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Date April 1991

ESTIMATING ABUNDANCE OF COTTONTAIL RABBITS USING LIVE TRAPPING AND VISUAL SURVEYS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gary Randolph McWherter

May 1991

ABSTRACT

Density estimates for a cottontail rabbit (<u>Sylvilagus floridanus</u>) population on a 25-ha area at TVA's Land Between the Lakes, Stewart County, Tennessee, were calculated using mark-recapture models with live-trapping and visual surveys data. Field work was conducted from 8 March 1985 to 1 March 1986.

Rabbits were live-trapped with 50 box traps for 15 consecutive days during March, August, and December 1985 resulting in 2250 trapnights. A total of 114 rabbits were captured on 241 occasions resulting in a trap success of 10.7%. The number of individual rabbits captured during each trapping period was 40, 46, and 66 for March, August, and December, respectively. Sex ratios favored females during all 3 trapping periods but none differed significantly from 1:1. The overall sex ratio was 46 males to 68 females which was significantly different from 1:1 ($P=0.019$). Live-trapping data were used with Program CAPTURE to provided density estimates of 1.8, 2.4, and 2.4 rabbits per ha for March, August, and December, respectively. These estimates were lower with low probability of capture, individual heterogeneity in capture probability, and trapping design contributing to the negative biases.

A second census method was employed to provide estimates that were independent of trapping bias. Rabbits were marked with pelage dyes or reflective ear tags to allow identification of marked rabbits during visual surveys conducted during morning and evening hours subsequent to trapping periods. These marked-unmarked ratios were used with the Petersen-Lincoln Index to obtain estimates used in determining densities. Visual surveys conducted at night with aid of a spotlight (spotlight surveys) were the most productive yielding density estimates of 3.4, 3.3, and 3.6 rabbits per ha for March, August, and December, respectively.

Rabbits were most observable during morning surveys in June and July but observability decreased during fall and winter due to shifts in habitat use and decreased food. Rabbits remained observable throughout the year during spotlight surveys. Use of spotlight surveys enhanced density estimation efforts by providing independent samples of marked-unmarked ratios for use with Petersen-Lincoln Index and by providing a minimum number alive figure to evaluate the validity of mark-recapture estimates.

Reflective tags made detection of marked rabbits easy during spotlight surveys. Pelage dyes are recommended for morning surveys and reflective ear tags are recommended for spotlight surveys. Rabbit observability was enhanced by the presences of mowed strips 5 m wide and camp pads on the study area. Usefulness of visual surveys may be limited in areas which have few open areas to allow rabbits to be observed.

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INTRODUCTION

The eastern cottontail rabbit (*Sylvilagus floridanus*) has been pursued by millions of hunters throughout its North American range. Healthy cottontail populations are the desire of many small game hunters. Traditionally, most farms supported abundant numbers of rabbits because grown up fence rows and intermediate idle lands provided needed food and cover. However, with advances in farm mechanization and herbicides, changes in agricultural practices, and increases in double cropping, many farms became more efficient but often supported fewer cottontails (Wendell 1948, Madson 1959). The result was fewer lands which provided suitable cover and fewer cottontails. By the 1940's, researchers were investigating how to produce sufficient numbers of cottontails to satisfy hunters (Bowers 1965). The need to evaluate the success of management practices employed to increase cottontail numbers, such as habitat improvements and stocking efforts, prompted the use of mark-recapture methods for estimating population densities.

Mark-recapture methods were first used in fisheries biology as early as the seventeenth century (Petersen 1896 *in* Otis et al. 1978, Hayne 1949). Lincoln (1930 *in* Otis et al. 1978) first used the technique in estimating number of waterfowl based on band returns and, subsequently, the method has been applied to numerous aquatic and terrestrial species. Historical overviews of the development and refinement of mark-recapture, both theoretical and as it applied to individual species, were given by others (Cormack 1968, Otis et al. 1978, Seber 1982, and White et al. 1982).

One of the earliest studies which used mark-recapture data for cottontail population estimation was that of Allen (1938) in Kalamozoo County, Michigan. Allen (1938) indicated that success in trapping rabbits was influenced by factors such as weather, trap placement, and trap habits of individual rabbits. Dalke and Sime (1938) also found cottontail trapping success to be variable depending on factors such as seasons and sex and age classes. This response to traps by cottontails continued to plague studies of population characteristics and led researchers to use caution when drawing conclusions based on mark-recapture data alone (Schwartz 1940, Haugen 1942, Geis 1955, McDowell 1955, Moore 1955, Redd 1956, Peterle and Eberhardt 1959, Huber 1962, Eberhardt et al. 1963, Edwards and Eberhardt 1967, Brady 1973, and Anderson 1975).

Similar problems in live-trapping were concurrently experienced in mark-recapture studies involving other mammal species. Shortcomings were countered with advances in models of mark-recapture population estimation; models are now robust to violations of assumptions which confounded results of earlier mark-recaptures studies (Otis et al. 1978, Seber 1982, and White et al. 1982). Recently, some researchers have indicated that the newer models of population estimation are refined to the point that precise estimates can be obtained even though intrinsic and extrinsic factors may be influencing trapping results (Otis et al. 1978, Pollock 1981, Seber 1982, White et al. 1982, Nichols and Pollock 1983, Nichols et al. 1984, Moore and Kennedy 1985). However, quality of results are dependent on the amount of manpower expended (White et al. 1982).

One objective of this study was to obtain the most accurate estimate of rabbit density possible. To achieve this, a combination of current mark-recapture population models were used with live-trapping data and visual survey data.

A second objective was to evaluate the use the visual surveys as an aide to wildlife managers in obtaining reliable estimates of cottontail density. More specifically, are the practices of determining the proportion of marked rabbits in a population by visual surveys and estimates based on those ratios superior to live-trapping estimates alone? The visual survey method should provide a second estimate of density based on a sampling technique which is independent of live-trapping biases.

A third objective was to apply both closed and open model population estimators to the same mark-recapture data. Comparing the preformance of these 2 type estimators provided information on advantages and disadvantages of each type estimator.

This research is presented in 2 parts. Part 1 examines the first and second objectives and Part 2 examines the third objective.

Cooperators

This research project was conducted in conjunction with a U.S. Department of Agriculture and Tennessee Valley Authority (TVA) pilot study on integrated tick management (ITM) which began in October 1983 and continued until October 1987. The purpose of the ITM study was to evaluate ITM effectiveness in controlling nuisance ticks in high-use recreational areas. ITM involved a combination of pesticide applications, vegetative management, and host population management (Zimmerman 1986). Determining the relationships between tick and host populations was a concern of the ITM study. The ITM study included monitoring population levels of cottontails and monitoring tick infestations on cottontails. Some aspects of the design of the cottontail population research presented in this thesis were limited due to compliance with overall objectives of the ITM study.

PART 1: COMPARISONS OF RABBIT DENSITIES DERIVED FROM INDEPENDENT SAMPLES

CHAPTER I

INTRODUCTION

The idea of live-trapping animals and then obtaining a second sample by a independent means has been practiced on a number of species. Shooting has been used as a second sample method with rabbits (Allen 1938 and 1939, McDowell 1955) and bobwhite quail (Colinus virginianus) (Kellogg et al. 1972, Dimmick et al. 1982, O'Brien et al. 1985) while visual surveys have been used with deer (Strangaard 1967, Rice and Harder 1977, Silvy et al. 1977, Bartmann et al. 1987, McCullough and Hirth 1988) and with jack rabbits (Lepus califoricus) (Smith and Nydegger 1985) and wild rabbits (Oryctolagus cuniculus) (Southern 1940). No record was found of using spotlight or visual surveys as second samples for estimating population size of cottontail rabbits.

CHAPTER II

STUDY AREA

Study Area Description

The study was conducted at Land Between the Lakes (LBL), a National Recreation Area owned and operated by the Tennessee Valley Authority, located in western Kentucky and Tennessee. LBL is a 68,000-ha peninsula approximately 64 km long and 13 km wide, bordered by Kentucky Lake (Tennessee River) on the west and Lake Barkley (Cumberland River) on the east and a manmade connecting canal on the north (Figure 1).

Geologically, LBL is classified as part of the Mississippi Embayment and referred to as the Two Rivers Breaks Area by geographers (Eckel 1940). Topography is described as gently rolling, characterized by low gradient streams bordered by very broad flood plains. Elevation varies from about 110 to 183 m. The mean monthly temperature ranges from 3°C (January) to 26°C (July). Snows are fairly common but average less than 38 cm annually (Cooney and Burgdorfer 1974).

LBL is 86% forested with 96% of the forest in oak-hickory (Quercus-Carya) stands and 4% in white pine (Pinus strobus) and virginia pine (P. virginiana) plantings. The remaining open land consists of agricultural fields of

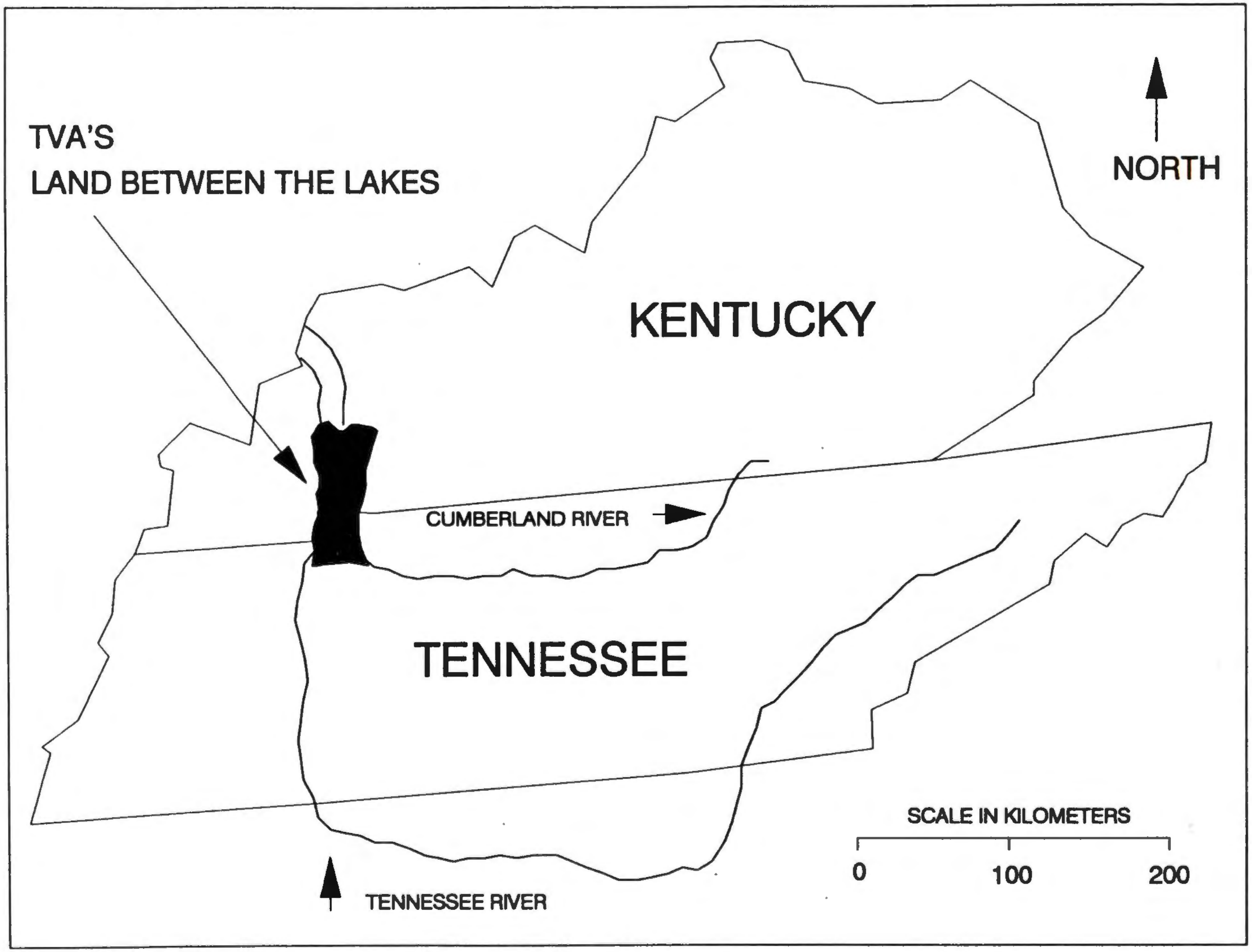

Figure 1. Study area located at Tennessee Valley Authority's Land Between the Lakes.

various sizes and small woods openings scattered throughout the peninsula. Thirty percent of the open land is in agriculture crop production. The remaining 70% of open land is maintained in an early successional stage by burning, mowing, or discing on a 4-year rotation basis.

Study Site Description

The study site was located at the southwestern corner of LBL in Stewart County, Tennessee, 20 km west of Dover, Tennessee (Figure 2). The area was a peninsula located on the eastern shore of Kentucky Lake and consisted of both pine and hardwood forest, old fields, and grassy areas maintained by mowing.

The site was surrounded by wooded areas dominated by mature oak-hickory stands that provided > 75% canopy (Figure 3). The major mid-story species were maple (*Acer* spp.), winged elm (*Ulmus alata*), black cherry (*Prunus serotina*), yellow poplar (*Liriodendron tulipifera*), flowering dogwood (*Cornus florida*), sweetgum (*Liquidambar styraciflua*), and blackgum (*Nyssa sylvatica*). Ground cover was > 75% and was primarily buckbrush (*Symphoricarpos orbiculatus*), greenbrier (*Smilax* spp.), Virginia creeper (*Parthenocissus quinquefolia*), Japanese honeysuckle (*Lonicera japonica*), and poison ivy (*Rhus radicans*). Saplings of mid-story tree species also were present.

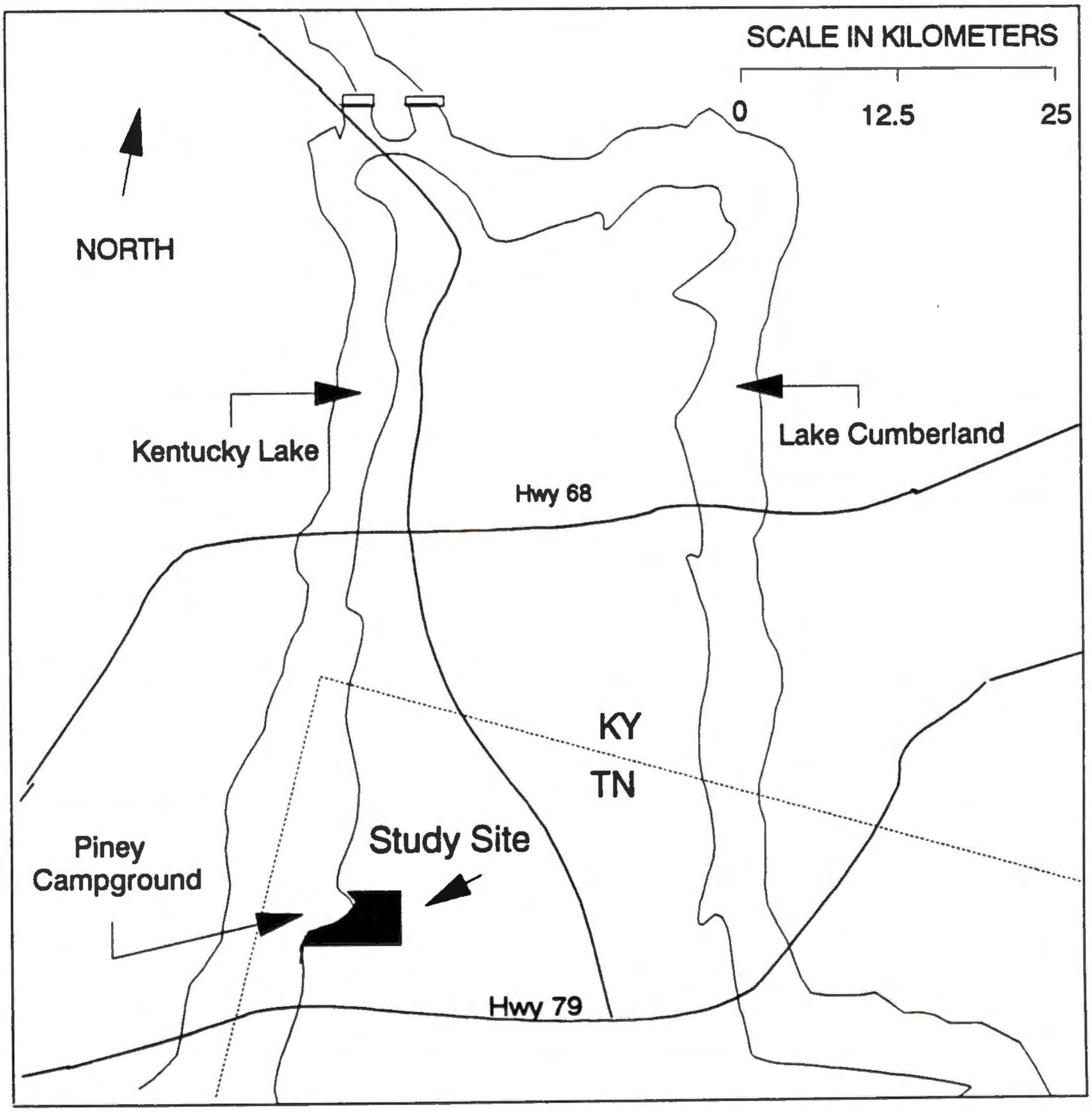

Figure 2. Map of Land Between the Lakes showing location of study site at Piney Campground, Stewart County, Tennessee.

