May 5, 1977

This letter is to rectify an inadvertent omission recently brought to my attention.

In 1974 I submitted a thesis at the University of Arizona entitled "The Influence of Rainfall on the Reproduction of Sonoran Desert Lagomorphs." This work compared reproductive data collected during a wet year and the following dry year (1972-73). The data were gathered during a contracted study for the International Biological Program. Mr. John Gray was the principal field investigator from March 1971 through April 1972. I assisted John in March and April 1972 and then continued the investigations until December 1973.

Mr. Gray very generously offered me the use of his raw data which I included in my thesis without properly acknowledging his contribution to the work. Although the use of Mr. Gray's data was mentioned in the acknowledgements, no citation for his unpublished data was made.

Hopefully, this late recognition of Mr. Gray's part in gathering the original data from March 1971 through April 1972 will properly establish his priority.

Rees L. Madsen

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THE INFLUENCE OF RAINFALL ON THE REPRODUCTION OF SONORAN DESERT LAGOMORPHS

by

Rees Low Madsen

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THE UNIVERSITY OF ARIZONA

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STATEMENT BY AUTHOR

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SIGNED: Rees Low Madsen

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

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Professor of Biological Sciences

23 April 1974
Date

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I wish to express my gratitude to Dr. Charles R. Hungerford, my major professor, for his continual and patient guidance throughout this research. Appreciation is also extended to the other committee members, Dr. Norman S. Smith and Dr. H. Ronald Pulliam, for their helpful suggestions and criticisms.

Thanks are offered to Dr. E. Lendell Cockrum, who contributed valuable advice and material to this project.

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I am indebted to John P. Grey for the use of data which he collected during the year previous to my study.

For their encouragement and confidence, I wish to thank my wife and family.

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ABSTRACT

During the period of March, 1971, through December, 1973, 290 *Sylvilagus audubonii*, 403 *Lepus californicus*, and 402 *Lepus alleni* were collected from the Avra Valley, Arizona. The sex ratios of all three species did not differ significantly from the expected 1:1. Pregnant females of all three species were collected during every month of the year, extending the previously established breeding season of each. Reproductive activity was at its highest mainly during the January-February-March period and again in the July-August period. The lowest percentage of reproductively active females was found during the October-November-December period of each year. Twenty per cent appears to be the basal rate of reproductive activity in all three species during this study. The lack of summer rains in 1973 cut the breeding seasons short by four to five months. In *Silvilagus auduboni* and *Lepus alleni*, a significant increase was noted in the annual mean litter sizes of 1972 and 1973. In *Lepus californicus*, a significant increase was seen in the annual mean litter sizes of 1971 and 1972. Monthly censuses were conducted on the Silverbell bajada. Densities for *Silvilagus auduboni* and *Lepus californicus*, the two species encountered on the census routes, were computed.

INTRODUCTION

Lagomorphs have long been recognized as important herbivores in the Sonoran Desert. Their position as potential competitors with domestic cattle for the sparse grazing available in the southwest was documented by Vorhies and Taylor (1933).

Their relative size and mobility in comparison with the desert rodents increases the effect of the lagomorphs on habitats. For this reason alone, more detailed data on these species (*Sylvilagus auduboni*, *Lepus californicus*, and *Lepus alleni*) are needed. Besides competing with man's livestock and utilizing his cultivated crops, the lagomorphs occupy a significant niche in the ecological relationships in the Sonoran Desert. They are among the largest, natural primary consumers. In order to better understand the workings of the desert and its inhabitants, it is necessary to know more about the rabbits and hares.

In an attempt to provide basic information on these animals concerning their reproduction, population levels, and the effects of site variables (principally rainfall and vegetative growth) on these parameters, this study was instituted in March, 1971, and continued through 31 December, 1973.

THE STUDY AREA

The Sonoran Desert, because of its great diversity of climate, topography, and soil types, supports by far the most numerous and varied plant communities of any of the four North American deserts. As a result of this diversity, Shreve (1951) identified seven subdivisions of the Sonoran Desert. Tucson, Arizona, lies within that subdivision classified as the crassicaulescent desert or the Arizona Uplands. The climate here is characterized by high daily temperatures, cool nights, and low annual rainfall.

The study area was located about 56 kilometers (40 miles) northwest of Tucson in the Avra Valley which runs in a north-south direction along the Santa Cruz River. This river is typical of the region in that it contains water only rarely, usually after the heavy summer rainfall.

The lower outwash slopes or bajadas (Shreve 1913) are heavily cultivated. The principal crops are cotton (*Gossypium hirsutum*), milo maize (*Sorghum vulgare*), and lettuce (*Lactuca sativa*) with some corn (*Zea mays*), alfalfa (*Medicago sativa*), and grains. Those areas of the lower bajadas not under cultivation are characterized by nearly pure stands of *Larrea* sp. and *Franseria* sp.

