REPRODUCTION OF THE WILD COTTONTAIL RABBIT IN NORTH CENTRAL OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Rabbits are one of the major game species of Oklahoma. Information presented in the present study shows that in the past six years rabbits have not dropped below fourth place among the state's game species in the total number killed. In 1958, in Oklahoma rabbits were second only to bobwhite (*Colinus virginianus*) in the total number killed. Even in years of very low populations, 1959 and 1960 for example, the rabbit ranked high as a game species.

Rabbits add variety to the game list of Oklahoma and also create year around sport for hunters. Because of its well-known ability to multiply, the rabbit can absorb much of the hunting pressure presently directed towards species with lower reproductive capacity. However, the reproductive capacity of any game species must be known for proper management. The present study was made in order to obtain more knowledge concerning the reproductive capacity of the cottontail rabbit (*Sylvilagus floridanus alacer*) of the Southern Prairie region. While much work has been done on the cottontail rabbit in other regions of the United States, it has been neglected by both game administrators and researchers in this region.

The main objective of the present study was to provide information desirable to the regional management of the cottontail rabbit. Specific objectives were: (1) to determine the prevalence of pregnancy and average litter size; (2) to determine the length of breeding season; and (3) to determine the age, weight and sex ratios of adults and juveniles at different seasons.

CHAPTER II

THE STUDY REGION

The present study was restricted to a portion of Payne and Noble counties in northcentral Oklahoma north of the Cimmarron river. This region was chosen mainly because of its accessibility to the investigator. Collections were made from Noble county only during the last month of collecting, when it became apparent that a sufficient sample could not be obtained in Payne county.

Several descriptions of the vegetation of this area are available (Bruner 1931, Blair and Hubbell 1938, Duck and Fletcher 1945). In general, the collecting region can be characterized as the western edge of the tall grass prairie interspersed with "Cross timbers" and timbered ravines. Tall grass prairie is found on loam and clay-loam soils, while post oak-blackjack oak forests are found on sandy sites. Small areas of clay-pan soils support only xeric short grasses; the timber in ravines is mostly on deep alluvial soil. Approximately one-fourth of the area is under cultivation, and most of the remainder is grazed.

Gray and Galloway (1959) describe the "Cross timbers" as an extensive wooded area of rolling to hilly sandstone uplands covered with scrubby oak timber in which old growth is more or less open and park-like; and where cutting and burning has been followed by prolific sprouting of the post and blackjack oaks to form many brushy thickets. Characteristic plants of the "Cross timbers" include as dominants, post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*), with smooth sumac (Rhus glabra), and buckbrush (Symphoricarpus orbiculatus) being understory dominants. These plants intrude into the grassland forming an ecotone between the forest and grassland (Fig. 1). In the present study, very few rabbits were collected from the mature "Cross timbers" due to the extremely low population found there in all seasons. However, some areas as shown in Figure 1 were used by rabbits during the fall and winter months.

The principal plants of the prairie habitat type include such plants as little bluestem (Andropogon scoparius), big bluestem (Andropogon gerardi), Indiangrass (Sorghastrum nutans), and switch grass (Panicum virgatum). These plants also intrude into the forest-grassland ecotone. Any large unbroken expanse of the prairie habitat type was used very little by the rabbit (Fig. 2).

The timbered ravines follow the natural drainage pattern of the region. Some characteristic plants of the timbered ravines are: American elm (Ulmus americana), bur oak (Quercus macracarpa), hackberry (Celtis occidentalis), green ash (Fraxinus pennsylvanica), and greenbrier (Smilax bonanox). This habitat type was greatly utilized by rabbit where it was bordered by cultivated fields. It was most used, however, during the growing season. During this time, the cultivated fields were used for feeding and the timbered ravines for shelter and escape.

The chief agricultural crops of the region are wheat, native hay, and alfalfa. Wheat fields are grazed by cattle in the fall and winter months. Both wheat and hay meadows are used as feeding areas by the rabbit in areas where protective cover is near, such as shown in Figure 3.

Pastures range in condition from extremely overgrazed to lightly grazed. Little use was made of any of them by cottontail rabbits.

Johnsongrass (*Sorghum halepense*) is a common invader in disturbed areas such as cultivated fields and roadside ditches (Fig. 4). This picture denotes the type of site in which the population of cottontail rabbits was highest in all seasons. These areas were almost pure Johnsongrass. Many areas similar to this were hunted owing to their relatively high productivity of rabbits. As many as five rabbits were collected in less than 500 square feet while in the surrounding area none could be found.

Weather Bureau data indicate the average growing season to be 207 days, extending from the first week in April to the last week in October. The average annual rainfall for the region is approximately 33 inches. Table I summarizes the climatological data for the study region during the period samples of rabbits were taken. It should be noted that from March until mid-August precipitation was below normal.

Fig. 1. View of the Forest-Grassland Ecotone.

Fig. 2. View of the Prairie Habitat Type.

Fig. 3. View of a Hay Meadow Bordered by a Timbered Ravine.

Fig. 4. View of an Area Invaded by Johnsongrass.

TABLE I

SUMMARY OF THE CLIMATOLOGICAL DATA FOR STILLWATER, OKLAHOMA IN 1964-65

	Temperature in Fahrenheit							Precipitation in inches			
Month	Av Max.	Av Min.	Overall Average	Range	Days Above 90	Days Below 32	Departure from Normal	Total	Departure from Normal	Days of Precip	Daily Range
March	63.5	32.	47.8	15-79	0	18	-1.8	1.02	-.84	4	.04- .69
April	77.3	51.5	64.4	27-90	1	2	+3.8	1.71	-1.15	7	.06- .78
May	82.4	60.	71.1	42-94	3	0	+2.5	4.04	-.58	10	.01-2.24
June	89.3	65.6	77.5	47-97	21	0	-.4	1.17	-3.07	9	.01- .37
July	99.1	71.4	85.3	55-107	30	0	+2.8	.27	-3.25	6	.03- .10
August	93.6	68.6	81.1	54-109	19	0	-1.2	7.30	+4.09	11	.02-2.25
Sept	83.7	62.1	72.9	42-98	11	0	-1.3	2.43	-.95	7	.02-1.71
Oct	75.4	45.1	60.3	29-89	0	1	-3.2	.54	-2.24	5	.05- .54
Nov	63.	42.8	52.9	13-83	0	9	+3.8	5.28	+3.43	11	.01-1.75
Dec	50.5	26.8	38.7	3-70	0	23	-2.1	.64	-.70	4	.01- .62
Jan	53.6	26.9	40.3	12-78	0	22	+2.4	1.59	+.43	6	.05- .80
Feb	54.9	25.8	40.4	5-75	0	22	-1.9	.91	-.44	3	.04- .47

CHAPTER III

METHODS

A total of 328 native cottontail rabbits were collected from March, 1964 to February, 1965. No predetermined schedule was followed for collecting these. They were taken at various time periods of month and day. Since the population of the region was low, no predetermined sample size was set. As large a sample as possible was taken each month of the sampling period.

Samples from the wild population of cottontail rabbits were taken either by walking areas in the dayling or driving fields at night and shooting the rabbits with a shotgun. Four additional rabbits were found dead along the county roads and included in the sample. The population in the region appeared to be too low to justify the time necessary for a productive trapping effort.