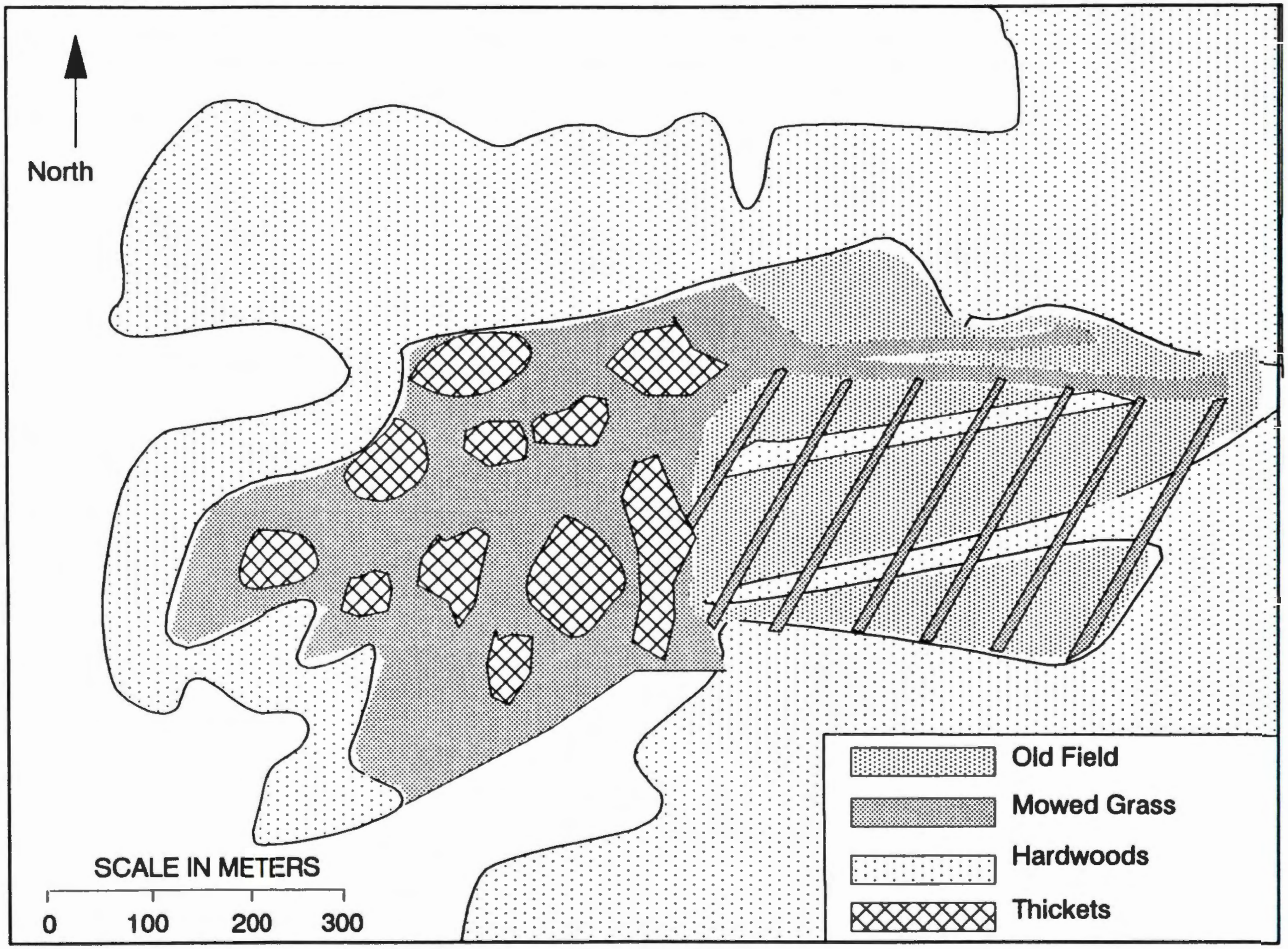

Figure 3. Habitat map of study area located at Piney Campground, Land Between the Lakes, Stewart County, Tennessee.

Within the wooded area was an old field (18-ha) 8 to 10 years old. The dominant tree and shrub species were shining sumac (R. copallina), and chickasaw plum (P. angustifolia) with stems < 10 cm in diameter. Red maple (A. rubrum), honey locust (Gleditsia triacanthos), eastern red cedar (Juniperus virginiana) and sweetgum were present. Ground cover was Japanese honeysuckle, greenbrier, blackberry (Rubus allegheniensis), multiflora rose (Rosa multiflora), tall fescue (Festuca arundinacea), broom sedge (Andropogon virginicus), and sericea lespedeza (Lespedeza cuneata).

Mowed grass in campsites (7-ha) was another habitat type. The campground portion of the study site was a mosaic of mowed grass, blackberry-honeysuckle-multifora rose thickets, patches of broomsedge, paved roads and 2 bathhouses. Hunting was not permitted on the study site.

CHAPTER III

MATERIALS AND METHODS

Field Data Collection

Trapping procedures. Box traps (Davis and Winstead 1980) were used to capture rabbits. Trap dimensions were 61 x 19 x 22 cm. Traps were constructed of 1.9 cm yellow poplar. Traps were placed, baited, and set the first afternoon of trapping. Traps were baited with 1/4 slice of apple. Approximately 3 to 4 hours after sunrise traps were checked for captures. If bait had been eaten or removed, another 1/4 slice was placed in the trap, otherwise a smaller portion was used to freshen the trap with apple scent. Traps received a fresh 1/4 slice of apple at least every 4 days.

Sexing and aging. Captured rabbits were measured using standard techniques (Debase and Martin 1974). Weight was measured to 0.01 kg by use of spring scales (Model 4, 2 g X 20 g, Douglas Homs Corp. Belmont, Ca.). Sex was determined by observation of secondary sex characteristics (Larson and Tabor 1980).

Age of rabbits was classified as either immature or mature. Rabbits with a hind foot measurement of $\geq$ 80 mm were classified as mature. The difficulty of aging live rabbits led to adoption of a 80 mm hind foot length criterion for distinguishing rabbits of at least 90 days of age (Bothma et al. 1972). Rabbits born in spring and first captured during late summer or fall were likely classified as mature, even though they may have been young of the year.

Tagging and marking. Captured rabbits were ear tagged with consecutively numbered Monel metal tags (No. 1005, size 3, manufactured by National Band and Tag Company, Newport, Kentucky). Trap location and comments concerning condition of rabbit or capture circumstances were recorded on a standard data sheet. Rabbits were released at the capture site following data collection.

Rabbits were also marked with pelage dyes or relective tags. In the case of pelage dyes tails and hind flanks were saturated with a 50:50 mixture of picric acid and 95% ethyl alcohol (bright yellow mark) or a mixture of rhodamine B powder and 95% ethyl alcohol (pink mark). Pelage dyes remained visible form 6 to 9 months (Brady and Pelton 1976). Some rabbits were marked with a 1 X 10 cm strip of reflective tape (3M Company, St. Paul, Minnesota). Reflective strips where attached to each metal ear tag by sliding the strip between the tag and ear until an equal amount of strip remained on each side of the metal tag (Figure 4). The 2 adhesive sides were then brought together resulting in a 5 cm reflective tag protruding upwards on the rear side of each ear. Reflective tag colors were gray and

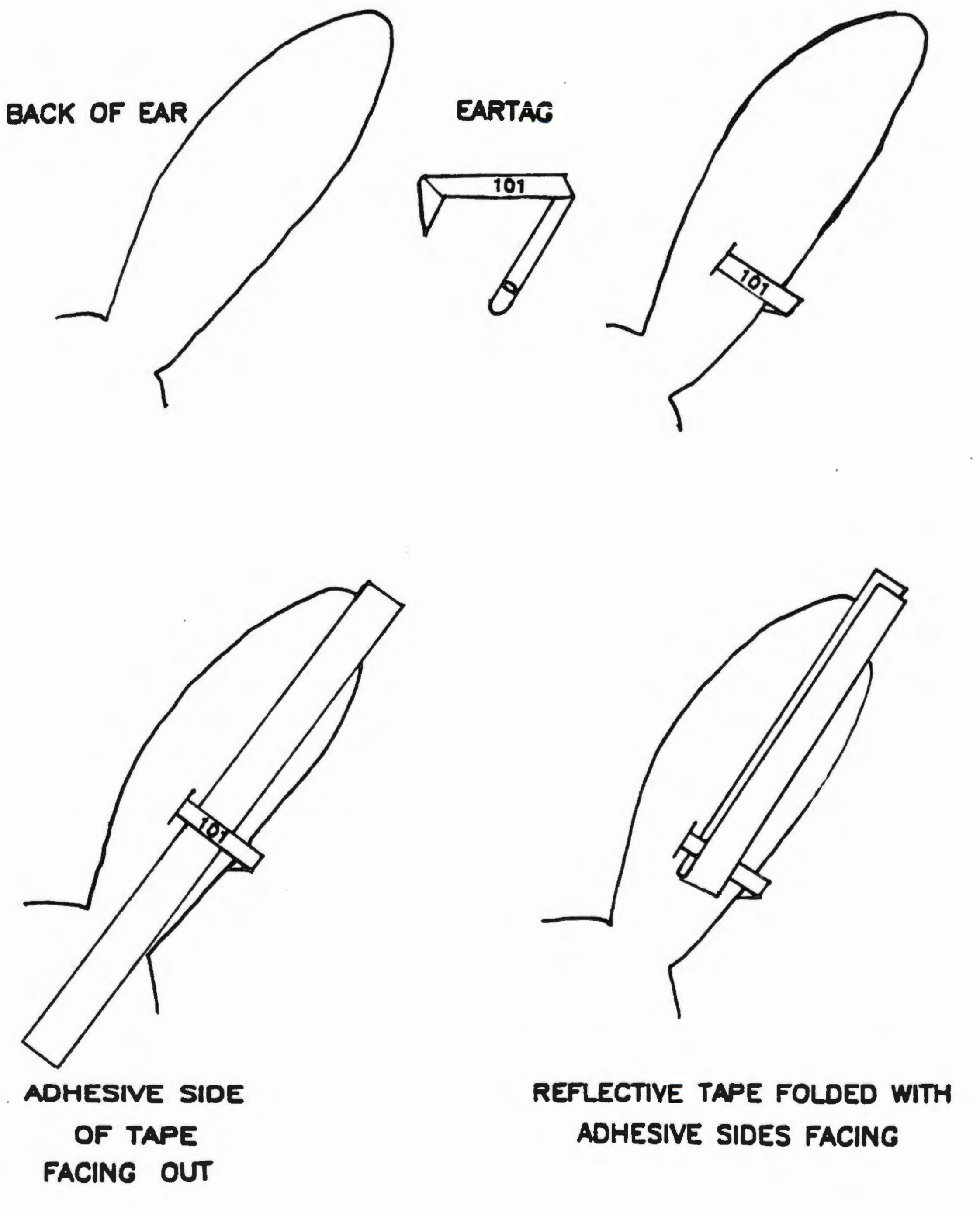

Figure 4. Diagram of metal and reflective tags used to mark captured rabbits at Land Between the Lakes, Stewart County, Tennessee.

red. All rabbits captured were restrained in a small mesh bag; this allowed rabbits to be handled with minimum stress.

Trapping design. Trapping design consisted of 50 box traps within a 25-ha area (Figure 5). Traps were operated for a period of 15 consecutive nights and trapping periods were referred to as 15 day trapping periods (FDTP). Trap density was 2 per ha consisting of 16 trap lines ranging in length from 100 to 600 m (Table 1). The number of traps per line ranged from 2 to 5 with the first trap location on each line determined by random selection of a number representing 10 to 100 m: the distance was measured from the beginning of the line. Subsequent trap locations were at 80 m intervals. Habitat features at the trap site, such as thickets and rabbit trails, were utilized to maximize the likelihood of captures but traps were not placed > 10 m from the designated point.

Visual surveys. Two types of visual surveys were used to observe rabbits. These included spotlight surveys, conducted 1 hour after sunset, and morning surveys conducted 1 to 2 hour after sunrise. Both types of surveys were conducted along a designated 6.6 km route established through the same 25-ha study site (Figure 5).

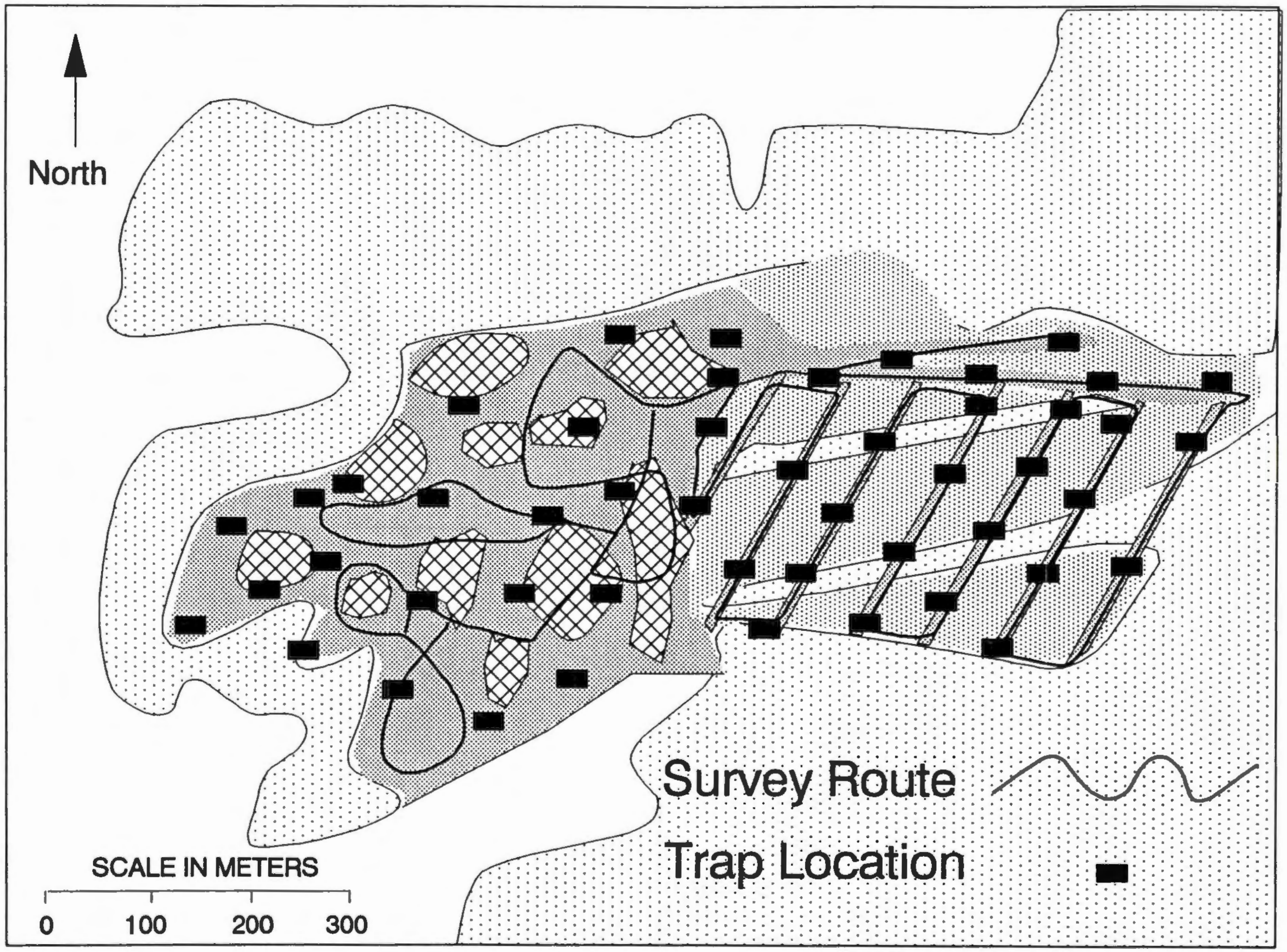

Figure 5. Map of study area at Land Between the Lakes, Stewart County, Tennessee, with visual survey route and locations of live traps displayed.

Table 1. Trap line number, length in meters (m), and number of traps located on each line for 15 day trapping periods conducted during March, August, and December 1985.

Line Number	Length (m)	Number of Traps
1	125	2
2	325	5
3	325	3
4	95	2
5	170	2
6	280	3
7	235	3
8	225	3
9	175	2
10	390	4
11	300	4
12	280	4
13	300	4
14	150	2
15	400	5
16	130	2

The old field portion of the study area contained 7 linear strips (5.0 m wide) that were mowed once a month for the purpose of this study. The purpose of these strips were: 1) To provide a clear path of travel during the surveys, thus minimizing noise and assuring that the same route of travel was taken on each survey. 2) To allow rabbits an open area to graze increasing the likelihood of observation and allowing rabbits to be viewed at greater distances before they flushed for cover.