On the upper bajadas, where fewer human disturbances have occurred, the vegetation is more representative of the

Sonoran Desert with Larrea sp. and Franseria sp. dominating. Also found in this region are Cercidium sp., Olneya sp., Acacia sp., and Carnegiea sp.

Rabbits (in this report, the term rabbits refers to both the rabbit, Sylvilagus auduboni, and the hares, Lepus californicus and L. alleni) were collected through the valley from the valley floor upwards on the bajadas to the foothills. All were collected along secondary roads.

The most productive areas for collecting were on the edges of tracts of natural desert vegetation. The cottontails were more abundant near the watercourses and other locations providing thicker vegetative cover. The jackrabbits were more readily found in areas of less dense vegetation and in barren fields. The Lepus alleni, particularly, were associated with large natural and artificial expanses practically devoid of plant life.

The rain gauges, vegetation transects, and census routes were located on the upper bajada on a tract of approximately 259 hectares (640 acres). This study area was 8 kilometers (5 miles) east of the town of Silverbell (T12S, R9E, portions of Sec 14, 15, 22, 23, 24).

METHODS AND MATERIALS

Reproductive Analysis

Lepus alleni, *Lepus californicus*, and *Sylvilagus audubonі* were collected from the Silverbell bajada and adjacent Avra Valley twice monthly at night with the aid of high intensity lights. From the start of this study in March of 1971 until April of 1972, an effort was made to collect 10 females of each species. In June of 1972 the rate of collection was reduced to five females of each species each month. This rate was continued to the end of the study in December of 1973.

Owing to the low densities found in the rabbit populations in this region, collections were made in the areas of natural vegetation remaining on the lower bajada among the cultivated fields as well as in those areas of unbroken natural vegetation on the higher reaches of the valley. However, the sample was unbiased in that an effort was made to collect every rabbit encountered, regardless of size or species, until the monthly quota of females had been reached.

The collected rabbits were refrigerated on arrival back on The University of Arizona campus and within 24 hours of collection the eyeballs, one half of the mandible, one humerus, and the reproductive organs were removed, tagged, and stored. Weight and standard measurements were taken and recorded along with the incidence of parasites, testes position, nipple pigmentation, lactation, and the number of visible implanted fetuses.

The reproductive organs were stored in 10 per cent formalin and analyzed within 2 weeks of collection as follows:

1. The testes were stripped of all associated structures, dried by rolling on paper towelling, and weighed to the nearest 0.1 gram.
2. The ovaries were grossly sectioned with a scalpel and examined macroscopically for the number and size of corpora lutea and corpora albicantia.
3. The presence or absence of striations of the uterine horns was recorded along with the number and location (left or right horn) of visible implantation sites.
4. The embryos were weighed to the nearest 0.1 gram, measured crown to rump to the nearest millimeter, sexed if more than half term, and aged by comparison with the references given below.

As no previous work has been done on the prenatal development of the species of rabbits involved in this study, the desert cottontail fetuses were aged from Rongstad's (1969) work on the gross prenatal development of the eastern cottontail (*Sylvilagus floridanus*). Jackrabbit fetuses were compared to the criteria in Gross (1967), which were modified from Bookhout's (1964) study of the snowshoe hare (*Lepus americanus*).

Aging Techniques

Following the methods of Lord (1959), the eyeballs were stored in 10 per cent formalin for at least 30 days after which the lenses were removed and dried in a vacuum oven at 80 C for 4 days. After drying, the lenses were weighed on a Metler balance to the nearest 0.1 milligram. It was found that drying for more than 4 days resulted in an additional loss of less than 1 per cent.

The closure of the epiphyseal cartilage was examined and recorded after the humeri had air dried for 1 week. The cartilage was examined by scraping with a scalpel held with the blade perpendicular to the surface of the bone. Any indentation, however slight, felt while scraping the scalpel over the area of the epiphyseal cartilage was taken as an indication that the cartilage was open. Those animals with an open epiphyseal cartilage were classified as juveniles and those with a closed cartilage as adults (Hale 1949). This classification was applied regardless of the time of year the animal was collected.

Census

Rabbits were censused monthly along a 7.8 kilometer (4.9 mile) route. The route consisted of four 1.6 kilometer (1 mile) strips, 0.4 kilometer (one quarter mile) apart. The 1.6 kilometer strips were oriented in a north-south pattern perpendicular to the main drainage on the study area. This was done to insure a representative sample of the dominant cover types and to avoid moving parallel to any of the washes through the atypical, dense vegetation occurring there.

