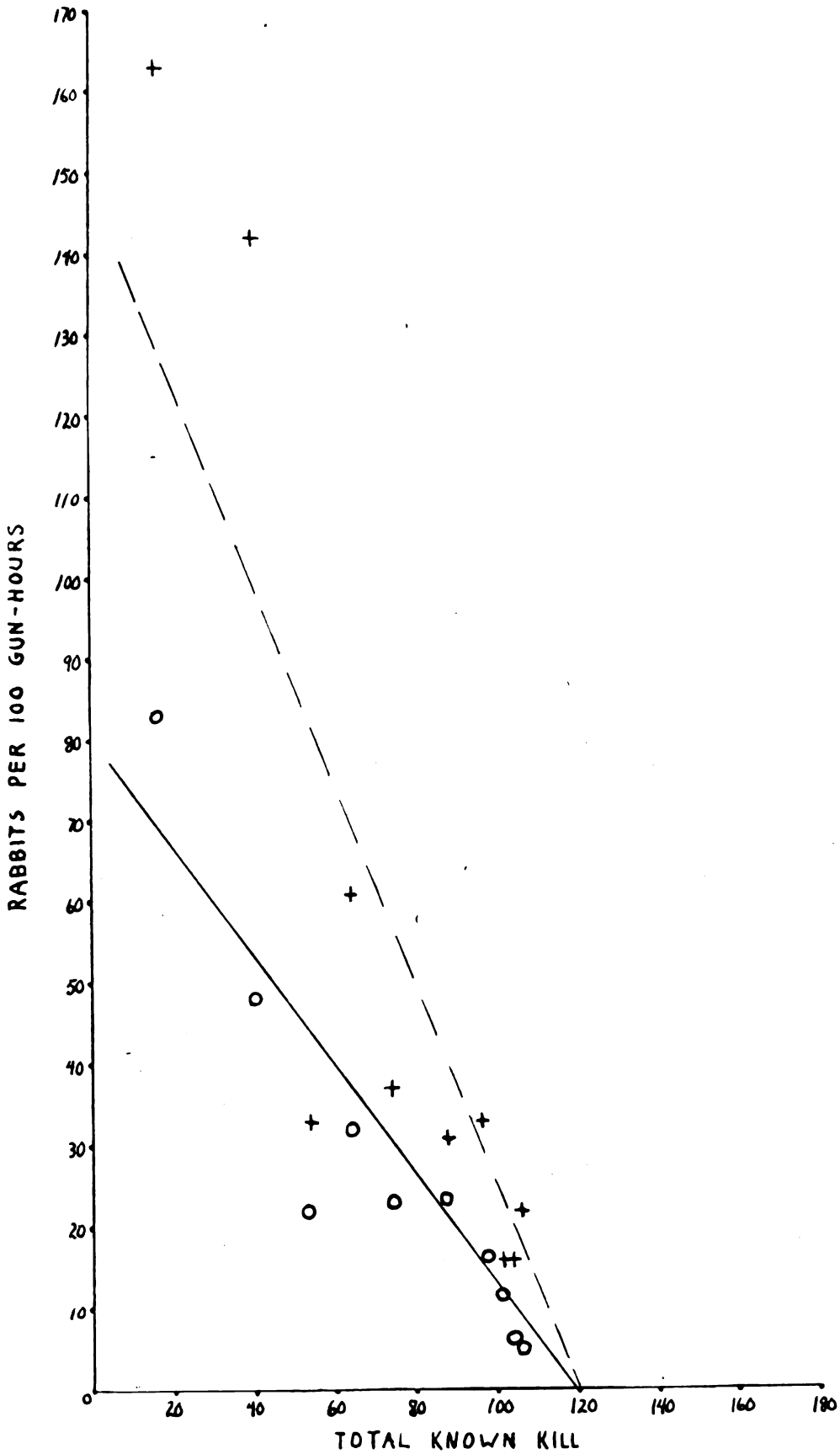


FIGURE 14

FALL POPULATION ESTIMATE BY

DE LURY METHOD

KELLOGG BIRD SANCTUARY AND FARM 1951, 1955

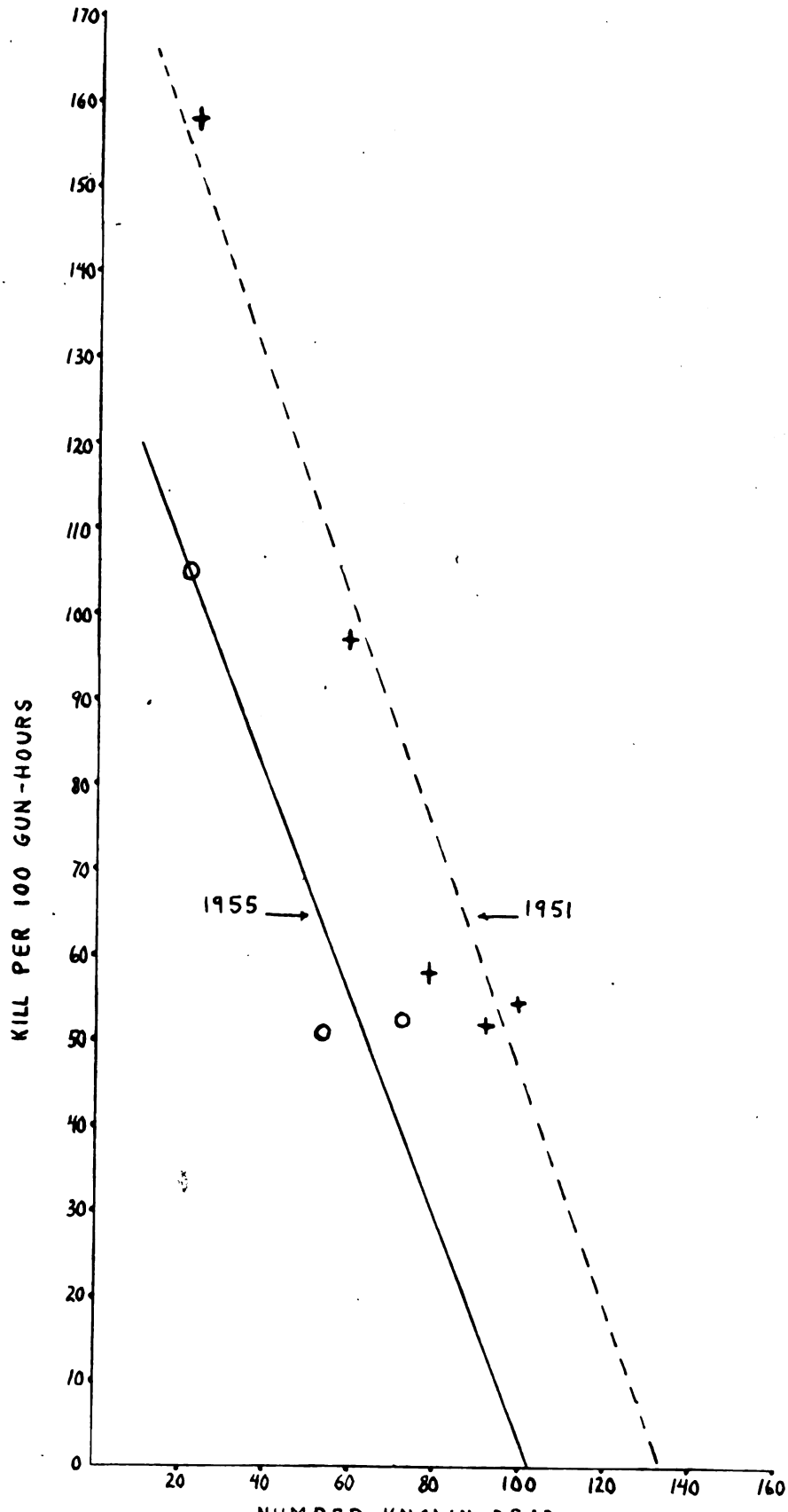


Table 19 compares population estimates by the DeLury method with those obtained by the Lincoln Index method. If the Lincoln Index values are correct, and the evidence overwhelmingly indicates that they are, then the population estimates based on changes in hunting yield consistently underestimated the population from 43 to 64 percent for the four years considered. The most likely explanation for this discrepancy is that harvestibility did not remain constant. Harvestibility may have changed during the shooting period because of an unequal probability of being shot among the various animals in the population.

Although this census method did not yield accurate population estimates, it was fairly consistent in its degree of underestimation. Therefore, if no trapping had occurred before the shooting period at the Sanctuary study area, a fair approximation of the fall population probably could have been obtained by doubling the DeLury population estimate. To illustrate this procedure hunting statistics for the 1946 hunting period collected by Pirnie (unpublished data) were used. The DeLury population estimate from these data was 120 (Figure 15). Doubling this a preseason population estimate of 240 was obtained which indicated a 37 percent kill. This population estimate and percentage kill is reasonable judging from observations made later when more data were available.

It can be concluded that the DeLury census method yields population estimates that are far too low. Values obtained seemed to fairly constantly underestimate the population and may provide reliable indexes of abundance.

TABLE 19

LINCOLN INDEX AND DELURY PRESEASON POPULATION ESTIMATES COMPARED
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

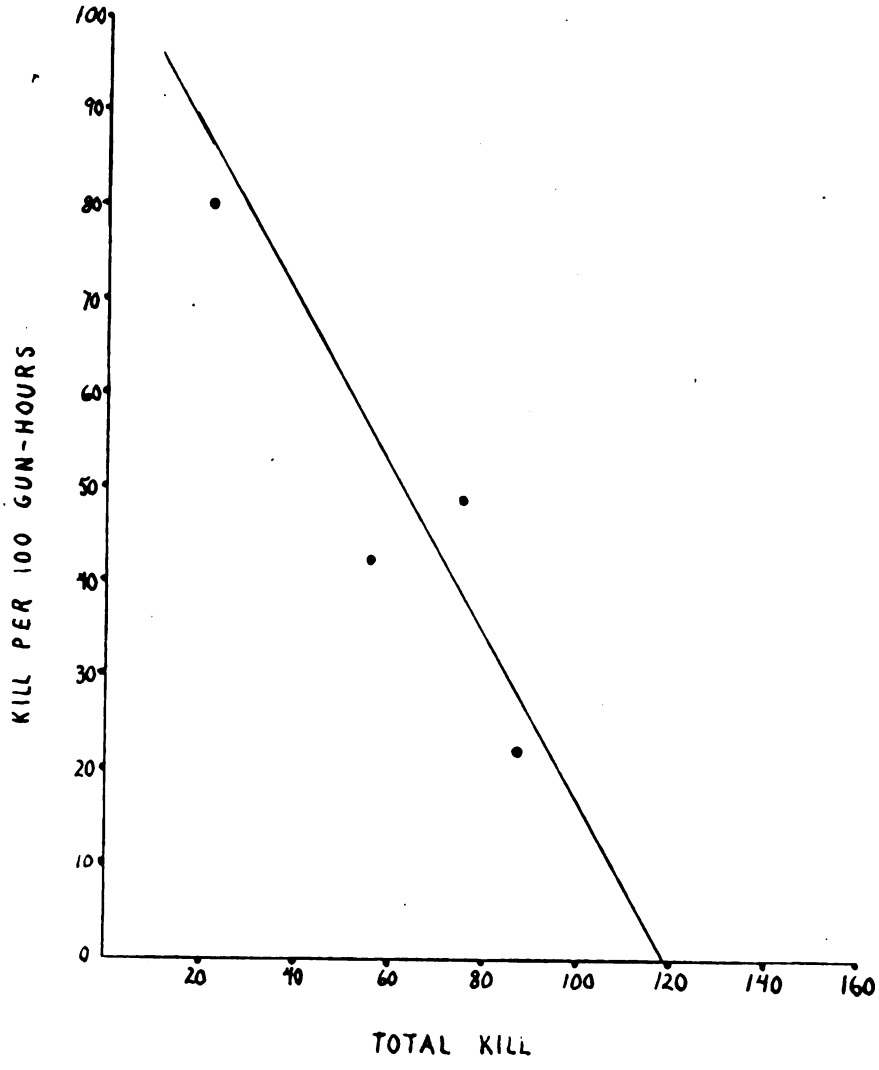
Year	Lincoln Index	DeLury	Percent Error in DeLury Method
1951	388	135	-65
1952	365	190	-48
1953	230	120	-48
1955	194	110	-43

FIGURE 15

FALL POPULATION ESTIMATE BY

DE LURY METHOD

KELLOGG BIRD SANCTUARY AND FARM 1946



Indexes of Abundance

Several types of data that could be used as indexes of abundance were collected during this study. These indexes were compared to population estimates believed to be reliable in order to appraise their accuracy. These data were of three main types: hunting kill statistics, live-trapping results and fall age ratios.

Hunting Kill Statistics

Hunting kill statistics were viewed in several ways. The accuracy with which the total kill, kill during a constant effort, and average rate of kill, reflect population levels was evaluated for both study areas. These indexes and the values upon which they were based are shown in Tables 20 and 21.

1. Total kill

Figure 16 shows a very strong positive correlation between the total kill and population level at the Forest. At the Sanctuary the total kill was also directly related to the population present but not as closely as at the Forest. In 1952 the kill was higher and in 1954 lower than would be expected from the known population level. These discrepencies can be explained by variations in hunting effort. 1952 had over twice the normal effort and 1954 had only about one-fourth the normal amount. It is important to observe that the total kill closely reflected population trends despite great fluctuations in hunting effort. The reason for this was that after about 140 gun-hours the rate of kill was very low. Consequently, the great increases in

TABLE 20

KILL STATISTICS AND INDEXES OF ABUNDANCE
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Year	Lincoln Index Estimate	Total Kill	Total Kill/Total Hours		Kill/Normal Effort	
			Hours	K/T-H per 100 G. H.	Kill	Hours
1951	388	123	146.1	84.2	123	146
1952	365	145	377.6	38.4	105	147
1953	230	94	374.0	25.1	65	167
1954	249	40	36.2	110.5		
1955	194	86	124.2	69.2	86	1242

TABLE 21

KILL STATISTICS AND INDEXES OF ABUNDANCE--KELLOGG FOREST
AUGUSTA, MICHIGAN

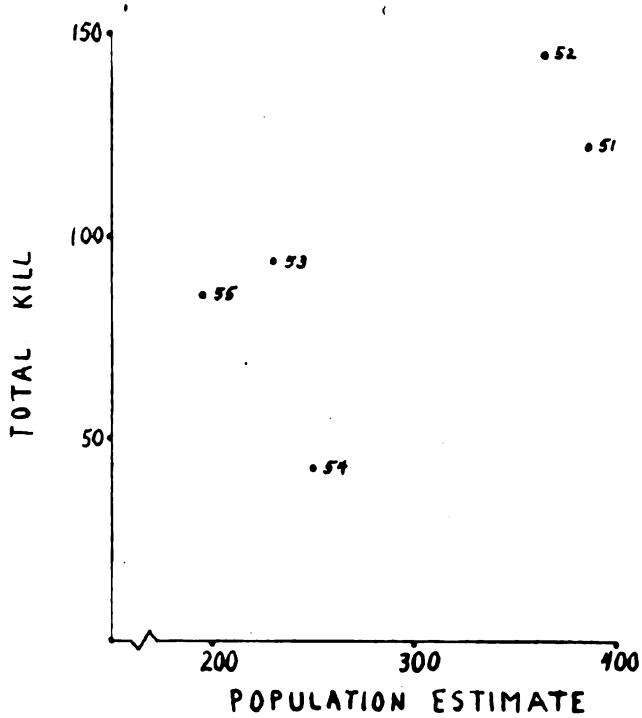
Year	Population Estimate	Total Kill	Total Kill/Total Hours		Kill/1st 1000 G.-H.		
			Hours	K/T-H (per 100 gun-hours)	Kill	Hours	K/1st 1000 G.-H. (per 100 G.-H.)
1951	526	267	2114	12.1	115	997	11.5
1952	345	196	2056	8.9	75	1006	7.4
1953	402	245	2310	10.1	91	993	9.2
1954	396	206	2349	8.8	80	994	8.0
1955	311	175	2229	7.8	69	1001	6.9

FIGURE 16

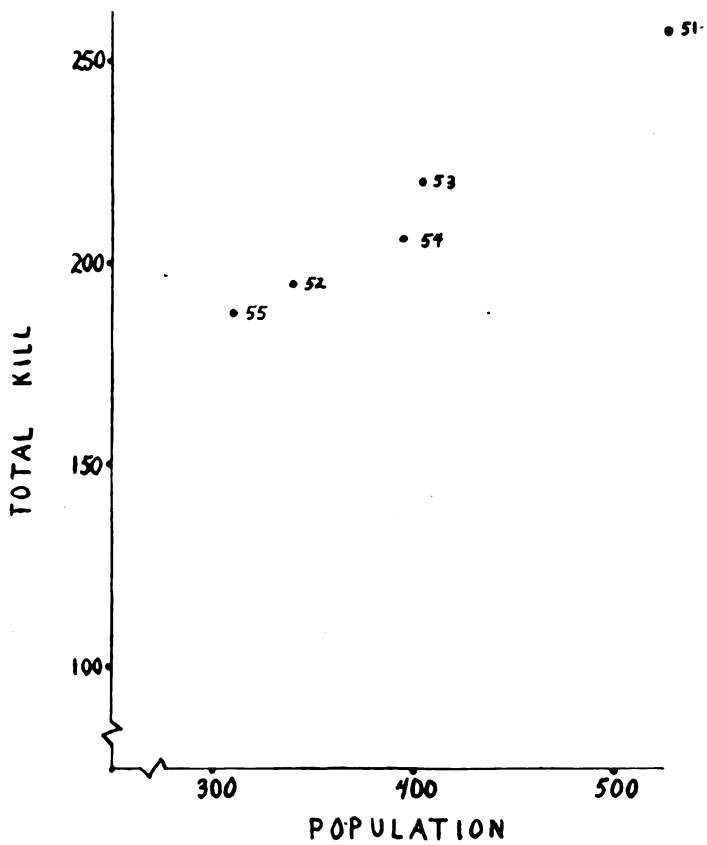
TOTAL KILL

COMPARED TO FALL POPULATION ESTIMATES

KELLOGG BIRD SANCTUARY AND FARM



KELLOGG FOREST



effort in 1952 and 1953 caused relatively small increases in the total kills. Therefore, the total kill was a somewhat useful index of abundance even when the total effort was not constant; and probably was an accurate index when the hunting effort was fairly uniform.

2. Kill during a constant effort.

Some of the variability shown above was due to differences in hunting effort. To avoid this difficulty the indexes considered here are based on comparable amounts of effort each year. At the Forest this effort was the first 1000 hours hunted. At the Sanctuary it was the "normal effort" of about 140 to 150 hours. This was selected as normal because it approximated the annual effort expended during the period 1932 to 1951. Because the effect of hunting pressure was being evaluated, hunting pressures other than the normal amount were applied in 1952, 1953 and 1954. During 1952 and 1953, a much heavier pressure was exerted so the kill for the normal effort was that made during about the first 150 hours of hunting. In 1954 only 36 hours were hunted. Since the kill during the normal effort would have to be estimated by a questionable extrapolation none was estimated for 1954. In 1951 and 1955 the total effort approximately equaled the normal effort so both kills were the same.

At the Sanctuary this index is expressed as the total kill so that the values are comparable to those recorded from 1932 to 1950 when hunting effort data were not available. At the Forest the index is given in terms of kill per 100 gun-hours.

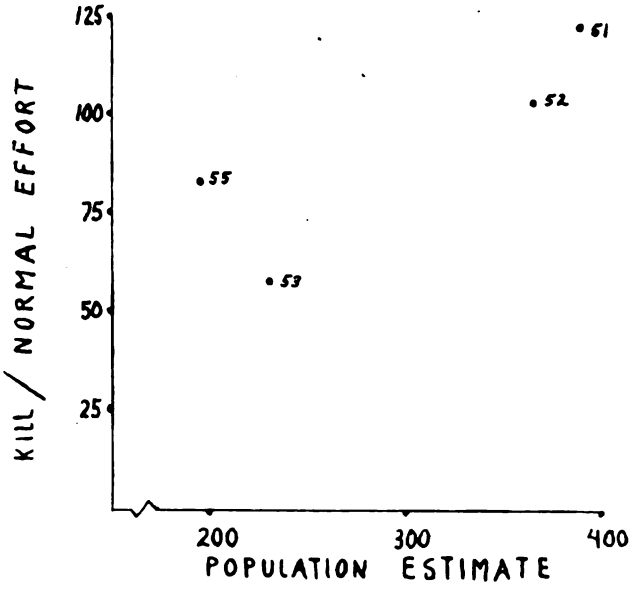
When the kill during a constant effort was compared to known population levels, a close positive relationship was evident on both

study areas (Figure 17) except for 1955 at the Sanctuary when the kill was too high. The reason for this discrepency seems to be as follows. During 1951 through 1953 most of the hunters were hunting for recreation. Some were elderly men physically unable to flush the maximum number of rabbits per hour hunted. Also, shooting accuracy often was poor. During 1955(and 1954 when total effort was decreased) rabbits were hunted only by those people connected with the rabbit research project. Rabbits were collected as quickly and efficiently as possible. The rates of kill in 1954 and 1955 (Table 17) were relatively higher thanin 1951, 1952 and 1953. If there had not been a marked change in hunter effectiveness during this study, it seems reasonable to believe that the kill made during fairly comparable amounts of effort would be a reliable index of abundance. Thus the total kills recorded by Pirnie (1949) from 1932 through 1947 and by Staebler from 1948 through 1950 are regarded as fairly accurately reflecting the fall population levels that existed from 1932 through 1950. It was the intention of both of these successive Kellogg Bird Sanctuary directors to keep hunting pressure constant each year and it is very unlikely that small variations in the effort from year to year could have greatly influenced size of the kill. This is especially true when it is realized that since the rate of kill at the end of the shooting period is low, even moderately large fluctuations in effort would influence the total kill very little. On both study areas the kill during a constant hunting pressure was apparently a satisfactory index of fall rabbit abundance.

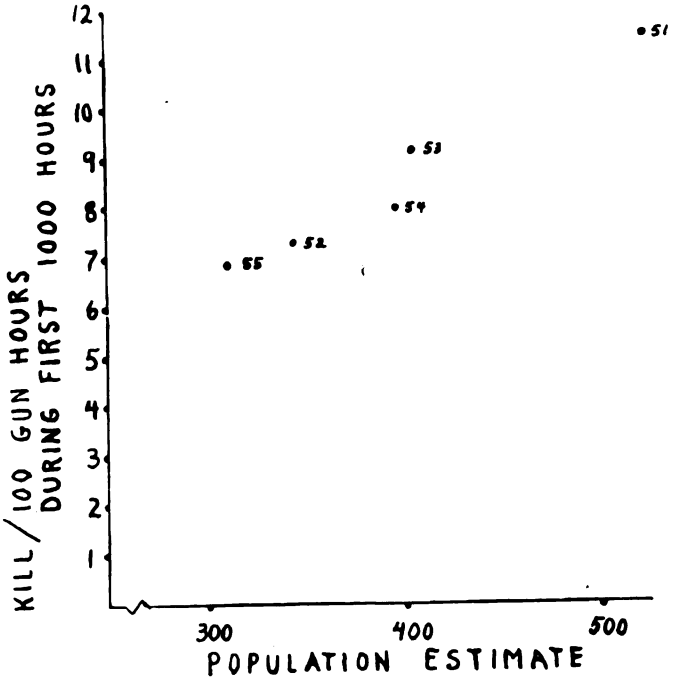
FIGURE 17

KILL DURING CONSTANT HUNTING EFFORTS
COMPARED TO FALL POPULATION ESTIMATES

KELLOGG BIRD SANCTUARY AND FARM



KELLOGG FOREST



3. Average rate of kill.

At the Sanctuary the rate of kill based on the total kill and total effort indicated very little correlation with population density (Figure 18). Wide variations in hunting effort and the change that occurred in hunter effectiveness in 1954 and 1955 was responsible for this. In contrast, rate of kill at the Forest showed a close correlation with population density. This would be expected since the effort was fairly constant each year. When based on wide variations in total effort the rate of kill is an unreliable index of abundance.

