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AN EVALUATION OF STRIP CENSUS METHODS
FOR COTTONTAIL RABBIT POPULATIONS
IN SOUTHERN MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Rainer Hans Brocke
1957

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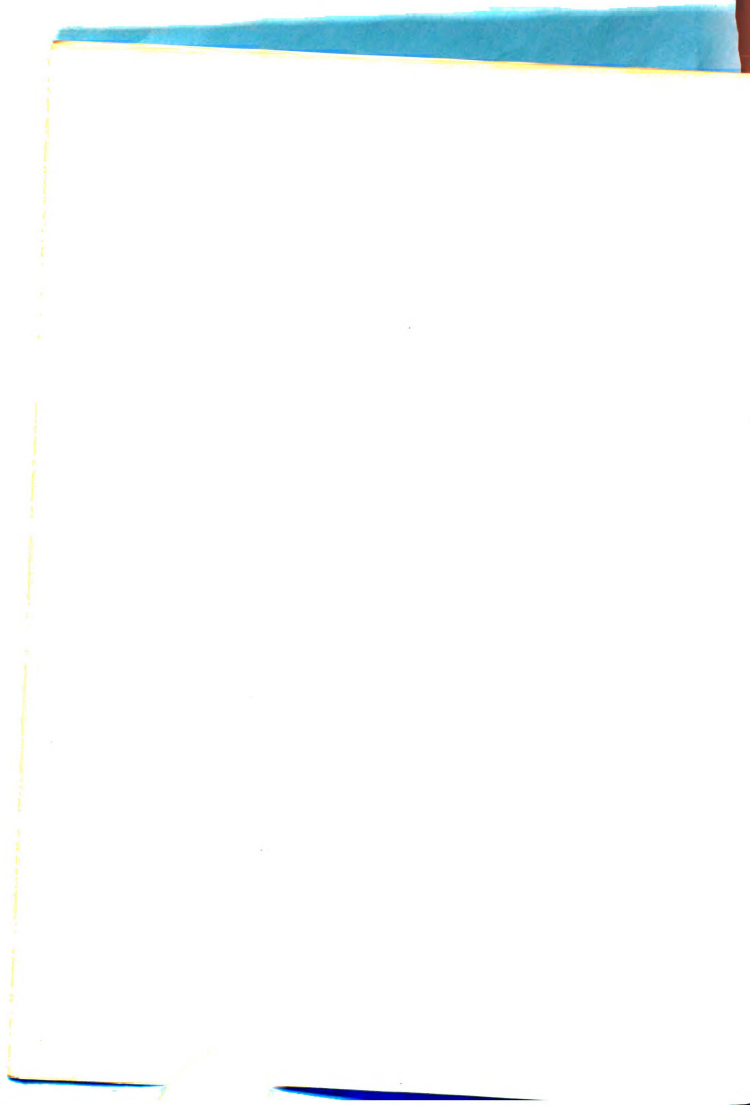
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AN EVALUATION OF
STRIP CENSUS METHODS FOR
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IN SOUTHERN MICHIGAN

By
Rainer Hans Brocke

AN ABSTRACT

Submitted to the College of Agriculture
Michigan State University of Agriculture
and Applied Science in partial
fulfillment of the requirements
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MASTER OF SCIENCE

Department of Fisheries and Wildlife

1957

Approved by

Peter J. Tack





ABSTRACT

Four strip census techniques, the King, Hayne, Kelker and Webb methods have been most widely used for game censusing. Investigators have found that strip censuses yield highly variable results and require large sample sizes.

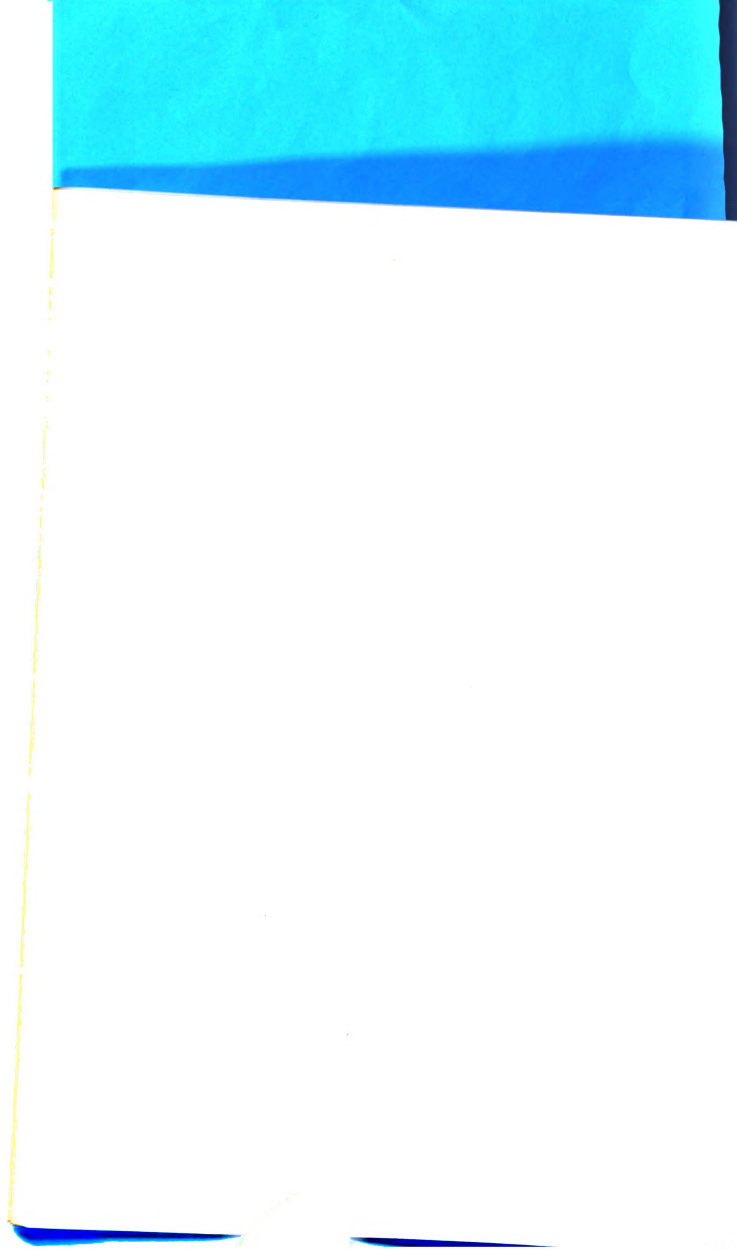
The present study was undertaken to determine the reliability of the King, Hayne, Kelker and Webb strip census methods for cottontail rabbit populations.

The field studies were conducted at the Kellogg Forest, the Kellogg Bird Sanctuary, and the Kellogg Farm; the latter two were treated as one area. These are part of the Michigan State University Kellogg Station in southwestern Michigan.

Strip censusing was begun on October 5, and continued through December 9, 1955. Census lines were 75 yards and 100 yards apart, marked with white strips of cloth.

Strip census population estimates were compared with Lincoln Index estimates, generally considered to be accurate. To obtain Lincoln Index values, rabbits were trapped and marked; public and controlled hunting provided the necessary second sample.

An artificial strip census model was set up to determine mathematical tendencies of the four strip census methods. The artificial population, based on field



observations, was located and censused on graph paper; these results are compared with the field study.

In 89.42 miles of census strips on both study areas, 26 rabbits were flushed. Strip census estimates ranged from 5.5 to 48 percent of the Lincoln Index value.

Generally, the King strip census method gave the lowest estimates and the Kelker method the highest and most variable. As determined by the theoretical strip census model, the Hayne method gave acceptable estimates, although values were also low in the field study.

Apparently, the extremely low estimates in the field are due largely to behavior patterns of the cottontail rabbit, such as erratic flushing and a tendency to "hole up" during cold weather.

From the present study, it seems apparent that strip census methods are not suitable or practical for measuring cottontail rabbit populations in southern Michigan.



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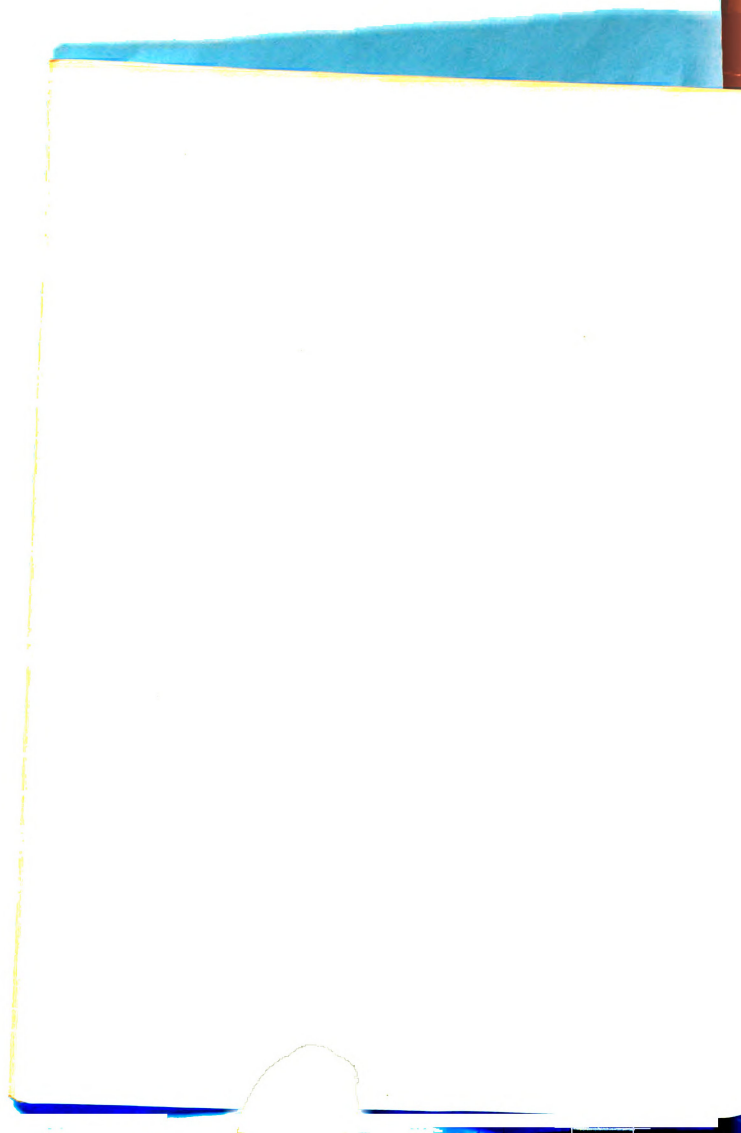
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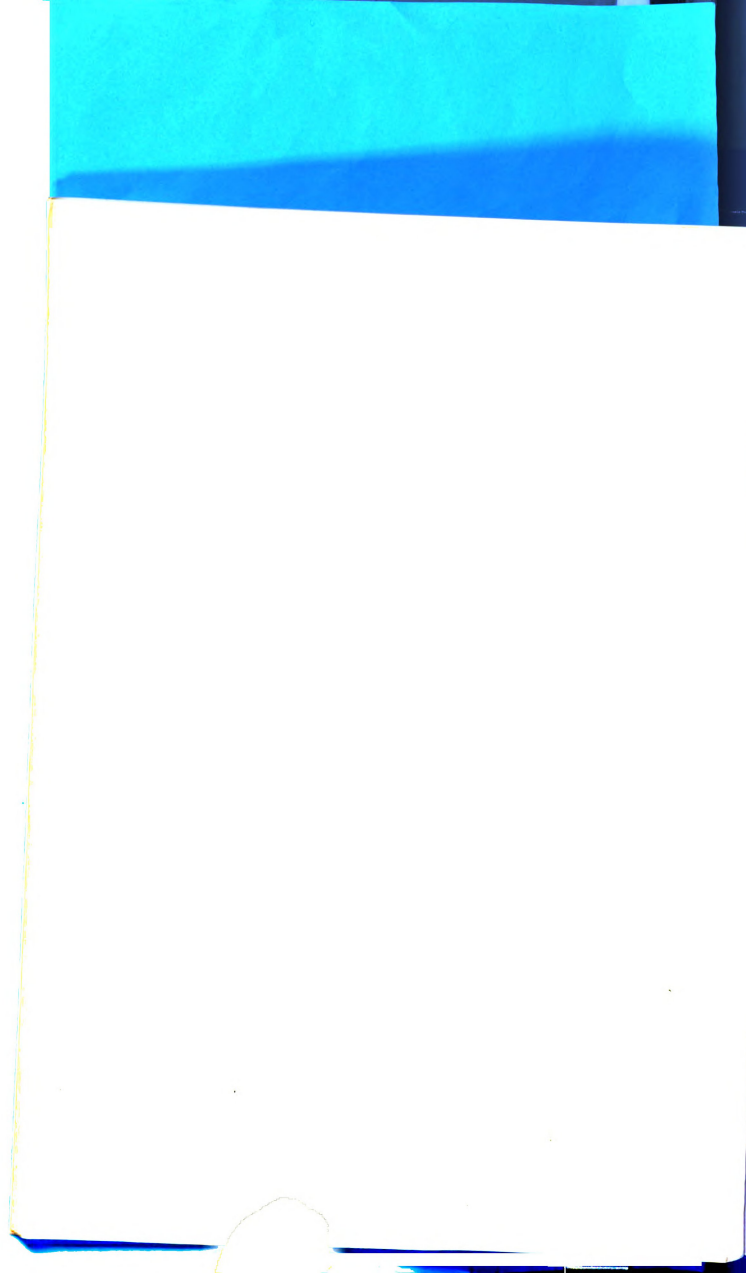
TABLE OF CONTENTS