The census route was covered in a zig-zag fashion, that is, south on the first strip, east 0.4 kilometer, north on the second strip, east 0.4 kilometer, south on the third strip, etc. An effort was made to walk the census route between the hours of 10 a.m. and 2 p.m. as this was the time of day jackrabbits were found to be most inactive and ". . . likely to react in a similar manner" (Lechleitner 1956, p. 91). The observer(s) recorded species and flushing distance at each encounter. Adult and juvenile sightings were not separated except in the case of two obviously young cottontails which flushed within 3 meters (10 feet).

The King Strip method reported by Hayne (1949) was used to compute the estimated population levels as Hayne's modified method proved to be unreliable with the low densities found on the study area.

In March and again in October of 1973, drive censuses were made through the upper bajada to provide a control for the strip censuses. In these drives, men were spaced at 30 meter (33 yard) intervals in March and at 40 meter (44 yard) intervals in October along a previously marked line. The drive moved south 1.6 kilometers (1 mile) through the study area to the paved Avra Valley Road. Here two or three men were stationed to count the rabbits crossing the highway. The drivers counted those rabbits passing back through the line between themselves and the man on their left. The man on the right end of the line also counted those rabbits passing the line on his right.

In March, the drive consisted of 38 men who covered an area of 181 hectares (448 acres). In October, the drive was made up of 22 men covering 155 hectares (384 acres).

Both drive censuses were manned by volunteers. While some of the drivers had spent time as hunters, hikers, and bird watchers and thus could be expected to be more reliable observers, some had no previous experience with this type of activity. No effort was made to determine the balance of experienced and unexperienced observers present in each drive. The close correspondence of the results of the drive censuses and strip censuses seems to substantiate the density estimates based on the strip censuses.

Vegetative Analysis

Two plant transects, each 1.6 kilometers (1 mile) in length, were established on the study area. The undisturbed site transect was situated along one of the census routes through an area of natural vegetation. The disturbed site transect was located along the gas pipeline clearing and road which passes through the study area. This second transect was traveled in a zig-zag pattern which crossed and re-crossed the road to provide a sample of the plants throughout the entire disturbed area. The disturbed area averages 40 meters (43.6 yards) in width. The presence of creosote bush (*Larrea tridentata*), the dominant natural species on this site, was used as an indicator of the edge of the disturbed area.

The overall plant coverage on the study area is fairly uniform with the exception of dense, linear strips of vegetation along the watercourses. Both transects were oriented perpendicular to these drainages to provide the most representative sample of the whole study area.

Except during February and May of 1972, both transects were sampled monthly in 1972 and 1973. A drop frame with an area of 1 square meter was used to take a sample every 20 meters (21.8 yards) along the transects. A record of each species encountered in each sample was made and the resulting data were used to calculate the per cent occurrence of the individual species. As the original intent was to work with species only, the data were recorded in a manner that prevented the calculation of the per cent occurrence of groups of plants (i.e., grasses, forbs, etc.). However, the number of species encountered after the summer rains made it obvious that to be manageable, the data would have to be condensed. As the data had been generated in a consistent manner throughout, it was decided to clump the individual plant species into groups of grasses, forbs, shrubs, trees, and cactus. Consequently, the relative abundances of the plant groups presented here are not representative of the actual field conditions, but rather are indices used to compare one month to the next.

The relative abundance figures were calculated from the per cent of occurrence figures as in the following example:

Species	Per cent occurrence	Relative abundance
A	65.0	65.0/130.0 = 50.0%
B	40.0	40.0/130.0 = 30.8%
C	25.0	25.0/130.0 = 19.2%
	100.0	100.0%

To arrive at the per cent occurrence figures for each of the different plant groups, the figures for the individual species in that group were totaled.

Rainfall

During 1972 and 1973, monthly readings of precipitation were taken from six accumulating rain gauges placed on the census and plant transect areas. These gauges were constructed from glass gallon jugs and straight-sided, metallic funnels (Coleman Company 1A). The gauges were placed in the middle of clumps of *Franseria deltoidea* to minimize the interference by livestock and wild animals. The tops of the surrounding vegetation was pruned back so as not to extend above the tops of the funnels. Approximately 100 milliliters of kerosene were poured into each gauge monthly to prevent evaporation of the collected rainfall.

The rainfall was measured by pouring the kerosene-water mixture into a graduated cylinder, allowing the two liquids to separate, recording the total amount of water in milliliters and using a conversion factor to change this figure into centimeters of rainfall. The mean of the individual readings was taken as the total monthly precipitation.

Rainfall data for 1971 came from the U. S. Weather Bureau recording station at the town of Silverbell, 8 kilometers (5 miles) to the west and 150 meters (500 feet) higher in elevation.

The IBP Avra Valley study plot included in Table 1 is a meteorological station operated by The University of

Table 1. The monthly precipitation (centimeters) on the upper bajada study area -- This study compared with the records of the town of Silverbell, 8 kilometers (5 miles) to the west, the 15 year mean at Silverbell, and the IBP Avra Valley study plot, 7.2 kilometers (4.5 miles) to the north.