Trapping Data

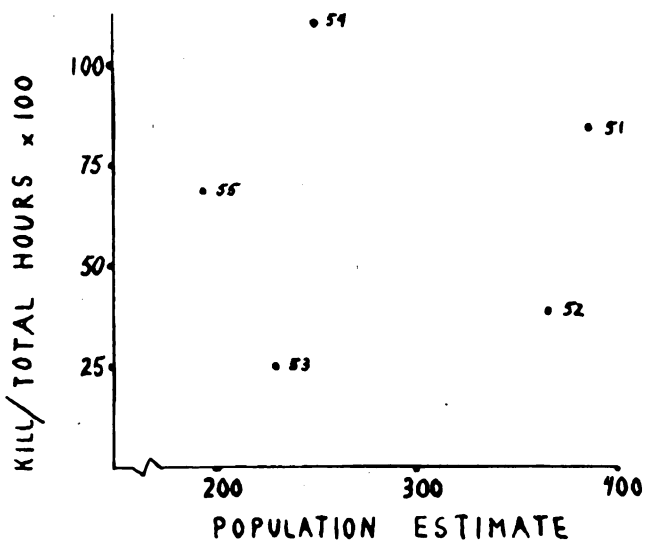
Four indexes to fall rabbit abundance were considered for both study areas: (1) total individuals tagged, (2) total captures (including repeats), (3) individuals handled per 100 trap-nights, and (4) total captures per 100 trap-nights. These data are tabulated along with population estimates in Tables 22 and 23.

At the Sanctuary (Figure 19), the total rabbits captured seemed to be a fairly reliable index to fall abundance. The total times rabbits were handled was less satisfactory because 1951 was high, and the two rates of capture also did not show a regular pattern when compared with population size. The chief reason for the unreliability of these indexes was the very high rate of capture in 1951. A heavier snow cover then perhaps was responsible for this. Allen (1938b) indicated that snow cover had a marked influence on trap success. These data indicate that the total number of animals captured probably accurately

FIGURE 18

RATES OF KILL
COMPARED TO FALL POPULATION ESTIMATES

KELLOGG BIRD SANCTUARY AND FARM



KELLOGG FOREST

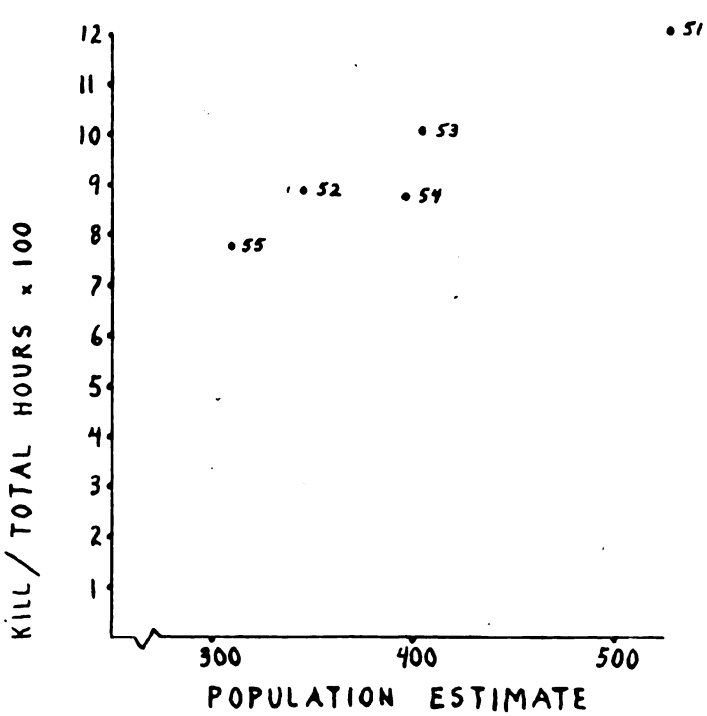


TABLE 22

TRAPPING DATA INDEXES OF ABUNDANCE--KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Year	Population Estimate	Total Ind. Captured	Total Times Rabbits Handled	Trap Nights	Ind./100 Trap Nights	Captures/100 Trap Nights
1951	388	161	462	1835	8.8	25.5
1952	365	129	290	2695	4.8	10.8
1953	230	123	213	2208	5.6	9.6
1954	249	120	208	1965	6.1	10.6
1955	194	97	157	1679	5.8	9.4

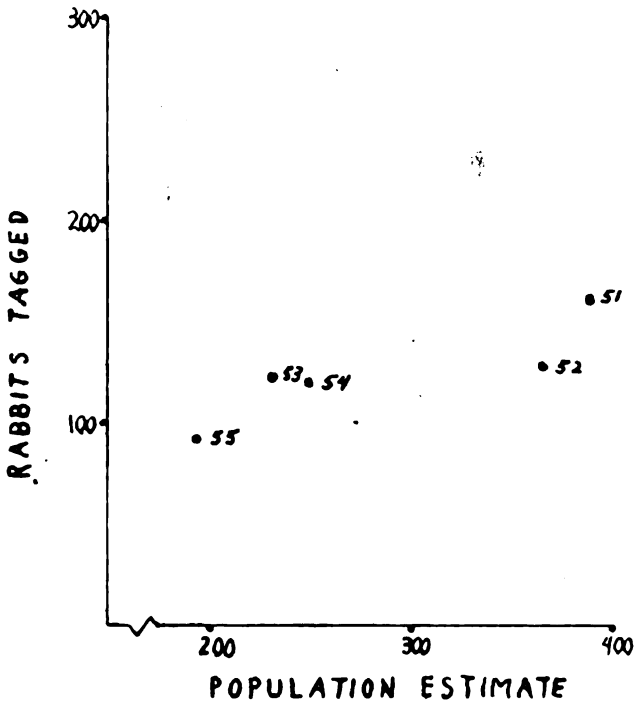
TABLE 23

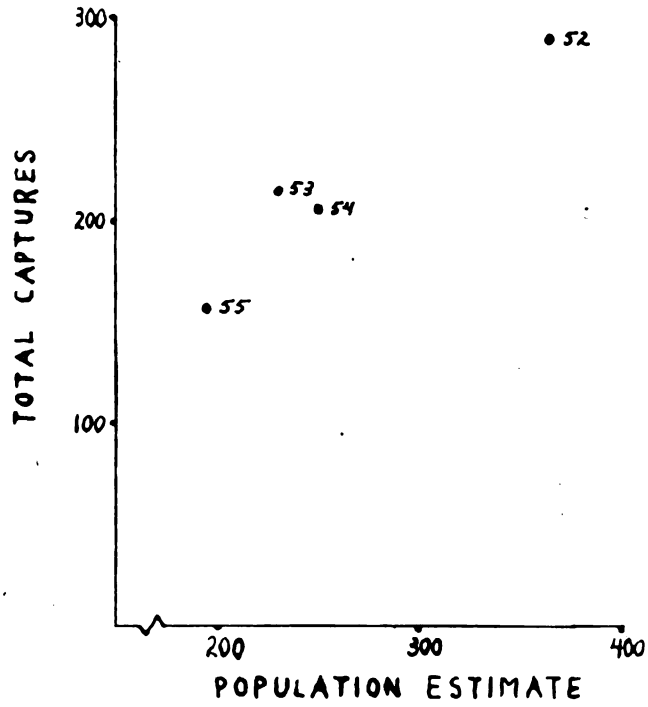
TRAPPING DATA INDEXES OF ABUNDANCE--KELLOGG FOREST
AUGUSTA, MICHIGAN

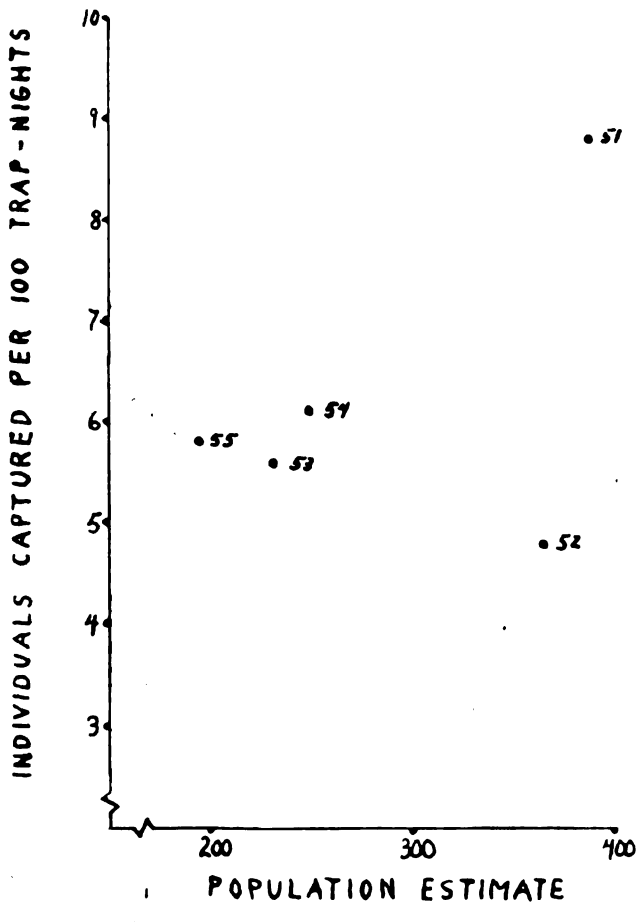
Year	Population Estimate	Total Ind. Captured	Total Times Rabbits Handled	Trap Nights	Ind./100 Trap Nights	Captures/100 Trap Nights
1951	526	130	164	2293	6.6	7.2
1952	345	118	167	2518	4.7	6.6
1953	402	117	150	2307	5.1	6.5
1954	396	123	177	2300	5.3	7.7
1955	311	143	241	2682	5.3	9.0

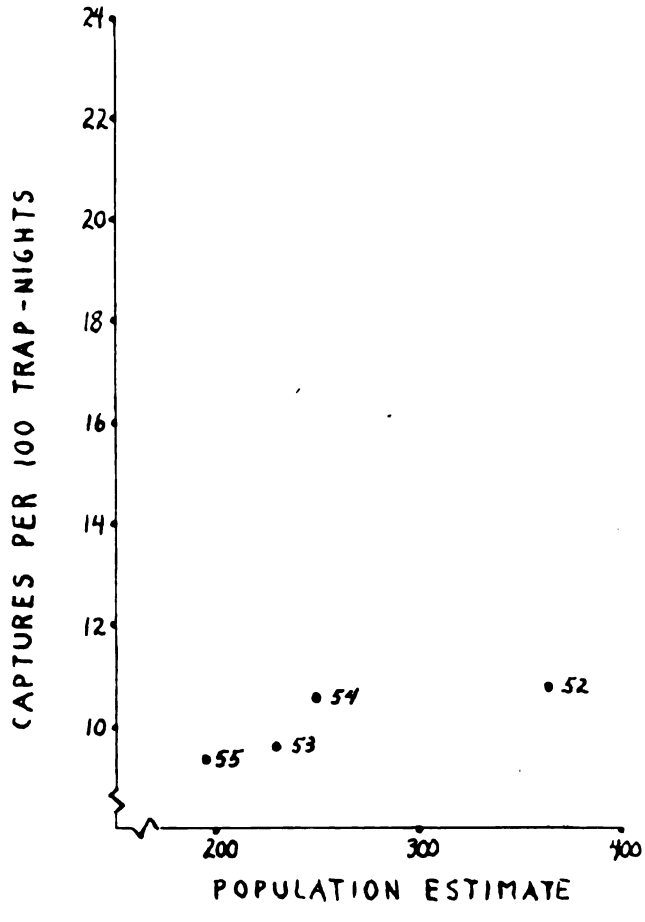
FIGURE 19

FALL TRAPPING DATA INDEXES OF ABUNDANCE
COMPARED TO PRESEASON POPULATION ESTIMATES
KELLOGG BIRD SANCTUARY AND FARM









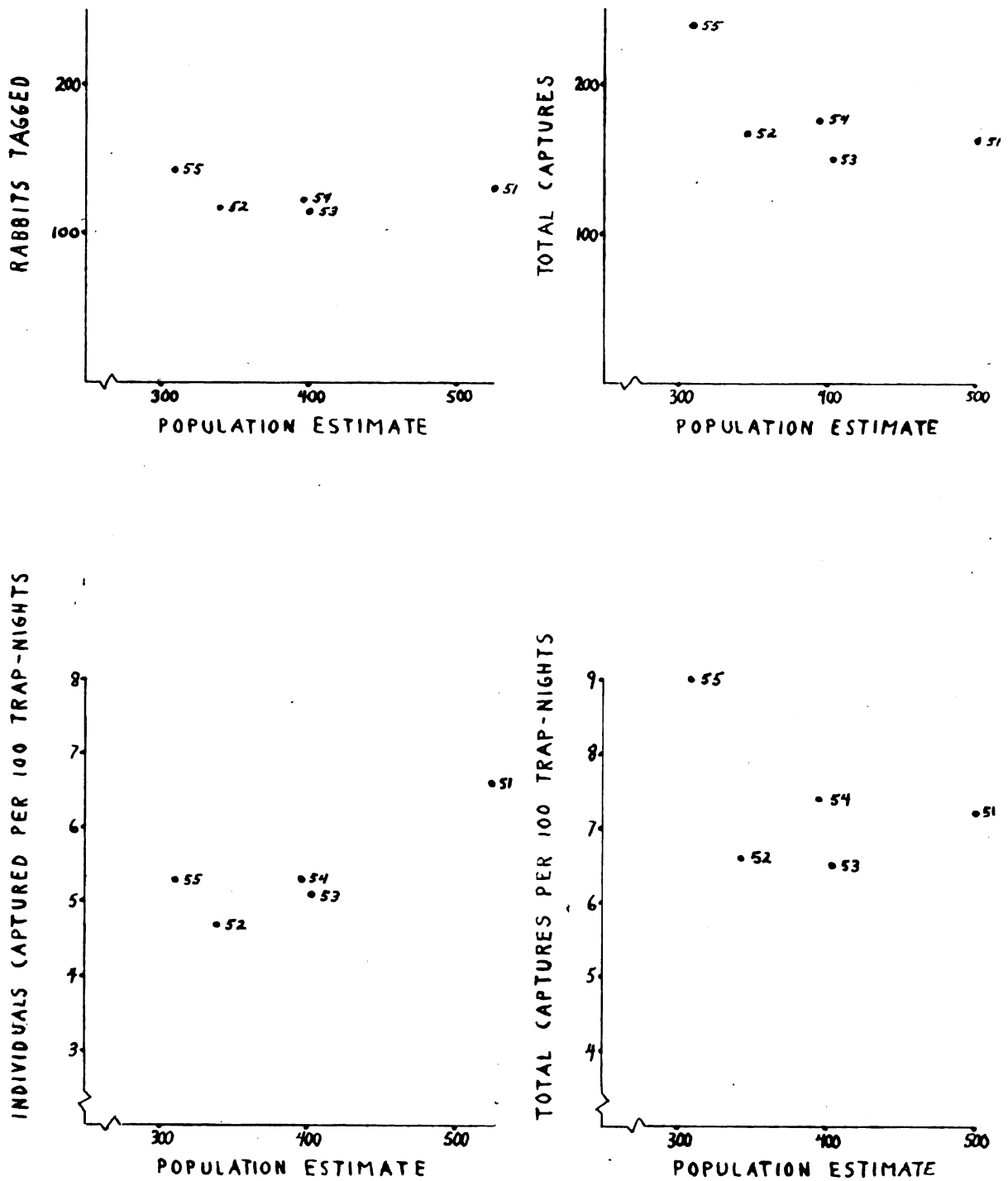
reflects the population density if the trapping is conducted under fairly constant conditions.

The accuracy of the individuals captured per 100 trap-nights was reasonably good, except for 1952 (Figure 19). The rate of capture that year was retarded because one trap line was conducted 22 days instead of the usual ten or twelve. This led to a marked accumulation of effort with little increase in the number of individuals captured during the last 12 days of the trapping period. However, this did not account for the entire reduction because if the last 12 days were omitted the rate of kill would still be only 5.7. The complete explanation is unknown.

At the Kellogg Forest (Figure 20) all trapping statistics were very unreliable indexes of abundance. In fact, the number of rabbits handled, total captures and total captures per 100 trap-nights all suggest an inverse relationship between the population index and the population density. Except for 1955 the number of individuals handled per 100 trap-nights fairly accurately seemed to reflect population levels. Since the individuals handled per 100 trap-nights is influenced by the total trapping effort, it is necessary for these values to be based on comparable amounts of trapping effort. The total effort at the Forest was constant during this study; therefore, the general lack of agreement between trap results and population density indicates that other factors are responsible for the magnitude of the catch. Consequently, trapping data as gathered at the Kellogg Forest are of doubtful value as indexes of abundance.

FIGURE 20

FALL TRAPPING DATA INDEXES OF ABUNDANCE
COMPARED TO PRESEASON POPULATION ESTIMATES
KELLOGG FOREST



The reason for the better agreement between trapping data population indexes and population densities at the Sanctuary than at the Forest are unknown. A marked difference in trap success prevailed between summer and winter. If this change in trap efficiency had occurred at different times each year it might have caused the inaccurate results observed. Another factor possibly contributing to the poor agreement at the forest was that the wooden traps were not functioning with full efficiency in 1951 which tended to reduce the catch during that year of high population density.

In general trapping data did not accurately reflect population levels. They were much less accurate than population indexes based on hunting kill statistics. However, under some circumstances population indexes based on trap results were fairly reliable. It seems likely that trapping results can be used as rough population indexes if the trapping is conducted under fairly comparable conditions.

Age Ratios

Because of their high annual mortality rate hunted cottontail rabbits are usually regarded as an annual crop. The crop is comprised largely of juveniles (Tables 24 and 25) and hence its size may be thought of as being determined by the success of juvenile production. Since fall age ratios reflect the magnitude of juvenile increment, it follows that changes in fall age ratios might be related to changes in population density.

Tables 23 and 24 permit comparison between fall age ratios and fall population densities at the two study areas. Mere inspection of

TABLE 24

SUMMARY OF RABBIT POPULATION DATA
KELLOGG BIRD SANCTUARY AND FARM 1950-1955
HICKORY CORNERS, MICHIGAN

Year	Relative Spring Populations	Fall Population	Hunting Kill Percent	Fall Age Ratio Juvenile/Adult
1950	Very high	500?	31?	4.3
1951	Very high	388	32	3.5
1952	Very high	365	58	2.6
1953	Very low	230	66	8.1
1954	Very low	249	22	13.2
1955	High	194	44	5.1

TABLE 25

SUMMARY OF RABBIT POPULATION DATA
KELLOGG FOREST 1951-1955
AUGUSTA, MICHIGAN

Year	Relative Spring Populations	Fall Population	Hunting Kill Percent	Fall Age Ratio Juvenile/Adult
1951	High	526	49	5.1
1952	High	345	56	4.2
1953	Low	402	61	10.4
1954	Low	396	56	13.6
1955	Low	311	57	17.3

these data indicates that fall age ratios were very poor indexes of abundance. The reasons for this are discussed beyond.

POPULATION FLUCTUATIONS

Kellogg Bird Sanctuary and Farm Study Area

Hunting kills recorded by the Sanctuary directors from 1932 through 1950 have been shown to probably accurately reflect changes in population density. Data for these years are plotted in Figure 21 along with hunting kills during a normal effort for 1951-1955. Although the kills fluctuated from year to year there has been no general trend toward either an increase or decrease. This is interpreted as indicating that the rabbit productivity of this area has not changed appreciably during the past 23 years. This is of particular interest when it is realized that rather marked environmental changes have occurred during this time. There has been a considerable increase in brushy cover in formerly open fields and a pronounced increase in growth of pine plantations. A marked change also occurred in predator numbers on the area. Foxes were practically non-existent on the area from 1932 through about 1940. Since then they have been common.

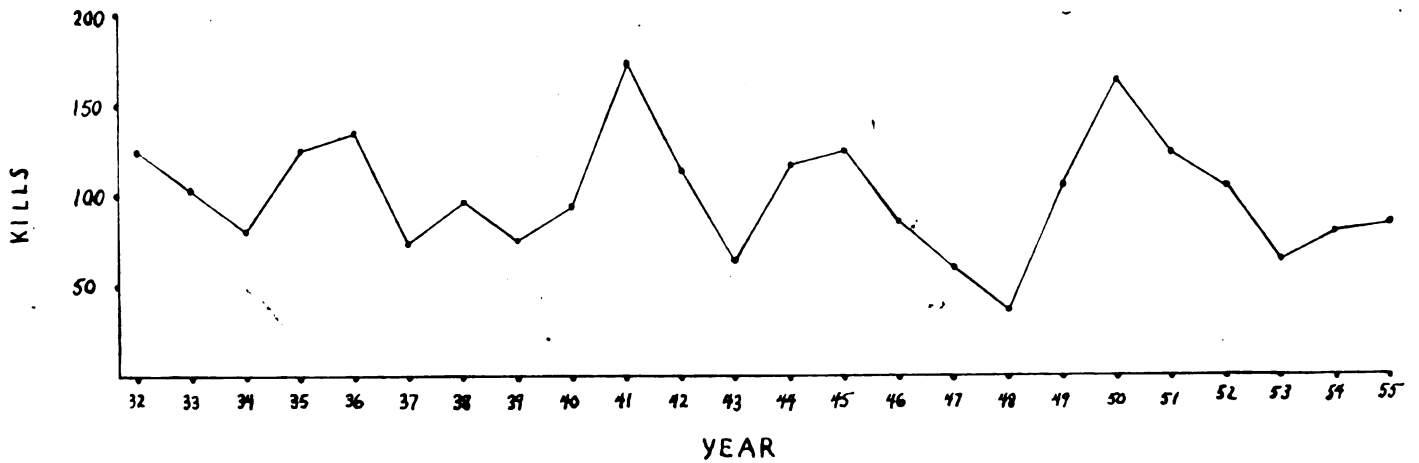
In 1936 Allen estimated the total fall rabbit population as 225 by the Lincoln index method using a shot sample to establish the marked fraction (Allen, 1938b). No further complete censuses were made until 1951. Calculated fall populations for 1951 through 1955 are summarized in Table 24. Some less accurate data for 1950 are added because age ratios were available for that year.

FIGURE 21

HUNTING KILLS

KELLOGG BIRD SANCTUARY AND FARM

1932 - 1955



Fall population levels were obtained by the Lincoln Index method except for 1950 when it was estimated from the hunting kill. The hunting kills are expressed as the percentage of the preseason population so that the extent to which the population was reduced by hunting (exclusive of crippling loss) can be readily seen. The juvenile:adult ratio is that which occurred in the hunting kill. Spring population levels were based on live trapping data. These data (Table 4) were rather meager and could only roughly reflect population levels. Spring population densities, therefore, are expressed merely as either high or low.

The following relationships are evident in Table 24:

1. From 1950 through 1952, when spring population densities apparently were high, the fall population densities were positively correlated with the proportion of juveniles present.
2. The extent of the hunting kill influenced the size of the next spring's population density. 1950, 1951 and 1954 had hunting kills of from 22 to 33 percent of the fall population and were followed by springs with high population densities. 1952 and 1953 had known kills of 56 to 66 per cent and were followed by very low spring populations.
3. There was an inverse relationship between spring population densities and fall juvenile proportions. 1953 and 1954 had low spring populations and higher fall juvenile per adult ratios than did the other years. The significance of this relationship in other regards is discussed beyond.

Kellogg Forest Study Area

A record of the total rabbit kill was kept by the forester in charge of the Kellogg Forest for the 1940 and 1946 through 1955 seasons. Hunting effort data gathered since 1947 indicated that between 1947 and 1950 the total hunting pressure gradually increased from 648 to 1772 hours. From 1951 through 1955 the pressure was constant at slightly over 2000 hunting hours per year. Figure 22 graphs the hunting kills that occurred on the Forest for those years for which data are available. The hunting kills in 1940, 1946, 1947, and 1948 may have been unrepresentatively depressed because of a lighter hunting pressure then. Probably general rabbit abundance levels have not changed much over the years considered.