If weather and manpower permitted, 4 surveys of each type were conducted per month. If clear and stable weather conditions existed, surveys were conducted on consecutive mornings or nights. Efforts were made to conduct surveys during periods of clear skies and low wind speeds. The survey procedure involved traveling a designated route at approximately 8 km per hour and counting the number of rabbits spotted. Efforts were made to note where rabbits ran when startled to avoid multiple counts on individual rabbits.

In addition to recording the total number of rabbits observed during each survey, numbers of marked, unmarked, and those whose marked status could not be determined also were recorded during survey periods which directly followed the FDTPs. Direction of travel along the survey route was alternated between each survey to avoid missing rabbits that could have avoided detection due to the activity on the area. For most surveys, a 4-wheel drive pickup truck was used to travel the survey route. However, when muddy conditions existed, a Honda[R] 200 TRX Quadwheeler was used. One or 2 persons conducted morning surveys; spotlight surveys required 2 persons. Two 300,000-candle power Q-Beam[R] spotlights powered by a car or deep cell battery were used as described by Smith and Nydegger (1985) for spotlight surveys.

Data Analyses

Statistical tests. Statistical tests determining goodness-of-fit to a 1:1 ratio were conducted for each FDTP on sex ratios using Chi-square (Steel and Torrie 1980). Chi-square tests of association were used to determine if sex ratios were independent of trapping period. Tests of association were performed using the CHI-SQ option of PROC FREQ of The Statistical Analysis System (SAS) (SAS 1982). PROC GLM of SAS was used to conduct t-tests and F-tests (ANOVA) in determining differences in rabbit movements between captures by sex and by FDTPs. F-tests were also used to compare of population estimates between FDTPs and visual surveys methods. All tests were conducted at the 95% level of significance.

Population estimation. Estimates derived using closed population models were obtained from live-trapping and visual survey data. Program CAPTURE (White et al. 1978) was used with live-trapping data while the Petersen-Lincoln Index (Lincoln 1930 in Otis et al. 1978) was used for mark-unmarked ratios obtained during visual surveys.

Program CAPTURE provided population estimates with 95% confidence intervals (CIs) using a series of models based on rabbit capture and recapture frequencies (Otis et al. 1978). Rankings of the most appropriate models were produced for each trapping period. Estimation models which Program CAPTURE provided were: 1) Null model (M_o) which assumed equal catchability; 2) Jackknife model (M_h) which assumed heterogeneity in individual capture probability; 3) Behavioral response model (M_b) which assumed an individual trap response (trap happiness or trap shyness); 4) Time model (M_t) which assumed that capture probability varied due to time; 5) And 4 models which assumed that a combination of these 3 sources of variation were influencing capture probability (M_{bh}, M_{ht}, M_{tb}, M_{tbh}). However, only the model which assumed behavioral response and individual heterogeneity in capture probability (Model M_{bh}) had a working formula available to calculate a population estimate (Otis et al. 1978, White et al. 1982). The top 4 models selected as most appropriate were considered in choosing the most reliable estimate from live-trapping data.

Population estimates were derived from visual surveys using a version of the Petersen-Lincoln model. The estimator, known as Chapman's modification of the Petersen-Lincoln Index (Chapman 1951 in Seber 1982), was

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{m_2} - 1,$$

where $\hat{N}$ = population estimate; n_1 = number of animals in the first sample (rabbits captured and marked in the FDTP prior to the visual survey); n_2 = number of rabbits in the second sample (total number of rabbits observed on the visual survey); m_2 = number of marked rabbits in the second sample (rabbits observed which has been marked in the previous FDTP). Estimates and standard errors of estimates [SE($\hat{N}$)] obtained from individual surveys were averaged to give mean estimates and [SE($\hat{N}$)] for the survey period. Standard errors of estimates were calculated by the formula suggested by Seber (1982):

$$SE(\hat{N}) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} .$$

Ninety-five percent CIs for survey estimates were computed by the method suggested by Otis et al. (1978):

$$\hat{N} \pm 1.96\ [SE(\hat{N})] .$$

If the above procedure produced a lower bound estimate less than the number of rabbits captured during that FDTP then the lower bound estimate was assumes to equal the number of rabbits captured during that FDTP (White et al. 1982). All CIs were at 95% level of confidence.

Mean maximum distance moved between captures. The mean maximum distance moved (MMDM) between captures was calculated by measuring the distance between traps in which rabbits were captured sequentially within a single trap period. Only the maximum distance moved was used for each rabbit. Zero measurements were not used in the calculations. The MMDM figure was used to estimate the amount of area which the trap design was influencing. This area of effect figure was derived by multiplying the MMDM by 0.5 and adding this distance to the outer perimeter of the trapping design (Otis et al. 1978). This boundary strip accounted for the additional area used by rabbits whose home ranges did not entirely lie within the trapping grid (White et al. 1982). This figure, an adjusted area (A), was used for calculation of density.

Density estimation. Density of rabbits per ha was determined by

$$\hat{D} = \frac{\hat{N}}{A},$$

where $\hat{N}$ = population estimate, A = adjusted area of effect, and $\hat{D}$ = estimated density (White et al. 1982).

CHAPTER IV

RESULTS

Trapping

Success rates. Three FDTPs were conducted during 1985. Traps were operated from 8-22 March, 31 July through 14 August, and 10-24 December resulting in 45 nights of trapping and 2250 trapnights (Appendix A). A total of 114 individual rabbits were captured on 241 occasions for an overall trap success of 10.7% (Table 2).

During the March FDTP 40 individuals were captured 59 times for a trap success of 7.9%. During the 31 July through 14 August FDTP (hereafter referred to as August FDTP) 46 rabbits were captured on 64 occasions resulting in a trap success of 8.5%. Of these 46 rabbits, 8 (17.4%) had been captured in the previous March FDTP. Trap success was greatest during December when 66 rabbits were captured on 118 occasions resulting in a trap success of 15.7% (Table 2). Of these 66 rabbits, 12 (18.2%) had been captured during the March FDTP, 10 (15.1%) had been captured during the August FDTP, 7 (10.6%) had been captured during both the March and August FDTP, and 37 (56.1%) were first captured during this December FDTP. Approximately 8 cm of snow fell on the first evening of trapping. The highest 1 night capture (17 rabbits, 34.0% success rate) resulted the morning after this snow.

Table 2. Cottontail rabbit capture results for 15 day trapping periods (FDTPs) conducted from 8 March 1985 through 24 December 1985 at Land Between the Lakes.

FDTP	Rabbits Captured	New Rabbits	Recaptures[a]	Total Captures	% Trap Success
March	40	40	19	59	7.9
August	46	37	18	64	8.5
December	66	37	52	118	15.7
Summary	152	114	89	241	10.7

[a] Number of recaptures within FDTP.

Sex and age ratios. Of the 114 rabbits captured in 3 FDTPs, 46 (40.4%) were male and 68 (59.6%) were female. This ratio was significantly different from an expected 1:1 ratio (df=1, X^2=4.25, P=0.019). The number of male and female rabbits re-entering traps subsequent to being captured in a previous trapping period was equal at 19.

Females out-numbered males 26 to 14, 25 to 21, and 38 to 28 for March, August, and December FDTPs, respectively (Table 3). All 3 ratios were not significantly different from 1:1. No significant association existed between FDTP and number of female and male rabbits captured (Table 3).

Sixteen (34.8%) immature compared to 30 (65.2%) mature rabbits were captured during the August FDTP (Table 3). During the December FDTP no rabbits captured were classified as immature. It is likely that most of the 66 rabbits captured during this FDTP were born the previous spring and summer. However, the 80 mm hind foot criterion indicated all had reached adult size. Test of association revealed age of captured rabbit was dependent on FDTP (df=2, X^2=37.137, P=0.009).

Table 3. Sex and age ratios for cottontail rabbits captured during March, August, and December 1985, 15 day trapping periods (FDTPs) at Land Between the Lakes.

	Sex			Age	
FDTP	Male	Female	X^2-Value[a] (Prob.)	Mature	Immature
March	14	26	3.60 (0.058)	40	0
August	21	25	0.523 (0.445)	30	16
December	28	38	1.515 (0.219)	66	0
Totals	63 46[b]	89 68[b]		136	16
X^2-Value[c] (Prob.)			1.046 (0.593)		

[a] X^2-Value and probability (Prob.) from goodness-of-fit test of expected 1:1 ratio for each FDTP.

[b] Number male or female of the 114 individual rabbits captured during the entire FDTP scheme.

[c] X^2-Value and probability (Prob.) from test of association between FDTP and sex.

Mean maximum distance moved between captures. Sixty rabbits were captured at least twice within a trapping period, resulting in 89 within period recaptures. Forty-one were recaptured in the same trap, leaving 48 recaptures to calculate MMDM between captures. The MMDM was 127.7 m for males, 121.2 m for females and 124.1 m for all rabbits (Table 4). No significant difference was found between male and female MMDM within or among trapping periods (Table 4). The maximum MMDM recorded for a single rabbit was 299.0 m.

Mortality and parasites. Six (5.3%) rabbits were known to have died during or subsequent to being captured. Two captured during the March FDTP died; 1 died during handling and 1 was killed most likely by a gray fox (Urocyon cinereoargenteus) while in a trap. One other rabbit, which was marked with a pelage dye, was reported by a campground attendent to have been killed by a hawk shortly after the March FDTP. Two were known to have died in traps during the August FDTP; both apparently died due to stress. During the December FDTP, 1 rabbit was known to have died and it was found dead in a trap with its hind quarters partially out of the trap apparently predatorized. The area was know to be inhabited by gray fox, red fox (Vulpes fulva), coyotes (Canis latrans), and various raptors.

Table 4. Mean maximum distance moved (MMDM) in meters between captures for rabbits captured within each 15 day trapping period (FDTP) conducted from 8 March 1985 through 24 December 1985 at Land between the Lakes.

	MMDM			t-test Results[a]		
FDTP	Males	Females	Sexes Combined	df	t	P[b]
March	126.5(6)[c]	140.4(8)	134.4(14)	12	0.324	.752
August	120.6(5)	83.0(4)	103.9(9)	7	-1.135	.314
December	129.0(14)	121.2(11)	125.6(25)	23	-4.000	.692
Periods Combined	127.7(25)	121.2(23)	124.1(48)	46	-0.323	.748
F Test Results[d]						
df	2	2	2			
F	0.03	1.41	0.76			
P[b]	.968	.268	.475			

[a] Test results of t-test comparing MMDM between male vs. females.

[b] P = Probability of a larger t or F value.

[c] Sample size in parentheses.

[d] Test results of one-way ANOVA comparing MMDM between the March, August, and December FDTPs for each sex and combined sexes.

Bot fly larvae (<u>Cuterebra cuniculi</u>) were found infesting rabbits only during the August FDTP. Seven (15.2%) rabbits captured during this FDTP had infestations in the neck region of the body.

Tick infestations were observed on most rabbits during all FDTPs. Four species were known to occur on rabbits at LBL. They were (<u>Amblyomma americanum</u>), (<u>Dermacentor variabilis</u>), (<u>Ixodes dentatus</u>), and (<u>Haemaphysalis leporispalustris</u>) (Zimmerman et al. 1988).

Visual Surveys

<u>Morning surveys.</u> Rabbits were readily observed during morning hours. Therefore, morning surveys were initiated on 17 June 1985 and conducted through 1 March 1986. Survey periods consisted of 2 to 4 individual surveys conducted on consecutive days when possible. Survey periods hereafter are referred to by the month during which the majority were conducted. Nine periods yielded 28 separate surveys (Table 5). The highest number of rabbits observed on a single morning survey was 49 in July. The lowest number observed was 0. No rabbits were observed on 7 surveys; this occurred twice during October and November, and once during December, January, and February. The highest mean number of rabbits observed was in July (n=4 surveys, $\bar{x}$=42, sd=5.6) and the lowest was in November (n=3 surveys, $\bar{x}$=0.3, sd=0.6).

Table 5. Number of surveys conducted (n), minimum (Min.), maximum (Max.), mean, and standard error (SE) of number rabbits observed during each period for morning and spotlight surveys conducted 17 June 1985 through 1 March 1986 and 25 March 1985 through 3 March 1986 respectively.

	Morning Surveys[a]					Spotlight Surveys				
Period	n	Min.	Max.	Mean	SE	n	Min.	Max.	Mean	SE
March	-	-	-	-	-	4	16	28	23.5	5.3
April	-	-	-	-	-	4	21	32	27.8	4.7
May	-	-	-	-	-	4	18	30	24.5	5.0
June	4	31	35	32.8	1.7	4	11	13	12.0	1.2
July	4	37	49	42.0	5.6	4	20	25	22.8	2.2
August	4	16	18	16.8	1.0	4	20	33	23.8	6.2
September	3	4	9	6.3	2.5	3	12	18	15.3	3.1
October	4	0	3	1.0	1.4	4	18	28	22.8	4.1
November	3	0	1	0.3	0.6	3	11	28	18.0	8.9
December	2	0	2	1.0	1.4	4	3	12	7.2	4.4
January	2	0	1	0.5	0.7	3	2	9	4.7	3.8
February	2	0	1	0.5	0.7	3	10	12	11.0	1.0

[a] No morning surveys conducted for March, April, and May.

The marked status of rabbits was determined following the August and December FDTPs. The 4 morning surveys conducted after the August FDTP yielded 67 observations of which 15 (22.4%) were marked, 45 (67.2%) were unmarked and 7 (10.4%) were rabbits whose marked status could not be determined (Table 6). The portions of the sample for which marking status was determined were 25.0% marked and 75.0% unmarked.

Two morning surveys were conducted following the December FDTP. No rabbits were observed on the first morning survey and only 2 rabbits, 1 marked and 1 unmarked, were observed on the second survey (Table 6). As few rabbits were observed during December and during morning hours in general, only 2 morning surveys were conducted during each of December, January, and February.

Spotlight surveys. Spotlight surveys were conducted from 3 March 1985 through 25 March 1986. Twelve spotlight survey periods resulted in 44 individual surveys (Table 5).

The maximum number of rabbits observed on a single survey was 33; this occurred during August 1985. The minimum number observed was 2 rabbits during January 1986. April had the highest mean at 27.8 (n=4 surveys, sd=4.7) rabbits. January had the lowest mean at 4.7 (n=3 surveys, sd=3.8) rabbits.

Marked status of rabbits was recorded following March, August, and December FDTPs (Table 7). A total of 94 rabbits

Table 6. Number of rabbits observed during morning surveys conducted subsequent to August and December 1985 15 trapping periods in which rabbits were marked with reflective tags and pelage dyes respectively.

Marked Status	August				December[a]			
	1	2	3	4	1	2	3	4
Marked	3	5	4	3	0	1	-	-
Unmarked	12	9	12	12	0	0	-	-
Undetermined	2	2	0	3	0	1	-	-
Total	17	16	16	18	0	2	-	-

[a] No third and forth morning surveys conducted during the December period.

Table 7. Number of rabbits observed during spotlight surveys conducted subsequent to March, August, and December 1985 15 day trapping periods in which rabbits were marked with reflective tags or pelage dyes.

Marked Status	March				August				December			
	1	2	3	4	1	2	3	4	1	2	3	4
Marked	5	5	7	5	13	9	9	7	1	5	4	1
Unmarked	8	11	18	16	19	11	11	14	2	4	3	3
Undetermined	3	10	3	3	1	1	0	0	0	3	3	0
Total	16	26	28	24	33	21	20	21	3	12	10	4

were observed during 4 spotlight surveys following the March FDTP; 22 (23.4%) were marked, 53 (56.4%) were unmarked and for 19 (20.2%), marked status was undetermined. For rabbits whose marked status could be determined, the marked and unmarked proportion of rabbits observed was 23.0% and 77.0%, respectively. Spotlight surveys conducted after the August FDTP resulted in observation of 95 rabbits with 38 (40.0%) marked, 55 (57.9%) unmarked, and 2 (2.1%) whose marked status was undetermined. Of rabbits whose marked status was determined, 40.9% were marked and 59.1% were unmarked. Spotlight surveys conducted following the December FDTP resulted in 29 rabbits observed with 11 (37.9%) marked, 12 (41.4%) unmarked, and 6 (20.7%) undetermined. Of those distinguishable 55% were marked and 45% were unmarked.

Population and Density Estimates

Estimate based on FDTP marked-recapture data. For each FDTP Program CAPTURE produced at least 4 population estimates (Table 8). Estimates for the March FDTP ranged from 42 to 66 rabbits. The estimate of 42 rabbits was produced by model M_{bh} and was selected as the most appropriate model for these data by Program CAPTURE.

Model M_{bh} indicated that both behavioral and individual heterogeneity responses were influencing the probability of capture. These factors made the process of obtaining a valid estimate by using mark-recapture models difficult.

Table 8. Population estimates ($\hat{N}$) and 95% confidence intervals (CI) for number of rabbits on the 25-ha study area for each 15 day trapping period using Program CAPTURE's closed model estimators.

Estimator[a]	March		August		December	
	$\hat{N}$	CI	$\hat{N}$	CI	$\hat{N}$	CI
Model M_0	66[2]	44 TO 88	85[3]	55 TO 115	86[3]	72 TO 100
Model M_h	64[3]	49 TO 78	108[4]	76 TO 141	119[4]	93 TO 144
Model M_b	44[4]	40 TO 52	52[2]	46 TO 62	70[1]	66 TO 77
Model M_{bh}	42[1]	40 TO 47	52[1]	46 TO 62	66[2]	66 TO 69

[1,2,3,4] = Indicates order of selection by program CAPTURE with 1 being the most appropriate and 4 being the lest appropriate model.