		Month												
Year	Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1971	Silverbell	0.08	1.50	T	0.53	0.00	T	2.29	15.88	7.32	7.98	0.28	2.90	38.76
	IBP							9.47	11.04	12.19	2.97	0.25	2.81	
	This Study													
1972	Silverbell	0.00	0.00	0.00	0.00	0.91	5.44	2.77	4.44	3.43	14.22	7.52	2.90	41.63
	IBP	0.00	0.00	0.00	0.00	0.33	1.65	5.61	5.59	4.32	9.91	4.70	1.52	33.63
	This Study	0.00	0.00	0.00	0.00	0.20	7.62	4.44	6.35	3.25	11.63	5.64	1.12	40.25
1973	Silverbell	0.51	7.01	8.86	0.20	0.81	0.89	2.26	0.00	0.00	0.00	1.68	0.00	24.91
	IBP	0.00	4.88	8.76	0.00	0.94	1.27	1.60	1.01	0.00	0.00	2.77	0.00	21.23
	This Study	1.19	6.76	8.43	0.48	0.96	2.59	0.66	1.55	0.15	0.00	4.22	0.00	26.99
1959-1973	Silverbell	1.60	2.21	1.78	0.64	0.28	0.91	3.73	6.32	3.71	1.83	2.21	4.37	31.06

Arizona Department of Watershed Management for the International Biological Program.

RESULTS

Rainfall

The normal precipitation pattern in the Sonoran Desert near Tucson has been described by Shreve (1951) as being divided into two major periods. The winter period begins in December and continues through the end of March or the middle of April. The summer rainfall is more strictly limited to July, August, and early September. Of course, precipitation can and does occur during all months of the year, but the major rains fall at these times. At Tucson the amount of precipitation is usually equally divided between the winter and summer rains.

The monthly precipitation totals presented in Table 1 show the winter rains of 1971-72 to have been practically nonexistent. In fact, the spring of 1972 (January through April) was the driest on record for the previous fifteen years. However, the extra heavy winter rains of 1972-73 brought the annual total for 1972 above the annual mean. The 1972-73 winter rains produced an unusually large abundance of forbs and grasses in the spring months of 1973.

Note the second departure from the normal precipitation pattern during this study, the virtual lack of summer rains in 1973. Thus, although the spring of 1973 was extremely favorable in terms of available vegetation, the deficient summer precipitation that year brought about the reverse situation with the abundance of forbs and grasses falling below the levels seen in the dry spring of 1972.

Vegetation

The above two rainfall deviations provided this study with an excellent opportunity to evaluate the effects of precipitation and the resulting vegetative response on the reproductive levels of the Sonoran Desert lagomorphs.

The scientific names of the plants encountered on both the disturbed and undisturbed site transects and their classification as to the major plant groups used in this study are found in Appendices A and B. All plant names follow Kearney and Peebles (1969).

As can be seen from Appendices A and B, the disturbed site supports more species than the natural area. Some of the plants found on the disturbed area are strictly disturbed site species and are not found elsewhere in the study plot. Other plants found on the disturbed site also occur on the natural areas but at such low frequencies as to not appear in the transect results.

Appendices C and D present the vegetative transect results in the form of per cent occurrence and relative abundance index for the major plant groups. These figures indicate a marked and rapid increase and decrease of plant life in response to the deviations from normal precipitation patterns mentioned earlier. The values for grasses and forbs, reported by Vorhies and Taylor (1933) and DeCalesta (1971) as comprising the bulk of the rabbit diet, are also presented in graphic form in Figures 1 and 2. As is evident, the winter-spring of 1972-73 had a higher than usual level of those plants shown to be the most important in the rabbit diet. The low levels of these same plants in the summer and fall of 1973, as compared to the 1972 results, indicates the response to the below normal precipitation of that period.

Reproduction

Table 2 shows the monthly rabbit collections from the Avra Valley. As indicated by the χ^2 values and associated probabilities, the sex ratios do not differ significantly from the expected 1:1.