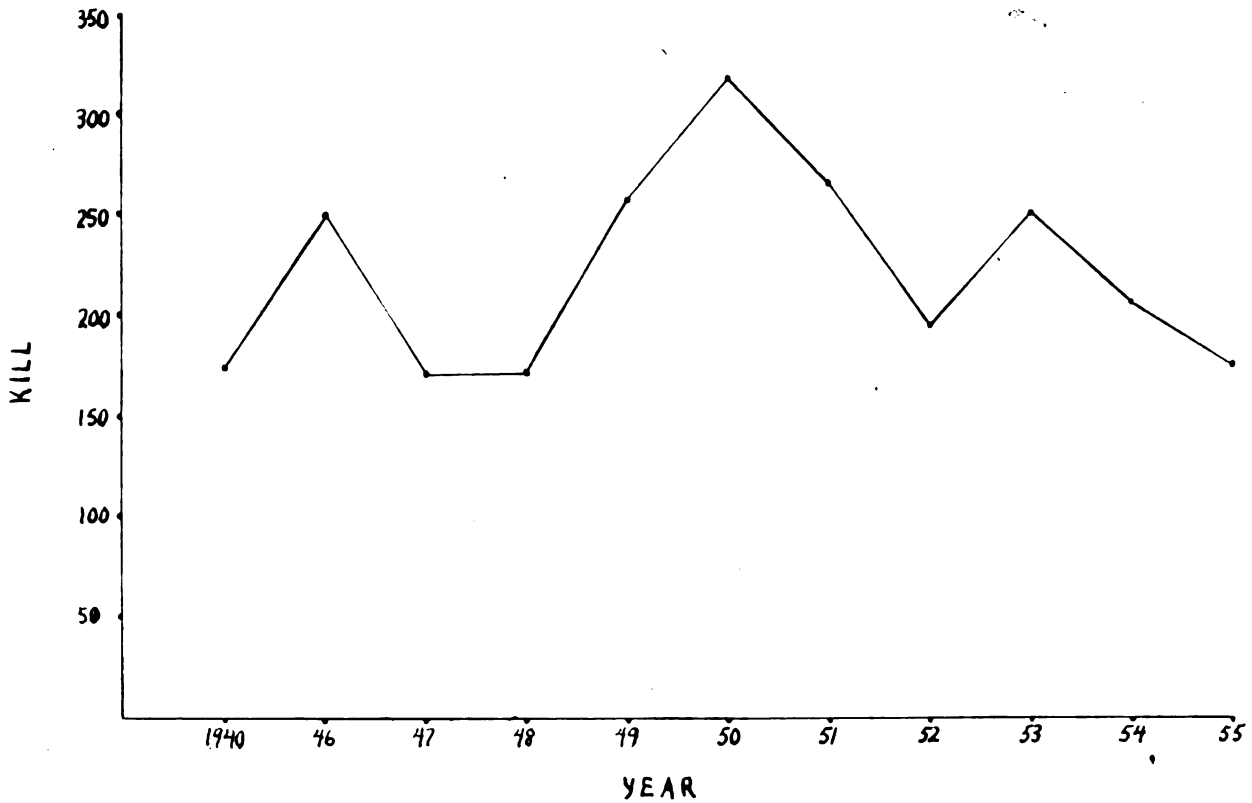
Population data for 1951 through 1955 are summarized in Table 25. Observations at the Sanctuary indicated that the spring population was largely a reflection of what was left at the end of the hunting season. No spring population data were available for 1951. Consequently the level is indicated as "high" judging from fall population and age ratio evidence. Based on the previous fall's population levels the spring population for 1952 is indicated as high and the other years as low.

Observations of Walter Lemmien, forester in charge at the Forest, support these conclusions for that area. For 1950 he reported "there is evidence of a better reserve supply (of rabbits) than in the past several years" and for 1951. "After the season, when the snow depth decreased, tracks indicated a good population of rabbits still on the

FIGURE 22

HUNTING KILLS

KELLOGG FOREST, 1940, 1946-55



area" (Lemmien, 1950, 1951). All other data were obtained in the same manner as at the Kellogg Bird Sanctuary and Farm.

Table 25 indicates little direct correlation between juvenile:adult ratios and population densities, except possibly during 1951 and 1952. Apparently an inverse relationship existed between spring populations and fall age ratios. Since the percentage kill remained rather constant at the Forest, spring populations generally reflected the population levels during the previous fall.

An inverse relationship between density of the breeding population and population increase has been observed in a number of studies. Errington (1945) and Kozicky and Hendrickson (1952) indicate that an inverse relationship exists between spring populations of quail and the magnitude of the following summers increase. Errington (1954) also has shown that muskrats display this relationship. In elk (Buechner and Swanson, 1955) a lowering of the population by hunting resulted in a very high incidence of pregnancies among yearlings. Southern (1948) in England noted that during a year when breeding populations were high there was a greater tendency for adult wild rabbits (Oryctolagus coniculi) to drive young from the warrens. Though behavior like this which would result in juveniles being driven from the study areas could explain the age ratios on the Kellogg Station, there was no evidence that this did occur.

The phenomenon of inversity possibly can be explained, at least in some cases, by the recent findings of Christian and Davis (1955). They observed an inverse relationship between mammal population density

and adrenal gland weight. Since increased adrenocortical activity is associated with a decrease in reproductive function, general physical condition, and resistance to disease, this may explain the lower rates of increase that commonly follow high population densities.

Population Increase and Mortality Analysis

Annual Population Increase

It is apparent that marked variations occurred in the size of the annual spring to fall increase. Since accurate spring population estimates are lacking for most years a precise statement of the size of the gain each year is not possible. However, the marked variations in juvenile:adult ratios that occurred from year to year indicate that juvenile production also must have varied considerably. At the Sanctuary study area, relatively large population increases probably occurred in 1953 and 1954 while those in 1951, 1952 and 1955 were relatively low. At the Kellogg Forest, 1951 and 1952 had relatively low increases while during the following three years they were relatively high. Tables 24 and 25 clearly indicate that high successful juvenile production occurred only following low spring populations.

The factors that directly influence the annual increase are as follows:

1. Average number of young per breeding female
2. Sex ratios of adults
3. Mortality of juveniles
4. Movements of juveniles.

It is not known if variations existed from year to year in the fecundity of adults. However, differences were evident in the dates at which young were successfully produced during the three years for which such data were available. These observations are shown in Table 26. The time of birth was calculated from the ages of juveniles at the time they were captured. The age was based on the criteria discussed by Petrides (1951). It is apparent from Table 25 that the early litters in 1953 were much more successful than those in 1951 and 1952. A Chi-square test indicated highly significant differences in the distribution of successful births. The high survival of early litters in 1953 probably contributed to the high juvenile:adult ratio that year.

A pronounced difference in the incidence of breeding by juveniles existed between 1951 and 1952 which had low age ratios and 1953 and 1954 which had high age ratios. During the first two years only one out of 88 females that had produced young was a juvenile. In contrast five of 21 breeders (24 percent) checked in 1953 and 1954 were juveniles. This difference is statistically highly significant. The high incidence of juvenile breeders appears to have been associated with a high survival of early litters in 1953. The young breeders were detected by having juvenile epiphyseal cartilages in the legs despite evidence of breeding indicated by nipple size and condition of the uterus. No association was found between precipitation or temperature during or before the breeding season and the incidence of precocial breeding or the size of fall age ratios.

Since sex ratios remained about even during the entire study, this factor can be disregarded as a factor influencing the annual population increase.

Little direct evidence concerning variations in juvenile morality is available. Possible mortality factors were predation and disease or parasites but the effects of these factors on the population is unknown. The incidence of warbles in 1951, when the increase was low was about twice that during the following two years when high increases occurred (Geis, 1956). It is known that warbles can kill individual rabbits; however, the effect that they have on a population is uncertain.

The effect of movement on population levels was investigated by Moore (1956). He concluded that movements into the Sanctuary and study area were slight. No information is available about the extent of movement away from the Sanctuary. At least a few animals leave the area because three tagged rabbits were shot outside. Two were about a mile southeast and one 13 miles south of the study area.

Adult Summer Mortality

Adult summer mortality was important in two ways. It influenced fall population densities and caused distortions in fall age ratios. In 1951 about one-third of the adults alive in June died before the following November. Juveniles no doubt were present in the fall whose parents were then dead. This meant that the age ratio found in the hunting kill was an exaggerated index of reproductive success. For example in 1951 the age ratio in the hunting kill was 3.5 juveniles

per adult. There was evidence (Table 32), however, that for every adult alive in November that there were about 1.5 adults present during the bulk of the breeding season. Therefore, the age ratio that truly reflects the rate of increase must have been 3.5 juveniles to 1.5 adults or 2.3 juveniles per adult.

When spring and fall populations are known, the number of young successfully produced per adult alive in the spring can be estimated by the formula:

$$a = \frac{Pf - As}{As}$$

where a is the number of young produced per adult living in the spring, Pf is the total fall population, and As is the spring adult population. The extent to which the calculated value differs from the fall juvenile:adult ratio reflects the extent of adult mortality. For example, in 1955, the spring adult population was conservatively estimated as 82 by doubling the number of animals actually handled in spring trapping. The fall population was estimated as 194 by the Lincoln Index method. Substituting these values in the above formula a juvenile:adult alive in the spring ratio of 1.4 was obtained. The observed fall age ratio was 5.1 juveniles per adult. The number of adults alive in the fall can be calculated from the relationship:

$$Af + Afaf = Pf$$

where Af is the fall adult population, af is the fall juvenile:adult ratio, and Pf is the total fall population. Thus, the number of

adults alive during the fall of 1955 was 32. This indicates a 61 percent adult mortality since spring. Following the same procedure the adult mortality between March and November, 1952 was indicated to be very slight (7 percent). This low estimate probably indicates that the spring population was underestimated. No estimate of adult summer mortality during 1953 and 1954 was made because very few adults were handled. It can be concluded that adult mortality between March and November can be at least as high as forty percent. This can cause the juvenile:adult ratio observed in the hunting kill to indicate an exaggerated rate of increase.

When the juvenile:adult alive in the spring ratio, and fall population level are known the adult breeding population can be estimated from the equation:

$$As = \frac{Pf}{a+1}$$

where the notation is the same as before. For example, in 1951, a was 2.3 and Pf, 388. This yields an estimated spring adult population of 188 which agrees well with the estimate for June of 108 obtained by the Lincoln Index Method.

Hunting Mortality

To test the effect of hunting pressure on rabbit populations the hunting pressure at the Sanctuary was varied while that at the Forest remained almost constant. In 1951 a hunting pressure believed typical of that which had been applied during previous years was exerted and a 32 percent kill resulted. During the next two years very heavy

hunting pressures were applied and known kills of 56 and 66 percent resulted. In addition to shooting, live traps, snares and a ferret, folling the hunting, were used to reduce the population. 1954 had a very light hunting pressure and only 22 percent of the population was taken.

Table 24 indicates the effect of these fluctuations in hunting pressures on population characteristics. The heavy kills were followed by low spring populations. These in turn were followed by high rates of increase as indicated by age ratios. The low spring populations which followed heavy kills apparently were compensated for by increased juvenile production. It can be concluded that although the hunting kill directly influenced population levels the following spring, it had little influence on the next fall population levels.

The 1953 and 1954 fall population levels of 230 and 249 which followed heavy kills in 1952 and 1953 were lower than the autumn population levels observed in 1951 (388) and 1952 (365). It might be thought, therefore, that the heavy kills did indeed influence the next year's population. During the previous 21 years though, there were many years when populations apparently were equally low (Figure 21). This is especially true when it is realized that rabbits are probably less harvestible now, because of more dense vegetation than they were in the 1930's and early 1940's. For example, in 1936 when Allen (1938b) measured the population at 225 the hunting kill was 56 percent. In 1955 Allen again visited the area and stated (personal conversation) that cover conditions were such that rabbits probably were more difficult

to bag. Therefore, the hunting kills made on the Kellogg Bird Sanctuary and Farm during the early years probably were percentagewise higher than those made in recent years. This would cause population levels during the early years to appear higher than they actually were.

Observations made in 1955 further indicated that the previous hunting kill had little influence on the following fall population. In 1954 the hunting kill was very light (22%). The following spring there was a high rabbit population. Despite high spring numbers, however, the fall population was the lowest of any during the study. Thus the low kill in 1954 did not result in an increase in the 1955 population. In fact the fall populations in 1953 and 1954, when known hunting kills during the previous seasons were 58 and 66 percent, respectively, were higher than that in 1955 which followed a kill of only a 22 percent. Based on his many years experience observing Sanctuary rabbit populations Pirnie (1949) observed, "Abundant rabbits in summer, however, did not always mean large numbers in December. In the summer of 1949, for example, the animals were abundant, but shooting that December was the poorest in 16 years!"

Observations made at the Kellogg Forest support those made at the Sanctuary. Low spring populations from 1953 through 1955 were followed by high age ratios (Table 25). Furthermore, the high spring population in 1952 was followed by a relatively low age ratio and the second lowest fall population density observed during this study. As was also observed at the Sanctuary, a high spring population can be followed by a low fall population.

TABLE 26

DISTRIBUTION OF BIRTH DATES AMONG JUVENILES LIVE-TRAPPED IN AUGUST AND SEPTEMBER--KELLOGG BIRD SANCTUARY AND FARM HICKORY CORNERS, MICHIGAN

Month	Percent Born		
	1951	1952	1953
March	5	9	13
April	27	23	63
May	44	18	10
June	22	45	13
July	2	5	0
Sample size	55	22	30
Fall age ratio, Juv.:Adult	3.5	2.6	8.1

Crippling Loss

Crippling loss as associated with the rabbit harvest at the Sanctuary would be expected to be lower than usually occurs elsewhere because of the manner in which the hunting was done. During the 1952 harvest, however, five rabbits were found dead that had been hit by shot on previous hunts. The percentage of the total crippling loss that these animals represented was unknown. The next year 36 dead rabbits were planted at random on the central part of the Sanctuary study area. These were planted early in the hunting period. There was ample opportunity therefore, for these animals to be found during later hunts. Hunters were asked to report any dead rabbits that they might find. Twelve of the planted rabbits were found which indicated that about one-third of the rabbits dead in the field were seen by hunters. Confidence limits around this expected recovery percentage at the 95 percent confidence interval are 20 to 53 percent.

Only one rabbit that year was found that had died of shot wounds. Four rabbits, however, were badly crippled and yet escaped by crawling under the farm dump, brush piles or into holes. Any estimates of the crippling loss based on the number found will obviously be minimal since bodies of rabbits which die in hiding probably are rarely seen again.

If it is assumed that the five rabbits found in 1952 represented one-third of the total number that died from gun shot wounds but were not recovered, the estimated crippling loss was 15 or about 8% of the known total kill. It seems likely that a crippling loss of at least

10 percent of the kill can be assumed to occur since the above estimate is minimal. Because of the wide confidence limit, however, this estimate may not be very accurate.

Since the known hunting kill on the Kellogg Forest was so high and because hunters frequently reported seeing dead rabbits, an attempt was made during the 1955-56 hunting season to measure the extent of the crippling loss there. The approach was the same used at the Sanctuary in 1953 but the project was conducted on a larger scale. A map of the Forest was gridded by lines 50 yards apart. From a table of random numbers (Snedecor, 1946) 103 intersecting points were selected. Dead rabbits, mostly collected during the previous hunting season, were planted precisely at these locations on the following days: October 30, 44 rabbits; December 24, 24 rabbits; December 26, 17 rabbits and January 10, 18 rabbits. The location of the planting points was facilitated because every other east-west line was marked as part of another study. The exact locations were determined by pacing from known points and the rabbits were dropped at the spot indicated. If they fell belly up, they were turned over, but no attempt was made to hide them. No snow cover was present on the days of planting except on the last date when there was scattered snow. All dead rabbits were tagged in each ear with Size 3, Style 1005, National Band Company fingerling-type tags. Forty-seven percent of the planted rabbits had tails dyed yellow.

Hunters were requested to bring in or report the exact locations of any dead rabbits found while hunting. They were also asked to

report any cripples that escaped. They were not told that dead rabbits were to be or had been planted. Ten rabbits were brought in. Twenty were reported by hunters and later found by the forester in charge. Six additional dead rabbits were reported by hunters and searched for but not found. One of these could not have been planted because it was reported before any rabbits had been set out. Only eight crippled rabbits were reported to have escaped.

Table 27 summarizes the plantings and recoveries of planted rabbits. It indicates that of a total of 103 rabbits planted 30 or 29.2 percent were found. If the January 10 planting is omitted because little hunting was done that late in the season, the recovery percentage was 35.3 percent.

Sixty percent of the rabbits found had yellow tails. Since only 47 percent of the total number planted had yellow tails, it seemed possible that yellow-tailed rabbits were more easily found. Since statistical analysis indicated that differences that great could be expected to occur only 20 percent of the time due to chance, it seems likely that this was true.

Seventy-six percent of the rabbits recovered were found within 10 days after planting, 17 percent were located from 11 to 20 days after planting and seven percent were reported from 21 to 70 days after being placed out.

The probability of being found was calculated, based on the number planted and the number of hours hunted 10 days after the planting. The mean probability of being found during the 10 day period following

TABLE 27

SUMMARY OF THE KELLOGG FOREST CRIPPLING LOSS EXPERIMENT--1955-56
AUGUSTA, MICHIGAN

Date Planted	Number	Number Recovered	Percent Recovered	Number Brought In	Number Reported and Found	Time Interval Between Planting and Recovery, Days					Probability of Recovery Within 10 days after Planting
						1-10	11-20	21-30	51-60	61-70	
Oct. 30	44	14	31.8	6	8	8	3	1	1	1	.00125
Dec. 24	24	8	33.4	1	7	8	0	0	0	0	.00266
Dec. 26	17	8	47.2	3	5	6	2	0	0	0	.00266
Jan. 10	18	0	0	0	0	0	0	0	0	0	
Totals	103	30	29.2	10	20	22	5	1	1	1	

planting was .00125 for the October 30 planting, while the mean probability for the December 24 and 26 plantings was .00266. Thus the December plantings were more than twice as likely to be found than were the October plantings. This difference was statistically significant. But because much less hunting was done in December the overall percentage recovery was only slightly higher than in October, despite the higher probability of recovery.

Table 28 lists the recoveries of non-planted rabbits. It indicates that there was from seven to nine true crippling losses found. The exact number is not known since circumstances indicate that one rabbit could have been lost from a hunter's coat while another possibly could have been hit by a car. It seemed reasonable to adopt eight as the number that were recovered. The following proportion then could be used to estimate the total crippling loss:

$$\frac{\text{number of planted rabbits found}}{\text{total number planted}} = \frac{\text{number of true crippling losses found}}{\text{total crippling loss}}$$

From the values observed in this study:

$$\frac{30}{103} = \frac{8}{X}$$

$$X = 27.5$$

Confidence limits around this value indicate that between 20 and 38 cripples were lost unless once chance in 20 had occurred. Thus the crippling loss was from eleven to 23 percent of the known kill. Since this estimate is minimal because some cripples probably die in locations

TABLE 28

SUMMARY OF NON-PLANTED RABBIT RECOVERIES, KELLOGG FOREST 1955
AUGUSTA, MICHIGAN

Date	Tag Number	Comments
Oct. 22	325	Reported and found
Oct. 23	?	Reported
Oct. 25	--	Possibly hit by car
Nov. 5	--	Hit by car
Nov. 24	--	Brought in
Nov. 27	--	Brought in--shot holes in ear
Dec. 27	--	May have been lost from hunter's coat
Jan. 1	3329	Reported and found
Jan. 3	--	Brought in--found dead sitting in form
Jan. 11	3444	Brought in

that make their recovery highly unlikely, it is probably safe to assume that 20 percent of the known bag were killed by hunting but are not recovered. The dense cover and heavy hunting pressures at the Kellogg Forest created a situation that would be expected to favor a high crippling loss.

Judging from the results of this experiment, the number of cripples found can be multiplied by four to obtain an estimate of the total crippling loss. If a significant portion of the cripples that die do so in places where their recovery is not possible, even this correction factor may be too small. The reliability of this method of estimating the crippling loss depends on the uniformity of the following factors.

1. Cooperation of hunters in reporting dead rabbits.
2. The accuracy of hunters in reporting the locations of dead rabbits.
3. The ability of game area managers to find reported rabbits.
4. The proportion of crippled rabbits which die in places where it is unlikely to find them.

The last point merely influences the uniformity by which this procedure underestimates the total crippling loss. Since about 35 rabbits probably died as a result of shooting but were not bagged, it is somewhat surprising that only eight rabbits were reported to have been crippled and escaped. This indicates that many rabbits are probably fatally hit but are assumed to have been missed. This view is supported in that frequently hounds catch or find crippled rabbits that showed

no evidence of being hit when shot at.

The significance of these findings concerning the crippling loss at the Kellogg Forest is that they indicate that hunting caused the death of about seventy percent of the fall population during each of the past four years. Unless the rabbit population there soon fails to maintain its present level, here is additional strong evidence that even very severe hunting kills do not limit the populations in succeeding years.

Non-hunting Winter Mortality

It is difficult to accurately determine the non-hunting winter mortality because spring population estimates are only approximate. If it is assumed, however, that about half the population is handled during the spring trapping period (see Table 4) and that the crippling loss is ten percent of the hunting kill, then non-hunting mortalities on the Sanctuary for the winters of 1951-52, 1954-55 and 1955-56 were 29, 54 and 45 percent respectively of the fall populations not killed by hunting. 1954-55 had a very light hunting kill of 22 percent while the other years had moderate hunting kills of 32 and 44 percent. Thus it seems that the light hunting kill was associated with a higher non-hunting mortality than occurred during years of heavier kills. No estimates of the non-hunting mortality during the winters of 1952-53 and 1953-54 could be made because very few animals were trapped in the spring.

Since spring population levels seem to be strongly dependent upon the extent of the previous year's hunting kill, it seems likely that

the hunting kill was the most important source of winter mortality on the area except possibly for years when that kill was very light.

Age Composition of the Sanctuary Rabbit Population

The age composition in the hunting kill indicated the high mortality rate in the rabbit population (Table 29). The numbers of animals in each age class except juveniles was based on the age at which shot rabbits had been trapped. Since no trapping was done before 1951 the age distribution then can only be divided into the juvenile and one and one-half or older age groups. In 1952 six rabbits were shot that had been marked as adults in 1951, thus they were two and one-half years old or older. Every year a number of adult rabbits of unknown age were shot. Table 30 tallies the age distributions with those animals in the one and one-half years or older category prorated into one and one-half and two and one-half and over categories according to the ratio observed in 1952. This may have tended to exaggerate survival because 1952 followed only a moderate hunting pressure.

Based on five year totals 82 percent of the winter population was made up of juveniles, 14 percent rabbits one and one-half years of age and only four percent two and one-half or more years old. There was no record of any rabbit actually living longer than two and one-half years. Only 17 percent of the juveniles alive one winter survived until the next winter and only about five percent lived until the second winter. Atzenhoefer and Martin (1949) found survival rates of 12.5 and five percent over comparable periods of time in Ohio. It can be

TABLE 29

DISTRIBUTION OF RABBIT AGES IN HUNTING KILLS
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Year	JUV	Age in Years			
		1 1/2	1 1/2 or more	2 1/2	2 1/2 or more
1951	100	0	23	0	0
1952	140	16	31	0	6
1953	103	3	9	0	0
1954	50	0	3	0	0
1955	73	8	4	0	0

TABLE 30

DISTRIBUTION OF RABBIT AGES IN HUNTING KILLS
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Year	JUV	Age	
		1 1/2	2 1/2 or more
1951	100	17	6
1952	140	39	14
1953	103	10	2
1954	50	2	1
1955	73	11	1
Totals	466	79	24
Percent	81.9	13.9	4.2

concluded that the life expectency of a rabbit that lived to the first winter was less than a year. Also, the turnover rate (as defined by Petrides, 1951) of a population was less than four years.

When the age distributions in years following heavy (1953 and 1954) and following moderate or light kills (1951, 1952 and 1955) were combined (Table 31), it was apparent that the rate of survival was less during years of heavy hunting pressures. This difference was statistically highly significant. (It seems likely that differences in hunting pressure were responsible.) It has previously been shown that spring population densities were strongly influenced by the size of the hunting kill during the previous year. These age distribution differences further indicate that light hunting kills were not completely compensated for by non-hunting winter mortality.

1951-52 Life Equation Observations

A major objective during the first year of this study was to establish a table of animal gains and losses for Kellogg Bird Sanctuary and Farm cottontails. Such a table has been termed a life equation (Leopold, 1933) and shows the relative magnitude of mortality at various times during the year.

Most population values in the life equation were obtained by Lincoln Index population estimates and were calculated for several times during the year. These values are summarized in Table 15.