ABSTRACT	1
LIST OF FIGURES.	v
LIST OF TABLES	vi
INTRODUCTION	1
Background.	1
Purpose of this study	3
ACKNOWLEDGEMENTS	4
STRIP CENSUS TECHNIQUES	6
The Kellogg Forest	6
The Kellogg Bird Sanctuary and Farm	14
The Artificial Strip Census Model	19
RESULTS AND DISCUSSION	24
King Method	29
Hayne Method	30
Kelker Method	31
Webb Method.	33
Effective Width of Census Strip	35
General Discussion	38
SUMMARY	41
APPENDIX	43
Classification of Cover Types	48
Computing Formulas and Some Calculations	50
LITERATURE CITED	54



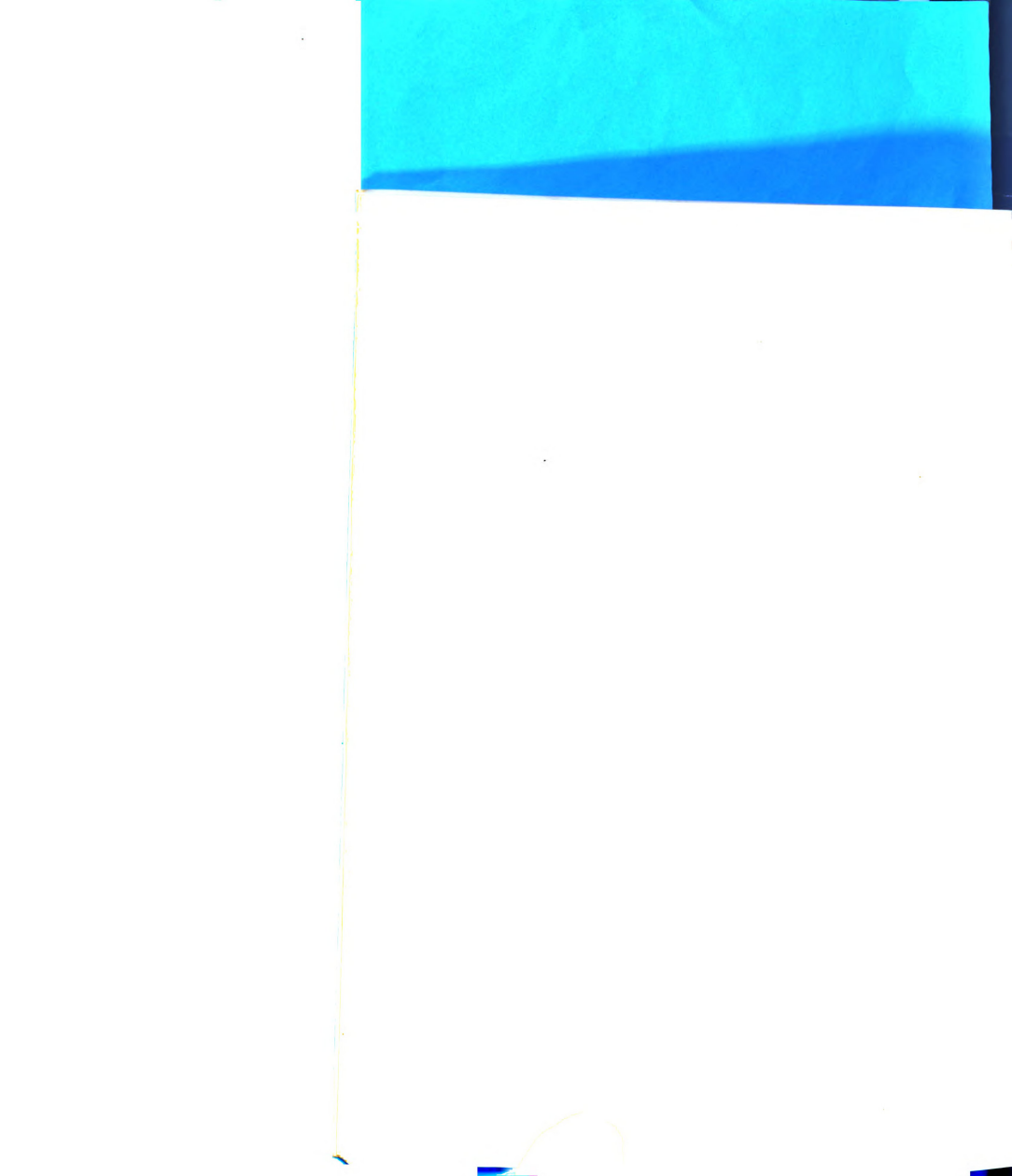
LIST OF FIGURES

1.	Cover map of the Kellogg Forest study area, showing vegetation types and locations of rabbits seen during strip censusing	9
2.	Aerial photo of the Kellogg Forest study area showing strip census lines	10
3.	Damaged census line marker. Such damage, probably by red squirrels, occurred repeatedly in some areas; some markers were completely removed	11
4.1	Cover type O ₂ ; open land with high grasses and some brush	11
4.2	Cover type D ₁ ; second growth deciduous woods . .	12
4.3	Cover type D ₂ ; mature deciduous woods	12
4.4	Cover type C ₁ ; conifer plantations with open understory	13
4.5	Cover type C ₂ ; conifer plantations with closed understory	13
5.	Cover map of the Kellogg Bird Sanctuary-Farm area, showing vegetation types and locations of rabbits seen during strip censusing	17
6.	Aerial photo of the Kellogg Bird Sanctuary-Farm study area, showing strip census lines . .	18
7.	Methods used in locating animals and obtaining census data in the strip census model	23
8.	Population estimates and confidence limits, 90 percent accuracy, for the strip census model . .	28
9.	Strip census form	44



LIST OF TABLES

I.	CALCULATED FLUSHING DISTANCES AND NUMBERS FOR EACH FLUSHING DISTANCE - STRIP CENSUS MODEL	21
II.	STRIP CENSUS POPULATION ESTIMATES - KELLOGG FOREST	25
III.	STRIP CENSUS POPULATION ESTIMATES - KELLOGG BIRD SANCTUARY-FARM AREA	25
IV.	POPULATION ESTIMATES - STRIP CENSUS MODEL . . .	26
V.	WEATHER DATA - KELLOGG FOREST	36
VI.	WEATHER DATA - KELLOGG BIRD SANCTUARY-FARM AREA	36
VII.	DATA USED TO MAKE STRIP CENSUS POPULATION ESTI- MATES - KELLOGG FOREST AND KELLOGG BIRD SANC- TUARY-FARM AREA	45
VIII.	STRIP CENSUS OBSERVATIONS - KELLOGG FOREST . .	46
IX.	STRIP CENSUS OBSERVATIONS - KELLOGG BIRD SANCTUARY-FARM AREA	47



INTRODUCTION

Background

A number of strip census techniques, also referred to as belt transect and cruising census methods have been devised to measure animal populations.

In general, a strip census estimates the population for a cruised strip of known length and computed width. This population density is then applied to the remaining portions of the area being censused.

Various modifications of strip censusing have been developed by different investigators to meet varying situations. These strip census methods differ essentially in one respect; the technique used to determine the width of the strip.

In 1931, King (Leopold, 1933) developed a strip census method for brooding ruffed grouse, in which the width of the strip was determined to be twice the average flushing distance of feigning hens. Fisher (1939) and Frank (1946) also used this method to measure grouse populations; Erickson (1940), and Krefting and Fletcher (1941) applied the King method to censusing deer.

Breckenridge (1935) developed a strip census method to measure wren populations. He used the perpendicular distance, at which flushing numbers showed a marked decrease, to calculate the width of strip.

Colquhoun and Morley (1941) estimated the density of birds in open areas by strip censusing during the spring season, when birds were prominent. They calculated a width of strip based on the normal identification distance of a bird species.

Webb (1942) censused showshoe hare populations using the sine of the average flushing angle to compute an average perpendicular flushing distance, on which the width of strip was based.

Kelker (1945) developed a strip census technique for deer, in which perpendicular sight distances from the line of travel are divided into belts. The belt in which the number of observations shows a pronounced decrease marks the edge of the effective width of strip.

Hayne (1949) showed that the average observed flushing distance, as determined by King, is not a good estimate of the average flushing distance of the true population, and should not be used to determine the width of strip. He proposed that animals be grouped according to flushing distance, using the sum of these groups to estimate the total population. This method has been used to census ruffed grouse (Palmer and Eberhardt, 1955). Hayne's modification of King's method will hereafter be referred to as the Hayne method.

King's, Hayne's, Kelker's and Webb's methods have been compared for censusing winter-lost deer by Robinette et al. (1954, 1956). They concluded that Kelker's method

was best suited to censusing dead deer.

Applications of the latter four methods have been generally used for most game censusing.