The reproductive activity of the collected females is summarized in Table 3. Upon examination and classification, it was noted that many of the females had recently given birth to a litter but were not yet pregnant again. In order to include these individuals in the estimates of reproductive activity, the category "lactating only" was introduced. The inclusion of all lactating females not visibly pregnant possibly inflates the estimated monthly levels of reproduction slightly as an animal collected during the first of the month could have dropped her litter

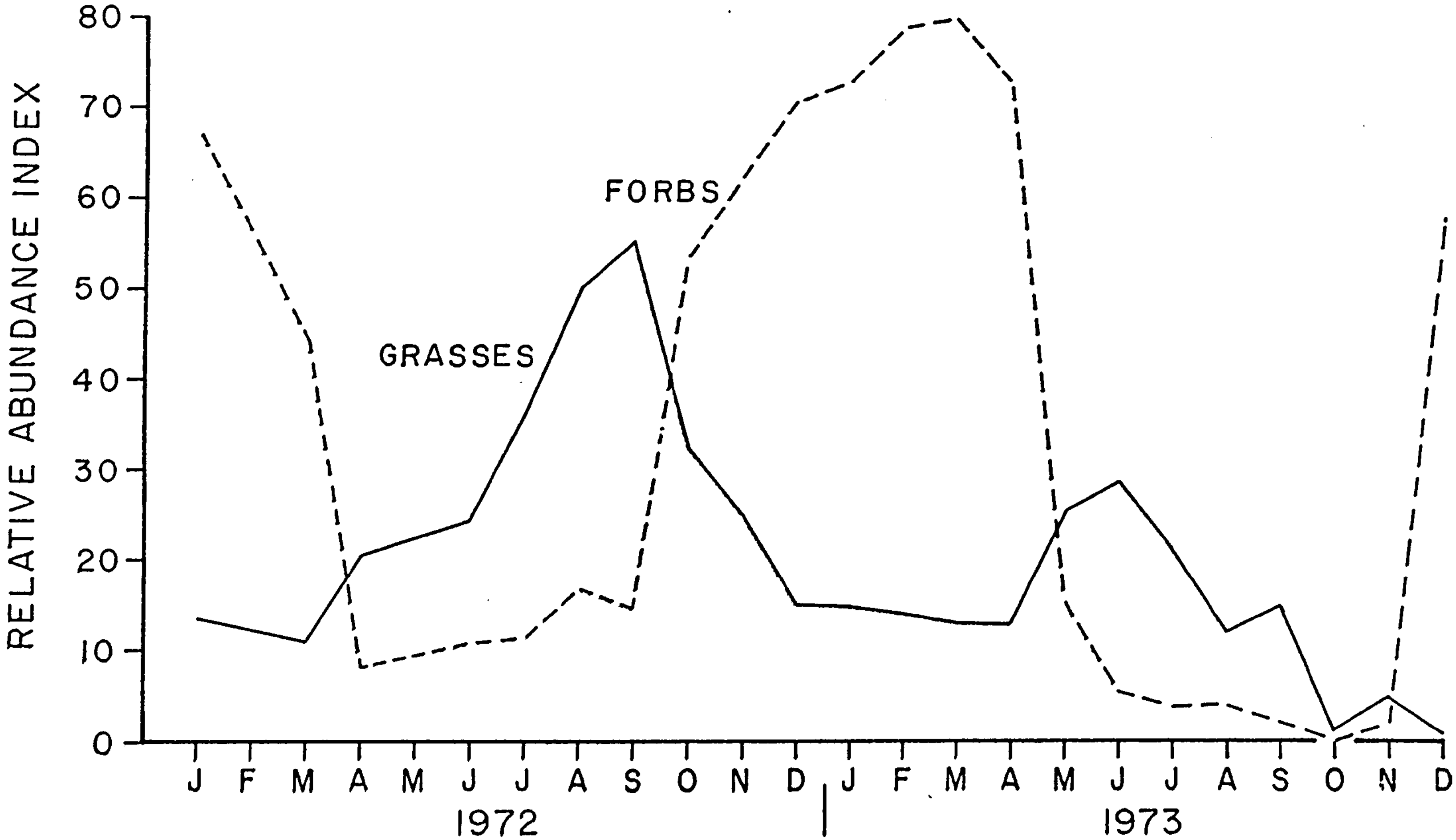

Figure 1. Relative abundance index for grasses and forbs on the disturbed site, upper bajada study area -- No sample taken during February or May, 1972.