[a] M_0 = Constant capture probability. M_h = Individual heterogeneity influences capture probabilities. M_b = Behavioral response influences capture probabilities. M_{bh} = Behavioral response and individual heterogeneity influences capture probabilities.

This problem was encountered in previous cottontail studies and was managed in a variety of ways (Geis 1955, Huber 1962, Eberhardt et al. 1963, Edwards and Eberhardt 1967, and Bailey 1969). Model M_{bh} was designed to be robust with respect to these factors but developers warned that resulting estimates should always be evaluated with caution when behavioral and heterogeneity have influenced capture probabilities (White et al. 1982).

However, from the 4 estimates produced by Program CAPTURE, selected was what appeared to be the most accurate estimate based on all known information about the population studied. The visual surveys aided in this process. Forty individual rabbits were trapped during this FDTP and 18 unmarked rabbits were observed on spotlight survey number 3 following this FDTP (Table 7). This gave a known total minimum number alive (MNA) of 58 rabbits which was 38.0% greater than the Model M_{bh} estimate selected as most appropriate. Model M_o was selected as the second most appropriate model and produced an estimate of 66 rabbits for the March FDTP data. This model also assumed a constant probability of capture; this was most often not the case considering the complexity of factors influencing cottontail live-trapping (Geis 1955, Huber 1962, Eberhardt et al. 1963, Edwards and Eberhardt 1967, and Bailey 1969). For the purpose of this study, Model M_o was selected as the best estimator for 2 reasons. One was that estimates from models selected as most appropriate appeared to be lower than the actual population; this is based on comparisons with MNA figures. Secondly, by using Model M_o it could be assured that estimates were calculated identically, allowing uniformity in comparing all 3 FDTP estimates. The March estimate of 66 rabbits was used in calculation of density estimates.

August FDTP estimates ranged from 52 to 108 rabbits (Table 8). Model M_{bh} estimated 52 rabbits and again was selected as most appropriate. This estimate also appears low considering that 46 rabbits were captured in this FDTP and an additional 19 unmarked rabbits were observed on spotlight survey number 1 following this FDTP. This MNA resulted in a total of 65 rabbits. The model M_o estimate was 85 rabbits which was probably a conservative estimate considering that juveniles were entering into the population at that time of year. The estimate of 85 rabbits was used in calculation of density for the August FDTP.

The estimates for December FDTP ranged from 66 rabbits for model M_{bh} to 119 rabbits for model M_h (Table 8). Sixty-six rabbits were captured and 4 unmarked rabbits were observed on survey number 2 bringing the total MNA to 70 rabbits. The possibility of no mortality during this period is unlikely. However, the possibility that all rabbits on the area were captured or observed is also unlikely. The model M_o estimate was 86 rabbits and this estimate was used in calculating the density of rabbits during the December FDTP.

A boundary strip of 62.05 m (one-half the overall MMDM of 124.1 m) was added to the grid perimeter. This area (11.35-ha) was added to the grid area (24.69-ha) to derive the total area affected by the trapping scheme. The adjusted area, 36.04 ha, was used in calculating rabbit density during all 3 FDTPs due to no differences being found in MMDM among FDTPs. Calculated densities for March, August, and December FDTPs were 1.83, 2.36, and 2.39 rabbits per ha, respectively (Table 9).

<u>Estimates based on visual surveys.</u> Population estimates were derived using Chapmans's (1951) modified Petersen-Lincoln Index on mark-unmarked ratios obtained from visual surveys. August was the only morning survey period which sufficient mark-unmarked data were collected to calculate estimates. Estimates ranged from 118 to 188 rabbits. The mean of the 4 estimates was 164 rabbits and the CI ranged 52 to 324 rabbits (Table 10). Density was estimated at 4.55 rabbits per ha with a CIs ranging from 1.44 to 9.00 rabbits per ha (Table 9).

Spotlight survey data were sufficient to calculate estimates for March, August, and December periods. March estimates ranged from 95 to 149 rabbits and the CIs ranged from 45 to 237 rabbits (Table 11). Density was estimated at

Table 9. Density estimates ($\hat{D}$) and 95% confidence intervals (CI) for number of rabbits per ha based on 15 day trapping period (FDTP) data using, Program CAPTURE, and morning and spotlight survey ratios data using the Petersen-Lincoln Index.

FDTP	$\hat{D}$ Model M_o	CI	$\hat{D}$ Morning	CI	$\hat{D}$ Spotlight	CI
March	1.83	1.22 - 2.44	[a]	[a]	3.41	1.59 - 5.24
August	2.36	1.53 - 3.19	4.55	1.49 - 7.58	3.33	1.94 - 4.69
December	2.39	2.00 - 2.77	[a]	[a]	3.61	2.11 - 5.38

[a] No density estimates possible from the March or December morning survey data.

Table 10. Estimated number of rabbits ($\hat{N}$) and 95% confidence intervals (CI) on the 25-ha study area. Estimates derived using the Petersen-Lincoln Index with marked-unmarked ratios observed during morning surveys subsequent to the August 15 day trapping period. Four survey estimates averaged to give mean $\hat{N}$ for period.

Survey Period/ Number	$\hat{N}$	CI
August/		
1	188	52 to 324
2	118	55 to 181
3	160	58 to 262
4	188	52 to 324
Mean	164	54 to 273

Table 11. Estimated number of rabbits ($\hat{N}$), standard error (SE), and 95% confidence intervals (CI) on the 25-ha study area. Estimates derived using the Petersen-Lincoln Index with marked-unmarked ratios observed during spotlight surveys subsequent to the March, August, and December 15 day trapping period. Four survey estimates averaged to give mean $\hat{N}$ for period.

Survey Period/ Number	$\hat{N}$ (SE)	CI
March/		
1	95 (25.3)	45 to 145
2	115 (30.6)	55 to 175
3	133 (33.2)	68 to 198
4	149 (44.8)	61 to 237
Mean	123 (33.5)	57 to 189
August/		
1	110 (18.9)	74 to 146
2	121 (25.6)	70 to 171
3	121 (25.6)	70 to 171
4	128 (31.3)	67 to 189
Mean	120 (25.4)	70 to 169
December/		
1	134 (53.9)	66 to 240
2	112 (25.5)	66 to 162
3	107 (13.2)	81 to 133
4	168 (40.0)	93 to 242
Mean	130 (32.2)	76 to 194

3.41 rabbits per ha with a CI ranging from 1.25 to 6.58 rabbits per ha (Table 9).

August spotlight estimates ranged from 110 to 128 rabbits with a mean of 120 rabbits and a CIs which ranged from 70 to 189 rabbits (Table 11). This translated to a density estimate of 3.33 rabbits per ha with a CI ranging from 1.86 to 5.25 rabbits per ha (Table 9).

December spotlight estimates ranged from 107 to 168 rabbits with a mean estimate of 130 rabbits and a CI range of 66 to 242 rabbits (Table 11). Density was estimated at 3.61 rabbits per ha with CIs ranging from 1.83 to 6.72 rabbits per ha (Table 9). No significant difference was found between mean estimates for the 3 spotlight survey periods (df=2, F=0.38, P=0.696). Comparison between spotlight and morning survey estimates for August revealed no significant differences (df=3.3, T=2.56, P=0.077).

CHAPTER V

DISCUSSION

Evaluation of Visual Surveys as a Measure of Abundance.

Morning surveys. Morning survey means were highest during June and July but declined dramatically during fall and winter months (Figure 6). This decline was most likely a factor of changing activity patterns of rabbits rather than a dramatic drop in the population level. Difficulty in observing rabbits during the late fall and winter months was expected due to decreased availability and palatability of foods which rabbits typically graze during summer (Allen 1938, Haugen 1943, Anderson and Pelton 1976). Additionally, decreased cover and the shifting of rabbits to winter cover would explain lower numbers observed during fall and winter morning survey periods.

Reasons for low means observed during August and September are difficult to determine from these data. June and July appeared to be the months during which rabbits were most observable during morning surveys. Rabbits were found to be most active during daytime hours during spring months in Michigan (Allen 1939). This could have been the case in the present study and may have been detected if morning surveys could have been conducted during March, April and May 1985.

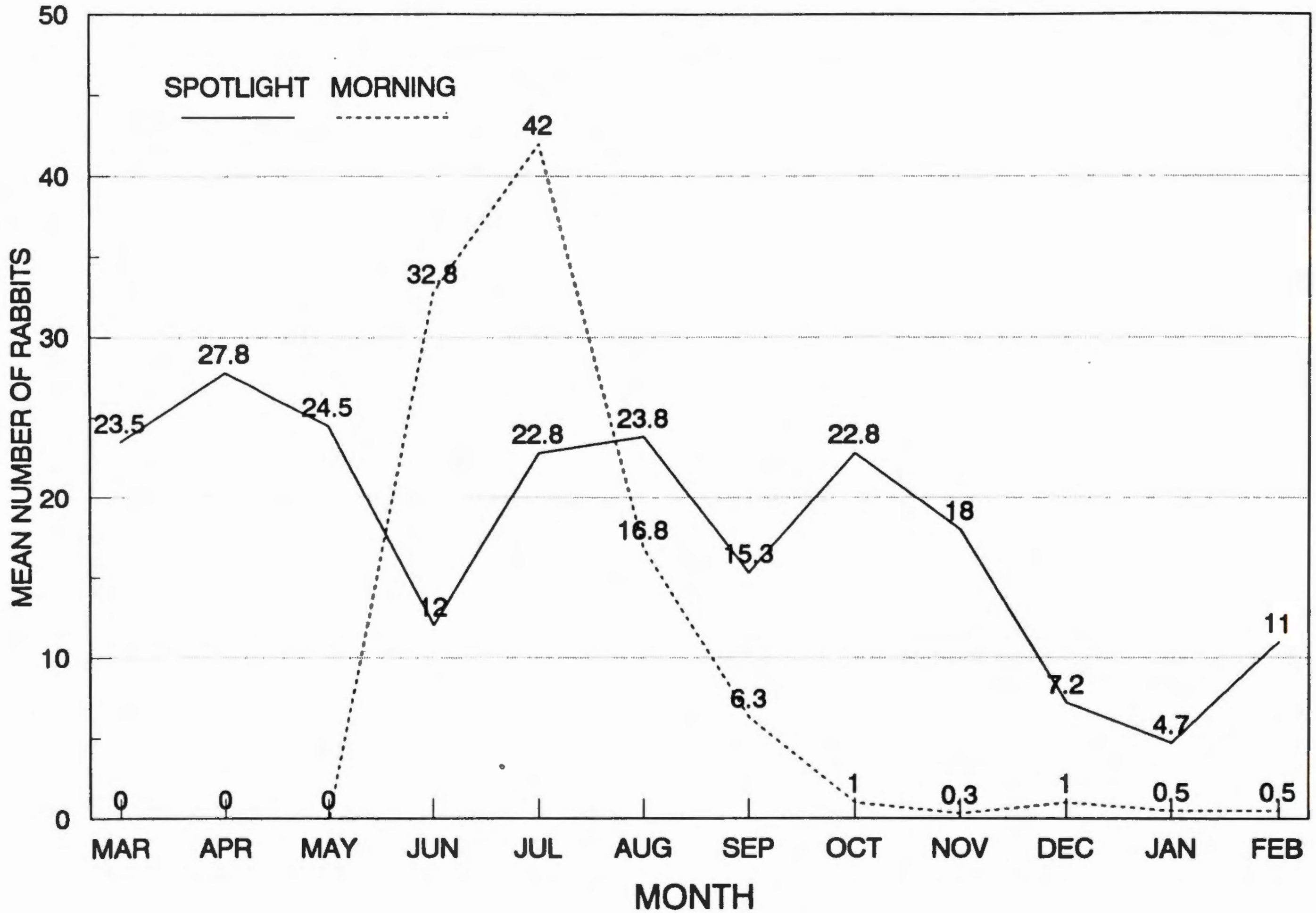

Figure 6. Mean numbers of rabbits observed during morning and spotlight survey conducted monthly from 25 March 1985 through 3 March 1986 at Land Between the Lakes.

Rabbits tended to move from open areas into cover more readily during morning surveys than during spotlight surveys. The mowed areas around camp pads and mowed strips in adjacent areas proved to be an asset in observing rabbits during both morning and spotlight surveys.

Spotlight surveys. Spotlight survey means did not decline during fall as dramatically as did morning survey means (Figure 6). September, October, and November means remained > 15 rabbits, indicating that rabbits remained observable later into fall during evening hours as compared to morning surveys. March through November all had relatively high means, with the exception of June, making it difficult to determine the best month for observing the maximum number of rabbits. However, October maybe be best suited for conducting a yearly census considering observations were high during that period and that reproduction has ceased at that point.

Evaluation of Density Estimates.

Estimates based on FDTP mark-recapture data. Comparisons of Program CAPTURE estimates and MNA values indicated that Program CAPTURE gave low estimates in this study. Causes appear to be low probability of capture ($\hat{p}$), presence of trap heterogeneity, and trapping design.

Program CAPTURE estimates have shown negative bias in other studies. Performance of Program CAPTURE estimators in the present study was similar to that for a bobwhite quail population which was live-trapped at Tall Timbers Research Station in Florida (O'Brien et al. 1985). A second determination of the proportion of marked quail in the population was made by shooting (O'Brien et al. 1985). These ratios were applied to Chapman's (1951) version of the Petersen-Lincoln model and were compared to CAPTURE estimates from live-trapping. As with the present study, all CAPTURE estimates were less than those derived by using ratios obtained from a second method using the Petersen-Lincoln model. Under-estimation was attributed to low $\hat{p}$ and individual capture heterogeneity (O'Brien et al. 1985). Both of these factors were encountered in the present study.

Program CAPTURE also resulted in low estimates when used with live-trapping data obtained from a striped skunk (<u>Mephitis mephitis</u>) population of known size in North Dakota (Greenwood et al. 1985). Negative biases were attributed to a $\hat{p} < 0.30$ and the use of only a minimum number of trapping occasions (Greenwood et al. 1985).

Low $\hat{p}$ had a similar effect on CAPTURE estimates in the LBL rabbit population. The average $\hat{p}$ for March, August, and December FDTPs was 0.06, 0.05, and 0.09, respectively. The conservative estimates produced by Program CAPTURE were not unexpected considering that developers of the program recommended a $\hat{p}$ of no less than 0.30 and a rectangular trapping grid with at least 144 traps for the program to perform to its full potential (White et al. 1982). These conditions were not attainable in this study.

Estimates based on visual surveys data. Density estimates derived from marked-unmarked ratios observed during spotlight surveys were 85.8%, 39.8%, and 51.2% higher than CAPTURE estimates for March, August, and December, respectively (Figure 7). An advantage of the visual survey method was being able to obtain marked-unmarked ratios not subject to live-trapping bias. The first sample, the FDTPs, allowed for a large number of trappable rabbits to be marked. The second sample, visual surveys, allowed a random sample of trapped and untrapped rabbits to be observed and recorded. It was an assumption that the second sample was representative of the true proportion of marked rabbits in the population but there was no means of testing this assumption.