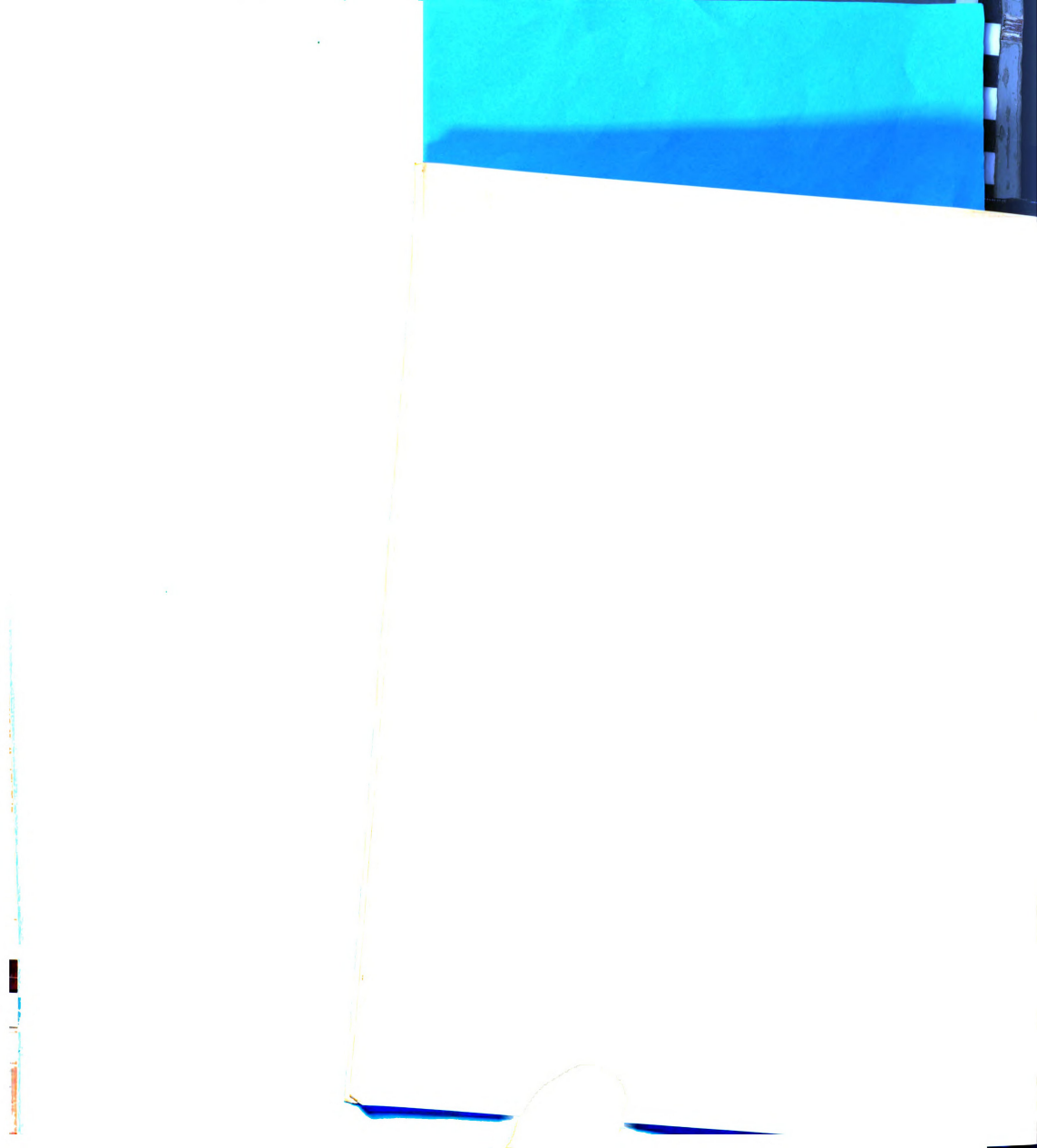
Characteristically, strip census methods yield highly variable results and require large sample sizes, often not feasible in a practical situation. These disadvantages are indicated by Fisher (1939), Palmer and Eberhardt (1955) and the present study.

Purpose of this Study

This project was undertaken to determine the reliability of population estimates by the King, Hayne, Kelker and Webb strip census methods for the cottontail rabbit, Sylvilagus floridanus mearnsii (Allen).

Estimates by the Lincoln Index method, generally considered to give reliable results, were used as a comparison.

In order to get some idea of the theory involved in strip censusing, an artificial strip census model, based on field data was also made. Estimates obtained by the model are discussed and compared with the field study.



ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Dr. George A. Petrides of the Department of Fisheries and Wildlife who helped develop the project and provided many suggestions.

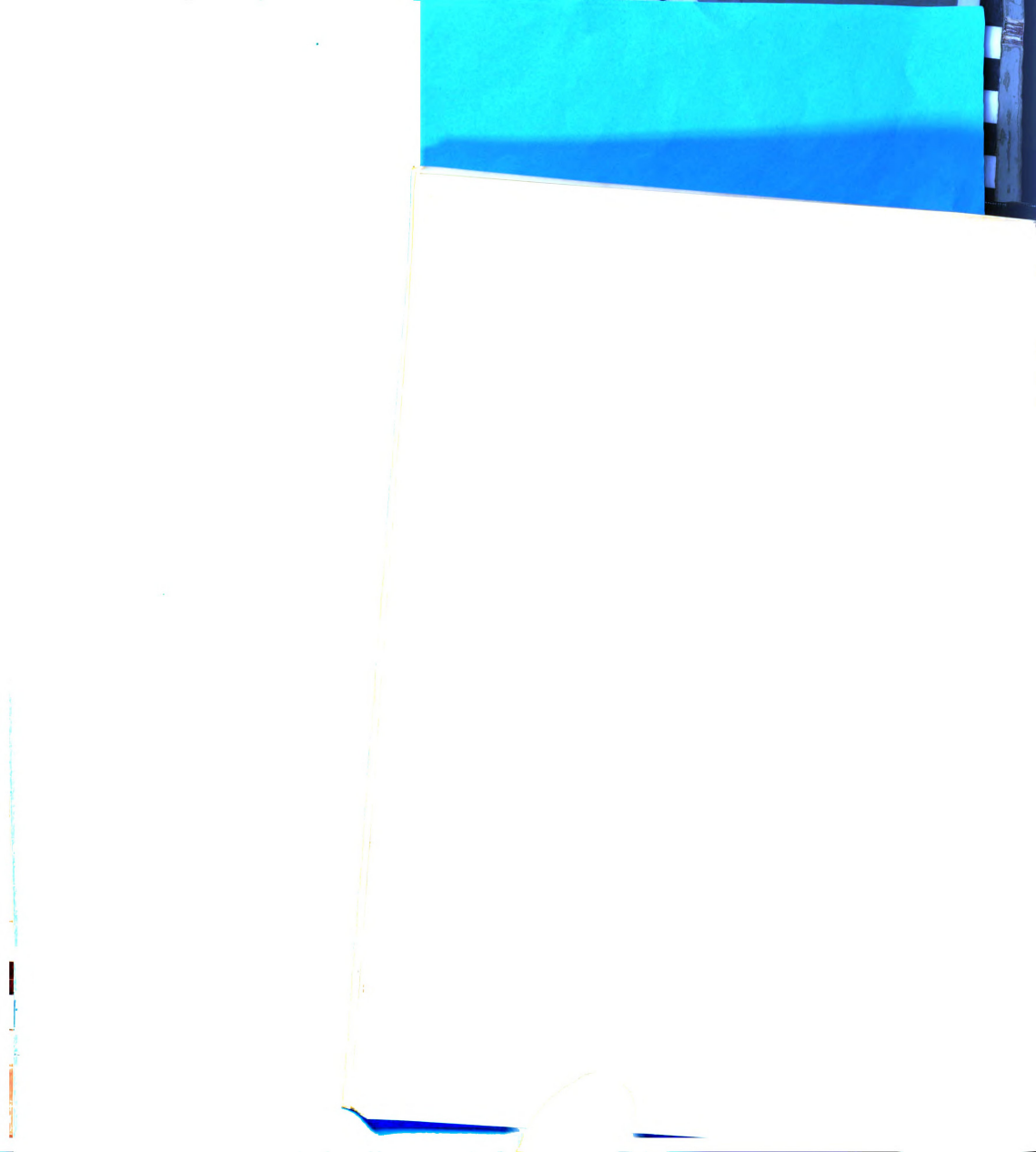
Deep gratitude is due to Dr. Don W. Hayne of the Department of Zoology, the originator of one of the strip census methods tested. His guidance has proved invaluable in the execution of the study and the statistical analysis of the data.

I am grateful to Mr. Roswell D. Van Deusen and Mr. Walter Lemmien, directors of the Kellogg Bird Sanctuary and Kellogg Forest of Michigan State University, who went out of their way to provide station facilities. Mr. Van Deusen has also done most of the photographic work included in this thesis.

Grateful acknowledgement is due to Dr. Aelred D. Geis, a Ph.D. candidate in 1956, with whom a part of this study was completed. He provided useful suggestions, and the guidance of a senior graduate student.

Thanks are due Mr. Norman Barry of the Kellogg Forest, Mr. Allen England and Mr. Jack Gilbert of the Kellogg Bird Sanctuary and others who helped during trapping and controlled hunting.

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Finally, I extend my sincere gratitude to my wife who typed the manuscript, made suggestions, and above all was a constant source of encouragement.



STRIP CENSUS TECHNIQUES

The field study was conducted on two separate areas; the Kellogg Forest, the Kellogg Bird Sanctuary and the Kellogg Farm; the latter two, adjoining one another, are treated as one area. These are part of the Michigan State University Kellogg Station, a demonstration unit in southwestern Michigan.

During the previous five years, Geis (1956) directed a study on rabbit population dynamics on these areas as research toward a doctorate degree. To obtain tagged-untagged ratios for Lincoln Index population estimates, a rabbit trapping and marking program during each fall season had also been conducted. Since the Lincoln Index estimates were useful to both studies, the writer worked with Geis running the trap lines.

A description of the study areas and the techniques used on each will be given under corresponding headings. The methodology used in the strip census model will follow in a separate section.

The Kellogg Forest

The Kellogg Forest area is roughly rectangular in shape, and occupies about four-fifths of a square mile. It is located in T1S, R9W, Section 22.



The area is approximately bisected by meandering Augusta Creek, flowing in a southerly direction (Fig. 2). The land rises east and west of Augusta Creek and gives way to rolling topography, characteristic of this part of the state. Originally farmed, the land was soon abandoned because of the unproductive nature of the sandy soils. A small portion has been retained as farmland.

Purchased by W. K. Kellogg, the eroded land was converted into a wildlife area and donated to Michigan State University in 1931. Large conifer and hardwood tree plantations were made, and various shrubs were planted with the intention of improving wildlife habitat. The resulting cover is a varied heterogenous patch-work of coniferous and deciduous vegetation (Fig. 1, Fig. 4 and appendix p.48).

Eighteen strip census lines were established, 100 yards apart. A surveyors compass was used, and lines were marked with strips of white cloth (Fig. 4.1). The 18 strips were divided into three routes, so that every third strip, and a total of six strips, would be covered on each route. A coverage of all 18 strips, or three routes was completed in three census days (Fig. 2). Four complete coverages were made.

To equalize effects of time of day over all the strips censused, direction of traverse for the last two coverages was reversed.

Strip censusing was begun on October 5th, 1955 and







Figure 1. Cover map of the Kellogg Forest study area, showing vegetation types, and locations of rabbits seen during strip censusing. (●⁷)

Figure 2. Aerial photo of the Kellogg Forest study area, showing strip census lines.

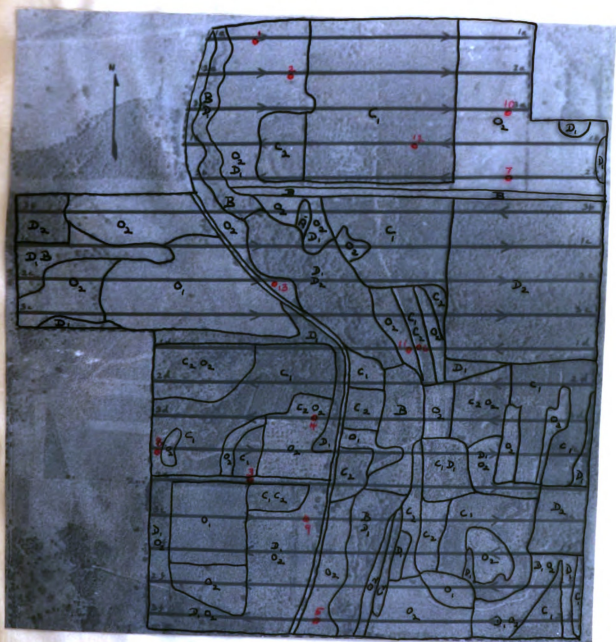
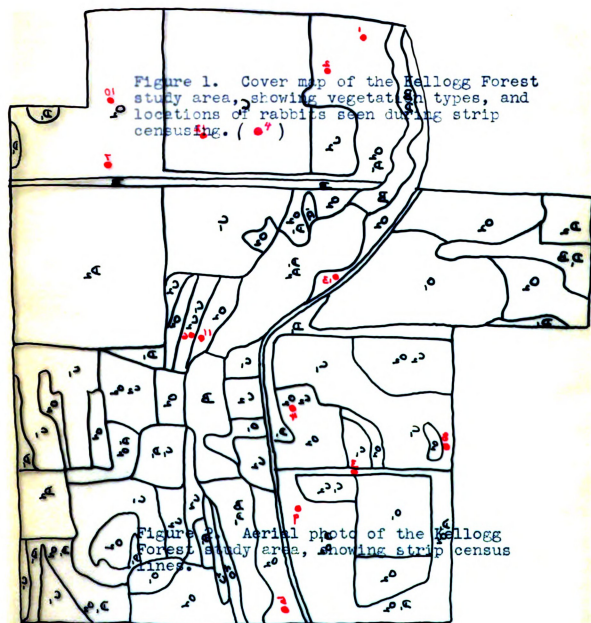


Figure 1
Figure 2



strip 7



Figure 2





Figure 3

Damaged census line marker. Such damage, probably by red squirrels, occurred repeatedly in some areas. Sometimes markers were completely removed.