To determine whether an apparent difference between the weight of male and female rabbits existed, the weight of each rabbit was taken with a spring-type scale, which measured to the nearest quarter of a pound. Further accuracy of the weights was not needed since the weight of an individual probably varies daily according to its consumption of food and its activity.

Measurements in millimeters were taken of the hind foot and ear. The length of the ear from the botton of the notch to the top of the pinna was taken. These measurements were taken to test for a sex difference.

Sex determinations for all age groups were made by examination of the internal sex organs.

Visual observation of body size, weight and development of the sex organs were the criteria used for the separation of rabbits into adult or immature classes. Lord (1963) states that measurement of body weight appears to be a feasible method of estimating the age of cottontail, at least until they are 100 days old. Schwartz (1941) was unable to distinguish young of the year from adults in gross study of the reproductive organs, color of the pelage, condition of the teeth, size or total length. He did class males weighing more than 907 grams, and females weighing more than 963 grams from March to September as adults. Majors (1955) states that juvenile males can be distinguished from adult males by the turgid appearance of juvenile testes as compared to the flaccid state of adults testes. Juvenile females, which had not yet been pregnant, were distinguished from adult females until the close of the breeding season by the size and development of the uterus. A composite of these techniques was used to age the animals.

The uterus of each female was removed and examined macroscopically for embryos. Some early pregnancies were probably missed using this method. The number of dead, and of live embryos was recorded. Dead embryos were separated from living ones by their general appearance. The dead embryo loses its translucent appearance. Brambell and Mills (1948) found that embryos, once dead, become limp and distorted by the pressure of the uterus; the brain especially collapses, the cervical flexure is lost, the embryo loses its translucent appearance, becomes opaque and whiter in color, and the embryonic fluids escape from the membrane which collapse about the embryo. The embryos were removed from the uterus and measured for crown-rump lengths. The age of the embryos and conception dates of each pregnant female were calculated using growth data developed by Schwartz (1942). Ovaries from pregnant females were fixed in F.T.A. solution and subsequently cut with a scalpel into sections about 1 mm. thick. Attempts were then made to count the corpora lutea under a dissecting microscrope. After several unsuccessful attempts to get a dependable count of the corpora lutea, this was abandoned.

Females nursing young were determined by the presence of milk in the mammary glads.

Each male was examined for the position of the testes in relation to the scrotum. Each testis and its epididymis was removed from the animal and cleaned of all excess flesh. The combined weight of the testis and epididymis was taken using a balance-type scale.

A smear was made from the anterior portion of each epididymis and checked for presence or absence of spermatozoa.

CHAPTER IV

RESULTS AND DISCUSSION

Population Density and Sample Size

Rowan (1954) describes animal cycles as changes in numbers from low to high and back again at recurring intervals. It is well known that the cottontail rabbit population fluctuates from time to time. The western hares and rabbits experience violent fluctuations, but whether these represent a periodic cycle or an irregular irruption is not yet known (Leopold, 1933). In the present study no estimates of density of animals per unit of area were attempted. However, relative numbers for a six-year period were estimated using information compiled by the Oklahoma Game Division's Annual Hunter Success Report (Table II) as an index.

TABLE II

YEARLY STATISTICS OF RABBIT HUNTING SUCCESS IN OKLAHOMA

Year	1958	1959	1960	1961	1962	1963
Hunters	133,090	102,346	37,572	39,560	36,620	39,280
Average Kill	20.0	16.0	11.3	9.3	4.9	8.7
Total Kill	2,659,138	1,637,536	424,564	363,952	179,438	341,736
Rank as Game Species	2nd	3rd	4th	4th	4th	4th

The data in Table II suggest that rabbit populations do fluctuate, and that during the period of the study the population was relatively low compared to some years. The monthly samples taken during this study cannot be used to reflect fluctuations in the population, since variations occurred in the amount of time spent collecting and in the number of hunters doing the collecting. The data in Table II also suggest that the rabbit population was high in 1958 but crashed in 1959 and reached a low in 1962. Since 1962, however, there has been a steady increase in the population. Between 1962 and 1963 there was a 90% increase in the total number killed by state hunters. This suggests perhaps that the population is increasing.

The relationships between the fluctuations and environmental, physiological, or psychological factors are not understood. Much speculation has been done, however, concerning what factors cause populations to fluctuate. Clark (1949) states that direct human action predator or parasite relationship, disease, cosmic influences and climatic variations are thought to affect fluctuations. Green (1964) working with cottonrats (*Sigmodon hispidus*) suggests that stress caused by population density affects the productivity of a population. French, *et al*. (1965) suggest that a sociopsychological factor caused decreasing fertility with increasing population density of jackrabbits. Regardless of the density dependent factor affecting a fluctuating population, the influence is probably greatest at population highs. Therefore, since the rabbit population of this region was low, the effect of any density dependent factor on reproduction should be correspondingly low.

The sample obtained in the present study included 142 adult males, 132 adult females, 21 immature males and 33 immature females. Table III shows the number, sex and age of rabbits collected monthly.

TABLE III

NUMBER, SEX RATIO AND MEAN WEIGHT IN POUNDS OF COTTONTAIL RABBITS, MARCH, 64-FEBRUARY, 65, PAYNE COUNTY, OKLAHOMA

	ADULTS						JUVENILES					
	Males			Females			Males			Females		
Month	No.	% of Adults	Mean Wt.	No.	% of Adults	Mean Wt.	No.	% of Juveniles	Mean Wt.	No.	% of Juveniles	Mean Wt.
March	16	64.	2.25	9	36.	2.22	-	-	-	-	-	-
April	11	57.9	2.30	8	42.1	2.47	-	-	-	-	-	-
May	7	57.5	2.21	5	42.5	2.6	-	-	-	-	-	-
June	6	54.5	2.33	5	45.5	2.9	3	42.8	1.08	4	57.2	1.38
July	7	43.8	2.32	9	56.2	2.5	5	41.6	1.1	7	58.4	1.43
Aug.	14	51.8	2.16	13	48.2	2.85	5	27.7	1.5	13	72.3	1.68
Sept.	16	57.1	2.28	12	42.9	2.75	6	40.	1.71	9	60.	1.91
Oct.	15	48.4	2.35	16	51.6	2.45	-	-	-	-	-	-
Nov.	16	57.1	2.35	12	42.9	2.52	2	100.	-	-	-	-
Dec.	14	46.7	2.66	16	53.3	2.5	-	-	-	-	-	-
Jan.	6	27.3	2.37	16	72.7	2.45	-	-	-	-	-	-
Feb.	14	56.	2.44	11	44.	2.5	-	-	-	-	-	-

Population Congregations

No quantitative data are available on population congregations in the present study. However, congregations of rabbits were noted during the course of this study as stated previously. McCabe (1943) reported the centering of numbers concentration of cottontails at "focal points" during low years. He stated that cottontails were not to be found on the usual normal range, but occurred in some numbers in and around towns and villages. He says further that he believes that the shrinkage to "focal points" during low years is a population behavior characteristics of cottontails in southern Wisconsin. This same phenomenon was also noted in the present study. Cottontail were most numerous near towns and farmsteads.