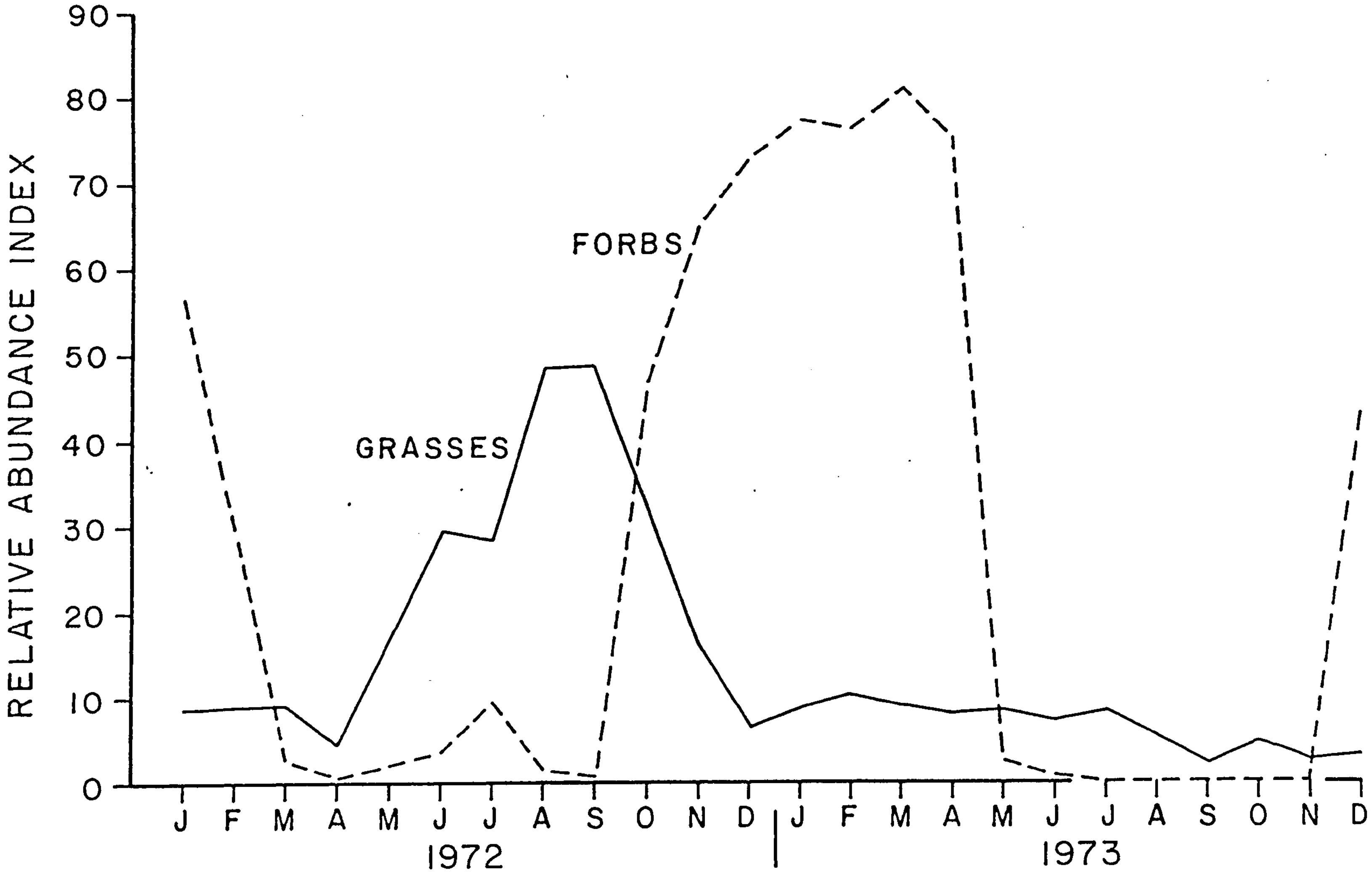

Figure 2. Relative abundance index for grasses and forbs on the undisturbed site, upper bajada study area -- No sample taken during February or May, 1972.

Table 2. The monthly and annual summaries of the rabbits collected in the Avra Valley, Arizona.

	S. auduboni			*L. californicus*			*L. alleni*		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1971									
Jan									
Feb									
Mar				2	1	1			
Apr	9	3	6	5	2	3	4	3	1
May	19	13	6	23	12	11	12	6	6
Jun	19	6	10	22	12	10	16	6	10
Jul	15	5	10	24	14	10	7	3	4
Aug	10	6	4	15	8	7	16	9	7
Sep	4	1	3	18	8	10	16	7	9
Oct	3	1	2	24	14	10	14	4	10
Nov	5	3	2	14	4	10	24	14	10
Dec	2	1	1	12	2	10	22	12	10
	86	42	44	159	77	82	131	64	67
	(χ^2 = .046, $p < .25$)			(χ^2 = .158, $p < .50$)			(χ^2 = .068, $p < .25$)		
1972									
Jan	5	5	0	21	12	9	15	5	10
Feb	3	1	2	24	14	10	22	12	10
Mar	10	8	2	23	11	12	17	7	10
Apr	11	5	5	14	4	10	21	12	9
May									
Jun	9	4	5	6	1	5	11	6	5
Jul	11	6	5	6	1	5	6	1	5
Aug	9	4	5	9	4	5	7	2	5
Sep	6	1	5	5	0	5	13	8	5