Marked-unmarked ratios from visual surveys enhanced efforts to estimate the population size in this study. Use of a second independent sample has aided population estimation efforts in earlier studies as well. Shooting subsequent to live-trapping was used by Allen (1938) to determine the proportion of rabbits which had been marked. This second sample was applied to Lincoln's model (Lincoln 1930 in Otis et al. 1978) to provide a population estimate

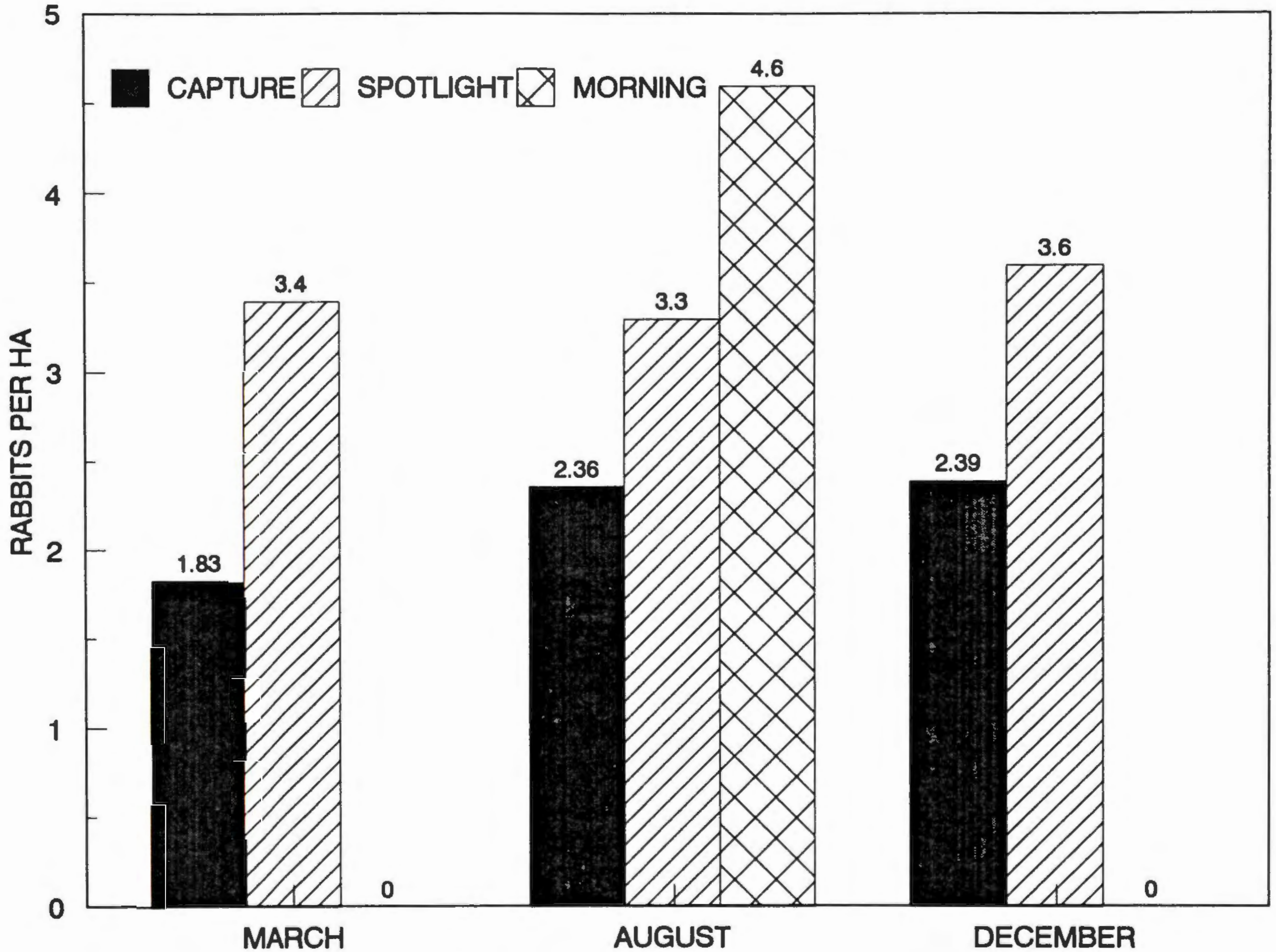

Figure 7. Density estimates of rabbits from Program CAPTURE, using live-trapping data, and from marked-unmarked ratios derived from morning and spotlight surveys using Petersen-Lincoln Index.

from the marked-unmarked ratios free of the biases of live-trapping cottontails. Allen sugested that this method provided a more reliable estimate than 1 obtained using live-trapping data only.

A cottontail study at Kellogg Station, Battle Creek, Michigan, revealed that using a second sampling method to determine the marked-unmarked ratio yielded a more accurate population estimate than using live-trapping data alone (Geis 1955). As mentioned previously, a similar conclusion was reported by O'Brien et al. (1985) for bobwhite quail.

In this study visual surveys served a dual benefit. The MNA figure obtained from observing unmarked rabbits during surveys indicated that Program CAPTURE estimates were low. As with the O'Brien et al. (1985) study, estimates derived from marked-unmarked ratios obtained through visual surveys were more reliable than those based solely on live-trapping data. An under-estimation of rabbit density on this study area would have occurred without the aid of visual surveys.

It was unfortunate that estimates could not be derived for the March and December morning survey periods. The difference between the August morning and spotlight survey estimates was 44 rabbits (164 vs. 120). It was interesting that these 2 estimates were not closer considering that both estimates were obtained from the same population with the same proportion of rabbits marked. Forty-one percent of rabbit observed by spotlight were marked contrasted to only

25.0% during morning surveys. One possible explanation for this is that rabbits that move the most during evening hours are also most likely to encounter traps and be observed at night. It is also possible that the reflective tape used during the August survey period could have been less detectable on rabbits during morning hours. In some cases the gray colored reflective tags were difficult to detect. However, it is unlikely that detectability of marks could have accounted for all discrepancy between the spotlight and morning surveys.

Conducting visual surveys when larger numbers of rabbits can be observed should provide sufficient data for estimation models to produce reliable population estimates. Morning surveys in July yielded the greatest number of observed rabbits but trapping success was typically low at this time, requiring more effort to mark a sufficient number of rabbits by live-trapping. If maximum results were to be obtained using morning surveys, then trapping efforts must be intensified or some alternative means of capturing and marking rabbits must be employed.

The seasonal time frame for observing rabbits using spotlight surveys appears to be more flexible. Rabbits remain observable throughout the fall and trapping success tends to improve at this time as well. Autumn appears to be the time when a maximum number of rabbits can be marked by live-trapping and then observed during spotlight surveys.

In the present study, visual surveys aided in determining rabbit densities for Piney Campground at LBL. One factor which was crucial to successful implementation of this method was having an area which allowed rabbits to be observed in a uniform manner over the entire study area. The mowed campground area and, most importantly, the mowed strips outside the campground area, allowed rabbits to be observed that otherwise might not have been detectable. The mowed strips seemed to provide areas which rabbits would graze during evening hours.

Another factor imperative to success with this method was the visibility of marks. Pelage dye marks, which were retained up to 5 months, were used during March and December FDTPs. The picric acid marks were sometimes difficult to detect during spotlight surveys at distances > 50 m, but marks of rhodamine B were detectable at distances > 50 m during both types of surveys. The reflective tape appeared highly visible during spotlight surveys and this method of marking was superior over pelage dyes for determining marked status using spotlight surveys. This is supported by the percentage of undetermined marks with each method. The percentages of rabbits which marks were undetermined for March and December spotlight surveys was 20.4% and 20.7%, respectively. The percentage of undetermined marks for the August spotlight surveys, when reflective tape was used, was only 2.1%.

CHAPTER V

SUMMARY AND CONCLUSION

1. A study to determine the population level of cottontail rabbits and evaluate the use of visual surveys in estimating cottontail numbers was conducted on a 25-ha area at Land Between the Lakes, Stewart County, Tennessee from 8 March 1985 through 3 March 1986.

2. Rabbits were live-trapped for 15 consecutive days during March, August, and December 1985 resulting in 45 nights of trapping, 2250 trap nights, and a trap success of 10.7%. A total of 114 rabbits were captured on 241 occasions.

3. Sex ratios favored female rabbits during each 3 FDTP but did not differ significantly from 1:1. Of the 114 rabbits captured in all FDTPs, 68 were female and 46 were male. This overall ratio was significantly different from 1:1.

4. A hind foot length of < 80 mm was used as the criterion for classifying rabbits as immature. Sixteen rabbits were classified as immature during the August FDTP. No rabbits were classified as immature during the March or December FDTPs.

5. Live-trapped rabbits were marked with pelage dyes or reflective ear tags. Marked-unmarked ratios were recorded on visual surveys which followed the 3 FDTPs. Visual surveys were conducted for 12 consecutive months 1 to 2 hours after sunrise (morning surveys) and about 1 hour after sunset (spotlight surveys) along a designated 6.6 km route throughout the study area. Two 300,000 candle power lights were used to aid in locating rabbits during spotlight surve0ys. Twenty-eight morning surveys and 44 spotlight surveys were conducted from 17 June 1985 through 1 March 1986 and 25 March 1985 through 3 March 1986.

6. Mark-recapture data from live-trapping were used with Program CAPTURE (White et al. 1978) to provide closed population estimates.

7. Marked-unmarked ratios obtained from visual surveys were used to compute population estimates under Chapman's (1951 in Seber 1982) modified version of the Petersen-Lincoln estimator.

8. Recapture locations were used to obtain a MMDM between captures of 124.1 m. MMDM was added to the trapping grid perimeter for calculating total area of effect. The adjusted area of 36.04-ha was used in calculating true density estimates from Program CAPTURE and visual survey Petersen-Lincoln population estimates.

9. Program CAPTURE model M_0 estimates of 66, 85, and 86 rabbits for March, August, and December FDTPs, respectively,

were accepted as best estimates of population size that could be obtained from the live-trapping data alone. These estimates were judged to be lower than the actual population level based on MNA figures derived using number of rabbits captured during FDTPs and number of unmarked rabbits observed during subsequent visual surveys. Negative biases in these estimates were attributed to low probability of capture, individual heterogeneity in capture probability, and trapping design.

10. Marked-unmarked ratios from morning surveys were obtained following August and December FDTPs. An average of 35.4% of rabbits observed were marked during the August survey period. One marked rabbit was observed during the December survey period. Spotlight surveys revealed that during March, August, and December periods, an average of 23.0%, 40.0%, and 55.0% of observed rabbits were marked respectively.

11. Morning survey ratios resulted in a population estimate of 164 rabbits for the August period. Population estimates from spotlight surveys were 123, 120, and 130 rabbits for March, August, and December periods, respectively.

12. Spotlight survey estimates were selected as the most reliable estimates and used in calculation of density. Density levels were estimated at 3.4, 3.3, and 3.6 rabbits per ha for March, August, and December, respectively.

13. Rabbits were most observable during morning surveys in June and July periods but observability decreased dramatically during fall and winter periods, probably due to shifts in habitat use caused by decreased cover and food.

14. Rabbits were observed during all spotlight survey periods. Highest means occurred in March, April, and May, and lowest means occurred during December and January periods. In late fall and winter, rabbits were observed more during spotlight surveys than during morning surveys.

15. Use of spotlight surveys after FDTPs enhanced density estimation efforts in 2 ways: 1) Spotlight surveys provided independent samples of marked-unmarked ratios which were not biased by unequal capture probabilities of live-trapping. These ratios applied to Petersen-Lincoln Index produced estimates that appeared to be the most reliable. An under-estimation of density most likely would have occurred without the aid of visual surveys. 2) MNA figures, obtained from spotlight surveys, were compared to population estimates to evaluate the validity of mark-recapture estimates. Comparisons of MNA figures and Program CAPTURE estimates revealed that Program CAPTURE under-estimated the population size and that Petersen-Lincoln estimates from spotlight survey ratios were probably closer to the actual population size.

16. Pelage dye marks were recognized more easily during morning surveys than during spotlight surveys. Marks of rhodamine B were detected easier than picric acid marks, especially at distances > 50 m during spotlight surveys. Pelage dyes are recommended for visual surveys conducted during daylight.

17. Reflective ear tags of red or gray color allowed for easy detection of marked rabbits at distances > 50 m during spotlight surveys. Reflective ear tags offer a potential for detecting marked rabbits which may not have been detected if rabbits are in thick cover. Reflective tags were sometimes visible before the rabbit could be observed.

18. Reflective ear tags of light gray color were at times difficult to see during morning surveys. It is recommended that a dark or brighter color ear tag be used if surveys are also to be conducted during daylight hours.

19. Rabbit observability was enhanced by the presence of mowed strips 5.0 m wide and mowed camp pads on the study area. Visual surveys usefulness may be limited in locations which have few open areas to allow rabbits to be observed.

20. Use of the spotlight survey method for obtaining marked-unmarked ratios may be preferred over the morning survey. Rabbits were most easily observed during summer months using morning surveys. However, trapping success during summer is generally low and marking a sufficient numbers of rabbits to obtain valid estimates with mark-

recapture models requires more manpower and expense at this time of year. Spotlight surveys revealed rabbits were observable through the fall months. Trapping success is typically higher during fall when reproduction has ceased. The above indicates that fall, possibly October, may be the best time of year for conducting spotlight surveys subsequent to live-trapping.

PART 2: COMPARISON OF OPEN AND CLOSED MODEL DENSITY ESTIMATES OF RABBITS

CHAPTER I

INTRODUCTION

As part of a research project designed to test the effectiveness of ITM practices at LBL, rabbits were live-trapped at Piney Campground for the purpose of collecting ticks (Zimmerman 1986). This trapping was conducted independent of the FDTPs with the primary concern being assessment of tick infestation rates on rabbits. Another objective was to obtain population estimates from this live-trapping scheme. These data were relevant to this thesis in providing a comparison of estimates obtained using both open and closed mark-recapture population models on the same data. Comparing these estimates provided information on advantages and disadvantages of each type of population model under these conditions.

CHAPTER II

MATERIALS AND METHODS

Field Data Collection

Trapping procedure. The trapping scheme was designed to catch a maximum number of rabbits with a minimum amount of effort. Trap design, placement of traps, and the length of trapping periods were limited to addressing needs of the USDA/TVA tick study. Fifty box traps were positioned on a 16-ha area located within the 25-ha FDTP study area (Figure 8). This resulted in a density of 3.1 traps per ha. Traps were operated at approximately 4-week intervals for periods ranging for 3 to 8 days. These trapping periods were referred to as monthly trapping periods (MTPs).

Traps were selectively placed in runways and entrances to brush piles or large blocks of cover or any other location which might result in a capture. Traps were baited with apple. Upon capture, rabbits were anesthetized using intramuscular injections of 1:1 mixtures of ketamine HCl and acepromazine malelate. Anesthetizing rabbits allowed them to be examined for ticks. Results of ticks found on rabbits captured during MTPs were presented in Zimmerman et al. (1988). Criteria for determining sex and age of rabbits were the same as used in FDTPs. Rabbits were ear tagged with numbered Monel metal tags (No. 1005, size 3).

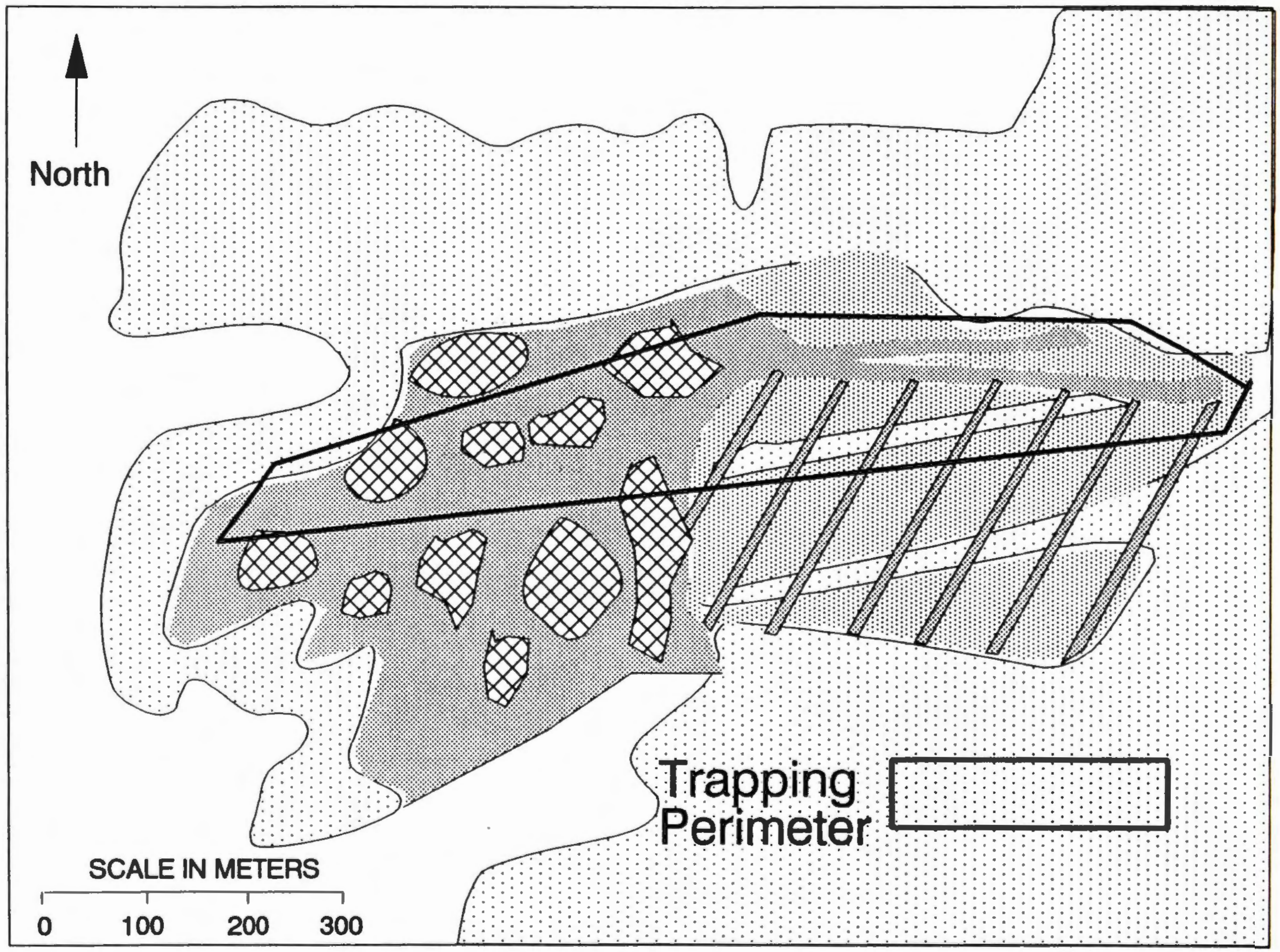

Figure 8. Map of study area located at Land Between the Lakes, Stewart County, Tennessee with 16-ha trapping perimeter which 50 box traps were used from 30 July 1984 through 3 July 1986.

Mean maximum distance moved for MTPs. Mean maximum distance moved between captures for MTPs were calculated identical to that described for the FDTPs.

Minimum number alive values. A MNA value was calculated from MTP data for comparison with population estimates. The MNA values were calculated by including the number of rabbits captured during a MTP plus the number of rabbits that were captured during any preceding MTP and during any following MTP (Lefebvre et al. 1982).