Figure 4.1

Cover type O₂. Open land with high grasses and some brush. (Refer also to appendix p. 48)



Figure 4.2

Cover type D_1 ; second
growth deciduous woods.



Figure 4.3

Cover type D_2 ; mature
deciduous woods.



Figure 4.4

Cover type C_1 : conifer plantations with open understory.



Figure 4.5

Cover type C_2 : conifer plantations with closed understory.

ended October 19th. Flushing distances recorded were determined by pacing; angles were obtained by using a protractor and field compass. Perpendicular distances were computed using flushing distances and angles. A copy of the form used to record all data is shown in Fig. 9 in the appendix.

Walking speed along strip census lines was approximately two miles an hour. Crossing the creek presented a small problem; canvas gym shoes were finally selected, which proved quite comfortable on warm days.

Weather data were obtained from a small weather station maintained at the Kellogg Forest.

Rabbits were captured in wooden and metal traps, and were marked with metal bands on the ears and picric acid, giving a bright yellow color, on the tails (Geis, 1956). Rabbits so marked were used to estimate the population by the Lincoln Index method (Appendix p. 52).

The Kellogg Bird Sanctuary and Farm

The Kellogg Bird Sanctuary-Farm area includes approximately four-fifths of a square mile of terrain similar to the Kellogg Forest.

The location is T1S, R9W, Section 8. The vegetation of the Kellogg Bird Sanctuary, with a similar origin and development as that on the Kellogg Farm, closely resembles the latter in complexity. The Kellogg Farm consists

chiefly of heavily pastured land with small patches of wildlife plantings (Fig. 5 and Fig. 6).

One-fifth of a square mile, located in two separate portions, was strip censused. To prevent disturbing the migrating waterfowl on Wintergreen Lake, located centrally in the area, the census lines were set back from the lake. Fences, animal enclosures and public areas restricted the censusing to more remote portions. Only those areas were censused for which Lincoln Index trapping data were available.

Strip census lines were laid out in the same manner as on the Kellogg Forest, with the exception that lines were 75 yards apart. Line directions, restricted by existing conditions were not consistent (Fig. 6). Census lines divided into a west (Route 1) and an east (Route 2), were run on the same or consecutive days.

Strip censusing began November 21, and ended December 9, 1955. Records were kept in the same manner as on the Kellogg Forest. Weather data obtained at the Kellogg Forest were used for the Bird Sanctuary-Farm area; the latter is only a little over a mile distant from the Forest. Trapping was carried out in the same manner as on the Kellogg Forest.

The shot sample of rabbits used to compute Lincoln Index estimates, were obtained by controlled collecting (Geis, 1956). Sub-populations were estimated for both route areas using the kill map, trapping map and the



Figure 5. Cover map of the Kellogg Bird Sanctuary-Farm study area, showing vegetation types and locations of rabbits seen during strip censusing. (•⁴)

Figure 6. Aerial photo of the Kellogg Bird Sanctuary-Farm study area, showing strip census lines.

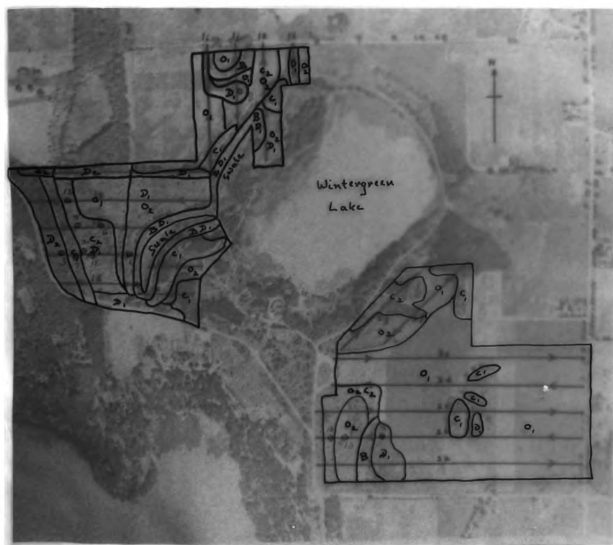


Figure 5
figure 6

Figure 5. Cover map of the Kellogg Bird Sanctuary-Farm study area, showing vegetation types and locations of rabbits seen during strip censuses. (••)

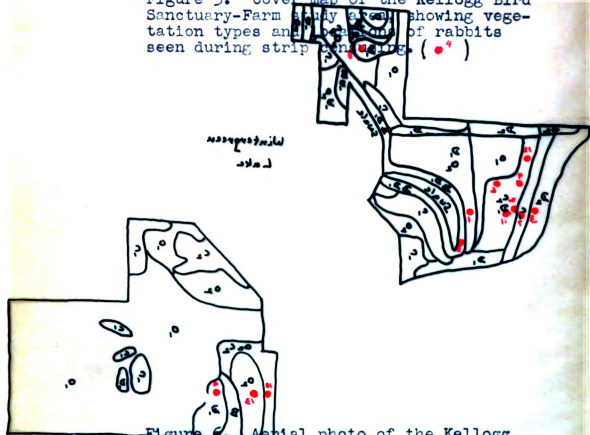


Figure 6. Aerial photo of the Kellogg Bird Sanctuary-Farm study area, showing strip census lines.

Figures 5 & 6

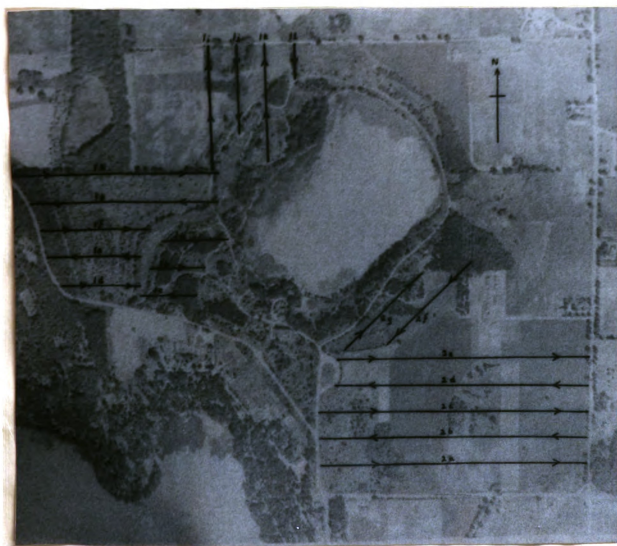
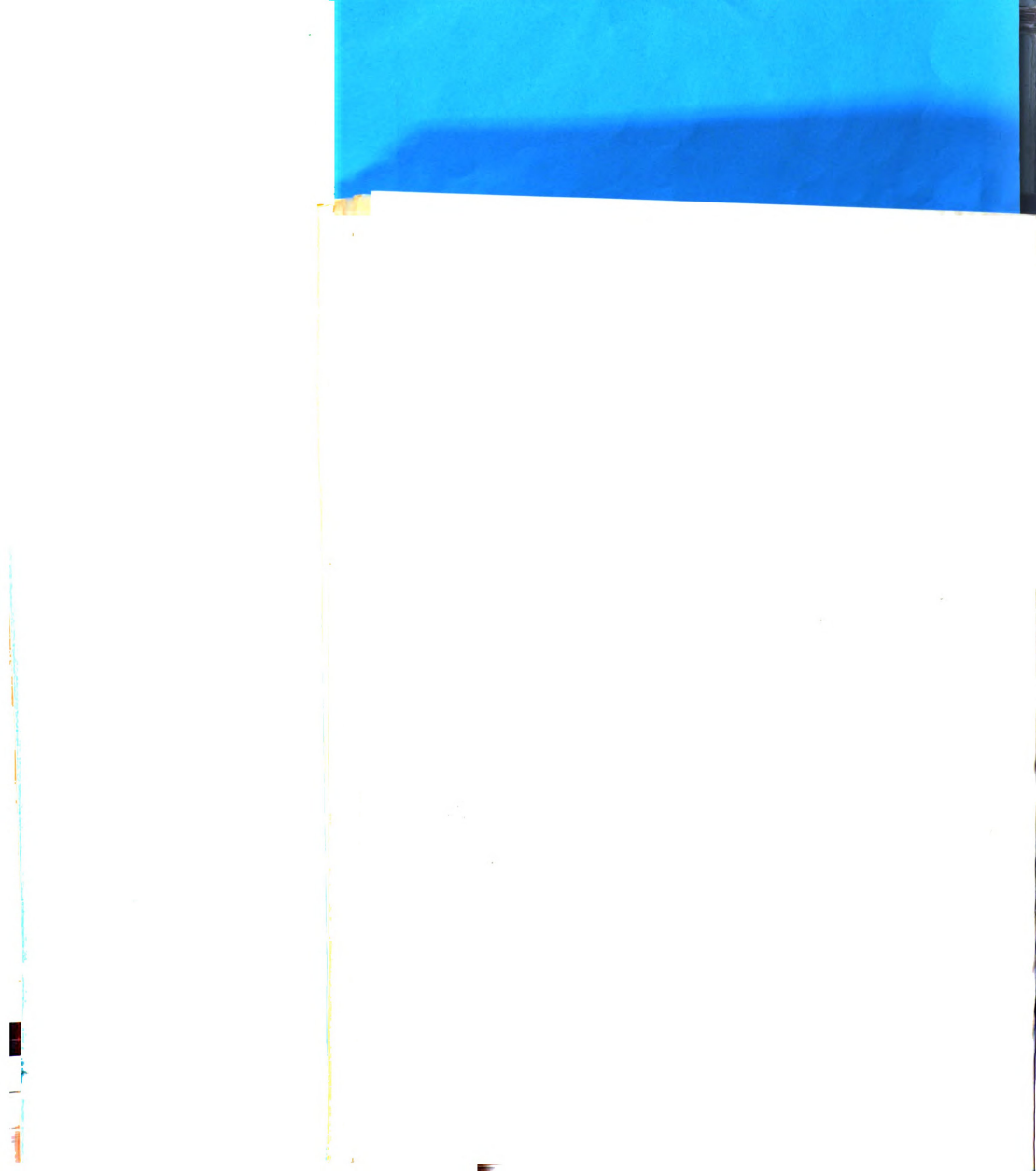


Figure 6



original data cards.

The Artificial Strip Census Model

The object of the strip census model was to obtain an estimate of theoretical strip census characteristics by approximating ideal field conditions on paper. This idea was suggested to the writer by Petrides and Geis. It was developed independently by Palmer and Eberhardt (1955), who employed a strip census model using an artificial grouse population. The latter authors used only the Hayne strip census method to estimate populations in their model. In this study, population estimates for the King, Hayne, Kelker and Webb methods are compared. The original field data were obtained by Geis on the Kellogg Bird Sanctuary.

From a sample of 61 observations by a group of hunters, the flushing distances were divided into nine convenient groups, the first eight at two yard intervals. A weighted mean flushing distance, calculated for each group, was assigned in order of increasing distance, to an artificial population of 200 rabbits in the observed proportions. (Table I).