Table 2.--Continued

	S. auduboni			*L. californicus*			*L. alleni*		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
Oct	8	3	5	7	2	5	6	1	5
Nov	6	1	5	9	4	5	9	4	5
Dec	10	5	5	9	4	5	16	11	5
	88	43	45	133	57	76	143	69	74
	(χ^2 = .046, p < .25)			(χ^2 = 2.443, p < .90)			(χ^2 = .174, p < .50)		
1973									
Jan	8	3	5	9	3	6	15	10	5
Feb	12	7	5	15	10	5	15	10	5
Mar	9	4	5	6	1	5	13	8	5
Apr	11	6	5	11	6	5	11	6	5
May	6	1	5	8	3	5	11	6	5
Jun	11	6	5	12	7	5	8	3	5
Jul	14	9	5	9	4	5	8	3	5
Aug	10	5	5	14	9	5	13	8	5
Sep	9	4	5	7	2	5	6	1	5
Oct	8	3	5	7	2	5	12	7	5
Nov	8	3	5	5	0	5	8	3	5
Dec	10	5	5	8	3	5	8	3	5
	116	56	60	111	50	61	128	68	60
	(χ^2 = .138, p < .50)			(χ^2 = 1.090, p < .75)			(χ^2 = .500, p < .75)		

Table 3. The monthly and annual summaries of the reproductive activity of the female rabbits collected in the Avra Valley, Arizona.

	S. auduboni			*L. californicus*			*L. alleni*		
	Preg.	Preg. and Lact.	Lact.	Preg.	Preg. and Lact.	Lact.	Preg.	Preg. and Lact.	Lact.
1971									
Jan	--	--	--	--	--	--	--	--	--
Feb	--	--	--	--	--	--	--	--	--
Mar	--	--	--	1			--	--	--
Apr	2	3		2		1	1		
May	3	3		3	6		1	1	
Jun	3	5	2	4	2	1	6	1	3
Jul	2	4	2	2	4	4	2	1	1
Aug		2	2	2	3	1	1	5	
Sep		1	1		5	2	2	3	4
Oct		1	1		2	5		3	6
Nov			1	1	1	2	1	1	1
Dec				3	4		3	4	
	10	19	9	18	27	16	17	19	15
1972									
Jan	--	--	--	1	4	3	4	3	1
Feb		2		1	9		1	7	1
Mar		1	1		6	5		5	4
Apr	1	2	2		6	4	2	3	1
May	--	--	--	--	--	--	--	--	--
Jun		3	1		3	1		4	1
Jul	2	3		2	2	1	1	4	
Aug	1	3	1		5			3	1
Sep		2	1		2	3		2	

Table 3.--Continued

	S. auduboni			*L. californicus*			*L. alleni*		
	Preg.	Preg. and Lact.	Lact.	Preg.	Preg. and Lact.	Lact.	Preg.	Preg. and Lact.	Lact.
Oct		1		1		4		1	
Nov		1	2	1	1			2	
Dec		1	1	2	2	1	2		1
	4	19	9	8	40	22	10	34	10
1973									
Jan		5			6		2	3	
Feb		3	2	1	3	1		3	2
Mar		5			4			2	2
Apr		5		1	3			5	
May	1	2			3			1	1
Jun		2	1		2	2		3	
Jul		5			3	1		2	2
Aug		2	1	1	3			1	2
Sep		1	1			3		1	2
Oct			1			1			2
Nov			1			1			2
Dec				1					
	1	30	7	4	27	9	2	21	15

in the latter part of the previous month and still be lactating.

In classifying the rabbits as pregnant or not pregnant, the problem arose of how to categorize those females with corpora lutea in their ovaries but with no discernible fetuses. The possible explanations for this condition are: (1) preimplant, (2) pseudopregnant, (3) resorption of the total litter, or (4) recent parturition with no post-partum conception, that is, the corpora lutea are of the just terminated pregnancy.

Possible explanation (2) has been disregarded on the basis of the report by Wight and Conaway (1962) that pseudopregnancy occurs but rarely in the wild. As for explanation (4), Lechleitner (1959) states that the identifiable characteristics of the corpora lutea change ". . . almost instantly . . . " (p. 72) upon the termination of the pregnancy to those of the corpora albicanta. Thus, a corpus albicans of a recent parturition would not be confused with a corpus luteum of a current pregnancy. I have assumed that the same situation exists in the event of the resorption of the entire litter. That is, the change from corpora lutea to corpora albicantia would be completed by the time the embryos were completely resorbed. In this manner, explanation (3) was also disregarded.

According to the foregoing, those females with corpora lutea but with no discernible fetuses were classified as being in the preimplant stage and included with the obviously pregnant females. If it happens that the above reasoning does not hold true regarding the rapid change of the corpora lutea to corpora albicantia upon the resorption of the entire litter, the amount of error introduced by including the class (3) females with class (1) will be negligible. This estimate is based on the number of females with discernible litters which were being resorbed in full. Of the 569 females collected over the entire study, only seven (one *Sylvilagus auduboni*, two *Lepus californicus*, and four *Lepus alleni*) were in this category. This indicates the percentage of discernible total resorptions during the study was less than 1.0 per cent for *Sylvilagus auduboni*, less than 1.0 per cent for *Lepus californicus*, and less than 2.0 per cent for *Lepus alleni*.