Data Analyses

Statistical tests. Tests for goodness-of-fit to an expected 1:1 ratio for sex ratios, tests of association between MTP and sex and age, t-tests for comparisons of MMDM between sex, and ANOVA tests for differences between population estimates and MNA values were conducted in the same manner as those for FDTP data. All tests were conducted at the 95% level of significance.

Closed population model estimates. Population estimation procedures used for MTP mark-recapture data were identical to those used for FDTPs mark-recapture data.

Open population model estimates. Mark-recapture data were analyzed as an open population using a data pooling approach described by Pollock (1982). Each MTP was treated as if it were a single trapping occasion. A rabbit captured during a MTP was parallel to a single capture. The series of MTPs were treated as 1 long term mark-recapture study with birth, death, immigration, and emigration operating in the population. In addition to providing a second set of estimates, pooling the data in this manner increases robustness of population estimators to trapping heterogeneity and trap response among animals (Pollock 1982) as well as the precision of estimates (Nichols and Pollock 1983).

Population estimates were calculated from MTP data using the open population Jolly-Seber (J-S) model estimator (Seber 1982) provided by Program JOLLY (Hines 1985). Program JOLLY, a computer program designed to estimate survival rate, population size, standard error of population estimate, and immigration rate from mark-recapture data bases estimates on models developed by Jolly (1965). J-S model estimates parameters based on number of animals marked before the trapping period and after the trapping period during which estimates are made. Therefore, no J-S estimates were derived for the first and last trapping periods (Pollock 1982). The standard errors of estimates, calculated by Program JOLLY, were used to compute CIs by the same method used for FDTP data.

Density estimates. Density estimates derived from MTP population estimates using Program CAPTURE and JOLLY were calculated identically to those describe for FDTP density estimates.

CHAPTER III

RESULTS AND DISCUSSION

Trapping

Success rates. From 30 July 1984 through 3 July 1986, 22 MTPs were conducted; 14 were 3 days in length, 7 were 4 days in length, and 1 was 8 days in length. Traps were operated for a total of 78 nights resulting in 3900 trap nights. A total of 157 individual rabbits were captured on 313 occasions for an overall trap success of 8.0% (Table 12, Appendix B). The highest success rate occurred during the 4-6 December 1985 MTP when 24 rabbits were captured. The 11-13 February 1986 MTP was the least successful with 4 captures.

Sex and age ratios. Males (n=71) comprised 45.2% and females (n=86) comprised 54.8% of rabbits captured (Table 13). This ratio did not differ significantly from an expected 1:1 ratio (df=1, X^2=0.7166, P=0.201). No association was found between MTP and sex of rabbits captured (df=21, X^2=215.2, P=0.796).

At capture 208 (74.3%) rabbits were classified as mature and 72 (25.7%) as immature. Eighty-four (54.9%) mature and 69 (45.1%) immature rabbits were captured during the 12 MTPs when immature rabbits would have been distinguishable.

Table 12. Cottontail rabbit capture results for monthly trapping periods conducted 30 July 1984 through 3 July 1986 at Land Between the Lakes.

Trapping Period	Trapping Occasions	Rabbits Captured	New Rabbits	Total Captures	% Trap Success
Jul 30-Aug 02	4	9	9	9	4.5
Aug 22-Aug 24	3	22	21	24	16.0
Sep 19-Sep 21	3	21	11	24	16.0
Oct 17-Oct 19	3	11	8	11	7.3
Nov 28-Nov 30	3	22	11	24	16.0
Feb 21-Feb 28	8	17	6	22	5.5
Apr 02-Apr 05	4	7	2	7	3.5
Apr 30-May 03	4	12	8	13	6.5
May 29-May 31	3	12	9	12	8.0
Jun 25-Jun 28	4	13	8	14	7.0
Jul 23-Jul 26	4	10	3	13	6.5
Aug 27-Aug 29	3	15	6	16	10.7
Sep 19-Sep 21	3	14	7	15	10.0
Oct 15-Oct 17	3	13	6	15	10.0
Nov 13-Nov 15	3	14	5	20	14.0
Dec 04-Dec 06	3	24	14	27	18.7
Feb 11-Feb 13	3	4	0	4	2.7
Mar 10-Mar 13	4	9	3	10	5.0
Apr 08-Apr 10	3	6	0	6	4.0
May 05-May 08	4	5	5	6	3.0
Jun 10-Jun 12	3	14	11	14	9.3
Jul 01-Jul 03	3	6	4	6	4.0
Summary	78	280	157	312	8.0

Table 13. Sex and age ratios for cottontail rabbits captured during monthly trapping periods conducted from 3 July 1984 through 1 July 1986 at Land Between the Lakes.

Trapping Period	Males	Females	Matures	Immatures
Jul 30-Aug 02	3	6	4	5
Aug 22-Aug 24	10	12	12	10
Sep 19-Sep 21	12	9	16	5
Oct 17-Oct 19	4	7	10	1
Nov 28-Nov 30	7	15	22	0
Feb 21-Feb 28	5	12	17	0
Apr 02-Apr 05	1	6	7	0
Apr 30-May 03	4	8	7	5
May 29-May 31	3	9	7	5
Jun 25-Jun 28	4	9	4	9
Jul 23-Jul 26	3	7	7	3
Aug 27-Aug 29	6	9	14	1
Sep 19-Sep 21	6	8	10	4
Oct 15-Oct 17	7	6	12	1
Nov 13-Nov 15	8	6	14	0
Dec 04-Dec 06	10	14	23	1
Feb 11-Feb 13	2	2	4	0
Mar 10-Mar 13	4	5	9	0
Apr 08-Apr 10	3	3	6	0
May 05-May 08	0	5	2	3
Jun 10-Jun 12	5	9	1	13
Jul 01-Jul 03	2	4	0	6
Summary	109 71[a]	171 86[a]	208	72

[a] Number of male or female of 157 individual rabbits captured during entire MTP scheme.

Mean maximum distance moved between captures. Movements within MTPs were difficult to detect due to the short length of trapping periods. Eighteen rabbits were recaptured in different traps resulting in a MMDM of 96.1 m. A significant difference was found between MMDM for male ($\bar{x}$=51.6 m, n=5) and female ($\bar{x}$=113.2 m, n=13) rabbits (t=2.966, P=0.009). The maximum distance moved for an individual rabbit was 243.0 m.

Population and Density Estimates

Closed population estimates with Program CAPTURE. Population estimates were calculated for all but 1 of the MTPs. During this 11-13 February 1985 MTP, only 4 rabbits were captured (Table 12). There were 7 other MTPs during which no rabbits were recaptured leaving 14 MTPs in which sufficient data allowed for the model selection process by Program CAPTURE. Models M_o and M_{bh} estimators were selected as most appropriate for 5 MTPs each. Model M_{tbh} was selected for 2 MTPs but no working estimator exists for this model so the second choice of Model M_{bh} was used for these 2 MTPs. Models M_h and M_{th} were each selected for 1 MTP.

The MTP data using Program CAPTURE appeared to yield conservative estimates. The highest estimate was 41 rabbits and the lowest estimate was 5 rabbits (Table 14). The mean of all MTP estimates was 18 rabbits (n=21, SE=10.2) and the CIs ranged from 5 to 65. Ten of the estimates were equal to

Table 14. Population estimates ($\hat{N}$) and 95% confidence intervals (CI) for number of rabbits on the 16-ha study area for each monthly trapping period using Program CAPTURE's closed model estimators and Program Jolly's open population estimator.

Trapping Period	CAPTURE*		JOLLY	
	$\hat{N}$**	CI	$\hat{N}$	CI
Jul 30-Aug 02	15 ^{Mb}	9 - 40	-	-
Aug 22-Aug 24***	41 ^{Mh}	29 - 54	68	22 - 319
Sep 19-Sep 21	21 ^{Mbh}	24 - 32	44	21 - 69
Oct 17-Oct 19	11 ^{Mb}	11 - 15	76	11 - 182
Nov 28-Nov 30	25 ^{Mbh}	22 - 32	53	23 - 84
Feb 21-Feb 28	38 ^{Mh}	21 - 55	40	17 - 65
Apr 02-Apr 05	7 ^{Mb}	7 - 10	23	7 - 38
Apr 30-May 03***	28 ^{Mh}	15 - 40	53	12 - 109
May 29-May 31	12 ^{Mb}	12 - 15	103	12 - 293
Jun 25-Jun 28	13 ^{Mbh}	13 - 17	96	13 - 197
Jul 23-Jul 26***	15 ^{Mh}	10 - 22	46	10 - 76
Aug 27-Aug 29	16 ^{Mbh}	16 - 22	66	15 - 117
Sep 19-Sep 21	16 ^{Mbh}	14 - 23	59	14 - 104
Oct 15-Oct 17	13 ^{Mbh}	13 - 16	58	13 - 105
Nov 13-Nov 15***	14 ^{Mbh}	14 - 17	46	14 - 78
Dec 04-Dec 06***	31 ^{Mbh}	24 - 37	71	24 - 137
Feb 11-Feb 13	-	-	17	4 - 36
Mar 10-Mar 13	20 ^{Mh}	9 - 31	23	9 - 48
Apr 08-Apr 10	6 ^{Mb}	6 - 8	12	5 - 63
May 05-May 08	5 ^{Mbh}	5 - 6	12	5 - 28
Jun 10-Jun 12	25 ^{Mb}	14 - 65	14	14 - 65
Jul 01-Jul 03	6 ^{Mb}	6 - 7	-	-
Mean	18		49	

* Program CAPTURE estimates with model selected as most appropriate indicated.

** M_0 = Constant capture probability. M_h = Individual heterogeneity influences capture probabilities. M_b = Behavioral response influences capture probabilities. M_{bh} = Behavioral response and individual heterogeneity influences capture probabilities.

*** Indicates Model M_0 was selected as most appropriate but Model selected as second most appropriate was used.

the number of rabbits captured in the corresponding MTP. Thirteen MTPs had estimates less than the MNA value for the corresponding MTP and there was no significant differences between the CAPTURE estimates and the MNA values (F=0.09, P=0.349) (Figure 9).

A combination of factors probably contributed to these low MTP CAPTURE estimates. One was the short length of trapping periods ($\bar{x}$=3.6 days). Trapping periods of this length typically do not allow a sufficient number of animals to be captured unless $\hat{p}$ is > 0.30 for animals in the population (White et al. 1982). The mean $\hat{p}$ for MTPs was 0.12 (n=14, SE=0.082) (Table 15). The combined effect of trapping period length and low $\hat{p}$ reduced the likelihood of obtaining reliable estimates from these data. Additionally, a larger number of traps operated in a rectanglar design, such as recommended by (White et al. 1982), would have allowed more reliable estimates under Program CAPTURE.

Open population estimates with Program JOLLY. The highest estimate using the J-S open model population estimators was 103 rabbits; this was calculated for the 29-31 May 1985 MTP (Table 14). The corresponding CI ranged from 12 rabbits, the actual number caught during that period, to 293 rabbits. The lowest estimate was 12 rabbits calculated for the 8-10 April and 5-8 May 1986 MTPs. The CIs for both of these period was 5 to 28 rabbits. The highest upper limit was 319 rabbits for the 22-24 August 1984 MTP and the lowest

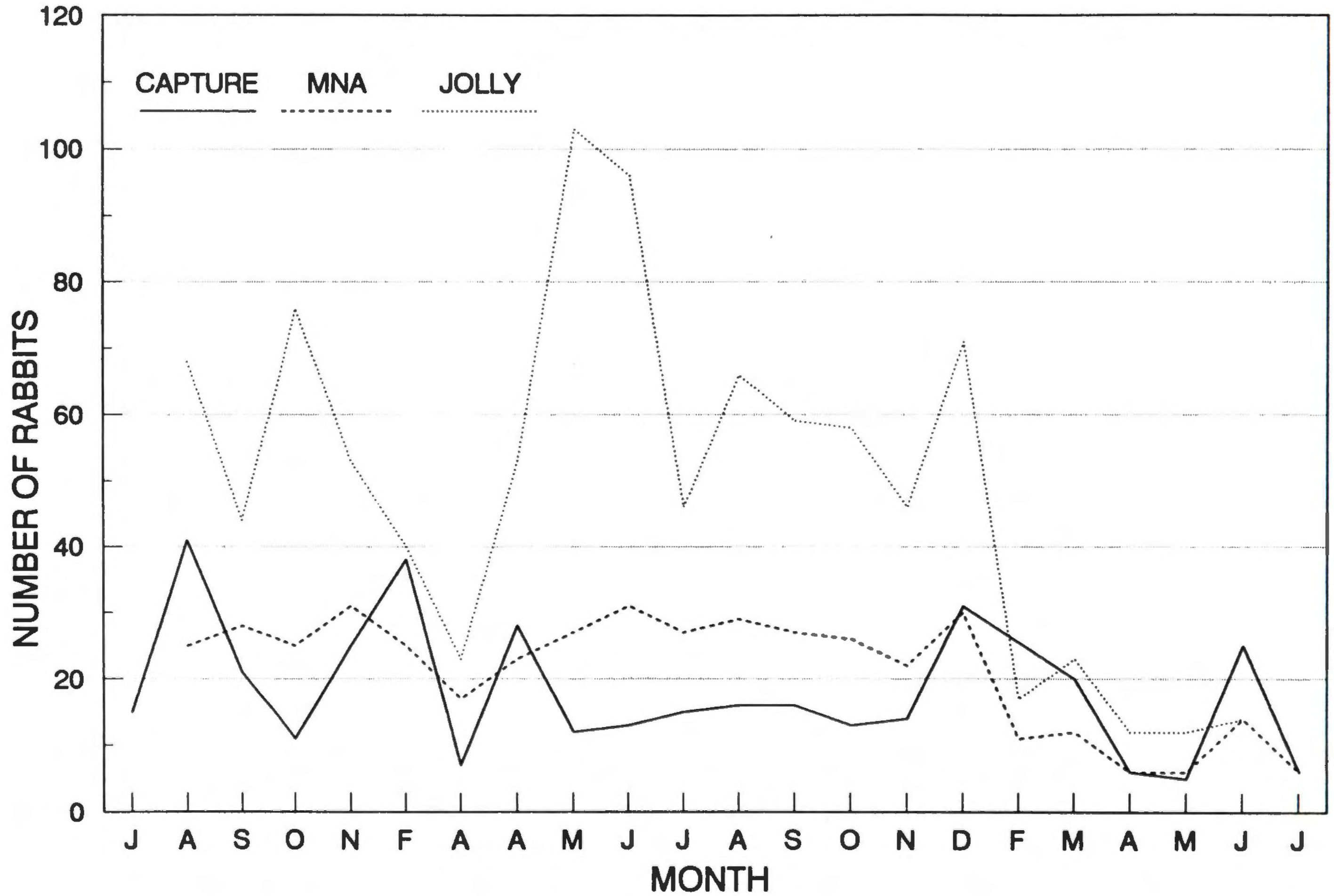

Figure 9. Comparisons of population estimates for number of rabbits on the 16-ha trapping area at Land Between the Lakes, using Program CAPTURE, Program JOLLY, and minimum number alive values from monthly trapping period mark-recapture data.

Table 15. Estimated average probability of capture ($\hat{p}$) of cottontail rabbits computed by Program CAPTURE for monthly trapping periods conducted 30 July 1985 thought 1 July 1986.

Trapping Period	$\hat{p}$
Jul 30-Aug 02	-[a]
Aug 22-Aug 24	.091
Sep 19-Sep 21	.139
Oct 17-Oct 19	-
Nov 28-Nov 30	.091
Feb 21-Feb 28	.080
Apr 02-Apr 05	-
Apr 30-May 03	.059
May 29-May 31	-
Jun 25-Jun 28	.054
Jul 23-Jul 26	.192
Aug 27-Aug 29	.076
Sep 19-Sep 21	.076
Oct 15-Oct 17	.082
Nov 13-Nov 15	.368
Dec 04-Dec 06	.122
Feb 11-Feb 13	-
Mar 10-Mar 13	.080
Apr 08-Apr 10	-
May 05-May 08	.154
Jun 10-Jun 12	-
Jul 01-Jul 03	-
Mean	.119

[a] No estimate calculated due to low number of captures or no recaptures.

limit was 4 rabbits for the 11-13 February 1986 MTP. For the 20 MTPs for which estimates were calculated, the mean population estimate was 49 (n=20, sd=26.8) rabbits and the CIs ranged from 4 to 319 rabbits.

In all but 2 MTPs, J-S estimates were greater than the MNA values (Figure 9). J-S MTP estimates were found to be significantly greater than MNA values (F=32.20, P=0.001) and significantly greater than CAPTURE MTP estimates (F=36.42, P=0.001). The J-S estimates appeared to present a more realistic account of the actual numbers of rabbits occupying the trapping area than did Program CAPTURE estimates. An exception to this was a lack of an increase in J-S estimates for April, May, and June 1986 which would be expected at this time of year. One obvious explanation for this was the low trapping success during these MTPs (Table 12). Another cause was that J-S estimates were based on captures occurring before and after the MTP and termination of trapping following these MTPs did affect these estimates in a negative way (Pollock 1982).