The production of young was estimated as the number of adult females times the average number of young produced by each adult

TABLE 31

AGE DISTRIBUTIONS FOLLOWING YEARS OF HEAVY HUNTING KILLS COMPARED TO THOSE FOLLOWING LIGHTER KILLS

Age	Following Heavy Hunting Kills		Following Moderate or Light Hunting Kills	
	Number	Percent	Number	Percent
Juveniles	153	91	313	78
1 1/2 years	12	7	67	17
2 1/2 years or more	3	2	21	5
Totals	168	100	401	100

female. The average litter size of eight observations made in this study was 5.6. Allen (1938a) working at the Kellogg Bird Sanctuary found that the average litter size to be 5.1. Haugen (1942) determined that the average litter size in twelve litters in Allegan County, Michigan, was 5.4 and Trippensee (1936) also working in southern Michigan calculated the figure to be 5.04. Five young per litter was judged to be a sufficiently close approximation for practical use.

The number of litters per female per year has been reported as follows: Four (Bedell, 1934); three or four (Leopold, 1933); two common, four possible (Trippensee, 1936); two or three (Dalke, 1937); two certainly, three probably (Gerstell, 1937); two (Allen, 1938a); five as a maximum (Hickie, 1940); and 3.8 (Schwartz). Haugen (1940) came to the conclusion that three or four litters a season are common in Michigan. Three and one-half litters per year was adopted as a reasonable figure for use in calculating production.

The hunting kill at the Sanctuary was known and crippling loss was estimated at ten percent of the kill. The extent of mortality was estimated from the differences in population estimates for various times. Table 32 gives the resulting life equation. The difference of three rabbits between November population estimates based on all observations and that obtained by adding the estimates for juveniles and adults was due to sampling variation.

So that the relative extent of mortality that occurred at various times during the year could be appraised, Table 33 was constructed. This lists the percentage mortality that occurred at various times

TABLE 32

LIFE EQUATION KELLOGG BIRD SANCTUARY AND FARM RABBITS, 1951-52
HICKORY CORNERS, MICHIGAN

Date	Age or Description	Calculated Size of Population Category	Gain	Loss	Total Population
June, 1951	Adults	108			108
Spring & Summer	Young born	945	945		1053*
August	Juveniles	349		596	457
November	Juveniles	318		31	426
November	Adults	73		35	391
November	All ages	388			388
Winter	Hunting kill	123		123	265
	Crippling loss	12		12	253
Spring 1952	Adults	140		113	140

*Not all of which were alive at one time.

TABLE 33

RELATIVE IMPORTANCE OF MORTALITY AT VARIOUS TIMES, 1951-52
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Mortality	Percentage of Total Annual Mortality	Percentage of Population Category Lost
Between birth and age 2 1/4 months	65.4	63.1
Between age 2 1/4 months and November	3.4	8.9
Adults between June and November	3.8	32.4
Hunting kill	13.5	31.7
Crippling loss	1.3	3.1
Non-hunting winter loss	12.4	29.1

based on the total annual mortality and the population to which it applied. It can be seen that the greatest mortality was among juveniles between birth and 2 1/4 months of age. This is probably a minimal estimate because the production of young by juveniles in their first year was disregarded. It is clearly evident that the size of the fall rabbit population is largely determined by the success of juvenile production.

Two other points also are of interest. A rather large number of adults died between June and November. And even during this year of light hunting pressure, the shooting kill made up the biggest part of the winter mortality.

If sufficiently detailed data were available so that life equations could have been constructed for other years of this study, it seems likely that they would differ from that in 1951-52 in several respects. During years following heavy hunting kills juvenile production or survival would have been higher. During years with heavy hunting kills the overall winter mortality would have been greater but the non-hunting winter mortality would have been numerically less.

HUNTING EFFORT AND SUCCESS AT THE KELLOGG FOREST

I. Introduction

The Kellogg Forest is a very heavily hunted public area on which the cottontail rabbit is the principal game animal. Hunting data on this area were collected to: (1) determine patterns of hunting effort, kill and success, (2) determine the distribution of effort, kill and success among the hunting public, (3) evaluate factors influencing hunting effort and success, (4) predict the probable effects of hunting seasons of various lengths, and (5) explain why rabbit hunting statistics display seemingly illogical relationships.

The chief reason for seeking this information was that hunting statistics from this area indicate what can be expected from other similar public hunting areas. This is especially true because the Kellogg Forest is located on rough, very poor land that is typical of the sort that falls into public ownership. A serious problem in public wildlife management is the provision of hunting areas for an constantly increasing number of hunters.

II. Methods

Hunters were required to obtain a hunting permit each year and to report at the Kellogg Forest office after each hunt. For the 1954 season, the hunters' occupations and whether or not they had hunted the area during the previous season also was determined when permits were issued.

The data collected after each hunt varied somewhat each year. Every year, however, the starting time, finishing time, party size, numbers of tagged, untagged animals bagged and tag numbers of marked rabbits were recorded. During the 1951 and 1954 seasons information on the use of dogs also was gathered. For the 1954 season, each hunter was assigned a permit number. Hunter's names, permit numbers and individual success was recorded each time they checked out.

The following weather data were collected at the Kellogg Forest as a routine procedure: maximum and minimum daily temperature, kind and amount of precipitation, snow cover, wind velocity and cloudiness.

The hunting data were organized as follows: The daily hunting effort and kill were cross tabulated by week of the season and day of the week. These tabulations are shown in Tables 34, 35, 36 and 37. A small amount of effort and kill registered by neighbors who reported only season totals could not be included in these tabulations. This accounts for the discrepency between the total annual kill and effort shown in Table 37 and that shown in these tables and others which depend upon knowing when during the season effort and kill occurred. The daily and weekly cross tabulations permitted the daily and weekly patterns of effort, kill and success to be readily determined. For the 1951, 1952 and 1953 seasons the hours hunted, kill and kill per 100 gun-hours experienced each day during the season was written on and punched into a punch card along with the following weather data: minimum temperature, maximum temperature, total precipitation, total snow fall, depth of snow on the ground, average wind velocity and cloud cover. This was done to

TABLE 34

DAILY HUNTING EFFORT AND RABBIT KILL 1951--KELLOGG FOREST
AUGUSTA, MICHIGAN

Week	Date		Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Totals
1	Oct. 15-21	G.H.*	103.5	28.5	13.3	23.2	29.7	117.0	97.8	413.0
		Kill	8	1	3	2	11	4	4	33
2	Oct. 22-28	G.H.	4.8	1.8	7.2	15.2	29.2	79.4	152.0	289.7
		Kill	0	0	0	2	4	11	23	40
3	Oct. 29-Nov. 4	G.H.	29.2	13.7	6.0	15.5	18.2	66.3	115.8	264.8
		Kill	2	1	2	4	2	11	12	34
4	Nov. 5-11	G.H.	21.0	12.5	2.5	16.5	5.5	90.5	100.0	248.5
		Kill	7	0	0	5	1	19	15	47
5	Nov. 12-18	G.H.	10.0	0.0	15.5	5.8	7.0	39.0	60.0	137.3
		Kill	0	0	4	5	0	4	3	16
6	Nov. 19-25	G.H.	9.8	13.7	4.0	30.5	35.8	67.5	100.5	261.7
		Kill	2	2	0	2	8	7	11	32
7	Nov. 26-Dec. 2	G.H.	7.5	10.5	11.5	19.5	11.8	60.5	61.8	183.0
		Kill	0	4	2	2	2	4	6	20
8	Dec. 3-9	G.H.	17.0	25.8	20.2	1.2	1.2	45.8	33.2	144.5
		Kill	4	4	0	0	0	3	5	16
9	Dec. 10-16	G.H.	9.8	11.5	37.2	5.5	5.8	8.5	22.0	100.2
		Kill	2	0	4	0	1	1	1	9
10	Dec. 17-23	G.H.	0.0	0.0	3.0	0.0	0.0	0.5	16.7	20.2
		Kill	0	0	1	0	0	1	0	2
11	Dec. 24-31	G.H.	9.0	1.0	6.0	9.8	8.0	4.0	13.0	50.8
		Kill	1	0	1	2	2	0	1	7
Totals		G.H.	221.5	118.9	126.6	142.8	151.2	579.0	772.8	2113.8
		Kill	26	12	17	24	31	65	81	256

* G.H. = Gun-hours.

TABLE 35

1952-1953 DAILY HUNTING EFFORT AND RABBIT KILL--KELLOGG FOREST
AUGUSTA, MICHIGAN

Week	Date		Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Totals
1	Oct. 20-26	G.H.*	107.0	34.8	29.0	32.8	29.2	82.8	109.0	424.5
		Kill	11	0	3	1	1	5	4	25
2	Oct. 27-Nov. 2	G.H.	24.0	19.2	17.0	11.2	8.8	55.5	27.8	163.5
		Kill	1	5	2	0	1	1	3	13
3	Nov. 3-9	G.H.	34.0	19.5	23.2	19.0	14.0	54.75	74.8	239.2
		Kill	4	2	2	5	3	2	11	29
4	Nov. 10-16	G.H.	20.5	15.5	8.0	1.0	5.88	29.75	31.8	112.2
		Kill	1	2	0	0	0	5	1	9
5	Nov. 17-23	G.H.	5.25	7.0	18.0	3.5	8.5	25.0	31.0	98.2
		Kill	0	2	1	1	0	2	5	11
6	Nov. 24-30	G.H.	13.2	0.0	0.0	4.0	12.5	43.0	39.0	11.8
		Kill	0	0	0	1	1	4	3	9
7	Dec. 1-7	G.H.	6.0	17.5	23.5	22.0	7.5	38.5	74.2	189.2
		Kill	1	3	4	2	1	4	11	26
8	Dec. 8-14	G.H.	8.5	20.5	0.0	7.0	13.5	30.8	58.5	138.8
		Kill	4	3	0	0	2	1	4	14
9	Dec. 15-31	G.H.	24.5	7.0	0.0	8.0	6.0	9.88	26.0	81.2
		Kill	3	0	0	1	2	0	2	8
10	Dec. 22-28	G.H.	4.5	0.0	0.0	7.5	7.0	50.0	29.0	98.0
		Kill	0	0	0	0	0	3	1	4
11	Dec. 29-Jan. 4	G.H.	6.5	12.0	3.0	32.0	7.0	49.5	57.5	167.5
		Kill	0	0	0	3	0	7	6	16
12	Jan. 5-11	G.H.	4.0	11.0	0.0	0.0	9.2	13.0	16.5	53.8
		Kill	0	1	0	0	1	4	2	8
13	Jan. 12-18	G.H.	3.0	3.0	8.0	7.0	10.5	0.0	14.0	45.5
		Kill	0	1	0	0	0	0	0	1
14	Jan. 19-25	G.H.	7.5	0.0	8.0	5.0	11.8	29.2	12.0	73.5
		Kill	1	0	0	0	0	0	0	1
15	Jan. 26-31	G.H.	1.0	10.0	3.0	12.5	11.5	24.0		62.0
		Kill	0	0	0	5	3	1		9
Totals		G.H.	269.5	177.0	140.8	172.5	162.8	535.5	601.	2059.
		Kill	26	19	12	19	15	39	53	183.

*G.H. = Gun-hours

TABLE 36

1953-1954 DAILY HUNTING EFFORT AND RABBIT KILL--KELLOGG FOREST
AUGUSTA, MICHIGAN

Week	Date		Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.	Totals
1	Oct. 20-26	G.H.*	90.8	35.0	20.8	24.5	84.2	118.0	12.5	388.8
		Kill	5	2	4	2	9	10	1	33
2	Oct. 27-Nov. 2	G.H.	22.5	24.0	18.5	27.2	77.8	117.5	15.0	302.5
		Kill	4	0	1	3	8	16	0	32
3	Nov. 3-9	G.H.	29.2	9.5	19.8	17.0	38.0	83.8	8.5	205.8
		Kill	3	0	1	0	3	7	3	17
4	Nov. 10-16	G.H.	22.5	12.8	10.0	8.0	44.0	52.0	3.5	151.8
		Kill	1	1	1	1	5	3	2	14
5	Nov. 17-23	G.H.	1.0	1.5	13.0	0.0	35.8	8.8	7.5	67.5
		Kill	0	1	1	0	0	1	3	6
6	Nov. 24-30	G.H.	3.0	14.2	48.8	24.2	30.5	62.8	12.0	195.5
		Kill	0	0	3	0	6	14	3	26
7	Dec. 1-7	G.H.	8.0	5.2	13.5	2.0	35.0	45.0	13.5	122.2
		Kill	2	1	4	0	3	8	1	19
8	Dec. 8-14	G.H.	4.5	2.0	2.5	20.0	26.5	47.0	8.2	110.8
		Kill	0	0	1	0	2	2	1	6
9	Dec. 15-21	G.H.	2.0	0.0	9.8	0.0	31.8	39.0	0.0	82.5
		Kill	0	0	0	0	8	2	0	10
10	Dec. 22-28	G.H.	4.0	8.0	16.0	0.0	39.0	81.2	25.2	173.5
		Kill	0	1	2	0	3	18	2	26
11	Dec. 29-Jan. 4	G.H.	14.0	8.5	12.0	25.0	7.5	57.0	13.5	137.5
		Kill	1	0	0	1	0	5	0	7
12	Jan. 5-11	G.H.	0.0	6.8	4.0	5.5	15.0	74.5	0.0	105.8
		Kill	0	1	1	1	1	4	0	8
13	Jan. 12-18	G.H.	0.0	6.5	15.8	29.0	18.5	38.0	0.0	107.7
		Kill	0	2	4	3	5	2	0	16
14	Jan. 19-25	G.H.	9.8	0.0	0.0	2.0	22.8	29.5	0.0	64.
		Kill	0	0	0	0	3	3	0	6
15	Jan. 26-31	G.H.	8.5	0.0	12.5	18.5	9.5	47.2		96.2
		Kill	0	0	2	1	0	4		7
Totals		G.H.	219.8	134.0	216.8	203.0	515.8	901.2	119.5	2310.0
		Kill	16	9	25	12	56	99	16	233

*G.H. = Gun-hours

TABLE 37

1954-1955 DAILY HUNTING EFFORT AND RABBIT KILL--KELLOGG FOREST
AUGUSTA, MICHIGAN

Week	Date		Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.	Tues.	Totals
1	Oct. 20-26	G.H.*	67.2	59.8	56.8	119.2	118.0	1.0	18.2	440.2
		Kill	5	2	4	13	5	0	1	30
2	Oct. 27-Nov. 2	G.H.	22.8	28.5	5.5	88.5	98.8	15.5	35.5	295.0
		Kill	4	0	0	11	9.	2	1	27
3	Nov. 3-9	G.H.	37.2	12.5	18.5	46.5	82.2	11.5	18.2	226.8
		Kill	1	1	2	6	5	1	2	18
4	Nov. 10-16	G.H.	27.2	4.0	1.0	34.5	70.2	1.2	5.8	144.0
		Kill	3	2	0	3	11	1	2	22
5	Nov. 17-23	G.H.	1.	10.5	0.0	41.2	46.8	2.5	2.0	104.0
		Kill	0	1	0	3	4	0	2	10
6	Nov. 24-30	G.H.	0.0	36.2	12.5	37.0	43.0	0.0	20.0	148.8
		Kill	0	5	1	1	8	0	2	17
7	Dec. 1-7	G.H.	10.5	30.0	7.25	62.0	97.0	6.5	13.0	226.2
		Kill	0	4	2	7	6	0	2	21
8	Dec. 8-14	G.H.	13.5	8.5	16.0	45.2	87.8	13.8	0.0	184.8
		Kill	1	2	1	5	10	1	0	20
9	Dec. 15-21	G.H.	15.8	11.8	2.5	49.5	57.2	0.5	20.5	157.8
		Kill	2	0	0	4	6	0	2	14
10	Dec. 22-28	G.H.	14.75	17.0	24.0	4.0	52.8	0.0	14.0	126.5
		Kill	6	0	3	0	2	0	1	12
11	Dec. 29-Jan. 4	G.H.	11.0	0.0	65.5	17.5	25.8	1.0	3.0	123.8
		Kill	0	0	3	0	0	0	0	3
12	Jan. 5-11	G.H.	0.0	1.25	1.25	17.2	2.0	0.0	7.0	28.7
		Kill	0	0	0	1	0	0	0	1
13	Jan. 12-18	G.H.	3.25	3.0	0.0	10.5	23.8	0.0	0.0	40.5
		Kill	0	0	0	0	3	0	0	3
14	Jan. 19-25	G.H.	0.0	4.0	16.5	15.0	0.0	0.0	0.0	35.5
		Kill	0	0	0	0	0	0	0	0
15	Jan. 26-31	G.H.	0.0	2.0	0.0	19.2	21.8	3.0	0.0	46.0
		Kill	0	0	0	1	0	0	0	1
Totals		G.H.	224.2	229.0	227.25	607.2	827.0	56.5	157.2	2328.5
		Kill	22	17	16	55	69	5	15	199

* G.H. = Gun-hours

permit climatic factors which might influence hunting effort and success to be evaluated.

In 1954 a different punch card was made out for each hunter that indicated the daily record of hours hunted, kill, dog use, effort with snow cover, the total effort and total kill. The fraction of total visits on which dogs were used or snow cover present was indicated on the card as well as the average visit length and kill per 100 gun-hours. Punched into each card was:

1. hunter occupation by a classification outlined beyond
2. whether or not the hunter had obtained a permit the previous year
3. number of visits
4. total hours hunted
5. total kill
6. number of cripples
7. week numbers during which hunting was done
8. kill per 100 gun-hours
9. average hunt length.

These cards were used to determine the effect of hunter occupation, previous experience with the area, number of visits and hours hunted on hunting success. They also revealed the distribution of hunting effort, kill and success among the hunters. In 1954 another type of punch card was also made out for each hunting party. These had recorded on them the: date, number and types of dogs used, party size, number of unrecovered cripples, kill, starting time, finishing time, hours hunted and the total gun-hours for the party. Punched into these cards were dog

use, amount of snow on the ground, whether it was a Saturday, Sunday, weekday or opening day, and the period of time during which the party hunted. From these cards the hourly distribution of hunting effort on Saturdays, Sundays, weekdays and opening day was determined as well as the effect of snow cover, party size and dog use on hunting success.

III. Patterns of Hunting Effort, Kill and Success

A. Yearly

Table 38 summarizes hunting effort and success for 1951-54. Hunting pressure each year was slightly over 2000 gun-hours. The effort expended in 1954 averaged 4.56 hours per acre. Total kills varied between 196 and 256. The mean yield over the four year period was 9.9 rabbits per 100 gun-hours, or about ten hours of hunting per rabbit bagged. Success rates seemed to be strongly associated with the size of the kill. Apparently the number of hours hunted during the entire season was not associated very strongly with either the kill or rate of kill. With other things equal the lowest total kill and highest rate of kill would be expected to take place when the least hunting effort was expended. Contrary to this expectation, 1952 which had the least effort experienced the second lowest rate of kill and 1954 which had the greatest effort had the second lowest kill. From the data in Table 37 it is apparent that some other factor influenced the hunting kill and success besides hunting effort expended. This matter is discussed beyond where success data and total kill are evaluated as indexes of abundance.

TABLE 38

YEARLY HUNTING EFFORT, KILL AND SUCCESS--KELLOGG FOREST
AUGUSTA, MICHIGAN

Year	Effort Hours	Kill	Kill/100 Gun-hours
1951	2114	267	12.1
1952	2056	196	8.9
1953	2310	245	10.1
1954	2349	206	8.8

Although the rabbit open season was increased from 77 days in 1951 to 104 days in 1952 no increase in hunting activity occurred. In fact 58 fewer hours were hunted in 1952 than in 1951. The average annual effort during the three years of 104-day seasons was 2238 hours in contrast to 2114 hours hunted during the 77-day season in 1951. Thus a 35 percent increase in season length was accompanied by an average increase in effort of only 5.9 percent. It should be pointed out, however, that the rabbit population was higher in 1951 than in any of the following three years. Effort in 1951 might have been less if the population level had been comparable to those in the following years.

B. Monthly

The monthly distribution of effort, kill, and success is tabulated in Table 39 for the individual and collective 1951-54 seasons. There was a regularly decreasing average hunting pressure of 47.1, 25.0, 18.2 and 11.3 hours per day respectively during each month from October to January.

Hunting success over the four year period averaged highest (11.5 rabbits per 100 gun-hours) in November, next highest (10.1) in December, next in October (8.6) and was lowest in January (7.9). A better comparison was probably obtained when 1951 was eliminated from consideration because it had no January hunting and five more days in October. November and December are equally good with October success slightly poorer than in January. Probably because of seasonal changes in vegetation and snow (see beyond) the rate of kill in January was greater

TABLE 39

MONTHLY EFFORT, KILL AND SUCCESS SUMMARY 1951-1954 SEASONS--KELLOGG FOREST
AUGUSTA, MICHIGAN

Month		1951	1952-53	1953-54	1954-55	Totals	52-54 Totals
October	Kill	78.	34.	49.	54.	215.	137.
	Hours	751.67	504.75	555.75	684.25	2496.42	1744.75
	Kill/100 g.h.	10.4	6.7	8.8	8.0	8.6	7.9
November	Kill	134.	62.	79.	70.	345.	211.
	Hours	924.00	644.75	754.00	674.50	2997.33	2073.25
	Kill/100 g.h.	14.5	9.6	10.5	10.4	11.5	10.2
December	Kill	44.	52.	62.	70.	228.	184.
	Hours	438.	528.75	523.50	771.85	2262.00	1824.00
	Kill/100 g.h.	10.0	9.8	11.8	9.1	10.1	10.1
January	Kill	Not open	35.	43.	5.	83.	83.
	Hours	Not open	380.75	476.85	198.00	1055.50	1055.50
	Kill/100 g.h.	Not open	9.2	9.0	2.5	7.9	7.9
Total	Kill	256.	183.	233.	199.	871.	
	Hours	2113.75	2059.00	2310.00	2328.50	8811.25	
	Kill/100 g.h.	12.1	8.9	10.1	8.5	9.8	

than that in October even though by January each year close to 50 percent of the population had already been bagged.

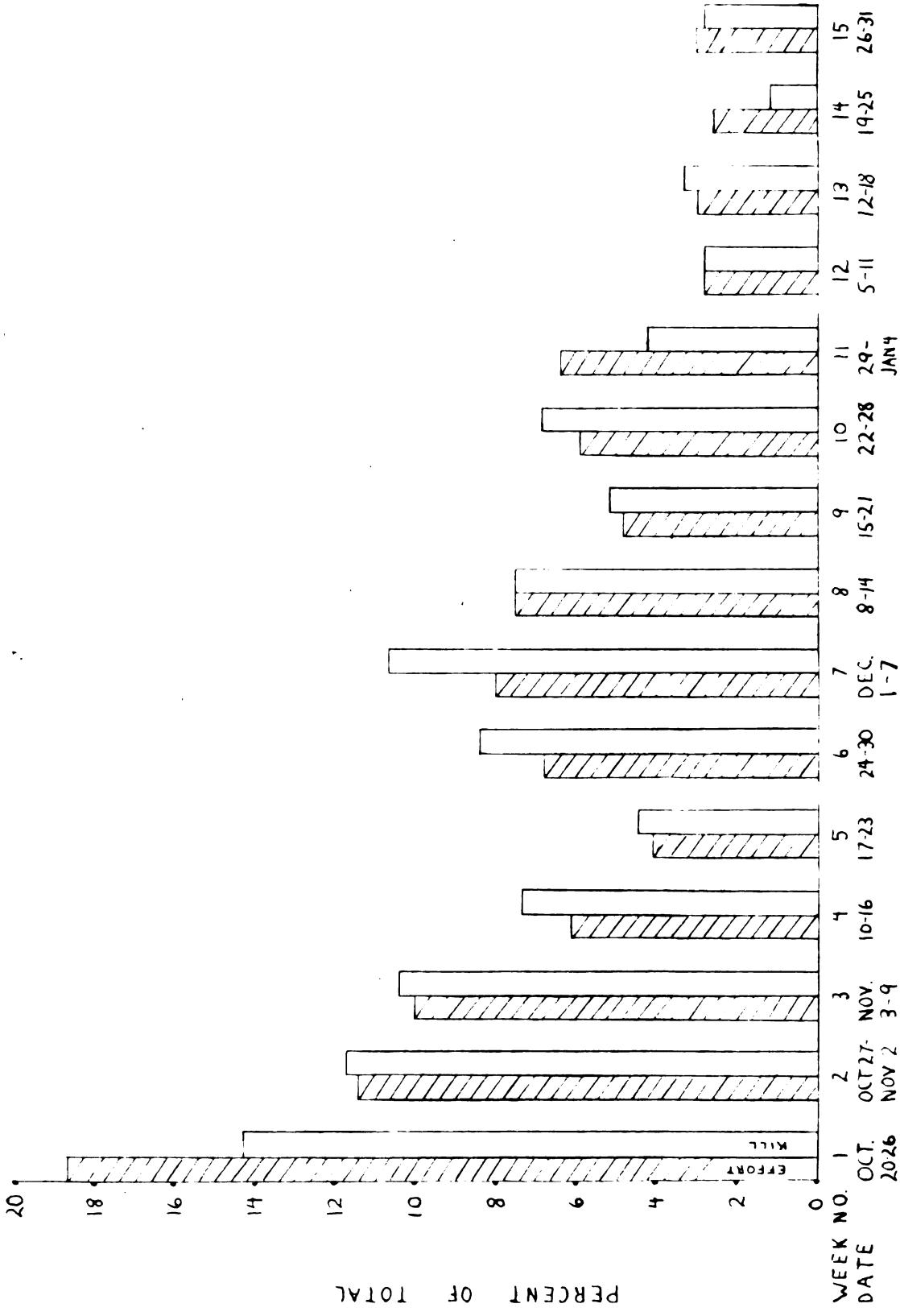
C. Weekly

A consideration of weekly fluctuations in effort, kill and success probably best shows the changes that occur during the season. Figure 23 shows the total weekly effort and kill for the 1952-54 seasons combined. 1951 was not included because different opening and closing dates were then in effect. Peak effort occurred during the first week (October 20-26) then gradually tapered off until the fifth week (November 17-23). Effort sharply increased for the next two weeks reaching a second peak during the seventh week, (December 1-7). This second peak was slightly less than half as high as the first. Effort then tapered off until it was uniformly low during the 12th week through the end of the season (January 5-31). Late season effort was very light compared to the expended early in the season. During each of the last four weeks effort was only about 14 percent of that registered during the first week of the season.