Weight and Measurements

Table IV shows the distribution of the weights of rabbits found in this study. The largest number of adult rabbits of both sexes occurred in the 2.5 pound class. Haugen (1942) found that weather, season, pregnancy, age and sex have a considerable effect on the weight of the cottontail. From the evidence presented in the study, the average weights of adults varies according to sex, pregnancy and season (Table III and Figure 5). In general, adult females are larger than adult males. March and December are the only months in which the average weight of the adult females was less than the average weight of the adult males; however, these average weight differences are minor. Majors (1955), Elder and Sowls (1942), Schwartz (1942), Haugen (1942), and Allen (1938) observed that in general females are heavier than males.

TABLE IV

WEIGHT FREQUENCY OF THE COTTONTAIL RABBIT

Weight	Males	Females
2.0	34	11
2.25	36	23
2.5	62	60
2.75	9	13
3.0	1	19
3.25	0	5
3.5	0	1

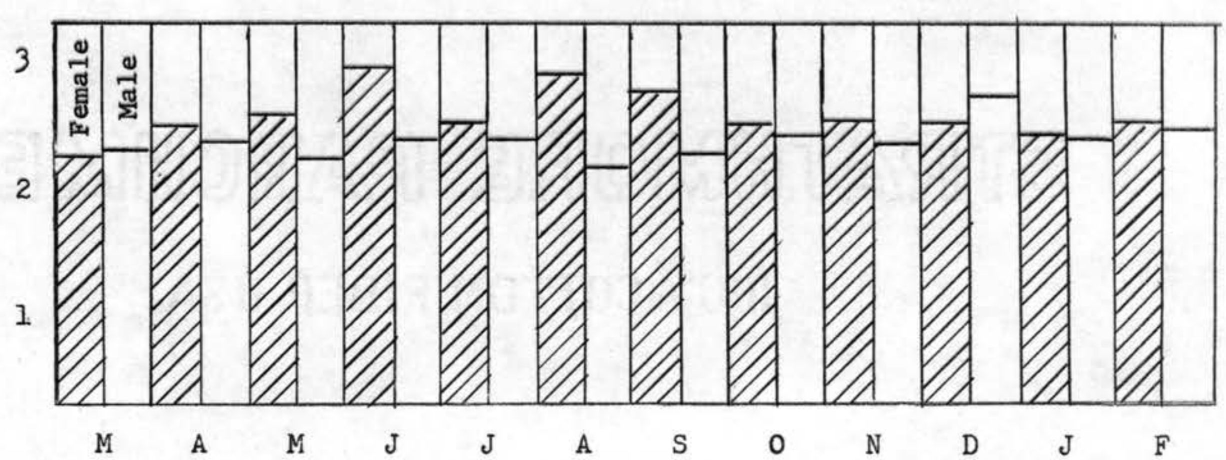

Fig. 5 Fluctuations in average weights of the cottontail rabbit.

The largest sex difference in weight occurred during the breeding season. This difference is due to an increase in the average weight of the female (Table IV). All the females weighing 3 pounds or more were collected during the breeding season except two collected in late September and one collected in October. Of these females collected in the breeding season, fifteen were lactating and pregnant, five were pregnant but not lactating and two were lactating but not pregnant. The largest female found was in September and weighed 3.5 pounds. She was lactating and pregnant. This increased average weight of females during the breeding season is probably due both to an increase in amount of flesh and their gravid condition (Haugen 1942).

Lord (1963) found that in August the mean weight of the cottontail increases. He attributed this increase as the result of the physiological preparation of the rabbits for the advancing winter. This late summer increase in weight was not observed in this investigation. There was a decrease in the average weights of the females and only a minor increase in those of the males between September and October (Fig. 5). Thereafter, until the beginning of the breeding season, the average weights of both sexes remained fairly constant (Table IV). Haugen (1942) found that except for minor fluctuation, the average weight of adult females changed very little during the fall months.

An increase in the average weights per month of adult males was observed after the close of the breeding season, until December (Table III and Fig. 5). Using their weights as an index, the males were in their best condition in December. Thereafter, the average weight decreased until spring. Elder and Sowls (1942) found a progressive loss in average weights of male rabbits in late winter and early spring. This weight loss may be due to scarity or poor quality of food in late winter.

Much greater fluctuation in average weight occurred in both sexes in the spring and summer months. This is probably due to the great fluctuation in the condition of succulent vegetation of different collecting areas in these months.

There were no significant sex difference in the length of the hind foot or of the ear (Table V).

TABLE V

MEASUREMENTS OF THE COTTONTAIL RABBIT

Sex	Hind Foot Average Length	Ear Average Length
Male	92.81	56.25
Female	91.58	55.35

Age Ratio

In the present study, cottontails were aged using a combination of characteristics. Adult cottontails can be distinguished from the young of the year until late summer by body size, weight and development of sex organs. However, any juveniles that were reproductively active, lactating and/or pregnant, were classified as adults using the described techniques. Table III shows the percentage of the monthly sample classified as juveniles. The percentages are low for every month and did not increase as the breeding season progressed. No juveniles were collected in October and only two in November. Majors (1955) found that in September, October and November the percentage of young were 66.7, 72.4, and 79.0 respectively. The low percentage of young obtained in the present study could be attributed to several factors: (1) small sample size; (2) high mortality of young; (3) method of collecting; (4) low productivity; and (5) breeding of juveniles.

Sex Ratio

The sex ratio of the 328 rabbits collected was found to be 163 males to 165 females, a ratio of 49.4 males to 50.6 females. Table VI summarizes the sex ratio data obtained by other investigators.

The sex ratio as determined from samples of the wild cottontail rabbit population probably varies according to: (1) season of year the sample is taken; (2) the method of collecting; (3) locality from which the sample is taken; and (4) the size of the sample. However, the sex ratio under normal conditions is almost 50:50, and departures from this ratio may not indicate the actual sex ratio but rather one resulting from different activities of the sexes when collecting was done (Schwartz 1942). Trautman (Trippensee 1936) in Ohio and Allen (1938) in Michigan found that females were less active than males during cold weather. Schwartz (1942) in Missouri found the sex ratio to be 50:50 in the winter season and suggests that this may indicate that the females do not "hole up" so commonly in central Missouri as they apparently do farther north.

In the present study adult males generally outnumber adult females (Table III). However, in the July, October, December, and January samples, females were the predominant sex. The predominance of females in December and January could suggest that not only do females not "hole up" in the winter in this region but that they are more active than males in the winter. But there is another possible explanation for the predominance of females during these two months. December and January samples were both taken from areas that had been heavily hunted. Therefore, if males are the more active sex, more males probably had been taken from the areas leaving the female as the predominant sex. The samples for

February and March were taken from areas that had experienced virtually no hunting. In both these months males predominated, which may indicate that they are the more active sex.

A greater percent of males were obtained during the spring months than at any other season. This preponderance of males may be due to a greater activity of this sex during the onset of the breeding season and therefore, these males, being more active, were more readily encountered by the hunter. It is interesting that in juvenile cottontail sample, the female was the predominance sex (Table III). This could indicate that juvenile females are more vulnerable to predation and therefore, the preponderance of adult males found in the spring months is a reflection of the time sex ratio.