Positions of the 200 rabbits were then located on graph paper, approximating a 1000 x 2000 yard area, each small square representing one square yard. A table of random numbers was used for this purpose, two sets of

random numbers being used to locate each animal (Fig. 7). To obtain Lincoln Index estimates, the first 160 animals (80%) were considered marked. Census lines were then located on the long axis of the graph paper and flushing distances and angles were determined by intersections of census lines with flushing distance circles. A protractor was used to measure angles. Perpendicular distances were readily determined by counting the squares, each side of a square representing one yard.

Five strip census surveys were made approximating a strip 100,000 yards in length.

TABLE I
CALCULATED FLUSHING DISTANCES AND
NUMBERS FOR EACH FLUSHING DISTANCE -
STRIP CENSUS MODEL

Flushing Distance Class in yards	Weighted Mean Flushing Distance	No. in class Pop. 61	Percentage of Pop.	No. in class Pop.200
1-2 yds	1.7 yds	11	18	36
3-4	3.3	13	21	42
5-6	5.3	10	16	32
7-8	7.3	9	15	30
9-10	9.8	6	10	20
11-12	11.7	4	7	14
13-14	13	1	2	4
15-16	15	4	6	12
17-50	28	3	5	10

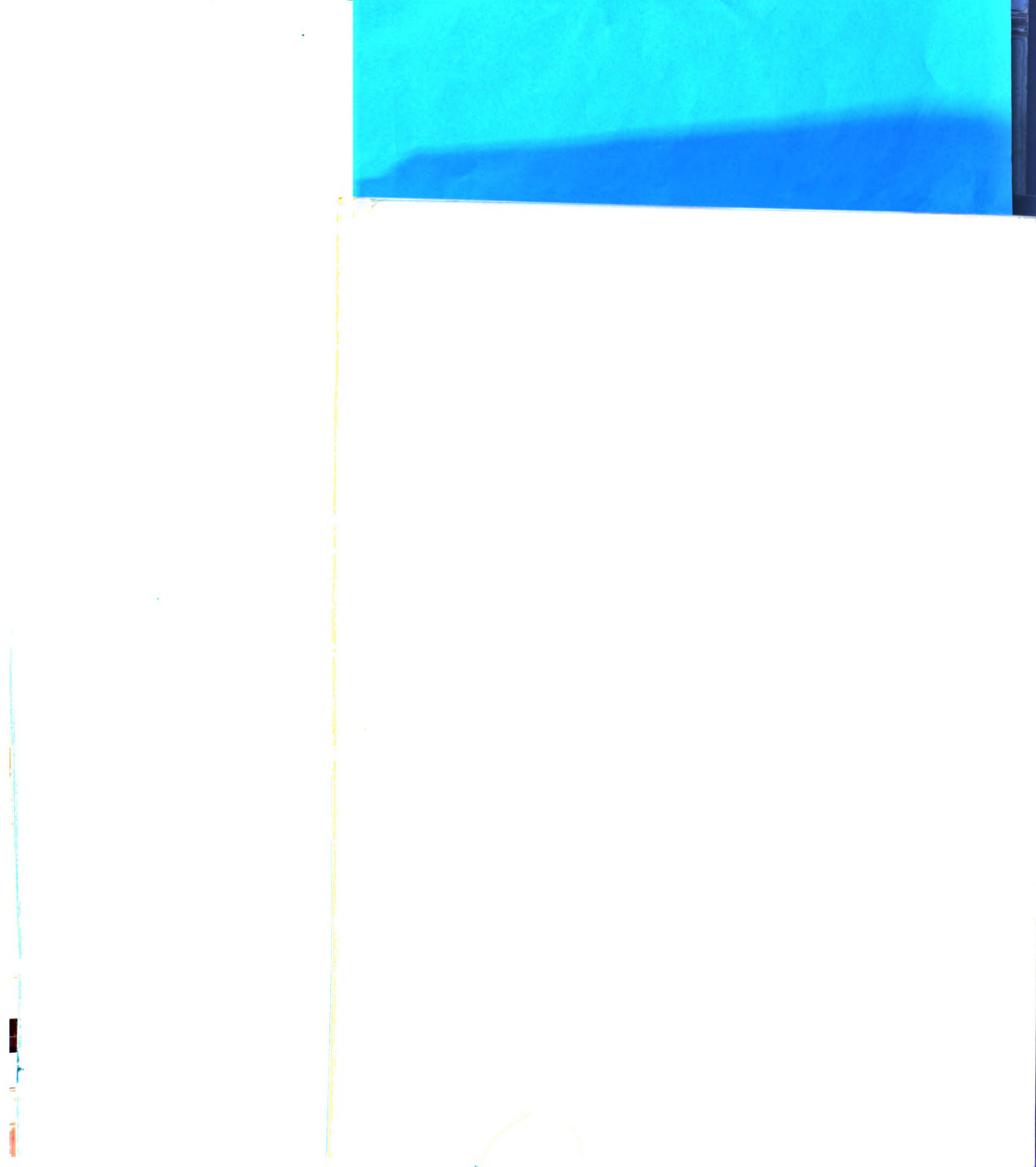




Figure 7

Methods used in locating animals and
obtaining census data in the strip
census model.

Legend:

Animal No. 16.

Marked.

Flushing distance, 28 yards.

Perpendicular distance, 7 yards.

Flushing angle 15° .

Location: Row 108, Column 72, Up 7, Right 3.

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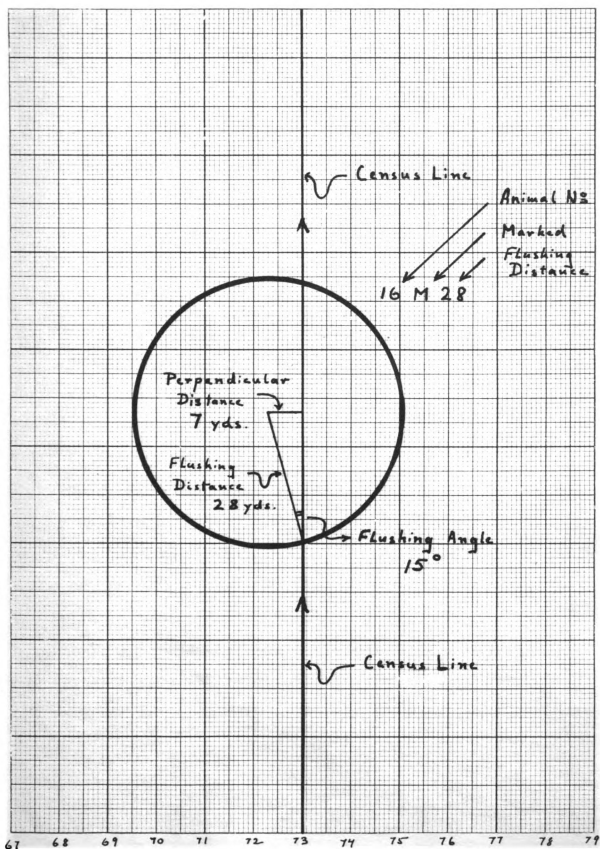
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RESULTS AND DISCUSSION

Discussion of strip census results, including comparisons with the strip census model are presented in the following six sections; the first four deal with the individual tendencies of strip census methods, followed by two sections on the effective width of strip, and a general discussion. Reference should be made to the appendix which includes a more detailed treatment of formulas presented in the text. Selected calculations and data used to make various estimates are also given in the appendix.

In 55.32 miles of census strips at the Kellogg Forest, only 13 rabbits flushed. Strip census estimates ranged from a minimum of 8 percent of the Lincoln Index value by the King method to 48 percent by the Kelker method. Thirteen rabbits were seen in 34.10 miles of census strips at the Kellogg Bird Sanctuary-Farm area. Strip census estimates ranged from 5.5 percent of the Lincoln Index value by the King method (Route 2 area), to 41 percent by the Kelker method (Route 1 area).

It is apparent that the strip census estimates are quite low; a part of the discrepancy seems explainable by the inherent mathematical tendencies of the King, Hayne, Kelker and Webb computing methods.

TABLE II

STRIP CENSUS POPULATION ESTIMATES - KELLOGG FOREST,
LINCOLN INDEX ESTIMATE WAS 311.

Data used to make estimates are given in
Tables VII and VIII in the appendix

Estimates	King Method	Hayne Method	Kelker Method	Webb Method	No. of Rabbits Observed
Pop. Est. 1st Cov.	125.63	241.79	362.00	164.20	5
2nd Cov.	125.03	130.24	103.77	125.03	2
3rd Cov.	9.61	17.12	103.77	37.11	3
4th Cov.	45.25	48.93	44.54	68.12	3
Mean	76.38	109.52	153.52	98.61	3.25
Pop. Est. Total Cov.	30.91	109.48	181.00	42.88	
Standard Deviation	58.36	100.22	141.76	56.90	
Standard Error	29.18	50.11	70.88	28.45	
Confidence Limits	112.85	172.16	242.12	134.17	
70% Level	39.91	46.88	64.92	63.05	

TABLE III

STRIP CENSUS POPULATION ESTIMATES -
KELLOGG BIRD SANCTUARY-FARM AREA.

Lincoln Index Estimate was 54 for Route 1 area, 39 for
Route 2 area. Data used to make estimates are given in
Tables VII and IX in the appendix.

Estimates based on Total Coverage	King Method	Hayne Method	Kelker Method	Webb Method	No. of Rabbits Observed
Route 1	6.05	8.06	22.13	8.71	10
Route 2	2.13	2.75	13.90	2.94	3

TABLE IV

POPULATION ESTIMATES - STRIP CENSUS MODEL

Known population 200, 5 surveys of 20,000 yds. each

Estimates	Lincoln Index	King Method	Hayne Method	Kelker Method	Webb Method	No. of obs- ervations
Pop. Est. 1st Survey	198.62	139.75	223.75	150.00	218.71	36
" 2nd Survey	232.00	112.22	185.55	300.00	195.94	29
" 3rd Survey	203.63	103.93	143.30	450.00	210.53	28
" 4th Survey	182.86	118.78	187.80	350.00	207.79	32
" 5th Survey	169.41	89.91	162.15	200.00	191.49	18
Mean	197.30	112.92	180.51	290.00	204.89	28.60
Standard Deviation	23.62	18.47	30.29	119.38	11.08	
Standard Error	10.59	8.28	13.58	53.53	4.97	
Departure from 200 in %	-1.35	-43.54	-9.74	45.00	2.44	
Confidence Limits 90 %	219.86	130.59	209.43	404.02	215.48	
" "	174.74	95.25	151.60	175.98	194.30	
No. of surveys re- quired for 15% accuracy, 95% conf.	2.55	4.76	5.00	30.12	.52	