Figure 23 shows the close association between the weekly kill and the effort expended. Essentially the pattern of kill was the same as for effort. Peaks occurred during the first (October 20-26) and seventh (December 1-7) weeks, however, the second peak was about 70 percent as great as the first. The reason for this relatively greater late peak in kill was the greater rate of kill experienced during the seventh week. Because of the low effort during the last four weeks the kill was also low. A total of only 61 rabbits were killed during the last

FIGURE 23

WEEKLY HUNTING EFFORT AND RABBIT KILL
KELLOGG FOREST 1952+1954 SEASONS COMBINED



four weeks of the 1952-54 seasons while the total kills for the 1st, 2nd, 3rd, and 7th weeks all exceeded that level.

The hunting success as measured by rate of kill is indicated in Figure 23 by the difference in length between the kill and the effort bars for each week. For example, in the first week the effort bar is much longer than the kill bar indicating a relatively low rate of kill. In contrast the seventh week had a kill bar longer than the effort bar indicating a much higher rate of kill. Figure 24 shows the weekly variation in hunting success in terms of kill per 100 gun-hours. It indicates a gradual increase in success between the first and seventh weeks and then an irregular decrease for the rest of the season. The last week experienced a slightly higher rate of kill than did the first week. Table 40 gives the numerical data on which Figures 1 and 2 are based and provide additional details. Since fluctuations in these values were generally similar each season the total mean values used in Figures 23 and 24 probably give a reliable indication of the fluctuations that can be expected to occur in the future.

It is noteworthy that hunting success did not decrease as the season progressed. It might be expected that the rate of kill would be proportional to the population present and that consequently it would decrease as the population was reduced in size by hunting. This was observed to happen on the Kellogg Bird Sanctuary and Farm where hunting did not start until December and then was conducted in an intense manner under fairly constant conditions. The reasons for this lack of a

FIGURE 24
WEEKLY VARIATION IN HUNTING SUCCESS
KELLOGG FOREST 1952-1954 SEASONS COMBINED

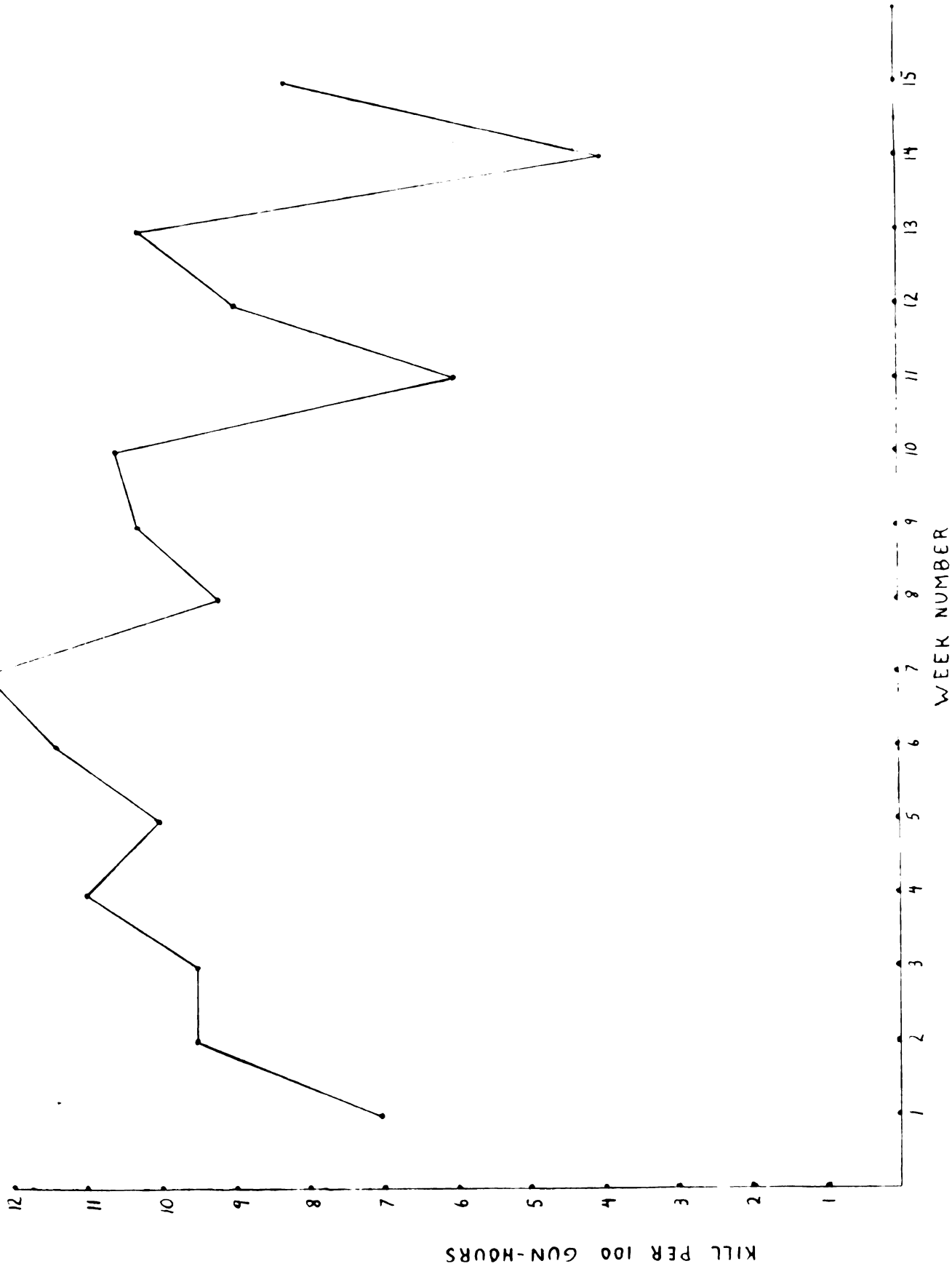


TABLE 40

WEEKLY DISTRIBUTION OF HUNTING KILL, EFFORT AND SUCCESS 1951-1954 SEASONS--KELLOGG FOREST AUGUSTA, MICHIGAN

Dates*	Week Number		1951	1951	1952	1953	1954	Weekly Total 1951-54	Weekly Total 1952-54	Percent of Total 1951-54	Percent of Total 1952-54	Kill per 100 G.H. 1952-1954
Oct. 20-26	1	Kill	33	25	33	30	121	88	13.9	14.3	7.0	
		Hours	413	424	386	440	1663	1250	18.9	18.7		
27-Nov. 2	2	Kill	40	13	32	27	112	72	12.8	11.7	9.5	
		Hours	290	164	302	295	1051	761	11.9	11.4		
Nov. 3-9	3	Kill	34	29	17	18	98	64	11.2	10.4	9.5	
		Hours	265	239	206	227	937	672	10.6	10.0		
10-16	4	Kill	47	9	14	22	92	45	10.6	7.3	11.0	
		Hours	248	112	153	144	657	409	7.5	6.1		
17-23	5	Kill	16	11	6	10	43	27	4.9	4.4	10.0	
		Hours	137	98	68	104	407	270	4.6	4.0		
24-30	6	Kill	32	9	26	17	84	52	9.6	8.4	11.4	
		Hours	262	112	195	149	7.8	455	8.1	6.8		
Dec. 1-7	7	Kill	20	26	19	21	86	66	9.9	10.7	12.3	
		Hours	183	189	122	226	720	537	8.2	8.0		
8-14	8	Kill	16	14	6	20	56	40	6.4	6.5	9.2	
		Hours	144	139	111	185	579	435	6.6	6.5		
15-21	9	Kill	9	8	10	14	41	32	4.7	5.2	10.3	
		Hours	100	81	82	158	421	321	4.8	4.8		
22-28	10	Kill	2	4	26	12	44	42	5.1	6.8	10.6	
		Hours	20	98	174	126	418	398	4.7	5.9		
29-Jan. 4	11	Kill	7	16	7	3	33	26	3.8	4.2	6.0	
		Hours	51	167	138	124	480	430	5.5	6.4		
Jan. 5-11	12	Kill		8	8	1	17	17	2.0	2.8	9.0	
		Hours		54	106	29	189	189	2.1	2.8		
12-18	13	Kill		1	16	3	20	20	2.3	3.3	10.3	
		Hours		46	108	40	194	195	2.2	2.9		
19-25	14	Kill		1	6	0	7	7	.8	1.1	4.0	
		Hours		74	64	36	174	174	2.0	2.6		
26-31	15	Kill		9	7	1	17	17	2.0	2.8	8.3	
		Hours		62	96	46	204	204	2.3	3.0		
Totals		Kill	256	183	233	199	871	615				
		Hours	2113	2059	2311	2330	8813	6700				

*Except for 1951 when the hunting season opened October 15 and closed December 31.

decrease in yield as the season progressed will be considered later after the factors influencing hunting success have been discussed.

D. Daily

Over a four year period about 35 percent of the total effort occurred consistently on Sundays, 25 percent occurred on Saturday and weekdays each had about 8 percent. The distribution of the kill was almost identical to that of the effort expended. This indicates that the kill is almost precisely a function of the effort expended when based on season-long totals over a 4 year period. The rate of kill was nearly the same each day. Week ends, however, had a slightly lower yield of 9.7 rabbits per 100 gun-hours in contrast to 10.2 rabbits per 100 gun-hours on weekdays. Statistical analysis indicates that this great difference could be expected 50 percent of the time due to chance alone. Therefore, the difference in success between week ends and weekdays is of doubtful significance. A summary of daily hunting statistics is given in Table 41.

It was thought that the amount of effort expended on the weekends might vary during the season. This was checked and it was found that except for the first week the amount of effort expended on weekends consistently ran about 60 percent of the total. During the first week only 42 percent of the effort was expended on the weekend. This was no doubt due to the great hunting pressure applied opening day which was always on a weekday.

TABLE 41

DAILY DISTRIBUTION OF HUNTING KILL AND EFFORT--KELLOGG FOREST
AUGUSTA, MICHIGAN

Day	Year 1951	1952	1953	1954	Total Kill	Percent of Total Kill	Year 1951	1952	1953	1954	Kill/ 100 g.h.
Kill:	Number Bagged						Percent of Total Kill for Each Year				
Sunday	81	53	99	69	302	34.7	31.6	28.9	41.5	34.7	9.7
Monday	26	26	16	5	73	8.4	10.2	14.2	6.9	2.5	10.9
Tuesday	12	19	16	15	62	7.1	4.7	10.4	6.9	7.5	9.2
Wednesday	17	12	9	22	60	6.9	6.6	6.6	3.9	11.1	9.6
Thursday	24	19	25	17	85	9.8	9.4	10.4	10.7	8.5	11.2
Friday	31	15	12	16	74	8.5	12.1	8.2	5.2	8.0	9.9
Saturday	65	39	56	55	215	24.7	25.4	21.3	24.0	27.6	9.6
Total	256	183	233	199	871	100.1	100.0	100.0	100.0	99.9	
Effort:	Number of Hours				Total	Percent of Total	Percent of Total Hours				
Sunday	773	601	901	827	3102	35.2	36.6	29.2	39.0	36.2	
Monday	222	270	120	57	669	7.6	10.5	13.1	5.2	2.4	
Tuesday	119	177	220	157	673	7.6	5.6	8.6	9.5	6.7	
Wednesday	127	141	134	224	626	7.1	6.0	6.8	5.8	9.6	
Thursday	143	172	217	229	751	8.6	6.8	8.3	9.4	9.8	
Friday	151	163	203	227	744	8.4	7.1	7.9	8.8	9.1	
Saturday	579	536	516	607	2238	25.4	27.4	26.0	22.3	26.1	
Total	2114	2060	2311	2328	8813	99.9	100.0	99.9	100.0	99.9	

E. Hourly

The hourly pattern of hunting effort on weekdays, Saturdays, Sundays and opening day during the 1954 season was determined by tabulating the number of hunters on the area at one-half hour intervals.

Fluctuations in effort are shown in Figure 25. A peak of hunting intensity occurred in all cases about 11:00 A.M. A lower second peak occurred about 3 P.M. on Saturdays and weekdays. On Sundays no afternoon peak was evident. Friley (1954) presented graphs showing changes during the day in pheasant hunting pressure at the Rose Lake Wildlife Experiment Station near Lansing, Michigan. These hunting pressure fluctuations were similar to those observed in this study except that the afternoon peak was relatively higher and about one hour later.

In 1951 the amount of effort expended between daylight and 10 A.M., 10 A.M. and 12:30 P.M., 12:30 P.M. and 3 P.M., and 3 P.M. to dark was tabulated (Table 42). This tended to obscure the peaks of effort but it affirmed that the greatest effort was in the morning. The rate of kill was greatest for the earliest period and decreased as the day progressed. This possibly indicated that early morning was the most successful time to hunt; however, the difference was not statistically significant because as great a difference could be expected to occur between 50 and 30 per cent of the time due to chance.

To further test the possible superiority of early morning rabbit hunting the effort and kill that took place then during the 1954 season was compared to that experienced later in the day. It was found that 600 hours were hunted and 59 rabbits bagged between daylight and

FIGURE 25

HOURLY DISTRIBUTION OF HUNTING EFFORT

KELLOGG FOREST 1954-1955 SEASONS

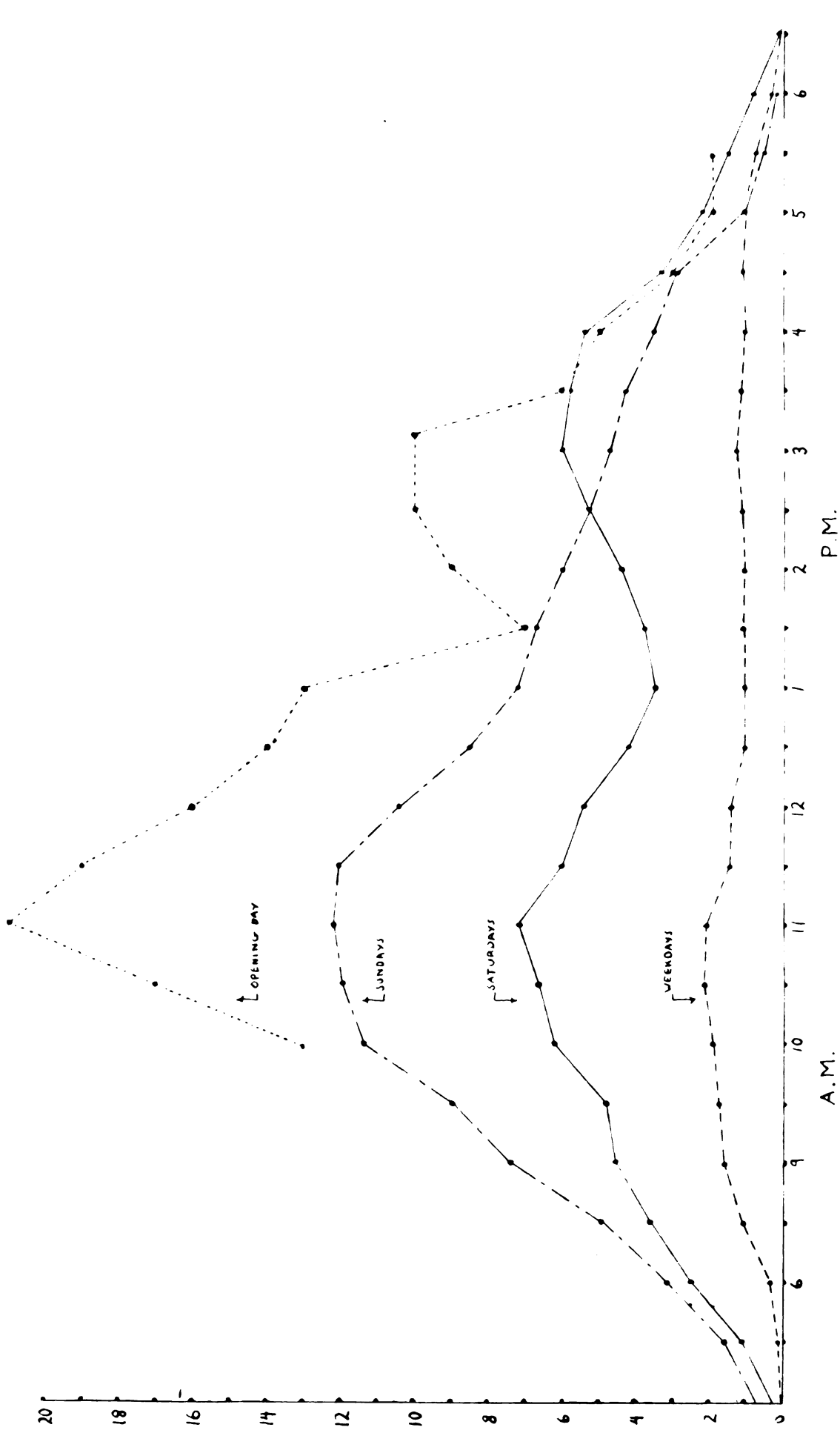


TABLE 42

DISTRIBUTION OF HUNTING EFFORT, KILL AND SUCCESS
1951 SEASON--KELLOGG FOREST
AUGUSTA, MICHIGAN

Time	Effort		Kill		Kill per 100 Gun-Hours
	Hours	Percent	Rabbits	Percent	
Light - 10 A.M.	604.3	28.3	82	32.2	13.6
10 A.M. - 12:30 P.M.	671.7	31.5	84	32.9	12.5
12:30 A.M. - 3 P.M.	486.0	22.8	51	20.0	10.5
3 P.M. - Dark	325.4	15.3	33	12.9	10.1
Unknown	45.4	2.1	5	2.0	10.9
	2132.8	100.0	255	100.0	12.0

10:30 for a success rate of 9.8 rabbits per 100 gun-hours. During the remainder of the day, 1,725 hours were hunted and 140 rabbits bagged for a yield of 8.1 rabbits per 100 gun-hours. When data from the 1951 and 1954 seasons were combined, the early morning yield was 11.7 per 100 gun-hours and for the remainder of the day 9.6. This difference was almost statistically significant at the 5 percent level. It seems likely that a larger sample would have indicated that a significantly higher rate of kill occurred early in the day and lessened as the day progressed.

IV. Distribution of Effort, Kill and Success Among the Hunters

A. Effort

The distribution of effort expended during the season by individual hunters ranged from four men who hunted only one-half an hour to two that each hunted over 78 hours. Most hunters spent a relatively short time on the area with two hours being the modal effort and four hours and 26 minutes the mean. Table 43 shows the distribution of effort among the hunting public with the effort grouped into hourly intervals. Eighty-five percent of the hunters hunted less than six and one-half hours.

Possibly a more natural way to classify the distribution of effort is by the number of visits made during the season. Table 44 shows this along with hunter success, average hunt length, and the extent to which dogs were used and hunting was done on days with snow cover. Sixty-five percent of the hunters visited the area only once and the number that hunted increasing numbers of times tapered off rapidly. Only seven

TABLE 43

DISTRIBUTION OF HUNTING EFFORT AMONG THE HUNTERS
1954-55 SEASON--KELLOGG FOREST
AUGUSTA, MICHIGAN

Length of Effort (Hours)	Number of Hunters	Percent of Total Hunters
.50 - .75	19	3.58
1.00 - 1.75	164	30.94
2.00 - 2.75	128	24.15
3.00 - 3.75	73	13.77
4.00 - 4.75	32	6.04
5.00 - 5.75	28	5.28
6.00 - 6.75	16	3.02
7.00 - 7.75	7	1.32
8.00 - 8.74	8	1.51
9.00 - 9.75	10	1.89
10.00 - 10.75	9	1.70
11.00 - 11.75	5	.94
12.00 - 12.25	3	.57
13.50 - 13.75	3	.57
14.25 - 14.50	4	.75
15.25 - 15.75	2	.38
16.25 - 16.75	4	.75
18.50	1	.19
19.00	1	.19
21.00	1	.19
22.25	1	.19
25.00 - 25.25	2	.38
27.50	1	.19
28.50	1	.19
33.00	1	.19
34.25	1	.19
36.75	1	.19
48.50	1	.19
75.25	1	.19
78.25	2	.38
	530	100.01

TABLE 44

DISTRIBUTION OF HUNTER VISIT FREQUENCY AND THE MEAN VISIT LENGTH, SUCCESS, DOG USE AND PERCENTAGE OF VISITS WITH SNOW COVER FOR EACH VISIT CATEGORY, 1954 SEASON--KELLOGG FOREST AUGUSTA, MICHIGAN

Number Visits	Number Hunters	Total Hours	Total Kill	Mean Hours Per Visit	Mean Kill per 100 Gun-Hours	Percent Dog Use	Percent Visits with Snow Cover
1	344	686.5	48	1.98	7.0	66	31
2	99	427.5	25	2.16	5.8	59	27
3	33	198.8	11	2.01	5.5	65	11
4	15	137.0	12	2.28	8.8	82	26
5	15	186.5	15	2.49	8.0	72	36
6	8	108.8	7	2.27	6.4	60	20
7	5	89.8	11	2.56	12.2	58	20
8	4	93.5	4	2.92	4.3	98	17
9	1	36.7	2	4.08	5.4	100	100
10	1	22.2	2	2.22	9.0	70	60
11	1	27.5	7	2.50	25.4	0	0
14	2	156.5	24	5.59	15.3	100	50
18	2	82.8	21	2.30	25.4	100	100
24	1	75.2	10	3.14	13.3	100	25

hunters visited the area ten or more times. Hunting success was fairly uniform among the visit categories except for the six hunters that hunted eleven or more times. Statistically, this group had highly significantly higher success than did the rest. All except one of this group were always aided by a dog. In none of the visit categories did hunters average even one rabbit per visit.

It was hypothesized that the rabbit hunting success for the one and two visit categories might have been higher had it not been that some of these hunters primarily sought pheasants or squirrels. To determine if this occurred, the hunting success of hunters that hunted one or two times between October 20 and November 10 was compared to that experienced by one of two-time hunters during the remainder of the season when only rabbits were hunted. The former group averaged 6.8 and 4.7 rabbits per 100 gun-hours for the one and two visit categories respectively. Those hunting only rabbits averaged 7.2 and 6.3 rabbits per 100 gun-hours. This is not a conclusive comparison since better hunting success normally is experienced later in the year. It is seen likely, however, that simultaneous hunting for other species had at most only a slight influence on rabbit hunting success. This is logical when it is realized that the Kellogg Forest offers relatively poor pheasant and squirrel hunting, and, therefore, most hunters seek rabbits.