The margin of the CIs produced for J-S estimates ($\bar{x}$=94.2, sd=72.4) were a great deal wider than those for the CAPTURE estimates ($\bar{x}$=12.9, sd=13.2). It was probable that the true population fell within the CIs for many of the J-S MTPs but a narrower margin was desired.

Density estimates. J-S estimates were used to calculate density estimates. An adjusted area of effect of 27.5-ha was calculated by adding 11.5-ha to the perimeter of the trapping area. Density estimate ranged from 0.44 rabbits per ha for the 8-10 April 1986 and 5-8 May 1986 MTPs to 3.74 rabbits per ha for the 29-31 May 1985 MTP (Figure 10).

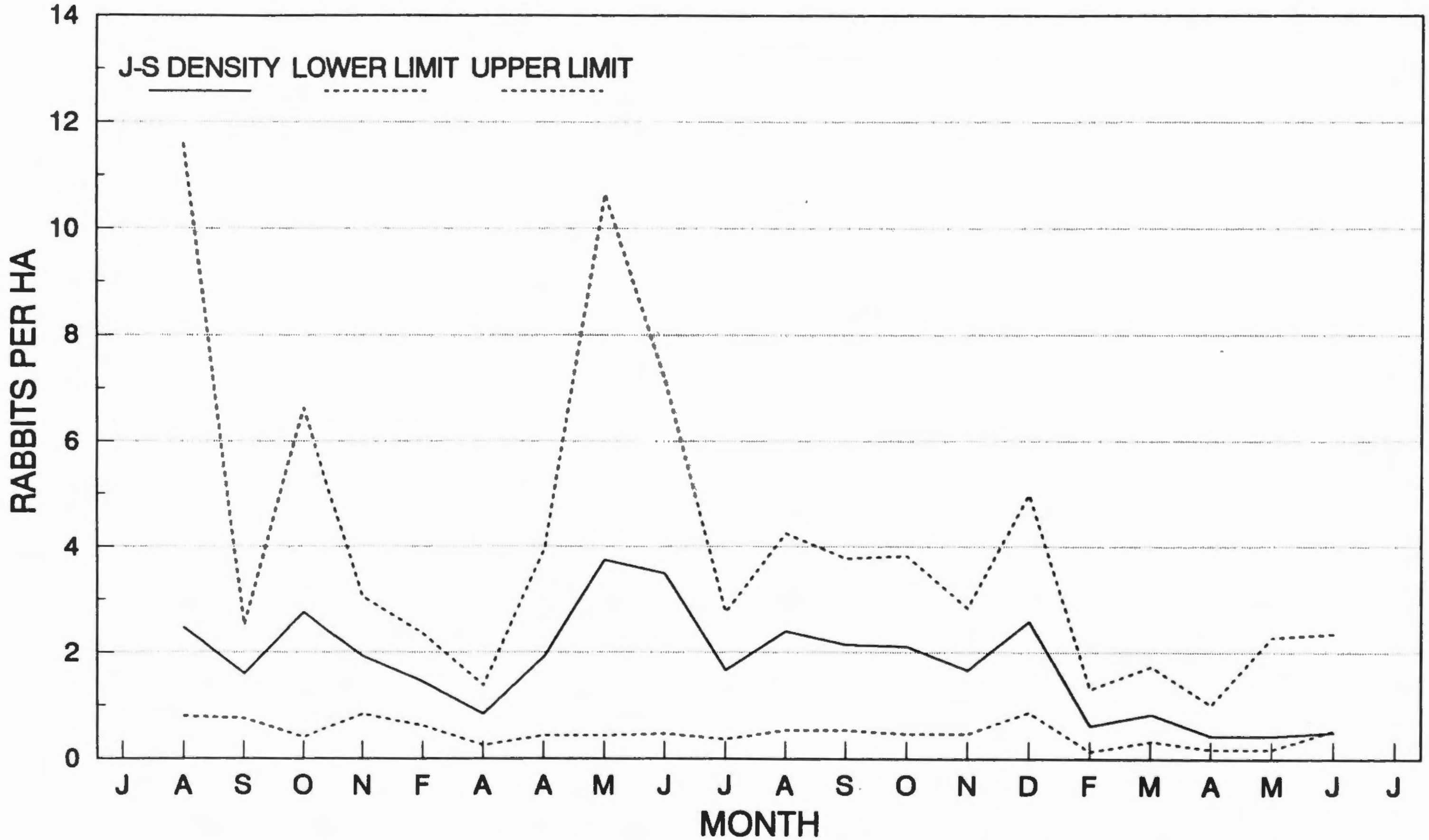

Figure 10. Density of rabbits per ha and confidence intervals derived using Program JOLLY with mark-recapture data obtained from monthly trapping periods at Land between the Lakes, Stewart County, Tennessee.

CHAPTER IV

SUMMARY AND CONCLUSION

1. Fifty box traps were placed selectively on a 16-ha area for the primary purpose of collecting ticks from rabbits and a secondary purpose of estimating rabbits numbers. Traps were operated from 30 July 1984 until 3 July 1986 for periods of 3 to 8 days resulting in 22 MTPs and 3900 trap nights.

2. A total of 157 rabbits were captured on 313 occasions for a trap success of 8.0%. The highest trapping success occurred during the 4-6 December 1985 MTP (18.7%) and the lowest success occurred during the 11-14 February 1986 MTP (2.7%). Males (n=71) comprised 45.2% and females (n=86) comprised 58.8% of the rabbits captured. Upon capture 74.3% of rabbits were classified as mature and 25.7% were classified as immature.

3. Within period recapture resulted in 23 rabbit movements and a MMDM of 118.4 m.

4. Program CAPTURE yielded closed population estimates from live-trapping data for 21 of the MTPs. The highest estimate was 41 rabbits for 22-24 August 1984 MTP and the lowest was 5 rabbits for the 5-8 May 1986 MTP. Estimates were believed to be low due to a short trapping periods, low $\hat{p}$, and inadequate trapping design.

5. Program CAPTURE estimates were not significantly different than the MNA values indicating that closed mark-recapture population estimation models provided little additional information on population size.

6. Program JOLLY produced J-S opened population estimates for 20 MTPs. The highest estimate was 103 rabbits for the 29-31 May 1985 MTP and the lowest estimates were 12 rabbits each for the 8-10 April and 5-8 May 1986 MTPs.

7. J-S estimates were significantly greater than MNA values and Program CAPTURE estimates indicating that J-S estimates were a more reliable estimate of the actual numbers of rabbits occupying the trapping area.

8. Calculated area affected by the trapping area was 27.5-ha. Density estimates using the J-S estimates ranged from 0.44 rabbits per ha for the 8-10 April 1986 and 5-8 May 1986 MTPs to 3.74 rabbits per ha for the 29-31 May 1985 MTP.

9. The J-S open population model using the pooling method (Pollock 1982) appeared to produce more reliable population estimates than closed population estimation models. This method would be recommended when determining population size from numerous live-trapping periods of short length.

LITERATURE CITED

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Allen, D. L. 1938. Ecological studies on the vertebrate fauna of a 500-acre farm in Kalamazoo County, Michigan. Ecol. Monogr. 8:347-436.

___________. 1939. Michigan cottontails in winter. J. Wildl. Manage.3:306-322.

Anderson, B. F. 1975. Some aspects of the movement, ecology, and susceptibility to hunting of the cottontail rabbit in Tennessee. M. S. Thesis, Univ. of Tennessee, Knoxville. 92 pp.

__________________, and M. R. Pelton. 1976. Movements, home range and cover use: Factors affecting the susceptibility of cotton tails to hunting. Proc. Southeastern. Assoc. Game and Fish Commissioners 30:524-535.

Bailey, J. A. 1969. Trap responses of wild cottontails. J. Wildl. Manage. 33:48-58.

Bartmann, R. M., G. C. White, L. H. Carpenter, and R. A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. J. Wildl. Manage. 51:41-46.

Bothma, J. du P., J. G. Teer, and C. E. Gates. 1972. Growth and age determination of the cottontail in south Texas. J. Wildl. Manage. 36:1209-1221.

Bowers, G. L. 1965. An evaluation of conttontail rabbit management in Pennsylvania. Proc. N. Amer. Wildl. Conf. 19:358-368.

Brady, J. R. 1973. Demographic characteristics of cottontail rabbit population on enclosed areas of natural habitat. M. S. Thesis, Univ. of Tennessee, Knoxville. 81 pp.

___________, and M. R. Pelton. 1976. An evaluation of some cottontail rabbit marking techniques. J. Tennessee Acad. Sci. 51:89-90.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses, Univ. California Publ. Stat. 1:131-160.

Cooney, J. C., and W. Burgdorfer. 1974. Zoonotic potential (Rocky Mountain Spotted Fever and Tularemia) in the Tennessee Valley Region. Ecologic studies of ticks infesting mammals in Land Between the Lakes. Amer. J. Tropical Med. and Hygiene 23:99-108.

Cormack, R. M., 1968. The statistics of capture-recapture methods. Oceanogr. Mar. Bio. Annu. Rev. 6:455-506.

Dalke, P. D., and P. R. Sime. 1938. Home and seasonal ranges of the eastern cottontail in Connecticut. Trans. N. A. Wildl. Conf. 3:659-669.

Davis, D. E., and R. L. Winstead. 1980. Estimating the numbers of wildlife populations. Pages 221-245 <u>in</u> S. D. Schemnitz, ed., Wildlife Management Techniques Manual. The Wildlife Society, Wash. D. C. 686 pp.

Debase, A. F., and R. E. Martin. 1974. A manual of mammalogy with keys to families of the world. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 329 pp.

Dimmick, R. W., F. E. Kellogg, and G. L. Doster. 1982. Estimating bobwhite population size by direct counts and the Lincoln Index. Proc. Natl. Bobwhite Quail Symp. 2:13-18.

Eberhardt, L. L., T. J. Peterle, and R. Schofield. 1963. Problems in a rabbit population study. Wildl. Monograph No. 10. p. 1-50.

Eckel, E. C. 1940. Engineering geology of the Tennessee Valley River system. Tennessee Valley Authority, Tech. Monograph 47.

Edwards, W. R., and L. L. Eberhardt. 1967. Estimating cottontail abundance from live trapping data. J. Wildl. Manage. 31:87-101.

Geis, A. D. 1955. Trap response of cottontails and its effect on censusing. J. Wildl. Manage. 19:466-472.

Greenwood, R. J., A. B. Sargeant and D. H.Johnson. 1985. Evaluation of mark-recapture for striped skunk abundance. J. Wildl. Manage. 49:332-340.

Haugen, A. O. 1942. Life history studies of the cottontail rabbit in southwestern Michigan. Amer. Midl. Nat. 28:204-244.

___________. 1943. Management studies of the cottontail rabbit in southwestern Michigan. J. Wildl. Manage. 7:102-110.

Hayne, D. W. 1949. Two methods for estimating population from trapping record. J. Mammal. 30:399-411.

Hines, J. E. 1985. Program "JOLLY": User instructions, (Draft). U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland, 5 pp.

Huber, E. P. 1962. Trap response of confined cottontail populations. J. Wildl. Manage. 26:177-185.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data wuth both death and immigration-stichastic model. Biometrika 52:225-247.

Kelloge, F. E., G. L. Doster, E. V. Komarek and R. Komarek. 1972. The one quail per acre myth. Proc. First National Bobwhite Quial Symossum. 1:15-20.

Larson, J. S., and R. D. Taber. 1980. Criteria of sex and age. Pages 61-88 in S. D. Schemnitz, ed., Wildlife Management Techniques Manual. The Wildlife Society, Wash. D.C. 686 pp.

Lefebvre, L. W., D. L. Otis, and N. R. Holler. 1982. Comparison of open and closed model for cotton rat population estimates. J. Wildl. Manage. 46:156-163.

Lincoln, F. C. 1930. Calculating waterfowl abundance on the basis of banding returns. U. S. Dept. Agric., Circular, 118:1-4.

Madson, J. 1963. The cottontail rabbit. Olin Mathieson Chemical Corporation, East Alton, Illinois. 55 pp.

McCullough, D. R. and D. H. Hirth. 1988. Evaluation on the Petersen-Lincoln estimater for a white-tailed deer population. J. Wildl. Manage. 52:534-544.

McDowell, R. D. 1955. Restocking with "native" cottontails. J. Wildl. Manage. 19:61-65.

Moore, D. W., and M. L. Kennedy. 1985. Factors affecting response of raccoons to traps and population size estimation. Amer. Midl. Nat. 114:192-197.

Moore, P. 1955. The strip intersect census. Trans. N. A. Wildl. Conf. 20:390-405.

Nichols, J. D., and K. H. Pollock. 1983. Estimation methodology in contemporary small mammal capture-recapture studies. J. Mammal. 64:253-260.

___________., and ___________, and J. E. Hines. 1984. The use of a robust capture-recapture design in small mammal population studies: A field example with Microtus pennsylvanicus. Acta. Theriologica 29-30:357-365.

O'Brien, T. G., K. H. Pollock, W. R. Davidson, and F. E. Kellogg. 1985. A comparison of capture-recapture with capture-removal for quail populations. J. Wildl. Manage. 49:1062-1066.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference for capture data on closed populations. Wildl. Monogr. 62:1-135.

Peterle, T. J., and L. L. Eberhardt. 1959. Is the Lincoln index reliable for cottontail censusing? Trans. N. A. Wildl. Conf. 23:261-271.

Petersen, C. G. J. 1896. The yearly immigration of young plaice into the Limfjord from the German Sea. Rep. Danish Biol. Sta. 6:1-48.

Pollock, K. H. 1981. Capture-recapture models: A review of current methods, assumptions, and experimental design. Stud. Avian Biol. 6:426-425.

___________. 1982. A capture-recapture design robust to unequal probability of capture. J. Wildl. Manage. 46:752-757.

Redd, J. B. 1956. Live trapping as a technique of estimating rabbit abundance. Va. Acad. Sci. Release No. 56:7.

Rice, W. R. and J. D. Harden. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wildl. Manage. 41:197-206.

SAS. 1982. 1982 SAS User's Guide: Statistics. SAS Institute, Inc., Carry, North Carolina. 584 pp.

Schwartz, C. W. 1940. Home range of the cottontail in central Missouri. J. Mammal. 21:386-392.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Griffin, London. 506 pp.

Silvy, N. J., J. W. Harden and W. D. Klimstra. 1977. On the relationship of animals marked to cost and accuracy of Lincoln estimates. Proc. Annual Conf. S.E. Assoc. Fish and Wildl. Agencies 31:199-203.

Smith, G. W., and N. C. Nydegger. 1985. A spotlight, line-transect method for surveying jack rabbits. J. Wildl. Manage. 49:699-702.

Southern H. N. 1940. The ecology and population dynamics of the wild rabbit. Annuals of App. Biol. 27:509-526.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach, 2nd Ed., McGraw Hill, New York. 663 pp.

Strandgaar, H. 1967. Reliability of the Petersen method tested on a roe-deer population. J. Wildl. Manage. 31:643-651.

Wandell, W. M. 1948. Agricultural and wildlife values of habitat improvements plantings of the Illinois black prairie. Trans. N. Amer. Wildl. Conf. 13:256-270.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1978. CAPTURE, a FORTRAN IV program for general computer use. Share Program Library Agency, Research Triangle Park, North Carolina.

__________, ______________, ____________, and ________. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, Los Alamos, New Mexico. 235 pp.

Zimmerman, R. H. 1986. USDA-TVA pilot project on integrated tick management progress report 1984. Tennessee Valley Authority, Land Between The Lakes, Golden Pond, Kentucky, 99 pp.

_____________, G. R. McWherter, and S. R. Bloemer. 1988. Medium-sized mammal hosts of Amblyomma americanum and Dermacentor variabilis (Acari:Ixodidae) at Land Between the Lakes, Tennessee, and effects of integrated tick management on host infestations. J. Med. Entomol. 25:461-166.

APPENDIX

APPENDIX A

Table 16. Results of cottontail rabbit 15 day periods conducted on a 25-ha study area at Land Between the Lakes from 8-22 March, 31 July through 14 August, and 10 through 24 December 1985.