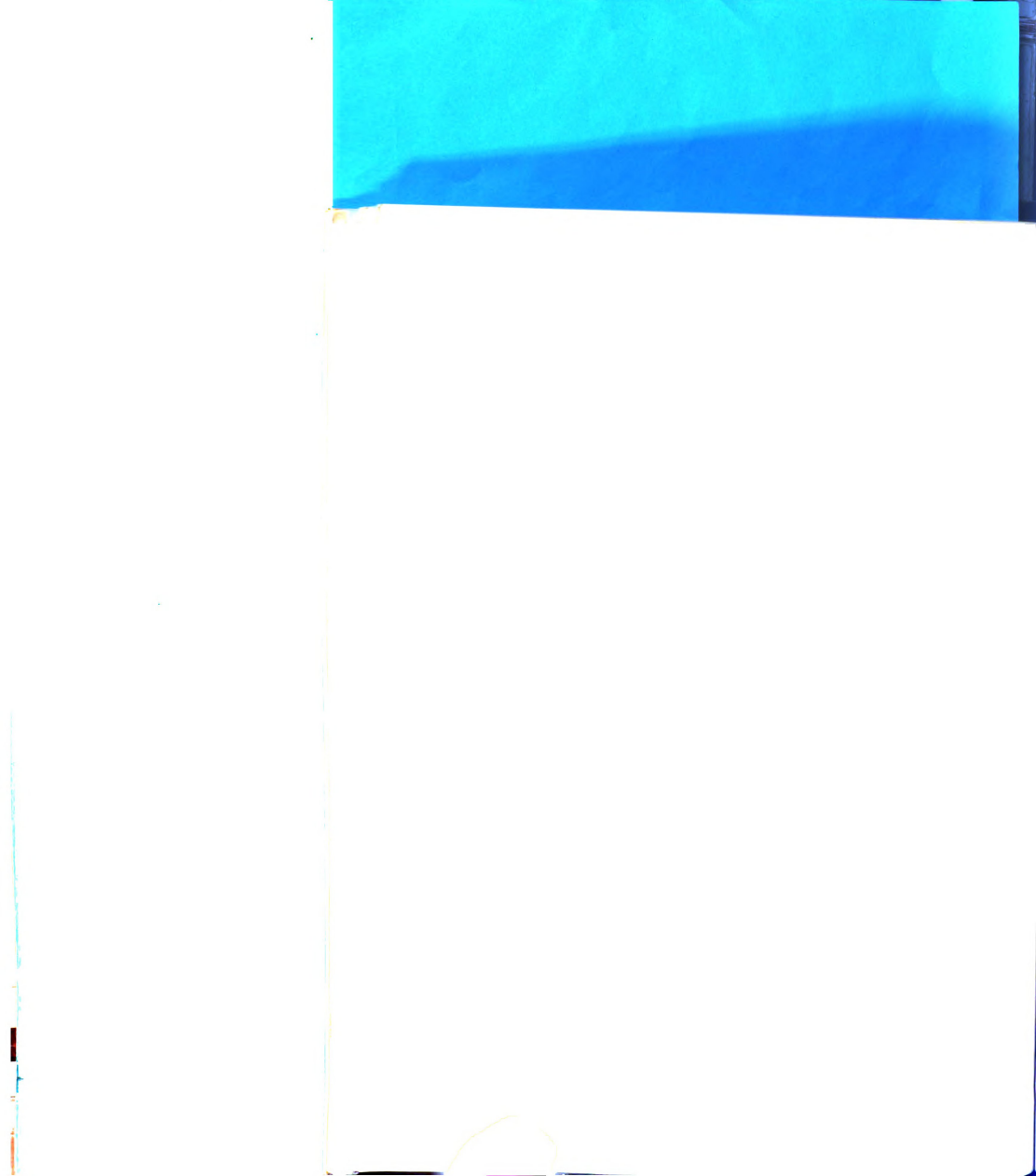
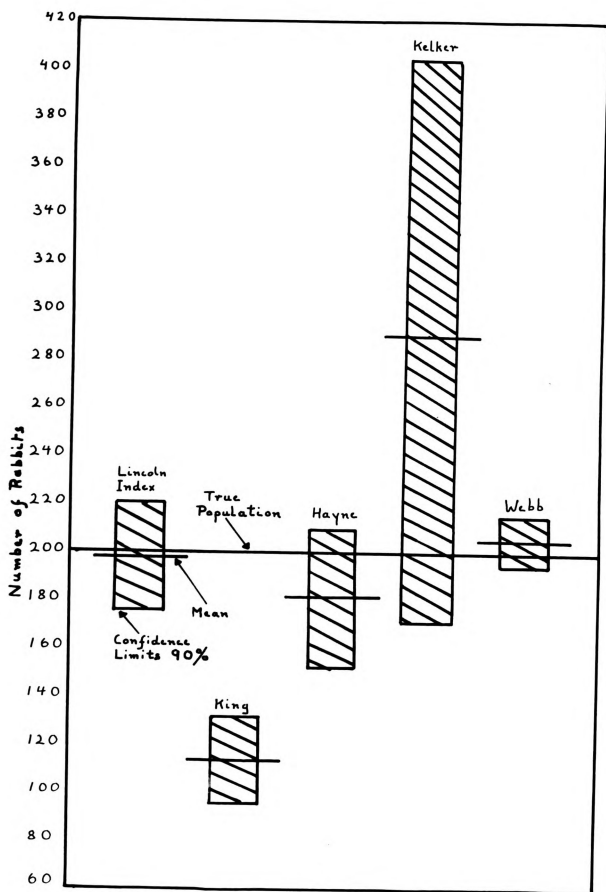




Figure 8

Population estimates and confidence limits,
90 percent accuracy, for the strip census
model.



King Method

$$P = \frac{AZ}{XY}$$

A = Total area of censused tract

Z = Number of rabbits seen

X = Total length of census line

Y = Twice the average flushing distance

P = Estimated total population

Refer also to appendix, p. 50.

In both field studies and the strip census model, the King method gave the lowest estimates (Tables II, III, IV). In the strip census model, the mean census estimate for five surveys (Table IV) is 43.5 percent less than the true population of 200. A project by Robinette et al. (1954, 1956) comparing the same strip census methods for winter-lost deer, showed that the King method generally gave the lowest estimates.

In theory, the tendency for the King method to give low values can be attributed to the over-sampling of the longer flushing distances, for which there is no correction in the formula (Hayne, 1949). Hence, the population estimate, based on a given number of observations for a wider strip, is lower.

It is also interesting to note that the mean population estimate, 76.38, of the four strip census coverages

at the Kellogg Forest is more than twice the estimate of 30.91 based on total coverage. This can be explained by the increase in weight of shorter flushing distances in estimates based on subdivided data; the ultimate end of this process results in the Hayne method of calculation. It is apparent that for any set of data, estimates by the King method would vary considerably according to data-group sizes.

From Table III it will be seen that population estimates at the Kellogg Bird Sanctuary-Farm area are actually lower than the number of rabbits seen during censusing; this is because the area covered in the strips is greater than the total census area.

Hayne Method

$$P = \frac{A}{2X} \left(\frac{F_1}{d_1} + \frac{F_2}{d_2} + \frac{F_3}{d_3} + \dots + \frac{F_n}{d_n} \right)$$

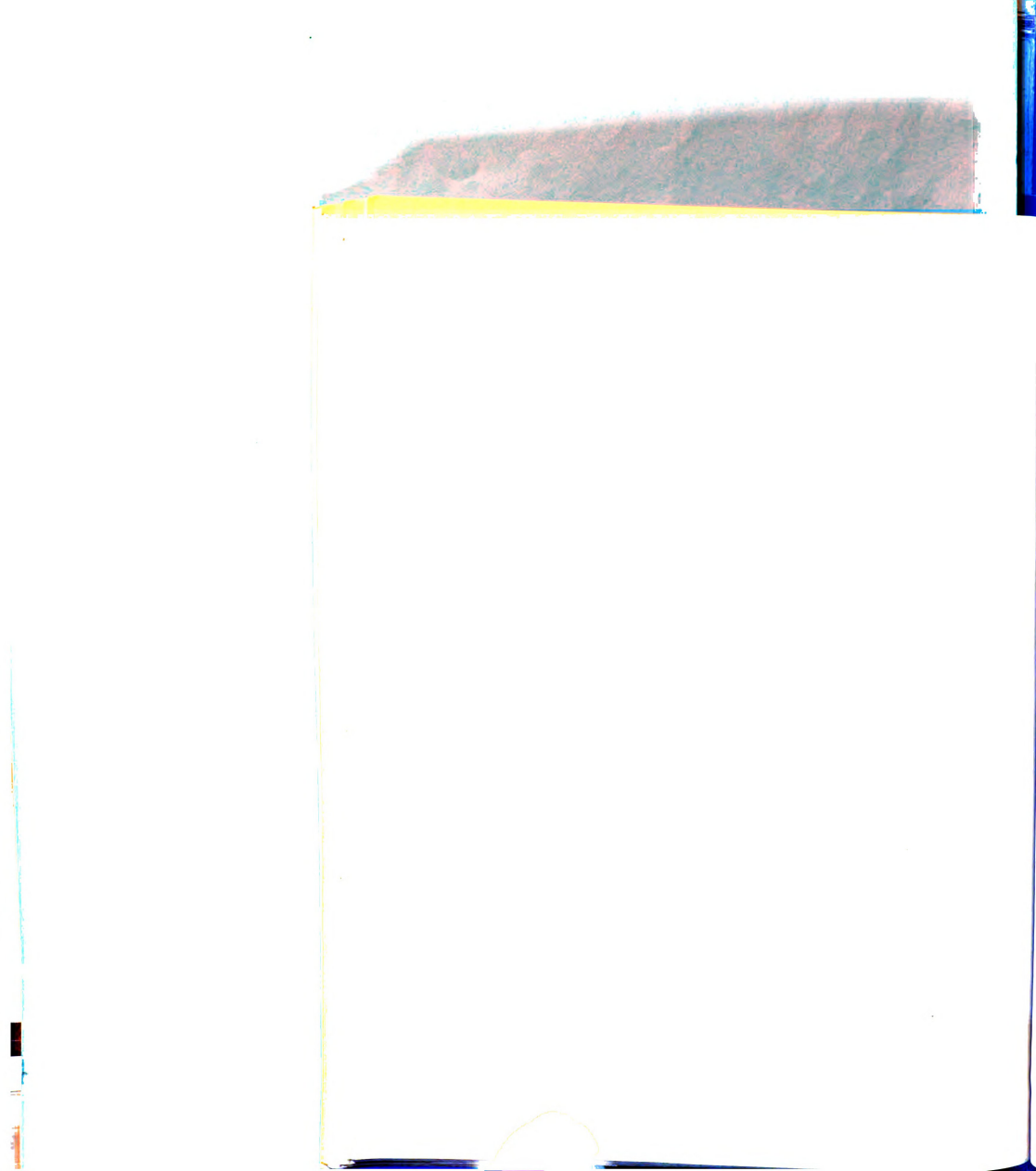
$F_1 - F_n$ = Numbers of animals observed to flush
at corresponding flushing distances.

$d_1 - d_n$ = The various observed flushing distances.

The meanings of other symbols is the same as given for the King method. Refer also to appendix p. 50.

In the theory and mechanics of the Hayne method of calculation, there seems to be no way to account for low values obtained in the field study.

In the strip census model, this method gave the most



satisfactory results (Table IV, Fig. 8). The mean estimate of five surveys is 9.74 percent less than the true population of 200, although the standard deviation of 30.29 is next to the highest. The greater accuracy of the estimate by the Webb method, compared to that by the Hayne method is due to chance, governed by a constant relationship to the King method. This is explained further in the text.

For the Kellogg Bird Sanctuary-Farm area, the population estimates are lower than the number of rabbits seen during the census. As mentioned above, this is the result of a greater area covered in the strips than in the censused tract.

Kelker Method

$$P = \frac{AZ}{X\bar{Y}}$$

$\bar{Y}$ = Twice the effective width of strip.

The meaning of the other symbols is the same as given for the King method. Refer also to appendix p. 51.

This method yielded the highest census estimates, both in the field study, and in the census model (Tables II, III, IV).

At the Kellogg Forest, the estimate of 181, based on total field coverage is probably the best one because the width of the strip is judged from the largest number of observations. In the present field studies especially,

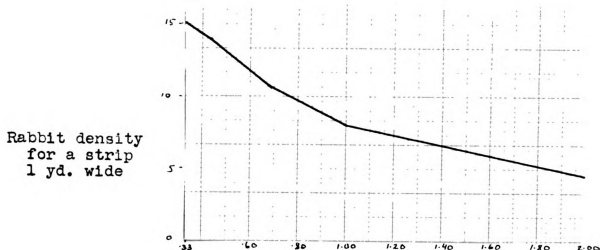
the small number of observations does not bear subdivision. In the strip census model, the mean estimate for five surveys was 45 percent higher than the true value of 200 (Table IV).

The standard deviation of estimates by the Kelker method for the Kellogg Forest data and the model was the highest of the four methods (Tables II, IV). Statistics were not computed for the Kellogg Bird Sanctuary-Farm area because the extremely low values would make them meaningless.