TABLE VI

SEX RATIO OF THE COTTONTAIL RABBIT AS REPORTED BY OTHER INVESTIGATORS

Investigator	Location	Sample Size	Male:Female Ratio	Method Collected
Allen (1938)	S. Mich	383	49:51	all methods
Elder & Sowls (1942)	Wisconsin	398	52:48	trap-shot
Haugen (1942)	SW Mich	825	50:50	live-trapped
Major (1955	Alabama	437	93.3:100	trap-shot road kill
Petrides (1951)	Ohio	222	55:45	shot
Schwartz (1941)	Missouri	254	47:53	trapped
Schwartz (1942)	Missouri	449	52.5:47.5	shot

Breeding Season

The breeding season of the cottontail rabbit in northcentral Oklahoma during the period of study extended from mid-February to early September. The first pregnant female was collected on March 6. Using Schwartz's (1942) aging technique, the embryos of this female were approximately twenty days old. There is some indication that this female was exceptional rather than the usual. The conception date for the next four females collected was calculated to be the first of March. This suggests that the males are ready to breed at a much earlier date than most of the females. The last pregnant female was collected September 19, and the embryos were estimated to be approximately twenty days old.

The term "breeding season" as used here refers to the length of time between the first effective coitions and the last effective ones of the season. Haugen (1942) used the term "breeding season" to refer to the length of time between the first fertile coitions of the season, and the time when the last young of the season are capable of independent existence. Using Haugen's (1942) meaning of the term, the breeding season for this region would end in October. Schwartz (1942) considered the breeding season to be time between the first mating and the birth of the last litter of the season.

Other investigators (Table VII) report that the breeding season varies according to locality and weather. Hamilton (1940) states the onset of the breeding season may be delayed by inclement weather.

TABLE VII

BREEDING SEASONS OF THE COTTONTAIL RABBIT

Investigator	Location	Length of Season
Allen (1938)	S. Michigan	February through July
Hamilton (1940)	New York	Late February to late August
Haugen (1942)	S. Michigan	Early March to early September
Majors (1955)	Alabama	January to September
Schwartz (1942)	Missouri	Early March to early August

Variation of Weight of Testes

It has been shown that a seasonal variation in the weight of the testes of cottontails occurs (Lord, 1961; Schwartz, 1942; Haugen, 1942; Hamilton, 1940; Trippensee, 1936). Trippensee (1936) states that the size and position of the testes seem to be directly correlated with the breeding condition of the animal. The mean weights of the testes by month in this study are as follows: March, 11.2 grams; April, 10.7 grams; May, 10.2 grams; June, 8.9 grams; July, 4.9 grams; August, 4.88; September, 1.09 grams; October, .63 grams; November, .65 grams; December, 1.1 grams; January 3.9 grams; and February, 6.7 grams. These weights, plotted in Figure 6, indicate that the male gonads reach their maximum development in March, decline slowly in weight until June and decrease rapidly between June and July. There was only a minor difference between the weights obtained in July and August. From July until a minimum was reached in October, there was a rapid decline in weight. The weight of the testes increased slowly in December but thereafter increased rapidly in weight.

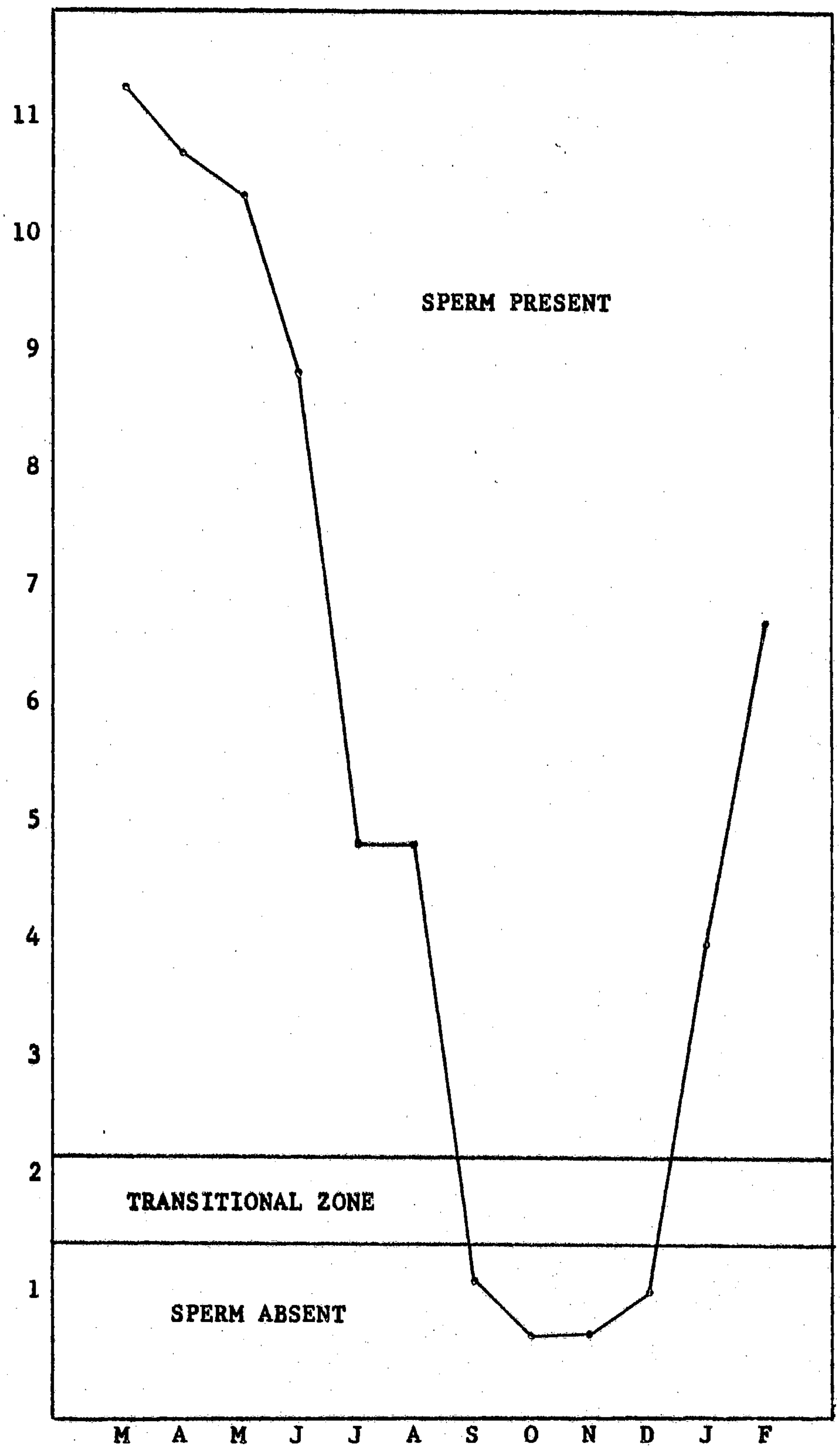

Fig. 6 Monthly Variation in Average Weight of Testes.

Schwartz (1942) found in Missouri that from a fall minimum a steady rise to the maximum in March occurs, followed by a smaller decrease during the next four months and a much more rapid decrease between July and September, when the minimum is reached again. Lord (1961), in Illinois found that the male gonads increase in weight rapidly from January to February, followed by a steady increase until April, and then a slow decrease until August where a rapid decline in weight occurred. The maximum weights obtained in the present study compared favorably with those recorded by Lord (1961).