The distribution of 1954-55 hunt lengths is tabulated by months in Table 45. In every month two hours was the modal visit length. January had an average hunt length of only 1.89 hours in contrast to October, November and December with averages of 2.35, 2.25, and 2.42

TABLE 45

DISTRIBUTION OF VISIT LENGTHS 1954-1955 SEASON--KELLOGG FOREST AUGUSTA, MICHIGAN

Length (Hours)	Number of Visits				
	October	November	December	January	Total
.50	1	4	7	2	14
.75	13	7	11	3	34
1.00	25	33	42	10	110
1.25	25	26	18	9	78
1.50	30	41	28	15	114
1.75	19	28	18	10	75
2.00	40	51	50	24	165
2.25	14	10	18	4	46
2.50	31	21	19	13	84
2.75	4	14	9	2	29
3.00	29	14	19	3	65
3.25	21	5	7	1	34
3.50	7	16	10	4	37
3.75	7	4	5		16
4.00	4	10	4		18
4.25	2	1	3		6
4.50	12	3	10		25
4.75		1	2		3
5.00	1	8			9
5.25				1	1
5.50		2	1		3
5.75		2			2
6.00	2	5			7
6.25			4		4
6.50	7		7		14
6.75					
7.00			9		10
7.25					
7.50					
7.75					
8.00					
8.25			2		2
Average length	2.35	2.25	2.42	1.89	2.31

hours per visit respectively. This difference is statistically highly significant and may have been associated with the poor hunting success experienced then.

B. Bag

The entire kill was made by only 19.6 percent of the hunters (Table 46). Four of every five hunters were totally unsuccessful. The 6.8 percent that killed two or more rabbits were responsible for 65.8 percent of the total bag. There was no great increase in the kill per 100 gun-hours as the number killed increased. The high kills apparently were due largely to the greater effort by the hunters that made them. When it is remembered that 85 percent of the hunters hunted less than six and one-half hours and it took an average effort of 11.7 hours to bag a rabbit it is not surprising that 80.4 percent bagged no rabbits. The hunters making high kills showed a tendency to use dogs and hunt on days with snow cover.

C. Success

Table 47 shows the distribution of success among the hunters in terms of kill per 100 gun-hours. Eighty-three percent averaged less than one rabbit per ten gun-hours; while only 4.9 percent managed to bag five or more rabbits per ten gun-hours.

An effort was made (Table 48) to determine if differences in success were due to chance alone. The Poisson distribution of the numbers of hunters expected in each kill category was calculated for each of four effort categories. The number of hunters in each kill

TABLE 46

DISTRIBUTION OF RABBIT KILL AMONG HUNTERS
1954-1955 SEASON--KELLOGG FOREST
AUGUSTA, MICHIGAN

Number Killed	Number Hunters	Kill 100 g. h.	Average[1] Dog Use Percent	Percent[2] Snow Cover
0	426	0	62.2	18
1	68	18.8	74.4	13
2	23	15.1	88.3	50
3	5	37.5	75.0	39
4	2	20.6	50.0	11
7	1	25.4	0.0	0
8	2	12.6	100.0	25
10	1	13.3	100.0	25
13	1	37.9	100.0	22
16	1	20.4	93.0	50

[1]Percentage of total effort during which a dog or dogs were used.

[2]Percentage of total effort during which snow cover was present.

TABLE 47

DISTRIBUTION IN HUNTING SUCCESS 1954-1955 SEASON--KELLOGG FOREST
AUGUSTA, MICHIGAN

Hunting Success Kill/100 g.h.	Number Hunters	Number Visits	Number Hours	Kill	Kill/ 100 g.h.	Percent Total Kill	Percent Total Effort
0 - 9.9	442		1554.50	22	1.4		
10.0 - 19.9	26	143	425.25	59	13.9		
20.0 - 29.9	16	65	209.00	49	23.4		
30.0 - 39.9	11	32	69.75	25	35.8		
40.0 - 49.9	9	10	22.50	9	40.0		
50.0 - 59.9	13	15	25.25	13	51.5		
60.0 - 69.9	4	4	7.75	5	64.5		
70.0 - 79.9	0	0	0	0	0		
80.0 - 89.9	4	5	8.75	7	80.0		
90.0 - 99.9	0						
100.0 - 109.9	4	4	8.00	8	100.0		
110.0 - 119.9	4	1	1.75	2	114.2		
0 - 19.9	468		1979.75	81	4.1	41	85
20.0 - 119.9	62		348.75	118	33.8	59	15

TABLE 48

OBSERVED DISTRIBUTION IN KILL IN VARIOUS EFFORT CATEGORIES COMPARED TO WHAT WOULD BE EXPECTED DUE TO CHANCE. 1954-1955 SEASON--KELLOGG FOREST AUGUSTA, MICHIGAN

	.5-2.00 Hours Number of Hunters		2.25-6.25 Hours Number of Hunters		6.50-12.25 Hours Number of Hunters		13.50-78.25 Hours Number of Hunters		Total Number of Hunters	
Kill	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
0	222	215.1	171	153.1	29	23.1	4	2.7	426	394.0
1	19	27.1	30	46.9	14	17.8	5	6.3	68	98.1
2	3	1.7	5	7.2	4	6.9	11	7.4	23	23.2
3	0	.1	2	.7	3	1.8	0	5.8	5	8.4
4		.0	0	.0	0	.3	2	3.4	2	3.7
5						.0	0	1.6	0	1.6
6							0	.6	0	.6
7							1	.2	1	.2
8							2	.1	2	.1
10							1	.0	1	.0
13							1		1	.0
16							1		1	.0

category for the four distributions was then added to yield an overall distribution of the kill that would be expected if chance alone was responsible for the variability in kill. This approach takes into consideration variability due to differences in effort and assumes that there is a single probability of success. The resulting distribution based on these conditions was then compared with that which was actually observed. The observed distribution had more hunters which killed no rabbits and which killed seven or more rabbits than would be expected where it is assumed that a uniform probability of success existed. Statistically, this difference was highly significant. Thus, there was less than one chance in 100 that the differences in success which were observed were due only to chance.

When differences in effort are taken into consideration, the variation in success due to chance accounted for more variation than might be expected from a more casual consideration of the matter. It could be expected that with a uniform rate of kill 7.1 per cent of the hunters would kill two or more rabbits and that their kill would make up 50.4 percent of the total bag. It was actually observed that 6.8 percent of the sportsmen killed two or more rabbits and that they succeeded in killing 65.8 percent of the total taken. If a uniform probability of kill existed it would be expected that 74.3 percent of the hunters would kill no rabbits. It was observed that 80.4 percent killed no rabbits.

Next the expected Poisson distribution kill for each effort category was calculated based on each category's average rate of success. Thus four different probabilities of success were used. These expected

distributions were then added as before and compared to the observed distribution. Again there were more hunters with no kill and a bag of 7 or more than would be expected due to chance. However, as would be expected, the difference was not as great as that observed previously. In fact it was not quite significant at the 0.05 level of probability. Thus it can be concluded that much of the variability in success observed in the first analysis was due to hunters in the different effort categories having different probabilities of success. This was probably due largely to the greater success experienced by those persons that hunted most often.

When the kill distributions in the individual effort categories were each compared with the Poisson distributions based on their individual probabilities of success, only the greatest effort category displayed a statistically significant departure from a uniform probability of success. The wide range of effort of from 13.5 to 78.25 hours in this category possibly contributed to this. The other effort categories extended over a much shorter period of effort. It was necessary for the greatest effort category to include a long period because so few hunters hunted more than 13 hours. Because of the small number of hunters involved it was not feasible to further subdivide the groups and make an analysis like that above. However, it was possible to divide the category into four parts each with seven hunters and test statistically the homogeneity of hunting success. The significant chi-square value which resulted indicated that hunting success within this group varied more than could be attributed to chance alone.

This analysis considered the variation that existed in effort expended so that that factor could not have been responsible for the differences noted.

This investigation into the homogeneity of hunting success may be summarized as follows:

1. Considerable variation in the distribution of the kill can be attributed to chance and to differences in amount of effort.
2. Observed variation in hunting success was significantly greater than could be attributed to chance when differences in effort were considered thus implying that real differences in hunter effectiveness existed.
3. The non-uniform rate of kill was due largely to the relatively few very successful hunters that hunted on the Kellogg Forest more than 13 hours.

VI. Effect of Weather on Hunting Effort

Tables 49-55 summarize the average daily effort expended under various climatic situations. The various climatic factors were considered separately for each month and the daily effort weighted so as to eliminate the influence of day of the week on hunting pressure.

During Octobers there was a longer hunting effort on clear days than on partly cloudy or cloudy days (Table 49). During the remainder of the season no trend was evident; however, there were only 8 clear days during the 153 days considered.

The daily minimum temperature (Table 50) had no noticeable influence on daily hunting effort. Perhaps this is because minimum

TABLE 49

RELATIONSHIP BETWEEN CLOUDINESS AND HUNTING EFFORT AND SUCCESS 1951 AND 1952 DATA COMBINED--KELLOGG FOREST AUGUSTA, MICHIGAN

Month	Cloudiness	Number Days	Total Hours	Weighted Hours	Kill	Hours Per Day	Kill/ 100 g.h.
October	Clear	6	364.8	231.6	35	39	9.6
	Partly cloudy	14	525.6	385.8	39	28	7.4
	Cloudy	9	366.4	167.4	49	19	13.4
November	Clear	1	21.0	21.0	7	21	33.3
	Partly cloudy	22	680.8	308.2	87	14	12.8
	Cloudy	37	885.1	559.4	102	15	11.5
December	Clear	4	92.2	32.1	12	8	13.0
	Partly cloudy	20	319.4	139.8	36	7	11.3
	Cloudy	38	532.0	316.4	47	8	8.8
January	Clear	3	22.5	22.5	4	7	17.8
	Partly cloudy	4	25.2	25.2	5	6	19.8
	Cloudy	24	332.8	175.2	26	7	7.8

TABLE 50

RELATIONSHIP BETWEEN MINIMUM DAILY TEMPERATURES AND HUNTING EFFORT AND SUCCESS
1951-1953 DATA COMBINED--KELLOGG FOREST
AUGUSTA, MICHIGAN

Month	Minimum Temperature	Number Days	Total Hours	Weighted Hours	Kill	Hours per Day	Kill/ 100 g. h.
October	11-15	1	34.8	34.8	0	35	0
	16-20	4	182.2	96.2	18	24	9.9
	21-25	8	481.5	330.0	41	41	8.5
	26-30	3	57.8	45.9	4	15	6.9
	31-35	6	208.8	155.1	28	26	13.4
	36-40	7	419.1	258.4	33	37	7.9
	41-45	11	423.8	273.8	13	25	3.1
	46-50	1	4.8	4.8	0	5	0
November	- -5	2	33.5	33.5	7	17	21.0
	-4- 0	0	--	--	--	--	--
	1- 5	2	22.8	23.0	4	11	17.6
	6-10	3	177.1	53.2	26	18	14.7
	11-15	6	187.0	61.2	12	10	6.4
	16-20	13	491.5	205.4	61	16	12.4
	21-25	18	538.0	285.2	58	16	10.8
	26-30	17	348.2	246.2	37	14	10.6
	31-35	11	173.2	110.4	21	10	12.1
	36-40	9	220.0	117.5	27	13	12.3
	41-45	4	117.5	68.6	16	17	13.6
	46-50	4	54.5	54.5	6	14	11.0
December	up to -5	9	72.7	58.5	8	7	11.0
	-4- 0	0	--	--	--	--	--
	1- 5	3	11.2	11.2	1	4	8.9
	6-10	9	111.2	69.1	13	8	11.7
	11-15	5	14.0	11.2	1	2	7.1

	16-20	10	207.5	149.8	31	15	14.9
	21-25	18	388.0	230.6	33	13	8.5
	26-30	20	366.8	196.4	33	10	9.0
	31-35	9	158.0	54.6	13	6	8.2
	36-40	7	103.2	68.2	20	10	19.4
	41-45	2	21.8	21.8	3	10	13.8
January	up to -5	6	16.5	16.5	2	3	12.1
	-4- 0	2	38.0	38.4	2	19	5.3
	1- 5	3	36.8	15.9	5	5	13.6
	6-10	6	139.2	59.0	16	10	11.5
	11-15	9	130.8	73.0	13	8	9.9
	16-20	9	114.0	78.0	10	9	8.8
	21-25	13	233.0	111.8	20	9	8.6
	26-30	9	123.8	70.8	10	8	8.1
	31-35	5	17.5	17.5	0	4	0
	36-40	1	7.0	7.0	0	7	0

TABLE 51

RELATIONSHIP BETWEEN MAXIMUM DAILY TEMPERATURES AND HUNTING EFFORT AND SUCCESS
1951-1953 DATA COMBINED--KELLOGG FOREST
AUGUSTA, MICHIGAN

Month	Maximum Temperature	Number Days	Total Hours	Weighted Hours	Kill	Hours per Day	Kill/ 100 g.h.
October	36-40	1	19.2	19.2	5	19	26.0
	41-45	5	287.4	233.6	34	47	11.8
	46-50	5	225.5	107.2	23	21	10.2
	51-55	6	415.8	158.2	13	26	3.1
	56-60	5	213.2	108.4	8	22	3.8
	61-65	5	94.2	94.2	11	19	11.7
	66-70	5	119.8	119.8	6	24	5.0
	71-75	4	249.0	173.1	16	43	6.4
	76-80	2	43.0	43.0	4	22	9.3
	81-85	3	146.5	146.5	11	49	7.5
November	11-15	1	30.5	30.5	2	30	6.6
	21-25	2	16.5	16.5	2	8	12.1
	26-30	9	398.2	215.8	42	24	10.5
	31-35	13	400.4	222.0	66	17	16.5
	36-40	8	165.8	114.6	17	14	10.3
	41-45	8	196.8	105.4	16	13	8.1
	46-50	15	316.2	233.0	45	16	14.2
	51-55	10	230.2	136.2	27	14	11.7
	56-60	6	83.8	83.8	9	14	10.7
	61-65	6	220.2	62.2	26	10	11.8
	66-70	9	198.5	64.4	12	7	6.0
December	11-15	3	22.5	22.2	1	7	4.4
	16-20	4	25.2	19.4	4	5	15.8
	21-25	7	62.5	62.5	5	9	8.0
	26-30	11	128.8	128.8	5	12	3.9
	31-35	22	396.4	215.2	46	10	11.6

6.2

	36-40	19	353.0	154.3	24	8	6.8	
	41-45	10	127.5	75.9	8	8	6.3	
	46-50	7	172.0	76.8	24	8	14.0	
	51-55	2	22.0	22.0	8	11	36.4	13.7
	56-60	6	147.2	57.4	13	10	8.8	
	61-65	1	17.0	17.0	4	17	23.6	
January	up to 10	1	0	0	.0	0	--	
	16-20	1	38.0	8.4	2	8	5.3	
	21-25	5	94.0	36.2	7	7	7.4	
	26-30	5	12.5	5.9	0	1	0	
	31-35	18	337.5	134.3	42	7	12.4	
	36-40	18	225.0	148.6	19	8	8.4	
	41-45	7	63.5	63.5	2	9	3.1	
	46-50	5	77.0	60.4	5	12	6.5	
	51-55	2	3.0	3.0	1	2	33.0	
	56-60	1	7.0	7.0	0	7	0	

TABLE 52

RELATIONSHIP BETWEEN MEAN WIND VELOCITY AND HUNTING EFFORT AND SUCCESS 1951-1953 DATA COMBINED
KELLOGG FOREST, AUGUSTA, MICHIGAN

	Mean Wing Velocity M.P.H.	Number Days	Total Hours	Weighted Hours	Kill	Hours Per Day	Kill/ 100 g.h.
October	0	2	178.0	97.0	13	48	7.3
	1	11	634.0	422.0	47	38	7.4
	2	8	446.2	189.4	54	24	12.1
	3	9	284.2	227.0	25	25	8.8
	4	7	130.2	130.2	14	19	10.7
	5	3	197.2	139.0	22	46	11.2
	6	2	6.5	6.5	0	3	0
November	0	4	138.0	91.3	7	23	5.1
	1	17	555.8	263.0	77	15	13.9
	2	24	633.0	333.8	65	14	10.3
	3	12	368.2	170.6	43	14	11.7
	4	18	344.8	206.8	48	11	13.9
	5	8	331.1	121.2	30	15	9.1
	6	1	7.5	7.5	0	8	0
	7	2	19.5	19.5	4	10	20.5
	8	1	10.0	10.0	0	10	0
	9	1	12.5	12.5	0	12	0
	11	2	0	0	0	0	--
December	0	4	181.2	40.2	19	10	10.5
	1	13	295.2	89.8	26	7	8.8
	2	21	322.8	245.6	25	12	7.7
	3	26	375.5	236.7	53	9	14.1
	4	18	263.5	176.2	29	10	11.0
	5	6	28.8	28.2	4	5	13.9
	6	3	5.0	5.0	1	2	20.0
January	1	8	168.0	45.6	18	6	10.7
	2	16	295.0	207.6	20	13	6.8
	3	12	189.2	108.3	22	9	11.6
	4	14	157.5	54.7	11	4	7.0
	5	6	31.2	31.2	7	5	22.4
	6	2	0	7.0	0	4	---
	7	2	0	2.9	0	2	---

TABLE 53

RELATIONSHIP BETWEEN PRECIPITATION AS RAIN AND HUNTING EFFORT AND SUCCESS
1951-1953 DATA COMBINED--KELLOGG FOREST
AUGUSTA, MICHIGAN

Month	Inches Rain	Number Days	Total Hours	Weighted Hours	Kill	Hours Per Day	Kill Per 100 g. h.
October	none	29	1453.2	959.1	114	33.1	7.8
	Trace-.09	5	289.4	176.5	32	35.3	11.1
	.10- .19	1	29.8	29.8	11	29.8	37.0
	.40- .49	1	24.0	24.0	0	24.0	0
	.70- .79	1	6.8	22.5	4	6.8	17.8
	1.0-1.09	1	7.2	7.2	0	7.2	0
	1.3 or more	1	1.8	1.8	0	1.8	0
November	none	73	1872.0	1680.7	236	23.0	12.6
	Trace-.09	9	301.8	104.2	27	11.6	8.9
	.10- .19	2	13.0	13.0	0	6.5	0
	.20- .29	2	46.0	46.0	6	23.0	13.0
	.40- .49	1	60.0	14.0	3	7.0	5.0
	.50- .59	1	8.8	1.9	1	1.9	11.4
	.80- .89	2	21.2	13.0	2	6.5	9.4
December	none	75	1230.9	812.4	126	10.8	10.2
	Trace-.09	12	125.0	78.4	16	6.5	12.8
	.10- .19	3	61.5	35.3	4	11.8	6.5
	.20- .29	1	2.0	2.0	0	2.0	0
	.40- .49	1	45.0	10.2	8	10.2	17.8
	.90- .99	1	25.8	25.8	4	25.8	15.5
January	none	52	783.8	517.3	72	9.2	9.9
	Trace-.09	7	60.2	37.4	6	5.4	10.0
	.10- .19	1	5.0	5.0	0	5.0	0
	.20- .29	1	8.5	8.5	0	8.5	0
	.30- .39	1	0	0	0	0	--

TABLE 54

RELATIONAHIP BETWEEN SNOWFALL AND HUNTING EFFORT AND SUCCESS 1951-1953 DATA COMBINED
KELLOGG FOREST, AUGUSTA, MICHIGAN

Month	Inches Snowfall	Number Days	Total Hours	Weighted Hours	Kill	Hours Per Day	Kill Per 100 g.h.
November	None	73	1818.6	1199.9	207	16.4	11.4
	Trace	6	127.0	78.9	18	13.2	14.2
	.1- .5	4	165.8	71.6	26	17.9	15.7
	1.0-1.9	2	20.5	20.5	6	10.2	29.3
	3.0-3.9	1	12.0	12.0	3	12.0	25.0
	5.0-5.9	2	61.2	61.2	3	30.6	4.9
	6.0-6.9	2	118.2	28.9	12	14.4	10.1
December	None	93	1072.3	707.7	104	9.7	9.7
	Trace	11	199.4	80.1	33	7.3	16.5
	.1- .7	5	70.2	43.3	6	8.7	8.5
	1.0-1.9	4	24.0	24.0	1	6.0	4.2
	2.0-2.9	3	51.2	45.4	5	15.1	9.8
	3.0-3.9	2	21.5	21.5	3	10.8	14.0
	4.0-4.9	3	5.8	5.8	1	1.9	17.4
	5.0-5.9	3	44.8	44.8	5	14.9	33.6
	8.0-8.9	1	1.0	1.0	0	1.0	0
January	None	61	416.9	275.2	32	4.5	7.7
	Trace	16	282.8	142.4	34	8.9	12.0
	.1- .5	5	18.0	18.0	1	3.6	5.5
	1.0-1.9	8	139.8	62.5	11	7.8	7.9
	2.0-2.9	1	0	0	0	0	0
	4.0-4.9	2	0	0	0	0	0

TABLE 55

RELATIONSHIP BETWEEN SNOW COVER AND HUNTING EFFORT AND SUCCESS 1951-1953 SEASONS--KELLOGG FOREST AUGUSTA, MICHIGAN

		1951-1952			1952-1953			1953-1954			Totals	
	Snow Cover	No. Days	Hours per Day	Kill per 100 g.h.	No. Days	Hours per Day	Kill per 100 g.h.	No. Days	Hours per Day	Kill per 100 g.h.	Hours per Day	Kill per 100 g.h.
November	None	14	16.2	14.0	25	12.2	9.7	24	11.6	9.4	12.8	10.7
	Scattered or 1"	8	17.1	12.1	1	0	--	1	14.5	0	10.4	11.2
	1"	8	17.1	16.2	4	9.7	9.1	5	21.8	14.6	16.7	14.7
December	None	10	21.8	7.7	10	6.4	9.2	12	8.9	11.6	12.1	9.2
	Scattered or 1"	0			15	9.1	10.2	7	7.4	8.5	8.5	10.1
	More than 1"	21	1.3	21.7	6	15.3	9.5	12	9.1	13.6	5.9	13.4
January	None				3	22.6	6.0	2	11.0	0	18.0	4.4
	Scattered or 1"				15	7.2	10.9	9	20.4	5.6	12.2	7.7
	1"				13	5.4	9.0	20	4.3	12.9	4.7	11.3

temperatures occur mostly at night.

When the daily maximum temperature was considered (Table 51) a greater effort was evident in Novembers on cool days. During Decembers, warm days tended to receive the most effort. No trend was evident during Octobers or Januarys.

During every month calm days tended to be hunted more than windy days (Table 52).

Except for January and December when the sample size was small a marked reduction in effort was associated with rain (Table 53). On the average effort was reduced by about one-half on days when rain fell. As would be expected on days with a heavy rain the reduction was even greater. Precipitation as snow had no effect on effort (Table 54). In fact, in December a slightly greater effort was expended on days with snowfall.

The association between snow on the ground and hunting effort (Table 55) was surprising. Days during December and January with snow cover had on the average less effort than did days with no snow cover. During January there were only five days without snow on the ground. During November there was a tendency toward greater effort on days having snow cover.

VI. Factors Affecting Hunting Success

A. Previous Experience With Area

Four hundred ninety-eight of the registered hunters in 1954 indicated whether they had hunted the area before. The 247 hunters with

previous experience averaged 10.5 rabbits per 100 gun-hours while the 251 who had not hunted the area before averaged only 4.3 cottontails per 100 gun-hours. A chi-square test indicated that there was less than one chance in 200 of the greater success of the experienced hunters having been due to chance.

A greater use of dogs by the experienced group may have had an influence on their success. The experienced group was assisted by dogs on 69 percent of their visits while the inexperienced group were aided by canines only 62 percent of the time. This difference was greater than the percentages indicate because experienced hunters averaged 2.8 hours per visit while the inexperienced group hunted only 1.7 hours per visit. No difference existed in the amount of hunting done with snow cover.