The high variability seems due to the subjective approach of the method. By inspection, the width of the strip is determined to be that distance on both sides of the line of travel at which the number of observations shows a marked decrease. (Appendix p. 51) This decision is often difficult to make; an example taken from field data follows.

Perpendicular distance from the line of travel in yds.	Number of rabbits seen	Accumulated number of observations per strip	Calculated density for strip one yard wide	Population estimate
.33	5	5	15.15	196.54
.43	1	6	13.95	181.00
.66	1	7	10.60	137.58
1.00	1	8	8.00	103.77
2.00	1	9	4.50	58.37

Data used to make estimates are given in Tables VII and VIII in the appendix.



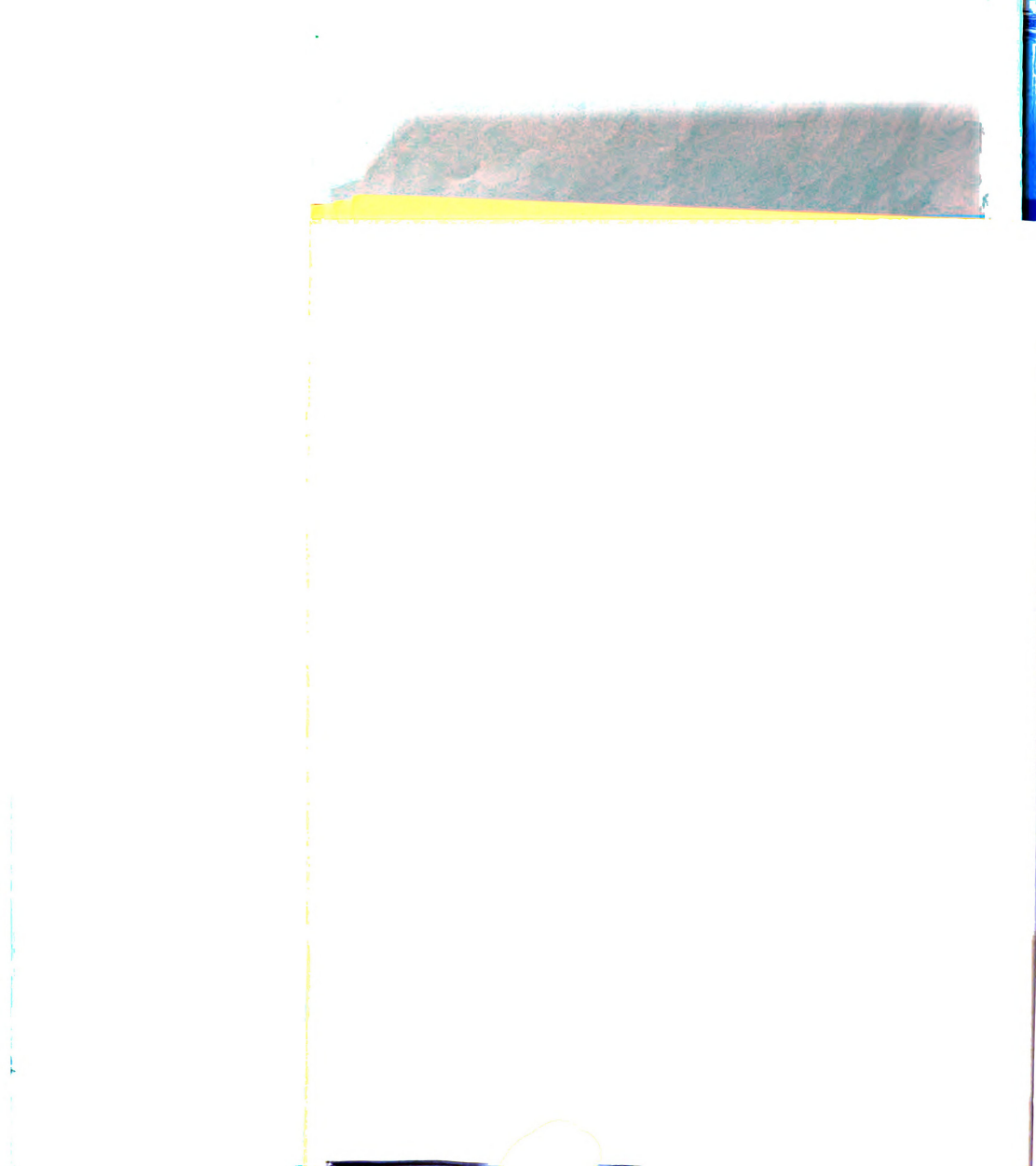
Perpendicular distance from the line of travel

It can be seen from the table and the graph that no outstanding decrease occurs in the density of observations from a perpendicular distance of .33 yard to 1.00 yard, after which there is an actual increase; thus a different decision would result in a considerable difference in population estimates. To make the present population estimate, the perpendicular distance of .43 yard was used.

It seems that the flushing behavior of rabbits is not suited to the operation of the Kelker strip census method, i. e., a constant level of observations along a perpendicular distance on both sides of the line of travel, followed by a sharp decrease in number of observations, is required.

Webb Method

$$P = \frac{AZ}{XY \sin D}$$



Sin D = sine of average flushing angle. The meaning of other symbols is the same as given for the King method. Refer also to appendix p. 51.

In the Kellogg Forest study, the two estimates by the Webb method of 98.61 and 42.88 (Table II) bear a constant relationship to the two respective estimates by the King method.

Hayne (1949) pointed out that the theoretical mean for any set of flushing angles is $32^{\circ}42'$. The sine of this theoretical angle is .54, so that estimates by the King method are doubled by the Webb method. This effect is shown in results obtained in the strip census model. (Table IV, Fig. 8) The average of all flushing angles in the model is $33^{\circ}27'$, the sine of which is .55; this does not differ significantly from the theoretical value.

Hayne observed that the deviation of flushing angles from the theoretical angle may show the degree of randomness of observations. Robinette et al. (1954, 1956) obtained average flushing angles ranging from 42° to 48° for their field study on winter-lost deer, indicating that a bias was present in the strip censusing. Apparently, the observer was not seeing animals ahead of him when they came into visible range. Hayne suggested that the observer, knowing his line of travel, looks more intently to the sides than ahead, recording more of the larger angles.

Kellogg Forest data showed that the theoretical angle

was exceeded considerably by an average flushing angle of $46^{\circ} 9'$ for all field observations. This seems to indicate that a similar bias as the one mentioned above, was present. It should be noted, however, that in several instances the flushing angle could not be determined accurately, because the rabbit had been in motion for some time before it was seen.

The extremely low population estimates obtained for the Kellogg Bird Sanctuary-Farm area, lower than the number of observations during censusing, are discussed above.

Weather data during strip censusing at the Kellogg Forest and Kellogg Bird Sanctuary-Farm area are presented in Tables V and VI. There seems to be no significant correlation between the number of observations and weather data. It is worth noting that on October 7, when Augusta Creek was almost twice as high as usual, standing water extended several hundred yards on both sides of the creek in some sections. These areas were thus removed temporarily as rabbit habitat.

Effective Width of Census Strip

To get an estimate of the width of census strip in which theoretically all rabbits were flushed, the following relationship was used:

$$\frac{W}{A} = \frac{F}{L} ; W = \frac{FA}{L}$$

TABLE V

WEATHER DATA - KELLOGG FOREST

Date	No. of Rabbits seen	Ave. Daily F ^o Temp. 8 am-5 pm.	Min. Temp. F ^o	Precipitation in inches	% Cloud Cover
Oct. 5	1	63	58	1.02	100
6	2	68.67	61	2.09	100
8	2	54	46	.22	0
9	1	65.50	36	0	0
10	1	63.33	37	0	0
11	0	56	36	0	0
13	1	51	33	.03	0
14	0	48.67	27	0	0
15	2	45.67	27	0	33.33
17	2	50.33	45	.09	96.67
18	1	50	39	.05	95.83
19	0	46.33	35	.02	83.33

TABLE VI

WEATHER DATA - KELLOGG BIRD SANCTUARY-FARM AREA

Date	No. of Rabbits		Ave. daily Temp.	Min. Temp	Prec. inches	% Cloud Cover
	Rt. 1	Rt. 2				
Nov 21	4		33	22	0	100
22	1		38	28	0	100
Dec 1	1		20	5	0	100
2			32.33	23	.08	100
3			33.67	29	.06	100
4			28	26	.15	90
5	2	2	23	21	.03	100
6	2		21.33	14	0	0
7			31	20	0	100
8			29.33	15	0	100
9		1	22.67	16	0	80

- W = Effective width of strip
 A = Total area of censused tract
 F = Fraction of the population seen during one coverage of 18 strips
 L = Length of census line in one coverage

For the Kellogg Forest area, the Lincoln Index value of 311 rabbits was used as the best population estimate; the number seen during each coverage was converted into a fraction of 311.

First coverage: $\frac{5}{311} = .0161$ etc.

Coverage	Rt. 1	Rt. 2	Rt. 3	Total No. of observations	Fraction
1st	1	2	2	5	.0161
2nd	1	1	0	2	.0064
3rd	1	0	2	3	.0096
4th	2	1	0	3	.0096
Total	5	4	4	13	.0417

The average fraction for all four coverages is:

$$\frac{.0417}{4} = .0104$$

Substituting in the above formula (Refer also to Table VII),

$$W = \frac{.0104 \times 2525880}{24340} = 1.08 \text{ yds.}$$

For the Kellogg Bird Sanctuary-Farm area, the west area (Route 1) had a Lincoln Index population estimate of

54 and the east area (Route 2), 39. The effective width of census strip for the west area was calculated to be 1.90 yds., for the east area, .07 yds.

If these low values are an indication of the actual effective width, the length of census line required to give adequate population estimates would be beyond normal practicability.

General Discussion

The highest strip census estimate for both study areas was only 48 percent of the Lincoln Index value. It seems probable that some factors other than strip census mechanics are responsible for the large discrepancies; estimates obtained by the model support this probability. The writer offers the following possible explanations, based on observations in the field.

On various occasions while running traplines in dense spruce and other conifer plantations, rabbits were observed to escape readily under cover of low branches, making them difficult to see. In open areas, on the other hand, rabbits often showed a tendency to "freeze". On one occasion, at the Kellogg Forest, while crossing a very promising glade with a sparse tangle of raspberry vines along a census route, no rabbits were flushed. With object of perhaps flushing a reluctant rabbit, the glade was thoroughly covered, and a rabbit flushed less than a

yard from the census line. A similar incident occurred during a strip census on the Kellogg Farm. Another person, walking several yards behind the writer, saw a rabbit which had not been flushed, next to the census line.

Another peculiar behavior pattern was observed during the late fall and winter rabbit hunts on the Kellogg Bird Sanctuary-Farm area. Patches of shrub cover and conifer plantations, often hundreds of yards long, were driven by a line of hunters. As a precaution, several men were stationed at the edges and far end of coverts, to intercept rabbits that might break out. At the beginning of the shooting period, rabbits broke cover only when hunters had reached the end of the patch, but later rabbits were observed to break cover as much as a quarter of a mile ahead of the line of guns. These rabbits were not seen by hunters in the line.

During particularly cold days in a comparatively warmer period, rabbit activity was reduced and cover was sought in brush piles and burrows. This could be plainly seen by following tracks in the snow, and is a fact well known to any rabbit hunter.

The behavior patterns mentioned above would result in a decrease in numbers of rabbits seen in the census strip and hence, a decrease in strip census population estimates.

From the present study, it seem apparent that strip censusing is not suitable for measuring rabbit populations in southern Michigan. It is possible that strip censusing



could give an index of population abundance; however,
indices can be obtained with less labor and effort.

SUMMARY

In 55.32 miles of census strips at the Kellogg Forest, only 13 rabbits were flushed. Strip census estimates ranged from a minimum of 8 percent of the Lincoln Index value by the King method to 48 percent by the Kelker method. Thirteen rabbits were seen in 34.10 miles of census strips at the Kellogg Bird Sanctuary-Farm area. Strip census estimates ranged from 5.5 percent of the Lincoln Index value by the King method to 41 percent by the Kelker method.