Spermatozoa were present in the epididymis of all the testes which weighed more than 2.1 grams (Figure 6). No testes below this weight was found until the latter half of September. Spermatozoa were absent in the epididymides of all the testes which weighed under 1.4 grams.

Figure 6 shows an area of over-lap in which some of the epididymides had spermatozoa and some did not. Of the total variation however, the transitional zone is small, from 1.4 grams to 2.1 grams, a range of only .7 grams. October is the only month in which no males that had spermatozoa in the epididymis were collected. One male in late November and three males in December had spermatozoa in the epididymis. All the epididymides from males collected in January were found to contain spermatozoa. Ecke (1955) assumed that the starting date of reproduction in the cottontail is largely dependent on the physiological or psychological condition of female rabbits because males appear to reach sexual readiness somewhat earlier than females. Hamilton (1940), observed in New York that living sperms may be observed in the testes of a majority of males well into September; usually by the middle of this month the testes commence to withdraw into the abdominal cavity and spermatogenesis stops.

Trippensee (1936) says "the size and position of the testes seem to be directly correlated with the breeding conditions of the animals. Although the size of the testes seems to be constant for different seasons, their position is somewhat variable and they move back and forth from a position within the body cavity through an opening into the scrotum. The testes are in the scrotum when the animal is in breeding condition, although sometimes one testis is found partly in the body cavity when the animal is handled." Schwartz (1942) found that in any season the testes may be withdrawn from the scrotum while the rabbit is being handled at the trap or as a result of shock received when the animal is shot. Schwartz (1942) concluded that the presence of the testes in the scrotum is not a reliable indication of sexual activity. Evidence in this study supports both Trippensee and Schwartz's findings. The shock presumably received by the animal when they were shot caused much variation in the position of the testes in relation to the scrotum. During the breeding season, testes were found in all possible positions: both ascended, one ascended and both descended.

Litter Size

The average litter size per pregnant female as determined by embryos of all ages, was 3.3. Litter size was generally lower than that found by other investigators: Trippensee (1936) in southern Michigan (5.04); Schwartz (1942) in Missouri (4.4); Hamilton (1940) in New York (4.5); Haugen (1942) in southwestern Michigan (5.4); Major (1955) in Alabama (3.1); and Lord (1961) in southern Illinois (4.77).

Conaway et al. (1963) used embryos that were twenty days or more in age to determine litter size, on the assumption that the critical stages when pre-natal mortality are most frequent were past. This pre-natal mortality probably is rather small, since the average litter in the present study, as determined by live embryos of twenty days or more in age, was also 3.3.

The mean number of live embryos per pregnant female varied monthly from 2.4 in July to 5.4 in June (Table XIII). There was an increase in the number of live embryos per pregnant female from the onset of breeding to June (Tables VIII and IX). In July there was a sharp decrease in the average number of live embryos per pregnant female. This decrease was mainly due to two females which contained only one embryo each. July is the only month in which females were found with only one embryo. Schwartz (1942), Barkalow (1962) and Lord (1961) reported a slight increase in the number of embryos per pregnant female in the early part of the season with a decrease in the latter part of the breeding season. Negus (1959), found that the mean litter size for the subadult rabbit was four, considerably smaller than the mean for adults (5.5). Therefore, it is quite possible that the number of young in the first-period litters may be smaller than the number in subsequent litters because young does probably bear their first litter at that time (Schwartz 1942). Negus (1959) also found there was considerable variation in the age at which sexual maturity is reached. If subadults were entering the breeding population from July on, this could explain the decrease in the average litter size.

The data of this study also support Lord (1961) and Barkalow (1962) who suggest that average litter size in the South is smaller than in the North.

TABLE VIII

SUMMARY OF BREEDING DATA FROM ADULT FEMALE COTTONTAILS

Date	Pregnant and Lactating	Pregnant and not Lactating	Lactating and not Pregnant	Not Lactating and Not pregnant	Mean no. of live Embryos	Range in no. of Embryos	Mean no. of dead Embryos
March	-	5	-	4	3.2	2-4	.20
April	2	4	2	-	4.	2-6	.18
May	2	3	-	-	4.3	4-5	.20
June	3	-	2	-	5.4	4-7	.66
July	5	-	4	-	2.4	1-4	.60
August	7	2	4	-	3.	2-4	.32
September	3	1	2	6	3.5	2-4	.25
October	-	-	-	16	-	-	-
November	-	-	-	12	-	-	-
December	-	-	-	16	-	-	-
January	-	-	-	16	-	-	-
February	-	-	-	11	-	-	-

TABLE IX

FREQUENCY IN NUMBER OF EMBRYOS PER PREGNANT FEMALE

	Number of Females						
No. of Embryos	March	April	May	June	July	August	September
1				2			
2	1	1				1	1
3	3	1	2	1	2	6	
4	1	2	1		1	2	3
5		1	2	1			
6		1					
7				1			

Resorption of Embryos

Of the thirty-seven pregnant females collected in this study, nine had embryos in the process resorption. Lord (1961) in a three-year study in Illinois found the percent of resorption quite low. In his study in 1959, no resorbing embryos were found; in 1958, eight percent of the females had embryos in resorption.

Figures in Table VIII show that the mean number of resorbing embryos per pregnant females ranged between .18 and .66. Conaway and Wight (1962) found that in most samples the values for partial litter resorption loss lie between .20 and .5 embryos per litters.

Except for one female in July which had two resorbing embryos and one female in August which had three resorbing embryos, all other cases of resorption involved only one embryo out of the litter.

Lord (1961) found no cases of total litter resorption; however, Conaway and Wight (1962) found six such cases in their study. In the present study no cases of total litter resorption was found.

Number of Litters Per Female Per Year

The base of each vertical line in Figure 7 shows the date on which each pregnant female was killed. The top of each line denotes the estimated date of conception as determined using Schwartz's (1942) method of aging the embryos. This figure also shows that in the first few months of the breeding season there were definite synchronized breeding periods but as the season progressed these periods became less synchronized. In the early part of the season, the conception dates for most of the rabbits were grouped into distinct periods from twenty-four to thirty-day intervals. Wight and Sadler (1963) found an approximate twenty-six-day interval between the conception dates of cottontails in Missouri throughout the breeding season, Conaway et al. (1963), reasoned that since the gestation period of the cottontail is about twenty-six to twenty-eight days (Hendrickson 1943, Marsden and Conaway 1963) it seemed valid to consider these periods as conception dates for successive litters. Conaway et al. (1963), Marsden and Conaway (1963) and Conaway and Wight (1962) found that after the onset of the breeding season, most females become pregnant again at each successive postpartum estrus. However, the data in this study indicate that the percentage of postpartum pregnancies is variable. Table VIII shows that a large percentage of the females collected in the breeding season were lactating but not pregnant, indicating that effective postpartum coition did not occur. Four of the eight females collected in April and three of the five females collected in