B. Hunter Occupation

People hunting during the 1954-1955 season were classified into the eight occupation categories shown in Table 56. More than twice as successful than any other category were the 13 unemployed persons. This group averaged 23.5 rabbits per 100 gun hours. On the average this group neither used dogs any more nor hunted more on days with snow cover than other groups. However, 69.3 percent had previous experience with the area compared to the 49.7 percent of the entire group. The next most successful group was supervisors and foremen closely followed by farmers, unskilled labor and skilled labor. The skilled and unskilled laborers made only 13 percent and 8 percent of their visits on days with snow cover so their success can not be attributed to this.

TABLE 56

HUNTER OCCUPATION AND SUCCESS, 1954--KELLOGG FOREST
AUGUSTA, MICHIGAN

Hunter Occupation	Number of Hunters	Number of Visits	Number of Hours	Total Kill	Kill/ 100 g.h.	Dog Use Percent	Percent Visits With Snow Cover	Hours per Visit	Rabbits per Visit	Visits per Hunter
Skilled labor	193	400	939.75	84	8.9	75	13	2.3	.21	2.1
Unskilled labor	123	256	669.75	69	10.3	61	8	2.6	.27	2.1
Business and profession	85	126	262.75	18	6.9	63	38	2.1	.14	1.5
Students	78	136	264.25	10	3.8	58	39	1.9	.07	1.7
Farmers	9	16	27.75	3	10.8	33	23	1.7	.18	1.8
Supervisors and foremen	7	17	43.75	5	11.4	72	28	2.6	.29	2.4
Unemployed	13	20	38.25	9	23.5	51	28	1.9	.45	1.5
Others	24	38	76.00	1	1.3	56	44	2.00	.03	1.6

Their dog use was a fairly high 75 percent and 61 percent respectively. Only seven men were in the supervisors and foremen group and there were only nine farmers, therefore, the representativeness of these categories is open to some question.

The least successful groups were business and professional men, students, and the "others" category in order of descending success. Contributing to the very low success (1.2 rabbits per 100 gun-hours) of the "other" group were six women that contributed one-fifth the group's effort but bagged nothing. The student group included some grade school children which no doubt influenced the success in that category. No data are available to explain the low success of the business and professional group.

C. Dog Use

In 1951 and 1954 when dog use was studied dog users were roughly twice as successful as non-dog users. In 1951 dog users shot 13.2 rabbits per 100 gun-hours while non-dog users averaged only 8.7. In 1954 the hunters using dogs killed 10.5 rabbits per 100 gun-hours in contrast to only 4.3 non-dog users. In both years the superiority of the dog-user's rate of kill was statistically significant.

Kinds of dogs used was recorded after each hunt in 1954 by the following classification:

1. beagle -- dogs believed to be or strongly resembling a pure-blooded beagle.
2. "hounds" -- all other hounds such as blue tick, black and tan, red bones and fox hounds.

3. bird dogs -- included setters, spaniels, retrievers and other breeds usually thought of as being best suited for bird hunting.
4. "mixed" -- dogs other than hounds that resembled no recognized breed.
5. "others" -- recognized breeds not mentioned above such as boxers, poodles, etc.

When more than one dog was used the appropriate code numbers were recorded. A total of 27 different combinations of kinds and numbers of dogs were used. The ten combinations hunted 40 or more hours are shown in Table 57. Hunters using beagles were by far the most successful, averaging 13.7 rabbits per 100 gun-hours. The use of two or three beagles did not increase success. Bird dog users had the lowest success of 5.1 rabbits per 100 gun-hours which was only slightly higher than the 4.2 kill made by non-dog users. The probability that the superiority of beagles over bird dogs was due to chance was less than 0.005.

In 1951 the kind and amount of dog use was not recorded after each hunt according to a code system as was the case in 1954. This resulted in a less precise record of dog use but the results are summarized in Table 58. The 1951 data indicates that the "mixed" dogs were associated with the highest success. As in 1954 the bird dog users had the lowest rate of kill except for those that used no dogs. It can be noted that in 1951, mixed dogs were used much more than in 1954. It is suspected that the different methods of recording the data may have been responsible for this.

TABLE 57

EFFECT OF DOG USE ON HUNTING SUCCESS, 1954--KELLOGG FOREST
AUGUSTA, MICHIGAN

Type Used	Weekdays		Saturdays		Sundays		Opening Day		Totals		Kill/ 100 g.h.	Percent of Total Effort
	G-H	Kill	G-H	Kill	G-H	Kill	G-H	Kill	G-H	Kill		
No dog	253.35	11	174.50	9	248.10	10	33.00	0	708.95	30	4.2	30.4
One beagle	254.0	37	116.25	21	156.50	14			526.75	72	13.7	22.6
Two beagles	79.50	13	77.75	8	107.75	11			265.00	32	12.1	11.4
Three beagles	54.50	3	25.50	2	48.00	9			128.00	14	10.9	5.5
One bird dog	51.75	3	87.25	2	43.25	3	13.00	2	195.25	10	5.1	8.4
Two bird dogs	11.00	1	17.90		12.00	0			40.90	1	2.4	1.8
One "hound"	14.25	0	25.25	1	53.00	6			92.50	7	7.6	4.0
One beagle and one "hound"	13.00	2	33.00	5	22.25	1			68.25	8	11.7	2.9
One mixed	20.50	1	17.75	0	25.00	3	4.00	0	67.25	4	5.9	2.9
One beagle and one mixed	13.00	0			13.00	2	14.50	1	40.50	3	7.4	1.7
All others	46.75	2	15.25	0	125.75	14	8.00	2	195.25	18	9.2	8.4
Totals	814.10	72	590.40	48	854.60	73	72.50	5	2328.60	199	8.5	100.0
Percent effort without dogs	31.2		29.6		29.0		45.5					

TABLE 58

DOG USE AND HUNTER SUCCESS, 1951--KELLOGG FOREST
AUGUSTA, MICHIGAN

Type of Dog	Gun-Hours	Kill	Kill per 100 Gun-Hours	Percent Total Effort
None	824.9	72	8.7	38.7
Beagle	678.6	99	14.6	31.8
"Hound"	182.1	24	13.2	8.5
Mixed	185.7	28	15.0	8.7
Hounds and bird dog	117.8	15	12.7	5.5
Bird dog	143.8	17	11.8	6.7
Totals	2132.9	255	12.0	

In both years the use of any kind of dog apparently increased hunting success. Also, during both years the rates of kill in the various dog type categories were not homogeneous when tested statistically.

For 1954 the amount of dog use also was determined for weekdays, Saturdays, Sundays and opening day. In each classification except opening day, about 30 per cent of the hunters' effort was without dogs. On opening day, 45 percent of the hunting parties did not use dogs. The overall average rate of dog use was 69.6 percent in 1954 and 61.3 percent in 1951.

D. Party Size

Data from the 1951 and 1954 seasons were examined to determine if any difference in success was associated with different size hunting parties. Hunters hunting alone had the best success of 12.8 rabbits per 100 gun-hours. The probability of their superior success being due to chance was less than 0.02 when compared with all other party sizes. Party sizes of four and five were next with yields of 11.5 and 10.1 respectively. Only 188 hours were hunted by parties with five hunters, therefore, the results may not be representative. Party size three had the next to the poorest success of 9.3 rabbits per 100 gun-hours. The poorest success was experienced when two hunted together with an average yield of 9.0 rabbits per 100 gun-hours. The better or poorer success rate of all party sizes except party size one were not statistically significant when a single group was compared to the rest.

The probabilities that the better success rate of individual hunters over party size two and three was due to chance, however, was less than 0.05 and 0.01 respectively. Yet the superiority of party size two over party size four was not significant. It can be concluded that individual hunters are the most successful while the differences in the success of other party sizes may not be significant.

The reason an individual hunter experiences the highest rate of success is unknown. Possibly an individual hunter has a higher rate of kill than two or more hunters because the number of rabbits flushed per hour by a party is not directly proportional to the number hunting while the accumulation of gun hours of effort is proportional to the party size.

E. Climatic Factors

This analysis, based on data collected during the 1951, 1952 and 1953 seasons was made on a monthly basis since it was thought that some factors might act differently at one time than at another. Also by breaking the season into shorter intervals the potentially complicating effects of changes during the season in rabbit abundance, density of cover, hunting effort, etc. were minimized. Tables 49-55 summarize the observations.

The following factors were observed to have no noticeable influence on hunting success during any month of the season: minimum temperature, wind velocity, and precipitation as either rain or snow.

During Octobers there was a tendency toward greater success on days having cool maximum temperatures. In Novembers the same tendency was

present though much weaker. In Decembers warm days were associated with the greatest success. Hunters were twice as successful on the 15 warmest days than they were during the 25 coldest days. In Januarys only a very slight tendency toward better success on warm days was shown.

The presence of snow cover in most instances was associated with an increase in hunting success. Based on December hunting statistics during the 1951 through 1954 seasons, on days with one inch or more of snow cover the average yield was 14.1 rabbits per 100 gun-hours in contrast to only 9.0 for the days in December not having snow cover. This difference is statistically highly significant. The superiority of hunting success on days having snow cover was much greater in 1951 and 1954 than in 1952 and 1953. In 1954, which is not shown in the table, the rate of kill on days without snow cover was 6.9 rabbits per 100-gun-hours in contrast to 10.2 for days having snow cover.

VII. Analysis of Factors Affecting Weekly Hunting Success

A factor that tends to limit the kill of some species, particularly pheasants (Shick 1952), is the decrease in yield per unit effort that occurs as the season progressed. As the yield decreases hunting effort becomes much reduced. As this did not occur on the Kellogg Forest it seems likely that the vulnerability of the rabbits and/or the efficiency with which they were hunted must have increased as the season progressed. The previous discussion has established that the use of dogs, presence of snow cover and hunter "experience" all influenced success.

A possible explanation for the observed trend in rate of kill would be that these factors fluctuated during the season in such a way that they counteracted the increased scarcity of the population. Data to examine this possibility are available for the 1954 season.

Figure 26 shows the fluctuations that occurred in the relative amounts of effort expended without dogs, with dogs and by hunters that visited the area eleven or more times. Effort expended with and without snow cover is indicated for each of the three success categories. It was previously pointed out that hunters visiting the area eleven times or more were about twice as successful as the average hunters. Therefore, effort expended by this group was used to indicate effort by experienced hunters. Only one frequent visitor did not use a dog, therefore, this category may also be regarded as being aided by dogs. Also indicated on Figure 26 are the weekly fluctuations in the kill per 100 gun-hours and the instantaneous rate of kill per 100 gun-hours. Both rates of kill are indicated so that a rate of kill not influenced by the population level (instantaneous) can be compared with the one (kill per 100 gun-hours) that would be expected to be influenced by population level changes. All other things equal, the instantaneous rate of kill would be expected to remain constant during the entire season while the kill per 100 gun-hours would decrease due to the decreasing population. There was a tendency for this actually observed in the data. Figure 26 shows that the instantaneous rate of kill early in the season was relatively lower than the kill per 100 gun-hour while

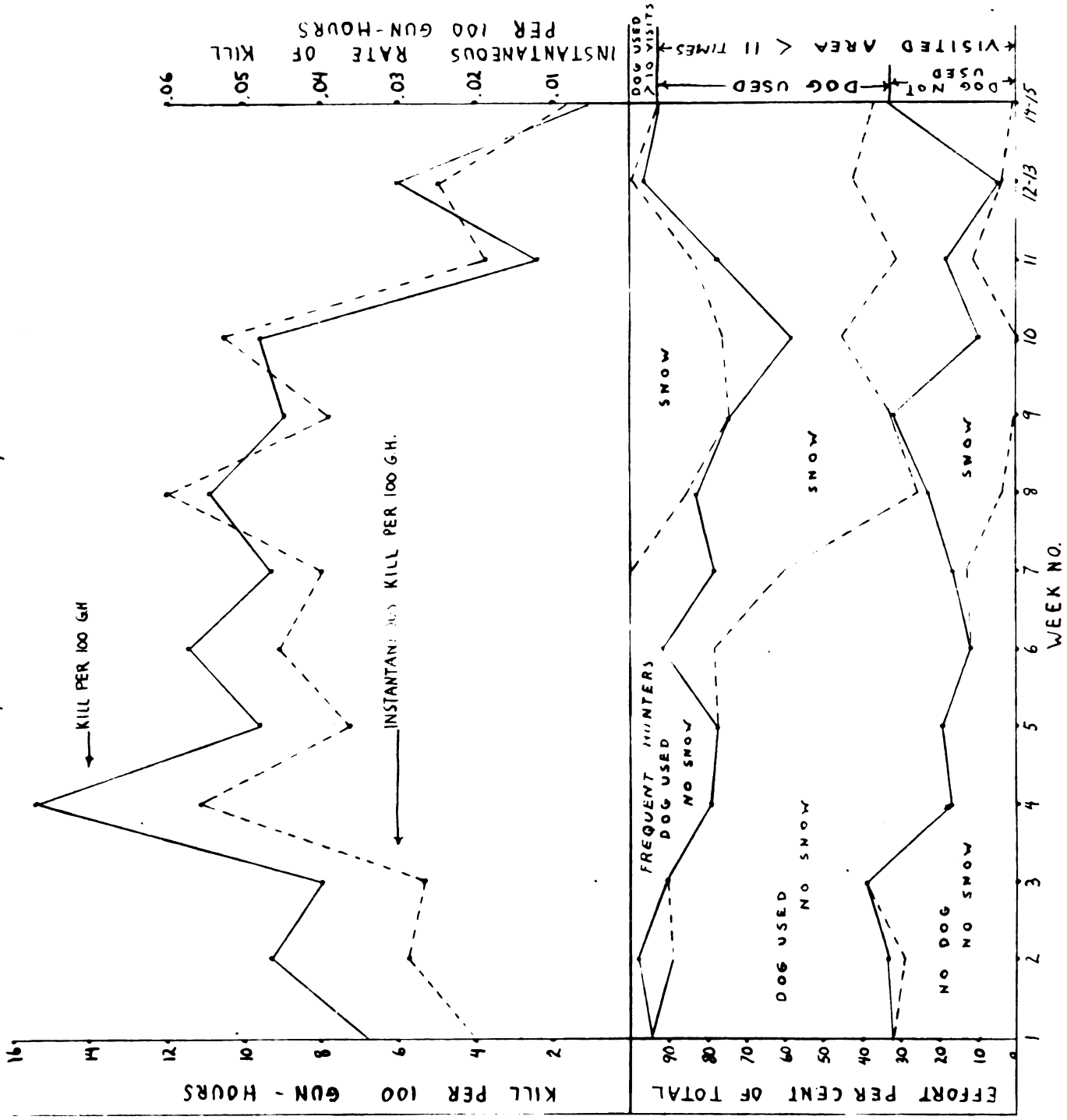


FIGURE 26
FLUCTUATIONS IN HUNTING SUCCESS AND FACTORS INFLUENCING HUNTING SUCCESS, KELLOGG FOREST, 1954

in the middle of the season the instantaneous rate of kill did not taper off quite as much as the kill per 100 gun-hours.

The preseason population estimate based on the tagged-untagged ratio in the hunting kill was used to calculate the instantaneous rates of kill. The population decreases at several times during the season were estimated as the preseason population minus the hunting kill. Actually the population was reduced to a greater extent than this due to the unrecorded crippling loss and natural mortality.

In an area where over 50 percent of the preseason population was reported bagged by hunters other mortality would be expected to be relatively low and recently obtained information indicates that the crippling loss is not great enough to markedly change the values. Any discrepency from this cause, however, would tend to force the calculated instantaneous rate of kill to be lower than they actually were. This may have been a contributing factor to the low instantaneous rate of kill noted during the last five weeks of the season. However, the general increase in instantaneous rate of kill during the first ten weeks indicates that this error was not important. The last four weeks of the season were grouped into two two-week periods so that the rates of kill would be based on larger samples.

It should be pointed out that the weekly fluctuations in the kill per 100 gun-hours during the 1954 season were somewhat atypical in that the highest success occurred during the fourth instead of seventh week and hunting success late in the season was relatively lower than

was noted in other years. Therefore, the fluctuations in the rate of kill during the 1954 season did not depart from what would be expected if the kill was determined by the population level as much as was the case during other seasons.

It is interesting to note that fluctuations in both rates of kill agree with each other closely. This indicates that the weekly magnitude of both rates are probably influenced by the same factors. Therefore, if the cause of the fluctuations in one of the rates of kill can be determined, then the same factors will be expected to also influence the other rate.

The weekly fluctuations in the over all instantaneous rate of kill per 100 gun-hours were much greater than could be attributed to chance. The probability of fluctuations as great as these being due to chance was only between 0.005 and 0.001 as indicated by a chi-square test. Thus, it is evident that the instantaneous rate of kill was not constant during the entire season.

To indicate if variations in the amount of effort expended by the various success categories were responsible for the weekly variations in success, the relative amount of effort expended each week by hunters in each category is indicated in Figure 26 directly below the corresponding rates of kill. Inspection of these data strongly suggests that the fluctuations in the rates of kill were due to the fluctuations in the relative amounts of effort expended in the different success categories. For example, the marked increase in the rates of kill noted during the fourth and tenth weeks were accompanied by increases in dog

use and in effort by experienced hunters. In ten of the 13 time intervals increases or decreases in dog use were paralleled by the expected increases or decreases in success. In general the greater amount of effort with snow late in the season may have contributed to holding up the rate of kill per 100 gun-hours. It can be noted that the sharp increase in the rates of kill during the eighth week was accompanied by a marked increase in snow cover. The least effort by experienced hunters occurred early and late in the season. This may have contributed to the low rates of kill experienced at those times. Although these relationships are evident from Figure 26, the situation in some weeks is somewhat confused because the variations in effort by the various success categories fluctuated in opposite directions with respect to their expected influence on success.

To obtain a clearer picture of these relationships the total weekly effort was divided into the six success categories already described. The instantaneous rate of mortality per 100 gun-hours was then calculated for each category each week (Table 59). As previously mentioned weeks 12 and 13, and 14 and 15 were combined because the effort expended then was quite low. The weekly instantaneous rate of kill per 100 gun-hours are shown in Table 58, along with the mean rate for each category. When no effort was expended during a week in a particular category the rate of kill is indicated by a dash. To avoid being misled by values based on very small samples an asterisk has been placed beside all values based on less than 15 hours effort. An example of how a small sample can be misleading is seen in the eighth week when a very high

TABLE 59

INSTANTANEOUS RATES OF KILL PER 100 GUN-HOURS IN VARIOUS SUCCESS CATEGORIES, 1954--KELLOGG FOREST AUGUSTA, MICHIGAN

Week Number	No dog, less than Eleven Visits		Dog used, less than Eleven Visits		More than ten Visits, Dog Used		Total Mean Inst. Rate of Mortality
	No Snow	Snow	No Snow	Snow	No Snow	Snow	
1	.004	---	.024	---	.077	---	.019
2	.018	.000*	.034	.012	.084*	---	.028
3	.015	---	.023	---	.056	---	.026
4	.023	---	.057	---	.086	---	.056
5	.019	---	.012	---	.112	---	.036
6	.023	---	.036	.040	.149*	---	.045
7	.028	.000*	.009	.068	.086	---	.040
8	.000*	.036	.111*	.049	.000*	.090	.060
9	---	.000	---	.054	---	.088	.039
10	---	.000*	.025	.069	.025	.124	.052
11	.000*	.000*	.000	.031	.000*	.000	.019
12-13	.000*	---	.022	.047	.000*	---	.025
14-15	---	.000	.000*	.014	---	.000*	.007
Mean	.014	.009	.027	.044	.075	.078	

*Value based on less than 15 gun-hours.

instantaneous rate of kill of 0.111 occurred in the dog-used, no snow, low visit category because one rabbit was killed during the four hours and 15 minutes hunted. Also, in twelve instances zero instantaneous rates of mortality occurred when less than fifteen hours were hunted. The seasonal mean values for each category are weighted means and therefore are not influenced by the small samples that occurred during some of the weeks.

The weekly instantaneous rate of kill per 100 gun-hours within each success category fluctuated less during the season than did the total weekly rates. This probably occurred because the factors which influence success within each success category were more nearly constant than were those influencing the total weekly rate of kill. When the uniformity of the instantaneous rate of kill within each success category was tested statistically, none differed significantly from a uniform rate of mortality for the entire season. After the mean instantaneous rate of kill per hour for each category had been determined it was possible to estimate the kill that would be expected each week in each category by multiplying the mean instantaneous rate of kill per hour for the category by the hours hunted. The total kill expected for each week should equal the sum of the expected kills for each category. In this way an expected kill was calculated that was based on the relative amounts of effort and different instantaneous rates of kill for the various success categories. This approach assumes that a uniform instantaneous rate of kill takes place within each category during the entire season. The weekly total, however, would not reflect a uniform

instantaneous rate of kill because the various weeks are made up of different proportions of the various success categories which have different instantaneous rates of kill.

When this calculated kill distribution (Table 59, column 2) was compared to that observed (Table 60, column 1) there was no statistically significant difference. If the success categories had been broken into more of the factors known to influence success, such as type of dog used, whether the hunter had hunted the area during a previous season and hunter occupation, the agreement probably would have been even closer.

When a kill distribution based on a uniform rate of kill (Table 60, column 3) was calculated, it differed from the observed distribution to a statistically highly significant extent. From this analysis the following points can be summarized:

1. Weekly fluctuations in the instantaneous rate of kill per 100 gun-hours varied significantly from a uniform rate of kill.
2. The weekly fluctuations in the rate of kill were caused largely by variations in the relative amount of effort expended each week by non-dog users, dog users and experience hunters, each with and without snow.
3. The weekly instantaneous rates of kill per 100 gun-hours experienced by groups constant with respect to dog use, effort with snow cover and experience did not vary significantly from a uniform instantaneous rate of kill per 100 gun-hours over the entire season.

TABLE 60

COMPARISON OF THE OBSERVED WEEKLY DISTRIBUTION OF KILL (1) WITH THE DISTRIBUTION EXPECTED IF THE KILL DEPENDED ON THE RELATIVE AMOUNT OF EFFORT BY VARIOUS SUCCESS CATEGORIES EACH OF WHICH CAUSED A DIFFERENT BUT UNIFORM INSTANTANEOUS RATE OF KILL (2) AND THE DISTRIBUTION IF THE KILL WAS THE PRODUCT OF A UNIFORM INSTANTANEOUS RATE OF KILL DURING THE ENTIRE SEASON (3). 1954-1955 SEASON--KELLOGG FOREST, AUGUSTA, MICHIGAN

Week	(1) Observed Kill	(2) Expected Kill Compound Rate of Kill	(3) Expected Kill Uniform Rate of Kill
1	30	39.0	49.7
2	27	25.1	30.9
3	18	18.8	22.0
4	22	13.9	12.8
5	10	9.9	8.9
6	17	12.0	12.2
7	21	20.7	17.0
8	20	16.3	12.6
9	14	12.9	10.0
10	12	11.3	7.5
11	3	9.6	7.1
12-13	4	4.6	3.9
14-15	1	4.9	4.4

A comparison of the mean instantaneous rates of kill per 100 gun-hours for the different categories reflects the influence on hunting success of the various factors considered (Table 61). These effects have been examined before, but this approach portrays the effects of the various factors somewhat more clearly because the influence of each factor can be indicated under constant conditions with respect to some other factor.

Table 61 indicates the instantaneous rates of kill per 100 gun-hours that occurred under various situations with respect to hunter experience, dog use and snow cover. In calculating these values only data from those weeks where at least some effort occurred in both of the situations being compared were used. This was done to reduce the complicating effect of seasonal influences and unrecognized factors. In addition to comparing the factors in question under the various situations considered, the weighted and unweighted mean values are also given. A question exists as to which mean more truly reflects the mean effect of the factor being considered. From the point of view of the impact that a factor can be expected to have on the rabbit population, the weighted mean is probably the more appropriate value, since it considers the greater effort expended in some categories than others. However, from the hunter's viewpoint the unweighted mean is probably more meaningful. The hunter would only be concerned about the change in the rate of kill that he could expect if he were in a different situation.