Num.	Sex	Age	Wt.	HF	March[a]	August	December
017	F	M	1.33	98		001000000000000	
021	M	M	1.04	88	000000010000000		
021	M	M	1.27	88			100000100000001
041	F	N	1.17	98	001001000000000		
041	F	M	1.27	98			000001000000000
043	F	M	1.36	92		000010100000000	
045	F	M	1.24	94		000100000010000	
051	M	M	0.99	81	000001000000000		
055	F	M	1.42	96	000010000000000		
055	F	M	1.46	97			010010000000000
063	F	M	1.25	84	000100000000100		
063	F	M	1.17	86			000000010000000
091	F	M	1.18	88	000000100000000		
091	F	M	1.37	85		010000000000000	
105	F	M	1.55	103			100000100000000
109	M	M	1.10	90	010000000000000		
111	F	M	1.22	82	000000010000010		
115	F	M	1.35	100			000001000000000
117	M	M	1.24	100	000100000000000		
123	F	M	1.32	90	010000100000000		
129	F	M	1.14	96		000010000000000	
133	F	M	1.36	94			000001000100000
135	M	M	1.44	93		000100000000000	
139	F	M	1.28	103	100000000010010		

Table 16. (Continued)

Num.	Sex	Age	Wt.	HF	March	August	December
141	F	M	1.34	98	100000000000000		
143	F	M	1.34	88	010000000000000		
145	F	M	1.14	88	010000000000000		
147	M	M	1.10	65	010000000000000		
147	M	M	1.10	94			000000100000000
149	F	M	1.34	91	010000000000000		
151	F	M	1.24	89	010000001000000		
151	F	M	1.35	95			010000000000000
153	F	M	1.41	97	001000000000000		
153	F	M	1.53	101			100000000000000
155	F	M	[b]	86	001000000000100		
157	M	M	1.14	89	001000010000000		
159	M	M	1.07	87	001000000000000		
161	F	M	1.29	89	000100000000000		
161	F	M	1.44	94		000100000000000	
161	F	M	1.42	96			100000000000000
163	F	M	1.02	86	000100000000000		
165	M	M	1.19	98	000010000000000		
165	M	M	1.30	97			000000000100000
167	M	M	1.22	90	000010000010001		
167	M	M	1.22	97		0100000000000000	
167	M	M	1.27	94			010000010000001
169	M	M	1.03	91	000001000000000		
171	F	M	1.03	89	000001000010000		
171	F	M	1.23	92			000000100000000
173	M	M	1.10	96	000000100000000		
173	M	M	1.32	88		000010000000000	
173	M	M	1.36	97			000000000100000
175	F	M	1.28	92	000000100000000		
177	F	M	1.07	84	000000010000000		

Table 16. (Continued)

Num.	Sex	Age	Wt.	HF	March	August	December
179	M	M	1.09	91	000000010001000		
179	M	M	1.18	90		000001000000000	
179	M	M	1.29	[b]			000000100000000
181	F	M	1.16	96	000000010000001		
181	F	M	1.31	92		000001000000000	
181	F	M	1.39	90			000000000000010
183	M	M	1.04	95	000000001010000		
183	M	M	1.18	92		000100000000000	
183	M	M	1.31	95			100000010000000
185	M	M	1.18	90	000000001000010		
185	M	M	1.32	97			000000010000000
187	F	M	1.18	85	000000000001000		
187	F	M	1.23	95			000000000001000
189	F	M	0.99	85	000000000000100		
189	F	M	2.25	91		000000000001000	
191	F	M	1.11	87	000000000000100		
191	F	M	1.24	91		000001000000000	
191	F	M	1.26	87			100000000000000
193	F	M	1.26	95	000000000000001		
199	F	M	1.10	91	000000010000000		
235	F	M	1.22	90			000000010000000
303	F	M	0.84	88		100000000000000	
305	M	M	1.25	89		000000000000011	
305	M	M	1.29	90			100000000000000
309	F	M	0.78	90		000001000000000	
319	F	M	1.51	84		010000000000000	
327	M	M	0.98	91			000000000100000
329	F	M	1.10	93			000000010000000
335	M	I	0.58	77		000000000100000	
337	F	M	0.65	85		000001000000010	
337	F	M	1.21	99		000100001001000	

Table 16. (Continued)

Num.	Sex	Age	Wt.	HF	March	August	December
341	F	M	0.68	87		000000010000000	
343	M	M	1.23	91			001011001000010
347	M	I	0.68	79		101001100000000	
349	F	I	0.29	64		100100000000000	
351	M	I	0.44	74		100100000000000	
351	M	M	1.14	95		000000010000000	
353	F	I	0.61	67		100000000000000	
353	F	M	0.89	88		001000100000000	
355	M	M	0.79	80		100000000000000	
357	F	I	0.59	79		100000000010000	
357	F	M	1.03	91			001000000001000
359	M	M	0.78	91		100000000100000	
361	F	M	0.85	85		110000000000000	
363	M	I	0.66	72		010000000000000	
363	M	M	0.95	88		000100000000000	
365	F	M	0.61	80		001000000000000	
365	F	M	1.18	96			001000110000010
367	M	M	1.00	88		001000000000000	
369	F	I	0.42	60		000100000000000	
371	M	I	0.49	71		000100000110000	
375	M	M	0.72	86		000000100000100	
377	F	M	0.91	92		000000010000000	
377	F	M	1.28	95			000000000000001
379	F	I	0.24	54		000000010000000	
381	M	I	0.48	72		000000010000000	
383	F	M	0.72	84		000000001001001	
385	F	I	0.32	62		000000000100000	
385	F	M	1.12	87			100110010000000
387	M	M	1.08	92		000000000010000	
389	F	M	1.21	85		000000000001000	

Table 16. (Continued)

Num.	Sex	Age	Wt.	HF	March	August	December
391	M	M	0.74	83		000000000001000	
391	M	M	1.18	91			000101000010000
393	M	I	0.29	63		000000000110100	
395	M	I	0.23	61		000000000001000	
397	F	I	0.13	57		000000000000100	
399	M	I	0.56	73		000000000000100	
801	F	M	0.66	83		000000000000010	
815	F	M	0.91	87			010000000000000
817	M	M	1.01	87			010000100000100
819	M	M	1.02	91			000100000000000
825	F	M	1.40	91			000000000100000
827	F	M	0.96	87			100100000100000
829	F	M	1.05	88			
835	F	M	1.35	97			010000000000001
841	M	M	1.42	100			000000000010000
845	M	M	1.24	92			001000000000000
847	M	M	0.87	88			101100001000000
849	F	M	0.82	90			000001010000000
851	F	M	1.15	98			000000100000001
855	F	M	1.14	89			000000010000000
867	M	M	0.99	90			100000000000000
869	M	M	1.16	87			100000001000000
871	F	M	1.06	88			100001000000000
873	M	M	1.06	96			101000100101000
878	F	M	1.14	98			100001000010000
877	M	M	1.11	88			100000000000000
879	M	M	1.10	97			100100000000000
881	F	M	1.08	82			001000101000001
883	M	M	1.18	91			000100000000100
885	M	M	1.22	92			000100000000000
887	F	M	1.40	101			000010000000000

Table 16. (Continued)

Num.	Sex	Age	Wt.	HF	March	August	December
889	M	M	1.21	91			000001000000000
891	F	M	1.03	87			000001000000000
893	M	M	0.91	90			000000100000001
895	F	M	1.11	94			000000010000000
897	F	M	1.03	98			000000000010000

[a] Series of charaters represents 15 trapping days. A 0 indicates rabbit was not captured and 1 indicates the rabbits was captured.

[b] Indicates missing data.

APPENDIX B

Table 17. Results of cottontail rabbit monthly trapping periods (MTP) conducted on a 16-ha study area at Land Between the Lakes from 30 July 1984 through 3 July 1986.

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
1	M	I	.[b]	80	1
1	M	M	1.20	93	3
3	F	I	.	79	1
5	F	M	1.70	94	1
5	F	M	1.45	93	4
7	M	M	0.95	91	1
9	F	I	0.27	62	1
11	M	I	0.74	76	1
13	F	M	1.58	94	1
15	F	M	1.42	95	1
15	F	M	1.46	97	2
15	F	M	1.00	93	9
17	F	I	0.24	65	1
17	F	M	1.15	93	5
17	F	M	1.30	98	8
17	F	M	1.61	97	11
21	M	I	0.81	85	2
21	M	M	1.00	61	3
21	M	M	1.15	93	5
21	M	M	1.13	91	18
21	M	M	1.90	92	19
23	M	I	0.69	80	2
25	M	I	0.62	76	2
25	M	M	1.10	86	5
27	M	M	1.05	93	2
29	F	M	1.38	91	2
29	F	M	1.53	94	8
29	F	M	1.34	93	10
31	F	I	0.50	75	2
31	F	M	0.70	84	3
33	F	I	0.52	75	2
35	M	M	0.62	88	2
37	F	I	0.84	95	2
37	F	M	1.05	98	3
37	F	M	1.18	98	6
39	M	M	1.28	96	2
41	F	M	0.96	90	2
41	F	M	1.15	87	6
41	F	M	1.22	89	16

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
43	F	M	1.32	93	2
43	F	M	1.44	92	5
43	F	M	1.22	93	6
43	F	M	1.36	95	7
45	F	M	0.70	83	2
45	F	M	0.84	92	3
45	F	M	1.24	92	6
47	F	M	1.38	91	2
47	F	M	1.40	93	3
47	F	M	1.30	93	5
51	M	I	0.50	74	2
51	M	I	0.70	80	3
53	M	I	0.60	78	2
55	F	M	1.54	99	2
55	F	M	1.50	95	3
55	F	M	2.32	95	6
55	F	M	1.50	93	7
55	F	M	1.50	99	9
55	F	M	1.46	99	13
57	M	I	0.26	67	2
59	F	I	0.36	67	2
61	M	M	0.76	90	2
61	M	M	0.98	90	3
61	M	M	1.36	98	12
63	F	M	0.88	83	2
63	F	M	0.96	94	3
63	F	M	1.00	92	4
63	F	M	1.90	92	5
63	F	M	1.00	85	6
63	F	M	1.16	88	9
63	F	M	1.13	90	10
63	F	M	1.20	92	11
63	F	M	1.19	85	18
63	F	M	.	88	19
65	F	M	1.40	93	3
65	F	M	1.10	98	6
67	F	I	0.62	78	3
69	M	M	0.94	89	3
69	M	M	.	90	4
69	M	M	1.00	91	5
71	F	I	0.20	51	3
73	M	I	0.22	58	3
75	M	I	0.20	52	3
77	M	M	0.72	87	3
79	M	M	1.08	92	3
81	M	M	0.60	85	3

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
83	M	M	1.30	95	3
85	M	M	1.55	93	3
85	M	M	1.20	96	6
87	F	M	1.09	97	4
87	F	M	1.30	92	5
89	M	M	1.20	92	4
91	F	M	1.20	91	4
91	F	M	1.20	90	5
93	M	M	1.15	99	4
95	F	M	1.06	90	4
97	F	M	1.41	95	4
97	F	M	1.40	96	5
97	F	M	1.29	92	6
99	M	I	0.41	68	4
101	F	M	1.20	94	4
101	F	M	1.21	93	5
105	F	M	1.25	.	5
107	M	M	1.00	95	5
109	M	M	1.20	90	5
109	M	M	1.10	92	6
111	F	M	1.25	90	5
111	F	M	1.10	99	6
113	F	M	1.10	90	5
115	F	M	1.22	97	5
115	F	M	1.35	95	7
115	F	M	1.49	98	8
115	F	M	1.39	98	16
117	M	M	1.23	99	6
119	F	M	1.30	90	5
121	F	M	1.22	97	5
123	F	M	1.40	95	5
123	F	M	1.10	95	7
123	F	M	1.32	95	13
125	M	M	1.11	87	5
125	M	I	1.12	93	16
127	M	M	1.00	89	5
129	F	M	1.10	90	6
129	F	M	1.34	86	7
129	F	M	1.40	86	11
129	F	M	1.22	90	18
131	F	M	1.25	90	6
131	F	M	0.24	89	16
131	F	M	1.43	96	18
133	F	M	1.00	81	6

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
135	M	M	1.10	99	6
135	M	M	1.10	92	8
135	M	M	1.10	90	11
135	M	M	1.24	93	15
137	M	M	1.17	96	6
141	F	M	1.35	97	16
147	M	M	1.03	90	18
147	M	M	1.00	95	19
151	F	M	1.31	89	8
151	F	M	1.22	90	17
161	F	M	.	98	16
165	M	M	1.20	93	12
169	M	M	1.10	78	7
175	F	M	1.60	90	20
195	F	M	1.30	98	7
195	F	M	1.44	91	12
197	M	M	1.30	85	8
197	F	M	1.34	98	15
197	F	M	1.42	88	19
233	M	M	0.64	80	9
235	F	M	1.20	90	9
235	F	M	1.25	89	11
235	F	M	1.12	88	12
235	F	M	1.17	89	15
235	F	M	1.19	93	16
237	F	M	1.49	91	9
301	F	I	0.22	55	8
303	F	I	0.16	53	8
305	M	I	1.35	90	8
307	F	I	0.29	59	8
307	F	M	.	.	12
307	F	M	1.20	91	13
307	F	M	1.13	94	18
309	F	I	0.28	58	8
311	M	M	1.12	88	8
313	F	M	1.38	.	9
313	F	M	1.50	96	11
315	F	I	0.68	75	9
315	F	M	0.91	83	10
317	M	I	0.41	70	10
317	M	M	.	.	14
319	F	M	1.30	91	10
319	F	M	1.33	91	12
321	F	I	0.53	81	10
323	F	I	0.58	74	10
323	F	M	0.80	88	12

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
325	M	I	0.66	77	10
327	M	I	0.48	74	10
329	F	I	0.21	59	10
329	F	I	0.46	70	11
329	F	M	0.74	89	12
329	F	M	0.89	86	13
329	F	M	1.12	93	14
329	F	M	1.12	95	15
331	M	I	0.28	55	9
331	M	M	0.50	88	12
333	F	I	0.21	61	9
335	M	I	0.17	49	9
335	M	I	0.39	67	10
337	F	I	0.30	62	9
337	F	I	.	.	10
337	F	M	0.68	91	12
337	F	M	0.90	95	13
339	F	I	0.21	53	10
341	F	I	0.70	89	11
343	M	I	0.90	85	11
343	M	M	1.14	.	14
343	M	M	1.20	98	15
343	M	M	1.23	88	16
343	M	M	1.09	92	17
343	M	M	1.06	93	19
343	M	M	1.22	91	21
345	M	M	1.20	98	11
347	M	M	0.74	84	15
355	M	M	1.18	98	16
357	F	M	1.09	95	16
363	M	M	1.00	90	18
377	F	M	1.19	95	16
377	F	M	1.13	.	17
377	F	M	1.41	99	19
383	F	M	0.71	87	12
383	F	M	0.80	82	13
389	F	M	1.27	91	16
393	M	M	1.20	98	18
403	F	I	0.23	56	20
405	F	I	1.92	59	20
405	F	I	0.40	70	21
407	F	M	1.34	94	20
409	F	I	0.25	55	21
411	M	I	0.44	75	21
413	F	I	0.47	77	21
413	F	I	0.55	84	22

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
415	F	I	0.19	55	21
417	M	I	0.10	47	21
419	F	I	0.42	70	21
419	F	I	0.51	80	22
421	F	I	0.51	76	21
423	M	I	0.19	49	21
425	F	I	0.45	70	21
427	F	I	0.24	57	21
429	M	I	0.21	55	21
431	M	I	0.21	54	22
433	M	I	0.70	82	22
435	F	I	0.31	60	22
437	F	I	0.35	70	22
803	M	M	0.90	98	12
803	M	M	1.08	95	13
805	F	M	0.50	88	12
807	M	I	0.51	78	12
809	M	M	0.98	85	12
815	F	I	0.36	68	13
817	M	I	0.58	76	13
817	M	I	0.70	81	14
819	M	I	0.44	75	13
819	M	M	0.95	92	15
819	M	M	1.00	90	16
821	M	M	1.14	93	13
821	M	M	1.12	95	14
821	M	M	1.11	99	16
823	M	M	1.13	93	13
823	M	M	1.14	92	14
823	M	M	1.13	94	15
825	F	M	1.34	92	13
827	M	I	0.68	72	13
827	M	M	0.78	94	14
829	F	M	0.90	92	14
829	F	M	0.98	90	15
829	F	M	1.02	89	16
829	F	M	1.16	90	18
831	F	M	1.10	88	14
831	F	M	1.10	96	15
833	F	M	0.67	86	14
835	F	M	1.23	92	14
837	F	M	1.07	98	14
839	M	M	0.70	88	14
841	M	M	1.38	99	15
843	F	M	1.20	95	15
845	M	M	1.18	98	15

Table 17. (Continued)

Number	Sex	Age	Weight (Kg)	Foot Length (mm)	MTP[a]
849	M	M	0.78	88	15
849	M	M	0.80	92	16
849	M	M	0.86	89	17
851	F	M	1.12	88	16
853	F	M	1.10	90	16
855	F	M	1.16	94	16
857	M	M	1.13	94	16
859	M	M	1.15	91	16
861	F	M	1.30	87	16
863	M	M	1.29	96	16
865	M	M	1.02	95	16
899	F	I	0.25	63	20
899	F	I	0.51	78	21

[a] Numbers represent the MTP which rabbit was captured (i.e. MTP 1 = 30 July - 2 August 1984; MTP 22 = 1 July - 3 July 1986).

[b] . indicates missing data.

VITA

Gary Randolph McWherter was born on 25 February, 1959 in Orlando, Florida. When Gary was 2, his family moved to Greeneville, Tennessee where he attended the city school system and graduated from Greeneville High School in 1977. Gary attended Lees-McRae College located in Banner Elk, North Carolina where he played football for 2 years. He earned an Associates Degree in Science in the spring of 1979. In September 1979 Gary enrolled in the Wildlife and Fisheries Science program at the University Of Tennessee, Knoxville (UTK). He Graduated with honors with a Bachelors Degree in Wildlife and Fisheries Science and minors in Biology, Forestry, and Zoology in March 1984. Gary was hired by Tennessee Valley Authority, Land Between the Lakes in April 1984 as a Wildlife Aid to work on an ectoparasite research project. In September 1987 he enrolled in a Master's Degree program at UTK. In May 1988 Gary began working with the Tennessee Wildlife Resources Agency (TWRA) as a Water Safety Officer and is presently employed by TWRA as a Wildlife Officer stationed in Carter County, Tennessee.

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L.H