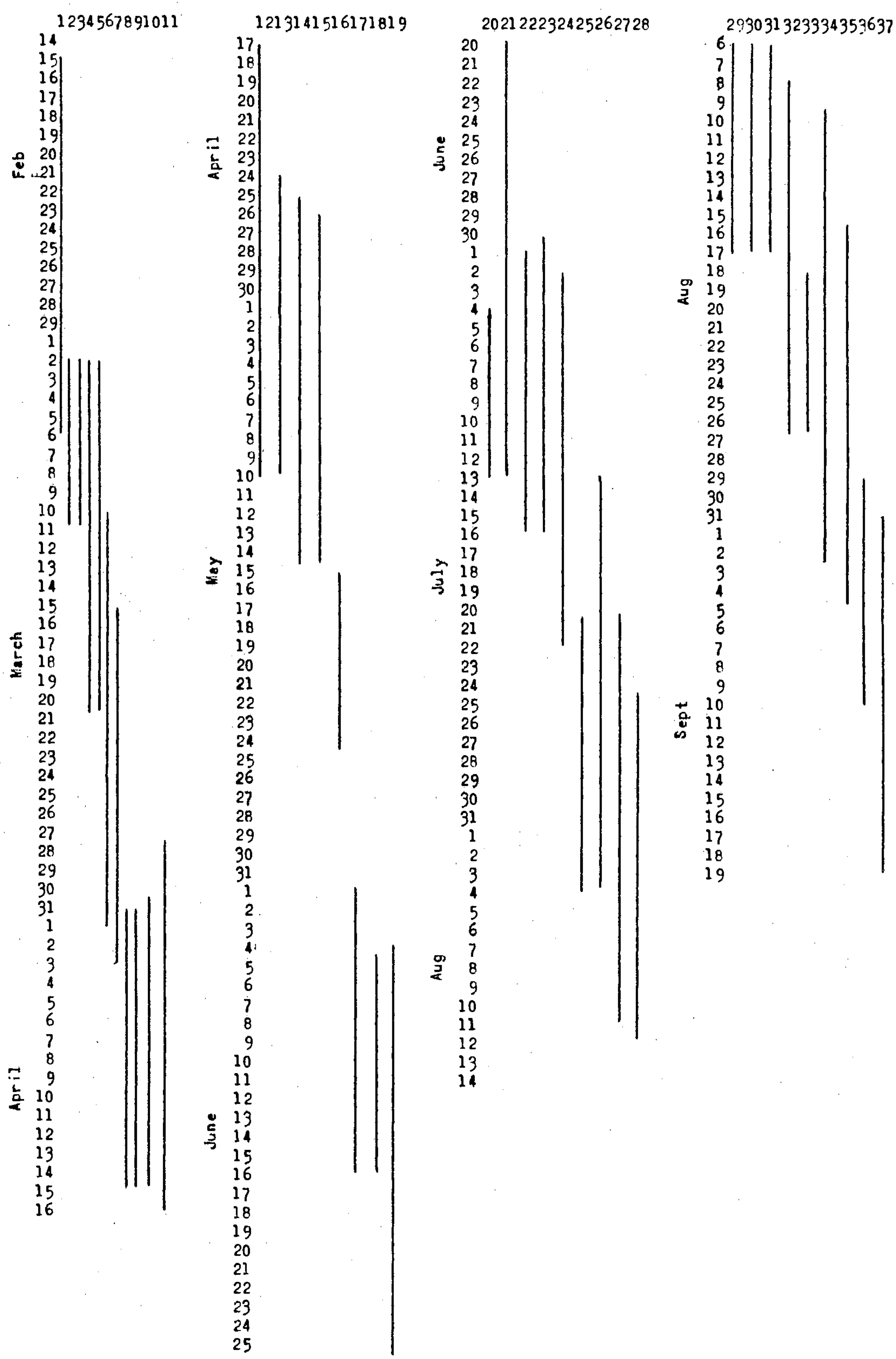

Fig. 7 Periodicity in Parturition

May were pregnant but not lactating. This could be an indication that all females do not breed immediately after parturation. The less synchronized breeding periods in the latter part of the breeding season may also indicate that all females do not have postpartum pregnancies. If the percent of postpartum pregnancies were high, more synchronized breeding periods should have been observed, since there were regular breeding periods in the early part of the season. Schwartz (1942) reports periodicity early in the season in Missouri, which became less regular as the season progressed. He states that these irregularities may be due to pseudopregnancy or to sterility. The irregularities in this study may be due to the infertility of the male. As the weight of the testes declined, the irregularities in the breeding periods increased. This may suggest, too, that as the fertility of the male declines, the probabilities of pseudopregnancies increase.

Four females were collected in March that were neither lactating nor pregnant. The last of these females was found on March 11, indicating some females are from one to four weeks later than other females in breeding. Fifty percent of the females collected in September were not involved in reproduction--neither lactating, nor pregnant. The first of these females was collected on September 5, indicating some females leave the breeding population early while other are involved in reproduction until early October.

The number of litters per female per year is probably quite variable due to irregular breeding of the female, pseudopregnancies, and infertility of the male. Therefore, while it may be possible for any given female to have as many as six litters per breeding season if breeding occurred after parturation, the normal number of litters per breeding season probably is less than six. It seems probable that the majority of the females have between four and five litters per year.

Factors Affecting Reproductive Success

"There has been considerable speculation as to what external stimulus is responsible for controlling the length of the breeding season in cottontails. The direct stimulus from pituitary secretions is, of course, responsible for the increased activity of gonads at the onset of the breeding season, and the decreased supply of hormones causes the retardation of gonad activity at the close of the season. No one, however, has adequately demonstrated what external factor or factors are responsible for the change in pituitary action" (Ecke 1955).

Hamilton (1940) suggested that inclement weather may delay the onset of the breeding season. Wight and Conaway (1961) found that severe weather can strongly influence the onset of breeding.

Bissonnette and Csech (1939) were able to promote testicular growth in males and nest building in females by subjecting rabbits to increased lighting at night.

Hammond and Marshall (1925) suggest diet and temperature as conditions responsible for setting the limits of the breeding season of domestic rabbits. Rabbits that were kept on a diet of succulent food throughout the year maintained breeding capacity and rabbits fed on an inadequate diet tended to breed in the regular breeding season. Fitch (1947) working with the Audubon cottontail (S. Audubonii vallicola) in central California found that: "Breeding is ordinarily limited to the late fall, winter and spring months--the growing season when green forage is abundant. In rabbits trapped during the dry season, the genitalia had retrogressed so that sex was not readily determined, and it was evident that breeding activity had ceased. The reproductive physiology may be controlled by the seasonal change in diet." Mossman (1955) found that the peak of reproductive activity in the brush rabbit (S. bachmani) lasts from January through May in both sexes, the period of infertility coinciding with the dry season in central western California.

Since the present study covered only one breeding season, no conclusion can be drawn as to what factors control the length of the breeding season. It is possible, however, that in this region severe weather does not stop breeding, but may hinder it to some extent and reduce the reproductive success of the population. This region was subjected to drought conditions from the onset of breeding in 1964 until mid-August (Table I). The drought conditions became increasingly worse as the breeding season progressed. Therefore, using the amount of rainfall as an index, the amount of succulent vegetation decreased as the breeding season progressed.