TABLE 61

INFLUENCE OF VARIOUS FACTORS ON THE INSTANTANEOUS RATE OF HUNTING KILL, 1954--KELLOGG FOREST AUGUSTA, MICHIGAN

Factor Being Examined	Situation	Less than 11 Visits		More Than 10 Visits	Mean	Weighted Mean
		No Dog	Dog	Dog		
Snow cover	No snow	.0176	.0269	.0143	.0196	.0241
	Snow	.0224	.0409	.0805	.0479	.0448
	Increase	.0048	.0140	.0662	.0283	.0207
	Percent Increase	27.3	52.0	463.2	144.3	85.8
		Dog Used				
		Snow	No Snow			
Visit frequency	11 visits	.0424	.0274		.0349	.0308
	10 visits	.0780	.0747		.0764	.0759
	Increase	.0356	.0473		.0415	.0451
	Percent Increase	83.9	172.8		118.9	146.4
		Less than 11 Visits				
		Snow	No Snow			
Dog Use	None	.0092	.0142		.0117	.0129
	Dog used	.0430	.0267		.0348	.0311
	Increase	.0338	.0125		.0231	.0182
	Percent Increase	367.4	88.4		197.4	141.4
		Snow	No Snow			
Visit frequency Plus Dog Use	11 visits No dog	.0107	.0142		.0124	.0129
	10 visits Dog used	.0495	.0805		.0650	.0683
	Increase	.0388	.0663		.0526	.0554
	Percent Increase	362.6	466.9		424.2	429.4

Table 61 indicates that the presence of snow cover was associated with an average increase in success of 86 percent or 144 percent depending upon whether weighted or unweighted means are compared. When examining the effects of snow it is interesting to note that among those hunters that visited the area less than eleven times, the non-dog users success was increased 27 percent while the dog users experienced an increase in rate of kill of 52 percent. The group that hunted more than ten times and used dogs showed a 463 percent increase in instantaneous rate of kill associated with snow cover. This indicates that the experienced hunters benefited more from the addition of snow cover than did the less experienced hunters. However, this indicated increase in success is probably considerably exaggerated because the success in the no-snow cover sample was based on only 38.5 hours effort and seemed low.

Hunters in the eleven or more-visit category averaged 119 percent higher success than those in the ten or less visit group judging from the unweighted means. In both cases dogs were used. The superiority of experienced hunters was greatest when no snow was on the ground.

Those hunters using dogs averaged 197 percent greater success than did hunters without dogs. When snow cover was present, dog users superiority over non-dog users was 367 percent. This value and consequently also the mean is believed to be too high because the success of the less-than-eleven visit, no-dog, snow category of 0.0092 is probably too low because of the small sample of 153 hours on which

the rate of kill was based. Evidence to support this view comes from the instantaneous rate of kill in that category when snow cover was not present. This rate was 0.0142 and it would be expected that the rate of kill with snow would be that great and probably greater. Despite this difficulty, it is probably safe to conclude that the use of dogs is even more beneficial with snow cover than without it.

When the effect of both visit-frequency and dog use are examined, the hunters that visited the area eleven or more times and which used dogs experienced 429 percent better success than non-dog users that hunted ten or less times. The increase instantaneous rate of kill was 0.055. When the effect of visit frequency alone was examined the increase in rate of kill was 0.045. Therefore, an increase of 0.010 can be attributed to the addition of dogs to high visit frequency. An increase of 0.018 was caused by dog use in the less than eleven visit category. Therefore, the experienced hunters seemed to benefit less from the addition of dogs than did the inexperienced group.

It is difficult to check the reasonableness of the magnitude of the effects of the various factors because no value is known to be correct and all values are based on samples. The most reliable value, since it is based on the largest sample, however, probably is that observed for the less-than-eleven visit, dog used, no snow category. Therefore, this instantaneous rate of kill of 0.027 was adopted as a base from which the maximum rate of kill can be estimated by adding the effects of snow and high visit frequency, and estimating the lowest instantaneous rate of kill by subtracting the effects of dogs. In this

manner values of 0.009 and 0.093 were obtained for the extremes in rates of kill. The corresponding observed values were 0.014 and 0.078. The estimated values are of the same general magnitude as the observed values which indicates that the apparent influences of the various factors on success are reasonable. It is also suggested, however, that the effects of the various factors may be slightly exaggerated due to sampling inadequacies.

Another approach to this analysis is to estimate the lowest value starting from higher values and subtracting out the appropriate effects. For example, the instantaneous rate of kill for the category expected to be most successful i.e. more than 10 visits, dogs used, snow cover, was 0.078 rabbits per 100-gun-hours. The instantaneous rate of kill increase in success caused by high visit frequency, dogs and snow cover were 0.045, 0.010 and 0.021 respectively judging from the differences in weighted mean values. Note that the dog effect appropriate for the more than eleven visit category was used here instead of the 0.018 increase evident in the less than eleven visit category. When these values were substracted from the value observed when they were present, the kill rate experienced for the least successful category i.e. no snow, no dogs, less than eleven visits was estimated as 0.002. Starting with the success rate observed in the less than eleven visits, dog used, snow cover category and subtracting out the effects of snow and dog use of the value of 0.0045 was obtained. Beginning with the kill rates observed for the less than eleven visit, dogs used, no snow; and more than ten visits, dogs used and no snow and removing the

appropriate effects values of 0.009 and 0.019 were left. A value of 0.014 was actually observed. Thus a general agreement of the same magnitude was present which tends to indicate that the estimated effects are reasonable.

VIII. Probable Effects of Seasons of Different Lengths

By considering the patterns of hunting effort, kill and success on the heavily-hunted Kellogg Forest, it was possible to draw some conclusions about the effects of seasons of different lengths than the present season of October 20 to January 31. Since all seasons except one were of the same length the probable effects of a longer season must be estimated largely by extrapolation. This practice is open to some question, but it probably yields a satisfactory estimate of what could be expected if the season was lengthened at the end. However, it would be very misleading to use this method to evaluate the effect of an earlier opening date.

If the season was lengthened through February, little increase in either effort or kill would occur, judging from the low effort and kill observed late in the present season. Also, in 1952 when an additional month of hunting was permitted, effort increased only 5.9 percent while the season length was 35 percent longer. About all a later closing date would accomplish would be to permit the occasional hunter who may want to hunt then the opportunity to do so. Because nearly all female rabbits becoms pregnant in March it seems like that for esthetic reasons February 28 should be the latest satisfactory closing date.

An earlier opening would be confronted with many situations which would tend to make rabbit hunting undesirable. Among them are: hot weather, very dense cover, small rabbits, lactating females, rabbits with warbles and a greater likelihood of hunters contracting tuleremia. These factors would probably make rabbit hunting unpopular with most hunters and consequently effort would be low. Many hunters express a strong preference for hunting rabbits even later than the current opening date. Also many people are prejudiced against shooting rabbits until cold weather sets in. Because of dense cover and hot weather, success during an earlier legal period would be as low or lower than that now observed early in the season. Because of the low effort and success the total kill would probably be quite low. Since the kill during an early period would probably be low it seems likely that an earlier opening would have little influence on the kill and and rate of kill during the remainder of the season. These views are supported by observations made in Iowa by Sanderson (personal communication) where the season opens September 15. There little rabbit hunting is done until November. The probable effects of lengthening the season at both ends can be summarized as follows:

1. Effort during an early extension of the season would probably be low, though, this is difficult to accurately predict.
2. Effort during a late extension of the season would be low.
3. Effort during the entire lengthened season would probably be only slightly greater than that now experienced.
4. The total kill, the early and late extensions of the current season would probably be low.

5. The total kill for the entire season would be only slightly higher than that now achieved during the current season.
6. The rate of kill during the early and late extensions of the season would be likely to be low.
7. Rate of kill for the entire season would be slightly lower than is experienced during the current season.

On the Kellogg Bird Sanctuary and Farm, it was observed that a high rabbit kill could be made when hunting was confined to a brief period between mid-December and mid-January. It was possible then to bag as high a percentage of the rabbit population there as was made on the Kellogg Forest with over five times the effort spread between October 20 and January 31. This indicates that a short season from November 15 or December 1 through January 15 would have almost as high a total kill as is now experienced between October 20 and January 31. As would be expected, the rate of kill would be much higher than that observed over the longer season. Also hunting effort during the shorter season would probably be greater than is now observed during the corresponding period in the current longer season. The total effort expended during the current season, however, probably is greater than that which would occur during the shorter season and this would restrict the recreational opportunities for many people.

If an increase hunting quality as indicated by rate of skill was desired while still providing a long period to hunt a season both opening and closing the season later than at present would be in order.

For example, a season extending from December 1 through February 28 would be almost as long as the current season and would offer much better hunting conditions and a higher rate of kill early in the season. With the current opening of October 20, early season success was low apparently due to dense cover, hot weather, lack of snow or other factors. Despite these difficulties enough rabbits were killed to cause a reduction in the rate of kill later in the season when hunting conditions were better. A low rate of kill would be expected to occur late during a long season regardless of the season's opening date.

Observations made on the Kellogg Bird Sanctuary and Farm support these views in that very high success occurred when hunting started in December. It tapered off as the rabbit population was reduced. An argument against having a later opening would exist if a sizeable non-hunting mortality of rabbits occurred during the fall and early winter. This apparently does not occur on the Kellogg Station and consequently a later opening would allow almost as many rabbits to be shot as would the current opening date.

MISCELLANEOUS OBSERVATIONS

Changes in Mammal Numbers on the Kellogg Bird Sanctuary and Farm Between 1934-35 and 1951-55.

Allen (1938b) presented a rather complete picture of the higher vertebrate life existing on the Sanctuary between the fall of 1934 and August 1937. The change that has occurred in the abundance of various species of mammals since Allen's study is noteworthy. Field work conducted during the present study, permitted observations to be made on the relative abundance of many mammal species in addition to rabbits. Since the population changes of these species may be interrelated, it was thought worth-while to briefly discuss these changes.

Rabbits have remained at about the same general population level. Fox squirrels (Sciurus niger) were common during both periods. Gray squirrels (Sciurus carolinensis) were not reported by Allen; however, they were trapped several times during the present study. Red squirrels (Tamiasciurus Andsonicus) were also not mentioned by Allen; however, by 1951 they were very common, probably due to the maturing of the conifer plantations. The skunk (Mephitis mephitis) was very common during 1934 and 1935. During Allen's two years of trapping skunks were handled 165 times. During the present study skunks were trapped only three times. If predation of rabbits, especially young, by skunks is very common, this marked drop in the skunk population should have created a more favorable situation for rabbits. In 1953 when rabbits were being snared in order to greatly reduce the rabbit population,

skunks fed on snared rabbits. A picture was obtained of a skunk tugging on a snared rabbit by means of a camera trap developed by Gysel and Davis 1956.

Judging from Allen's statements, longtail weasels (Mustela frenats) were not abundant during his study but were more abundant than during the period 1951-1955. Allen caught three weasels in one winter. The current effort trapped only one in five years. Both opossum (Dilelphis virginianus) and racoon (Procyon lotor) were not rare during Allen's study, but were apparently less common than during the period 1951-1955. Whitetail deer (Odocoileus virginianus) were not mentioned by Allen, so were apparently not present. Deer tracks were found on the Sanctuary during the summer of 1951 and four deer were seen by the writer in 1952. Sanctuary employees have seen wild deer several times during recent years. The only evidence of red fox as (Vulpes fulva) during 1934-35 were tracks seen for several days in January. Now tracks could be found on the area any time there was a tracking snow. Foxes were flushed twice during rabbit hunts and one was shot.

During the present study a reduction has apparently taken place in the number of thirteen-lined ground squirrels (Citellus treidesem-lineatus). Allen reports that they were the most abundant mammal larger than mice and they were much more abundant than chipmunks (Tanias striatus). This is no longer true. Grouna squirrels are no longer abundant although still fairly common. Chipmunks are evidently much more abundant than they formerly were. Allen reported only 2-3 pairs. The writer estimates that in recent years the chipmunk population of the area has been over 100 each fall. The reversal in the

relative numbers of ground squirrels and chipmunks is probably a reflection of the cover changes on the area. The formerly open grassy fields that offered suitable ground squirrel habitat have now grown brushy and are no longer used.

Meadow mice (Microtus pennsylvaninus), white footed mice (Peromyscus leucopus), prairie deer mice (Peromyscus maniculatus) and the short-tailed shrews (Blarina brevicauda) were common on the area during both studies.

The mammalian population changes that have occurred between 1934-35 and 1951-55 may be summarized as follows: The red fox, gray squirrel, opossum, racoon, deer, chipmunk and red squirrel have increased in numbers. The cottontail rabbit, fox squirrel, meadow mice, whitefooted mice, prairie deer mice and short tailed shrew remained at about the same population level during both studies. The skunk has undergone a very pronounced drop in abundance and thirteen-lined ground squirrels and long tailed weasels also apparently decreased.

Fox Food Habits Observations

Since the red fox (Vulpes fulva) is popularly thought of as an important predator on the cottontail, an effort was made to determine the extent to which local foxes fed on rabbits. During late winter and early spring of 1952, a total of 51 fox droppings were collected. Most of these were found on hillside pastures adjacent to the pond north of the farm dump. Many of the scats were not fresh and it is not known when they were deposited. Rabbit was found in 28 or 54.9

per cent of the scats. In 14 of the droppings, cottontail hair made up more than one-fourth the total volume. Small rodents, chiefly Microtus sp. and Peromyscus sp., were found in 39 (76 percent) of the scats. Chicken remains were found in 15 (29.4 percent). Unidentified material was found in 18 (35 percent). The objective of the analysis was to determine the incidence of rabbit only. Time was not taken to identify many items of low incidence. As a result a high percentage of unidentified material resulted.

Latham (1950) compiled the results of ten investigations of red fox food habits on 1795 scats and stomachs. (Eadie, 1953; MacGregor, 1942; Darrow, 1944; English and Bennet, 1942; Latham, 1943. Penn. Mammal Survey, unpublished; Wilson, 1948; Nelson, 1933). A comparison of the percentage occurrence of rabbits and chickens in this study with that observed in the compilation indicated a higher incidence of both rabbits and chickens in the Kellogg Bird Sanctuary and Farm scats that in the other studies. In contrast to the 54.9 percent rabbit and 29.4 percent chicken in Michigan only 35.2 percent of contained rabbit and 17.9 percent chicken in the other studies. These differences probably reflect differences in availability. During 1950 and 1951, rabbit populations were high on the Kellogg Station. Chickens were allowed on open range during the summer and when layers died during the winter, they were thrown on the manure pile and spread in the fields. Thus chickens, both fresn and otherwise, were almost always easily available.

During the winter of 1952 the stomachs of nine red foxes were obtained from a local fox hunter. One of these foxes was killed on the Kellogg Farm and the rest were taken in the vicinity. Only one contained rabbit remains. These foxes had apparently been hunting in a marsh environment, however, because 5 stomachs contained muskrats (Ondatra zibethiso) and three bog lemming (Synaptomys cooperi).

Foxes were tracked in the snow a total of 32 miles during the late winters in 1953 and 1954 mostly on the Kellogg Forest. No signs of rabbit kills were observed, although, 6 mice and 1 red-winged blackbird were caught. Unsuccessful attempts apparently were made to capture 29 mice, four cotton tails, two red squirrels, two fox squirrels, two pheasants and one quail. The foxes followed visited two dead animals, a fox which was dug from beneath the snow and a weasel. The cause of death of the weasel and fox is unknown. The results are indicative, of course, only of fox food habits during the season involved.

In a sample of 18 scats collected during the springs of 1953 and 1954 only five (28 percent) contained rabbit. This incidence is statistically significantly lower than that observed in the 1952 scats (55 percent). Fall population estimates for the autumn preceding the later sample were about 225 rabbits. In 1951 the fall population estimate was 388. This difference in population density possibly explained the difference between the two years in the extent to which foxes fed on rabbits. The lower incidence of rabbit in fox scats during years of lower rabbit abundance, however, should not be taken as evidence that the effect of foxes necessarily is less during those

years. The lower incidence in the later years probably merely reflected a lower availability of rabbits. There is no evidence to indicate that the individual rabbit's probability of being caught was less or that the percentage reduction of the rabbit population by fox predation was any lower during the years of low rabbit abundance than during the year of high rabbit numbers.

Data collected in this study does not permit the precise appraisal of the effect that fox predation has on rabbit populations. And, of course, foxes ranged on adjacent areas as well as on the rabbit study area, and scat analysis probably reflected feeding habits off the area as well as on it. Some conclusions, however, can be drawn. First, it is possible to have dense rabbit and fox populations living together. During 1951 the rabbit population was the densest that it was during any year of this five year study and fox tracks were evident whenever a tracking snow was present. It has previously been pointed out that rabbit populations have remained at approximately the same level during the past 23 years, and that very few foxes were present during the earlier years of this period, but later became common. Thus it appears that the increase in foxes had no effect on fall rabbit population levels. It is, of course, not known wnether or not some unknown compensating factor acted.

Winter Food Habits of Kellogg Bird Sanctuary and Farm Cottontails

During the winter of 1951-1952 observations were made of the extent to which rabbits fed on the various species of woody plants

found on the Kellogg Bird Sanctuary and Farm. Intensity of use classes for winter food were as follows:

A - heavy, eaten in preference to other nearby species.

B - moderate, eaten commonly but to a lesser extent than in A when the species occur red together.

C - light, rarely if ever eaten.

Since the importance of a species depends upon its abundance as well as the extent to which it is used, the following abundance classification with numerical values was used.

1 - rare

2 - infrequent

3 - common

4 - abundant

To obtain an indication of the relative importance of the various species in terms of both use and abundance each species was scored as follows: Importance rating equals the abundance scale designation times a numerical value for the use classification in which A = 5, B = 3 and C = 1. For example, sassafras which had an abundance rating of 3 and a use classification of A had an importance rating of 3 x 5 = 15. These observations are listed in Table 62.

In general these findings agree with other Michigan studies. There is some disagreement. Both Allen (1937) and Hickie (undated) indicate that gray and silky dogwoods were either heavily or moderately eaten. This study indicates that they were almost never eaten. Also, Allen did not even consider oaks as a rabbit food. This was probably because

TABLE 62

RELATIVE ABUNDANCE AND USE BY RABBITS FOR WINTER FOOD OF WOOD, VEGETATION, WINTER 1951-52
KELLOGG BIRD SANCTUARY AND FARM
HICKORY CORNERS, MICHIGAN

Scientific Name*	Common Name	Use Rating	Abundance Rating	Importance Rating
Rhus typhina	Staghorn sumac	A	4	20
Quercus borealis	Red oak	A	3	15
Quercus velutina	Black oak	A	3	15
Rhus Copallina	Dwarf sumac	A	3	15
Rubus idaeus	Red raspberry	A	3	15
Sassafras albidium	Sassafras	A	3	15
Carya ovata	Shagbark hickory	B	4	12
Lonicera sp.	Bush-honeysuckle	B	4	12
Populus gradidentata	Largetooth aspen	B	4	12
Populus tremuloides	Quaking aspen	B	4	12
Prunus serotina	Black cherry	B	4	12
Vitis sp.	Grape	B	4	12
Amorpha fruticosa	False indigobush	A	2	10
Crataegus sp.	Thornapple	A	2	10
Malus sp.	Apple	A	2	10
Rosa sp.	Rose	A	2	10
Rubus allegheniensis	Blackberry	A	2	10
Rubus occidentalis	Black raspberry	A	2	10
Acer rubrum	Red maple	B	3	9
Prunus virginiana	Choke cherry	B	3	9
Quercus alba	White oak	B	3	9
Amelanchier canadensis	Serviceberry	B	2	6
Castanea dentata	Chestnut	B	2	6
Celastrus scandens	Bittersweet	B	2	6
Fraxinus americana	White ash	B	2	6
Rhus glabra	Smooth sumac	B	2	6
Robina Pseudo-Acacia	Black locust	B	2	6
Sambucus canadensis	Common elder	B	2	6

Ulmus americana	American elm	B	2	6
Ailanthus altissima	Tree-of-heaven	A	1	5
Cornus florida	Flowering dogwood	A	1	5
Larix decidua	European larch	A	1	5
Cephalanthus occidentalis	Buttonbush	C	4	4
Cornus Amomum	Silky dogwood	C	4	4
Cornus paniculata	Gray dogwood	C	4	4
Picea Abies	Norway spruce	C	4	4
Pinus resinosa	Red pine	C	4	4
Pinus sylvestris	Scotch pine	C	4	4
Rubus villosis	Dewberry	B	4	4
Syringa vulgaris	Lilac	B	1	3
Vaccinum vacillans	Blueberry	B	1	3
Viburnum Lentago	Nannyberry	B	1	3
Viburnum Opulus	Highbush-cranberry	B	1	3
Cornus stolonifera	Red-osier dogwood	C	3	3
Picea glauca	White spruce	C	3	3
Pinus Banksiana	Jack pine	C	3	3
Juglans nigra	Black walnut	C	2	2
Juniperus communis var. depressa	Prostrate juniper	C	2	2
Juniperus virginia	Red cedar	B	2	6
Morus rubra	Red maple	C	2	2
Thuja occidentalis	Northern white cedar	C	1	2
Zanthoxylum americanum	Northern prickly ash	C	2	2

* Authorities for scientific names same as those in: Muenscher, W. C., 1950. Keys to woody plants. Comstock Pub. Co.

oak was not available to rabbits during his study. Open, recently abandoned farm-fields during Allen's study are now in a shrubby stage of succession and have an abundance of black oak reproduction in them.

Because black oak (Quercus velutina) ia s dominant species in the climax community of the study area and because rabbits were feeding so heavily on it, a study was made on the effect that rabbits have on oak reproduction. It was determined that many young oaks had had all new growth pruned back annually for many years. Rabbits were apparently slowing the rate with which abandoned fields were moving into the climax vegetative community (Geis, 1954). Allen found that rabbits fed moderately on Scotch Pine (Pinus sylvestris). During the present study no such feeding was noted. This was true despite considerable natural reproduction which made young trees available. Unless their food preferences have changed, it appears that more preferred rabbit foods were available during the winter of 1951-52 than in 1934-35. This seems likely because of the greater amount of woody cover currently on the area.

During the winter of 1954-55, 18 quadrats each eight milacres in size were studied. Three quadrats were located in each of the six cover types (T, S_1, S_2, S_3, W_1 and W_2) having woody cover. Plots sampled were selected at random. A total of 1412 stems of 30 species were counted. The percentage used for winter food and percentage that each species made up of the total stems are tabulated in Table 63. It can be seen that these data agree very well with the qualitative

TABLE 63

WOODY PLANT ABUNDANCE AND USE AS FOOD BY RABBITS FROM QUADRAT DATA
WINTER 1954-1955--KELLOGG BIRD SANCTUARY
HICKORY CORNERS, MICHIGAN

Species*	Number Unused Stems	Number Fed Upon	Percent Used For Food	Percent Total Stems
Rhus copallina	18	27	60	3.2
Rhus typhina	117	23	16	9.9
Malus sp.	1	0	0	.1
Quercus velutina	4	7	63	.8
Rubus idaeus	9	6	40	1.1
Sassafras albidum	11	29	72	2.8
Carya ovata	1	1	0	.1
Lonicera spp.	522	10	2	37.7
Populus grandidentata	5	1	0	.4
Populus tremuloides	14	0	0	1.0
Prunus serotina	58	2	3	4.2
Rosa sp.	9	5	36	1.0
Rubus allegheniensis	17	4	19	1.5
Rubus occidentalis	2	1	0	.2
Fraxinus americana	8	3	27	.8
Robina Pseudo-Acacia	1	0	0	.1
Sambucus canadensis	11	4	27	1.1
Cephalanthus occidentalis	1	0	0	.1
Cornus Amomum	82	0	0	5.8
Cornus paniculata	233	1	0	16.6
Cornus stolonifera	60	3	5	4.5
Juniperus communis var. depressa	1	0	0	.1
Juniperus Virginiana	1	2	0	.2
Castanea dentata	0	2	0	.1
Vaccinium vacilans	1	0	0	.1
Salix spp.	31	7	18	2.7
Prunus virginana	29	8	22	2.6
Cornus florida	4	9	69	.9
Carya glabra	0	1	0	.1
Rhus glabra	1	0	0	.1
Picea glauca	4	0	0	.3

*Authorities for scientific names same as those in: Muenscher, W. C., 1950. Keys to woody plants. Comstock Pub. Co.

impressions recorded in Table 62. For example, five of the six species listed in Table 63 as making up more than five percent of the total stems were in the abundant category in Table. The sixth was listed as common. The five species in which 40 percent or more of their stems had been fed upon by rabbits were all placed in "A" use category in Table 62.

Judging from the large amount of woody vegetation now found on the Sanctuary that is preferred rabbit food: but not eaten, it is apparent that winter food could not be a limiting factor of the population. Also, the food supply appears to be increasing as natural succession progresses and formerly open fields become more brushy.

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