Generally, the King method gave the lowest estimates followed by the Webb and Hayne methods; the Kelker method yielded the highest and most variable estimates. From a theoretical viewpoint, the Hayne method gave the most valid results, judging from the strip census model.

The effective width of strip, calculated from the relationship of the fraction of the total population seen during strip censusing, to the area censused and the length of the census route, was small for both study areas. Values ranged from .07 yard to 1.90 yards.

None of the strip census estimates obtained in the field were higher than 48 percent of the Lincoln Index value. Possible explanations for these low estimates include erratic flushing tendencies, "holing up" during cold weather, and rabbits escaping unseen by the observer.

The present study indicates that strip censusing is not suitable or practical for measuring cottontail rabbit populations in southern Michigan.



43

APPENDIX



117 11



A close-up photograph of a metallic surface, likely aluminum, showing a large, irregular, dark hole. A black and white checkered pattern is visible on the left side of the image, possibly a scale or a reference marker. The surface appears slightly worn and has some visible grain.

Figure 9

DATE: _____

AREA: _____

[illegible][illegible]



TABLE VII

DATA USED TO MAKE STRIP CENSUS
POPULATION ESTIMATES
KELLOGG FOREST AND KELLOGG BIRD SANCTUARY-FARM AREA

Statistic	Kellogg Forest	Kellogg Bird Sanctuary-Farm
Area (sq. yds.)	2,525,880	270,000 West, Rt. 1 353,440 East, Rt. 2
Length Rt. 1 (yds.)	7,920	3,268
" Rt. 2 "	7,920	4,236
" Rt. 3 "	8,500	
Total coverage Rt. 1 (yds.)	31,680	26,141
" " Rt. 2 "	31,680	33,890
" " Rt. 3 "	34,000	
Total, all routes (yds)	97,360	60,031
" " " (miles)	55.32	34.11

TABLE VIII

STRIP CENSUS OBSERVATIONS - KELLOGG FOREST

Observation No.	Route	Strip	Flushing Distance (yds.)	Perpendicular Distance (yds)	Flushing Angle in degrees
1	1	a	.33	.33	90
2	2	a	2.00	2.00	90
3	2	e	2.66	0	0
4	3	d	3.00	2.60	60
5	3	f	2.33	.43	10
6	1	d	1.00	1.00	90
7	2	b	.66	.66	90
8	1	e	28.30	0	0
9	3	e	16.00	0	0
10	3	a	4.30	3.06	45
11	1	d	3.33	2.33	45
12	1	b	2.33	0	0
13	2	c	4.66	4.60	80

TABLE IX

STRIP CENSUS OBSERVATIONS - KELLOGG BIRD SANCTUARY-FARM AREA

Observation No.	Route	Strip	Flushing Distance (yds.)	Perpendicular Distance (yds)	Flushing Angle in degrees
1	1	e	6.00	2.53	25
2	1	e	8.00	8.00	90
3	1	e	6.66	6.27	70
4	1	f	5.00	4.98	85
5	1	d	4.00	.70	10
6	1	f	4.33	4.33	90
7	1	e	14.00	0	0
8	1	j	4.33	0	0
9	2	b	13.00	9.19	45
10	2	b	5.00	5.00	90
11	1	e	22.00	9.30	25
12	1	g	11.00	7.77	45
13	2	b	4.00	.35	5

Classification of Cover Types

The average maximum visibility, as used below, is that distance at which rabbits could still be seen with reasonable ease, by the observer during late fall.

- O₁ - Open land with low, sparse grasses, ploughed fields. Average maximum visibility, 80 yards.
- O₂ - Higher grasses, some brush. Cornfields. Average maximum visibility, 40 yards.
Representative plant species: Red osier dogwood (Cornus stolonifera), gray dogwood (Cornus racemosa).
- B - Brushy. Heavy growth of woody vegetation. Average maximum visibility, 4 yards. Representative plant species: Tartarian honeysuckle (Lonicera tartarica), red osier dogwood (Cornus stolonifera), sassafras (Sassafras albidum).
- D₁ - Second growth deciduous woods. Average maximum visibility, 30 yards. Representative plant species: Large-toothed aspen (Populus granidentata), quaking aspen (Populus tremuloides), choke cherry (Prunus virginiana).
- D₂ - Mature deciduous woods. Average maximum visibility, 40 yards. Representative plant species: Black cherry (Prunus serotina), black oak (Quercus velutina), red maple

(Acer rubrum), white oak (Quercus alba).

- C₁ - Conifer plantations, open understory. Average maximum visibility, 15 yards. Representative plant species; White pine (Pinus strobus), jack pine (Pinus Banksiana), red pine (Pinus resinosa).
- C₂ - Conifer plantations, closed understory, dense growth of foliage near the ground. Average maximum visibility, 4 yards. Representative plant species: Norway spruce (Picea abies), Tamarack (Larix laricina).

Computing Formulas
and Some Calculations

King Strip Census Method

$$P = \frac{AZ}{XY}$$

A = Total area of censused tract

Z = No. of rabbits seen

X = Total length of census line

Y = Twice the average flushing distance.

P = Estimated total population.

This is the formula and symbolism of the King Method used by Fisher (1939).

Hayne Strip Census Method

The original formula, as given by Hayne (1949), is:

$$Nt = \frac{c}{2L} \left(\frac{F_1}{d_1} + \frac{F_2}{d_2} + \frac{F_3}{d_3} + \dots + \frac{F_n}{d_n} \right)$$

Nt = Estimate of total population per unit area.

L = Length of observers path.

$d_1 - d_n$ = The various flushing distances observed.

$F_1 - F_n$ = Numbers of animals observed to flush at corresponding flushing distances.

C = Conversion factor for area.

This was changed to:

$$P = \frac{A}{2X} \left(\frac{F_1}{d_1} + \frac{F_2}{d_2} + \frac{F_3}{d_3} + \dots + \frac{F_n}{d_n} \right)$$

where the meaning of symbols in brackets was retained, and others were changed to symbols described for the King method.

Kelker Method

The original formula given in the notes to University of Michigan students is:

$$A = \frac{8 \times D \times M}{11 \times H}$$

A = Acres/animal

D = Flushing distance of farthest zone which does not show a significant decrease in numbers seen.

H = Number of animals seen in included zones.

This was changed to:

$$P = \frac{AZ}{X\bar{Y}}$$

$\bar{Y}$ = Twice the effective width of strip.

Meaning of symbols other than $\bar{Y}$ is the same used in the King Method.

Webb Method

The original formula given by Webb (1942) is:

$$P = \frac{AZ}{2XY \sin D}$$

D = Average flushing angle in degrees.

Y = Average flushing distance.

The symbolism used is the same as that in the King Method with the exception of D and Y.

The symbol D was retained and Y was used to include 2 Y, giving: $P = \frac{AZ}{XY \sin D}$

Lincoln Index Estimates

Kellogg Forest

$$\frac{\text{Total Population}}{\text{Total Number Marked}} = \frac{\text{Number Shot in Sample}}{\text{Number Marked in Sample}}$$

143 Rabbits were marked pre-season

176 Rabbits were bagged during the hunting season

81 Rabbits bagged were marked

$$\frac{P}{143} = \frac{176}{81} ; \text{ Total Population} = \underline{\underline{310.7}}$$

Kellogg Bird Sanctuary-Farm Area

West Area, Route 1

36 Rabbits marked

24 Rabbits were shot in sample

16 Rabbits marked in sample

$$\frac{P}{36} = \frac{24}{16} ; \text{ Total Population} = \underline{\underline{54.0}}$$

East Area, Route 2

25 Rabbits marked

14 Rabbits were shot in sample

9 Rabbits marked in sample

$$\frac{P}{25} = \frac{14}{9} ; \text{ Total Population} = \underline{\underline{38.9}}$$

Standard Deviation & Standard Error

$$s^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}$$

$$s = \sqrt{s^2}$$

$$s_x = \frac{s}{\sqrt{n}}$$

$\bar{x}$ = Population estimate for one coverage or survey

n = Number of coverages.

Confidence Limits

$$\bar{x} \pm (s_x \times t)$$

$\bar{x}$ = Mean population estimate for total coverages or surveys.

Geis (1952)

"t" value for .30 and .10 and $n - 1$ d.f.

Number of Surveys Needed for Specified Accuracy

$$N = \frac{s^2}{(d\bar{y})^2}$$

N = Number of surveys needed

s^2 = Variance

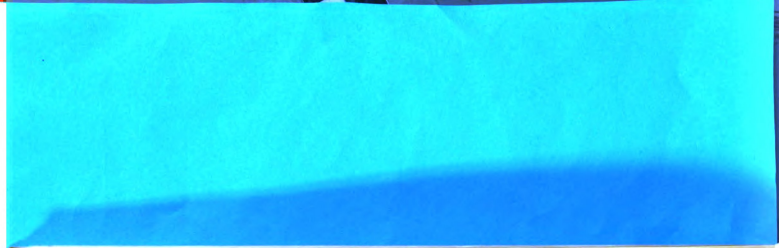
d = The standard error desired to obtain sufficiently accurate results, expressed as a fraction of the mean.
 $d = .075$ for 15% accuracy and 95% confidence.

$\bar{y}$ = Mean estimate for surveys.

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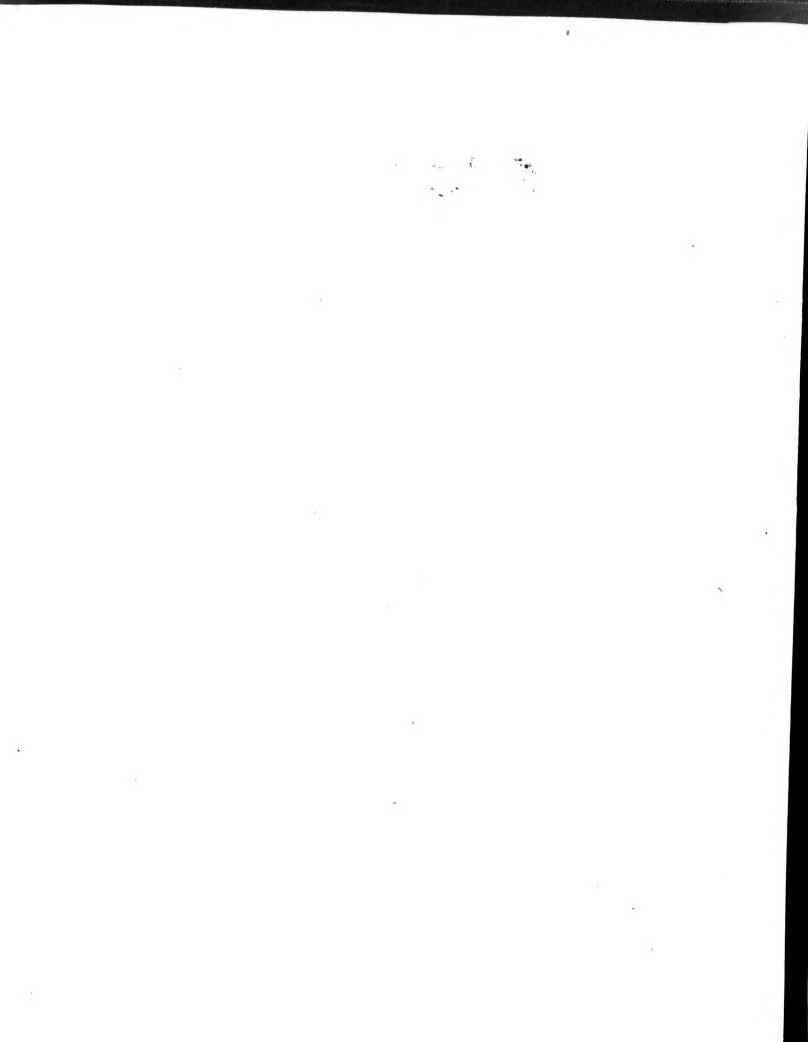




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