Figure 8 shows that as the rainfall increased in the first few months of the breeding season, the percent of pregnant females increased. However, in June when the amount of rainfall decreased there was also a decrease in percent of pregnant females which continued until the end of the breeding season. This may indicate that with decrease in succulent vegetation there is a concurrent decrease in fertility of the animal. Ecke (1955) suggests that some component of green vegetation, possibly vitamin E, is responsible for stimulating the pituitary glands of rabbits into the secretion of somatic nutritives, and consequently, determining the breeding condition of the animals. Another interesting fact related

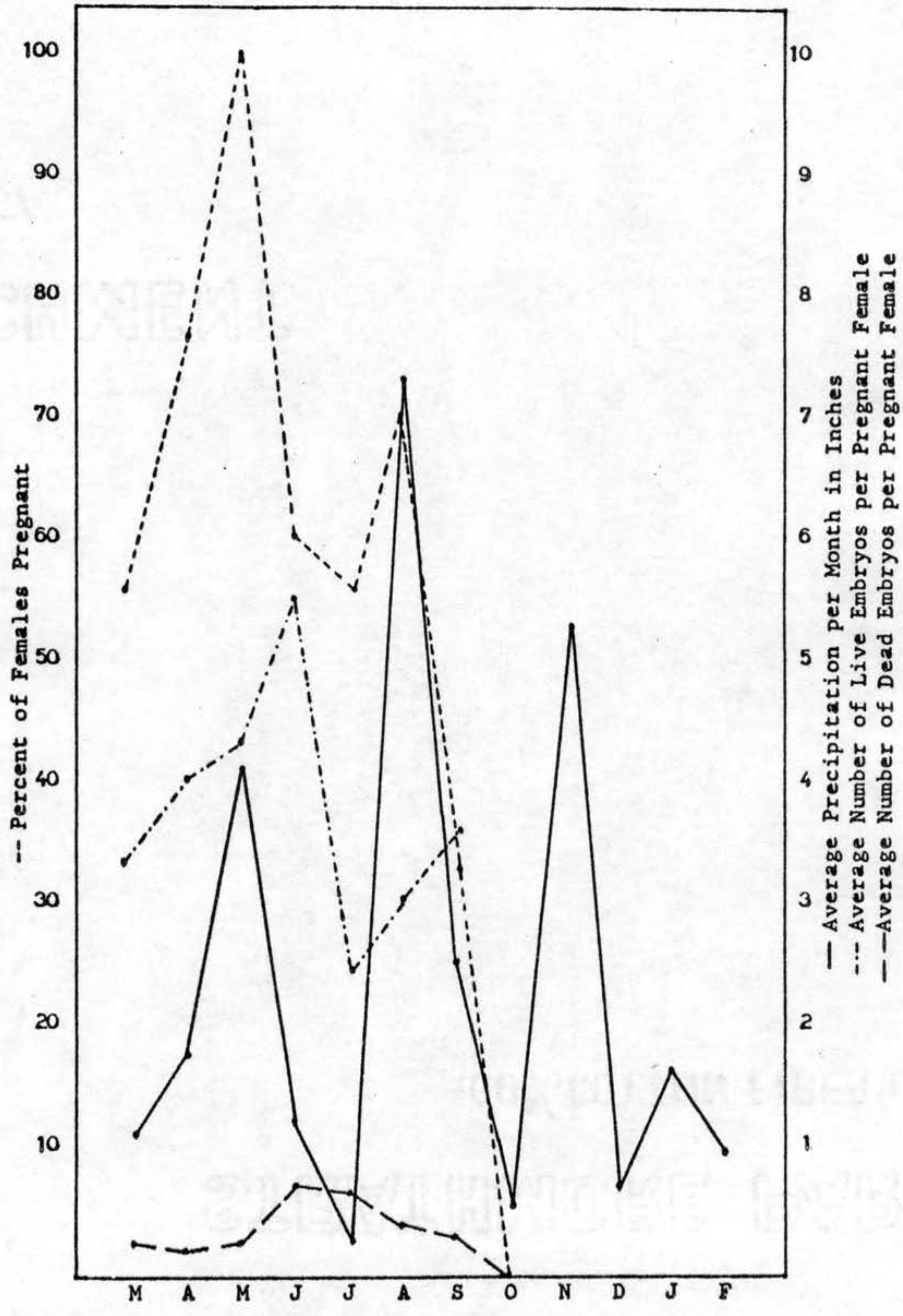

Fig. 8 Monthly Variation in Precipition, Percent of Pregnant Females, and Average Number of Dead and Live Embryos per Pregnant Female.

to this is the variation in the weight of the testes of the male (Fig. 6). There was a decrease in weight of the testes between all months except July and August. The high rainfall in August may have decreased the rate of testes regression.

Figure 8 also shows there is a correlation between the amount of succulent vegetation and the average number of live embryos per pregnant female. As long as the rainfall was sufficient to support a large amount of succulent vegetation, the litter size increased. All but one of the pregnant females collected in August had conceived before August 15, when the condition of the vegetation was poorest. Therefore, this may indicate that lack of some nutritional factor or factors in the dry vegetation decreases the ovulation rate or increases pre-natal mortality. The average number of dead embryos per pregnant female did increase through much of the breeding season and was higher than reported by other investigators, suggesting that the condition of the vegetation has an effect on pre-natal mortality. Schwartz (1942) suggests that a vitamin deficiency in the female could cause resorption of embryos.

CHAPTER V

MANAGEMENT IMPLICATIONS

Since the primary objective of this study was to provide information desirable to the regional management of the cottontail rabbit, a statement as to the management implications of the findings here reported seems appropriate. The findings of this study also point to questions which need answering before adequate management can be achieved. It is believed that adequate management should be directed mainly in keeping the population of rabbits in balance with available habitat. Following are several suggestions regarding how this might be done, and on how an unbalanced situation between the cottontail population and its environment may be recognized.

Since it was found that adult females breed from February to September and can have several litters consisting of an average of three young each during this period, it is apparent that the rabbit in this region have a high reproductive potential. A low rabbit density in any given area probably indicates a deficiency in the environment since it does not appear that factors intrinsic to the rabbit are responsible for it. The high reproductive capacity found in this study together with a prevailingly low population suggested that favorable environmental conditions generally were not available to the cottontail. It was noted that rabbits tended to congregate in small localized areas. Many of these areas consisted mainly of tall dense Johnsongrass. It has been postulated that this is a characteristic of population behavior during periods of low density. However, with the reproductive capacity the rabbits were shown to have, it seems apparent that there are presently some deficiencies in the environment; otherwise rabbits would have been more generally distributed. It will be well to be aware of any congregations developing in specific areas because they probably indicate that deficiencies are also developing in other areas. These deficiencies possibly could be identified by examination of the congregations of rabbits. Once the deficiencies are known, they might be manipulated in favor of the cottontail. Another point that should be made concerning congregation areas is that they are difficult to over-hunt. Many times it was thought that an area of this kind had been hunted out, only to find later that such an area was inhabited by as many rabbits as before. Either the habitat was sufficient to offer ample protection from predators including man, or immigration was occurring which would indicate that the environment was deficient.

The present study showed that rainfall through its effect on vegetation may have a direct relationship on the reproductive success of a population of rabbits. Therefore, irrigated land and areas bordered by irrigated land, rivers, creeks or impoundments will probably have a greater productivity than other less moist areas during periods of prolonged drought. The main reason for this higher productivity is probably that vegetation is more succulent, therefore, offering better nutrition for rabbits. Since irrigation for game management is probably economically unsound, plants resistant to drought established in areas subjected to frequent droughts might increase productivity. Small management areas around impoundments or seepages below dams could be established and thereby offer good hunting even during periods of prolonged drought. Areas of this kind would also keep population density of marginal habitat more stable. Marginal habitat areas would have a steady supply of rabbits from these congregations.

According to this study, the weights of the testes may be used as an index of the breeding condition of the male, although the position of the testes cannot. Heavy testes indicate that males are in breeding condition. Males with testes as small as 2.4 grams are not necessarily incapable of breeding. It is the female which presumably controls the length of the breeding season. To discover whether a population is reproductively active, the female must be examined for indications of breeding such as milk in the mammary gland or the presence of fetuses. Since some females enter the breeding population as much as four weeks later than others and some leave it quite early, no conclusion on the reproductive activity of a population should be reached without examination of several individuals.

Several points now may be emphasized:

1. The reproductive capacity of rabbits was such that presently no regulations on hunting are indicated;
2. The reproductive capacity of rabbits is sufficient to populate all available habitat;
3. It is extremely difficult to over-hunt an area of suitable habitat;
4. A large number of rabbits can be produced and can survive on small areas of suitable habitat.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study was undertaken to provide information desirable to the regional management of the cottontail rabbit. Samples from the wild population of cottontail rabbits were taken either by walking areas in the daylight or driving fields at night and shooting the rabbits with a shotgun. A total of 328 cottontail rabbits were collected from March, 1964 to February, 1965. Data collected from each animal included weight, and length of hind foot and ear. Females were examined for embryos and milk in the mammary glands. The testes of each male were weighted and examined for spermatozoa.

The largest number of adult rabbits of both sexes occurred in the 2.5 pound class. In general, adult females were larger than adult males.

The sex ratio was found to be 163 males to 165 females, a ratio of 49.4 males to 50.6 females.

The breeding season of the cottontail rabbit in northcentral Oklahoma during the period of study extended from mid-February to early September.

Data indicated that male gonads reach their maximum development in March, decline slowly in weight until June and decrease rapidly between June and July. Spermatozoa were present in the epididimis of all the testes which weighed more than 2.1 grams.

The average litter size per pregnant female as determined by embryos of all ages was 3.3. The average litter size per pregnant female as determined by embryos of twenty days or more in age was also 3.3.

The number of litters per female per year is probably quite variable due to irregular breeding of the female, pseudopregnancies, and infertility of male. Due to the length of the breeding season in this region, females born early in the season probably contribute to the density of the winter population.

The present data suggest that the current low density of rabbits is due to an environmental factor or to a combination of environmental factors and not to lack of reproductive capacity.

LITERATURE CITED

Allen, D. L. 1938. Breeding of the cottontail rabbit in southern Michigan. Am. Midl. Nat. 20:464-469.

Barkalow, F. S. Jr. 1962. Latitude related to reproduction in the cottontail rabbit. J. Wildl. Mgmt. 26:32-37.

Bissonnette, T. H. and A. G. Csech. 1939. Modified sexual photoperiodicity in cottontail rabbits. Biol. Bull. 77:364-367.

Blair, W. F. and T. H. Hubbell. 1938. The biotic districts of Oklahoma. Am. Midl. Nat. 20:425-454.

Brambell, F. W. R. and I. H. Mills. 1948. Studies on sterility and prenatal mortality in wild rabbits. J. Exptl. Biol. 25:241-269.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monographs. 1:99-188.

Clarke, C. H. D. 1949. Fluctuations in populations. J. Mammal. 30:21-27.

Conaway, C. H., H. M. Wight, and K. C. Sadler. 1963. Annual production by a cottontail population. J. Wildl. Mgmt. 27:171-175.

_______., and H. M. Wight. 1962. Onset of reproductive season and first pregnancy of the season in cottontails. J. Wildl. Mgmt. 26:278-290.

Duck, L. G. and J. B. Fletcher. 1945. A survey of the game and fur bearing animals of Oklahoma. Oklahoma Game and Fish Dept. Oklahoma City, Oklahoma.

Ecke, D. H. 1955. The reproductive cycle of the mearns cottontail in Illinois. Am. Midl. Nat. 53:294-311.

Elder, W. H. and L. K. Sowls. 1942. Body weight and sex ratio of cottontail rabbits. J. Wildl. Mgmt. 6:203-207.

Fitch, H. S. 1947. Ecology of a cottontail rabbit (Sylvilagus audubonii) population in central California. Calif. Fish and Game. 33:159-184.

French, N. R., R. McBride, and J. Detmer. 1965. Fertility and population density of the black-tailed jackrabbit. J. Wildl. Mgmt. 29:14-26.

Gray, F. and H. M. Galloway. 1959. Soils of Oklahoma. Oklahoma State Univ. Agric. Expt. Stat. MP-56.

Green, P. M. 1964. Density of population as a regulating factor in the reproductive potential of Sigmodon hispidus. Unpubl. Ph. D. Thesis. Oklahoma State Univ. 101 p.

Hamilton, W. J. Jr. 1940. Breeding habits of the cottontail rabbit in New York State. J. Mammal. 21:8-11.

Hammond, J. and F. H. A. Marshall. 1925. Reproduction in the rabbit. Oliver and Boyd, Edinburgh. 210 p.

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

Hendrickson, G. O. 1943. Gestation period in mearns cottontail. J. Mammal. 24:273.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York. 481 p.

Lord, R. D. Jr. 1961. Magnitudes of reproduction in cottontail rabbits. J. Wildl. Mgmt. 25:28-33.

______. 1963. The cottontail rabbit in Illinois. Illinois Dept. of Conserv. Tech. Bull. Number 3. Southern Illinois Univ. Press, Carbondale. 94 p.

Majors, E. 1955. Population and life history of the cottontail rabbit in Lee and Tallapoosa counties, Alabama. Unpubl. Master's Thesis. Alabama Polytechnic Institute, 119 p.

Marsden, H. M. and C. H. Conaway. 1963. Behavior and the reproduction cycle in the cottontail. J. Wildl. Mgmt. 27:161-170.

McCabe, R. A. 1943. Population trends in Wisconsin cottontails. J. Mammal. 24:18-22.

Mossman, A. S. 1955. Reproduction of the brush rabbit in California. J. Wildl. Mgmt. 19:177-184.

Negus, N. C. 1959. Breeding of subadult cottontail rabbits in Ohio. J. Wildl. Mgmt. 23:451-452.

Petrides, George A. 1951. The determination of sex and age ratios in the cottontail rabbit. Am. Midl. Nat. 46:312-336.

Rowan, W. 1954. Reflections on the biology of animal cycles. J. Wildl. Mgmt. 18:52-60.

Schwartz, C. W. 1941. Home range of the cottontail in central Missouri. J. Mammal. 22:386-392.

______. 1942. Breeding season of the cottontail in central Missouri. J. Mammal. 23:1-16.

Trippensee, R. E. 1936. The reproductive function in the cottontail rabbit (Sylvilagus Floridanus mearnsii Allen) in southern Michigan. Trans. N. Am. Wildl. Conf. 1:344-350.

United States Weather Bureau. 1964. Climatological data Oklahoma. U. S. Dept. of Commerce, Washington, D. C.

_______. 1965. Climatological data Oklahoma. U. S. Dept. of Commerce, Washington, D. C.

Wight, H. M. and C. H. Conaway. 1962. Determination of pregnancy rates of cottontail rabbits. J. Wildl. Mgmt. 26:93-95.

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