The ratio of the number of corpora lutea to the number of fetuses was calculated with the thought that if the ratios were higher during the periods of maximum breeding, the classification of all females as preimplant which exhibited the conditions set forth above would be further justified. The results of this calculation are shown in Figure 3.

As seen in Figure 4, the lowest percentage of reproductively active females in all three species was found during the October-November-December period of each year. Reproductive activity was at its highest mainly

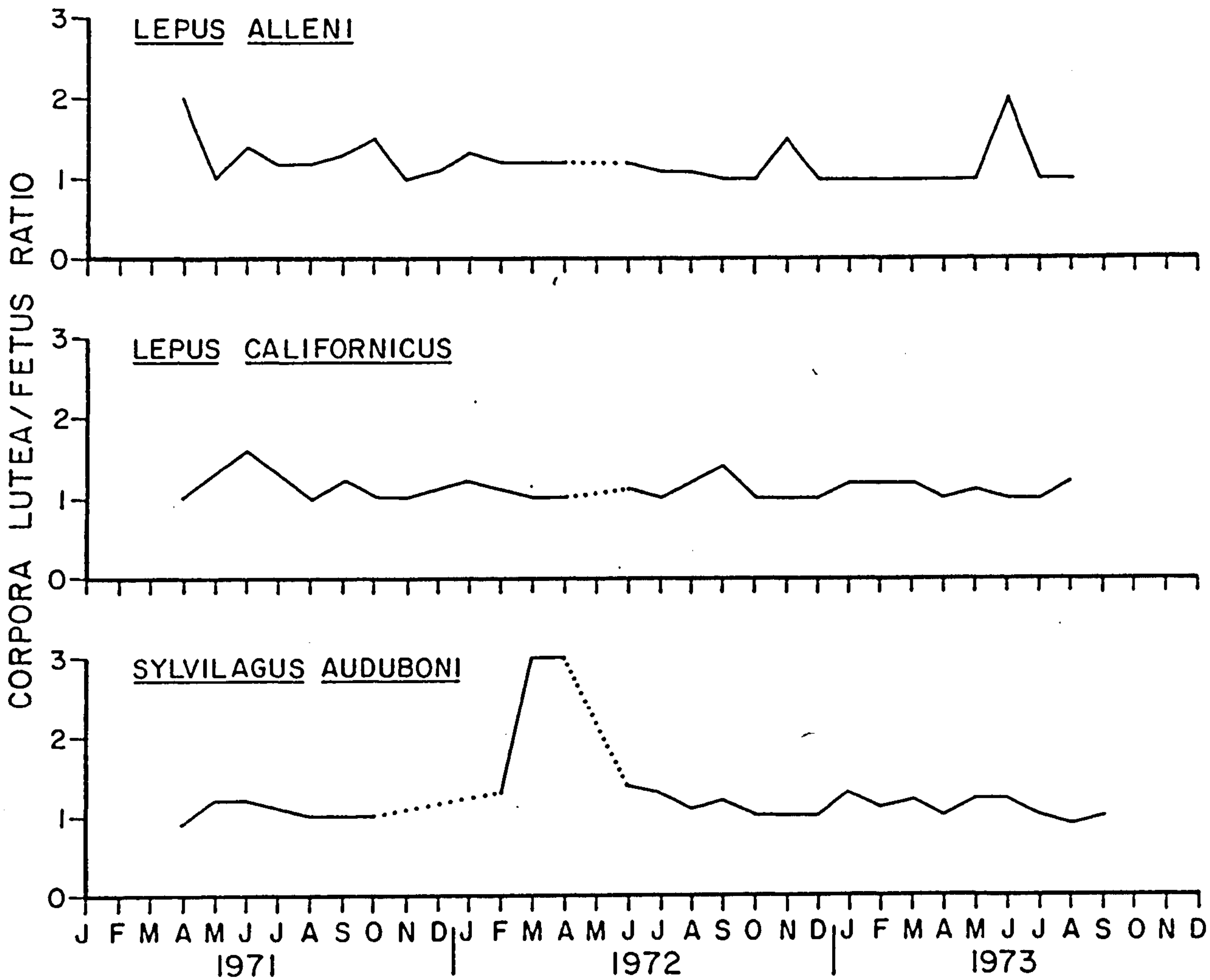

Figure 3. Ratio of the number of corpora lutea to the number of discernible fetuses in all pregnant females collected in the Avra Valley, Arizona.

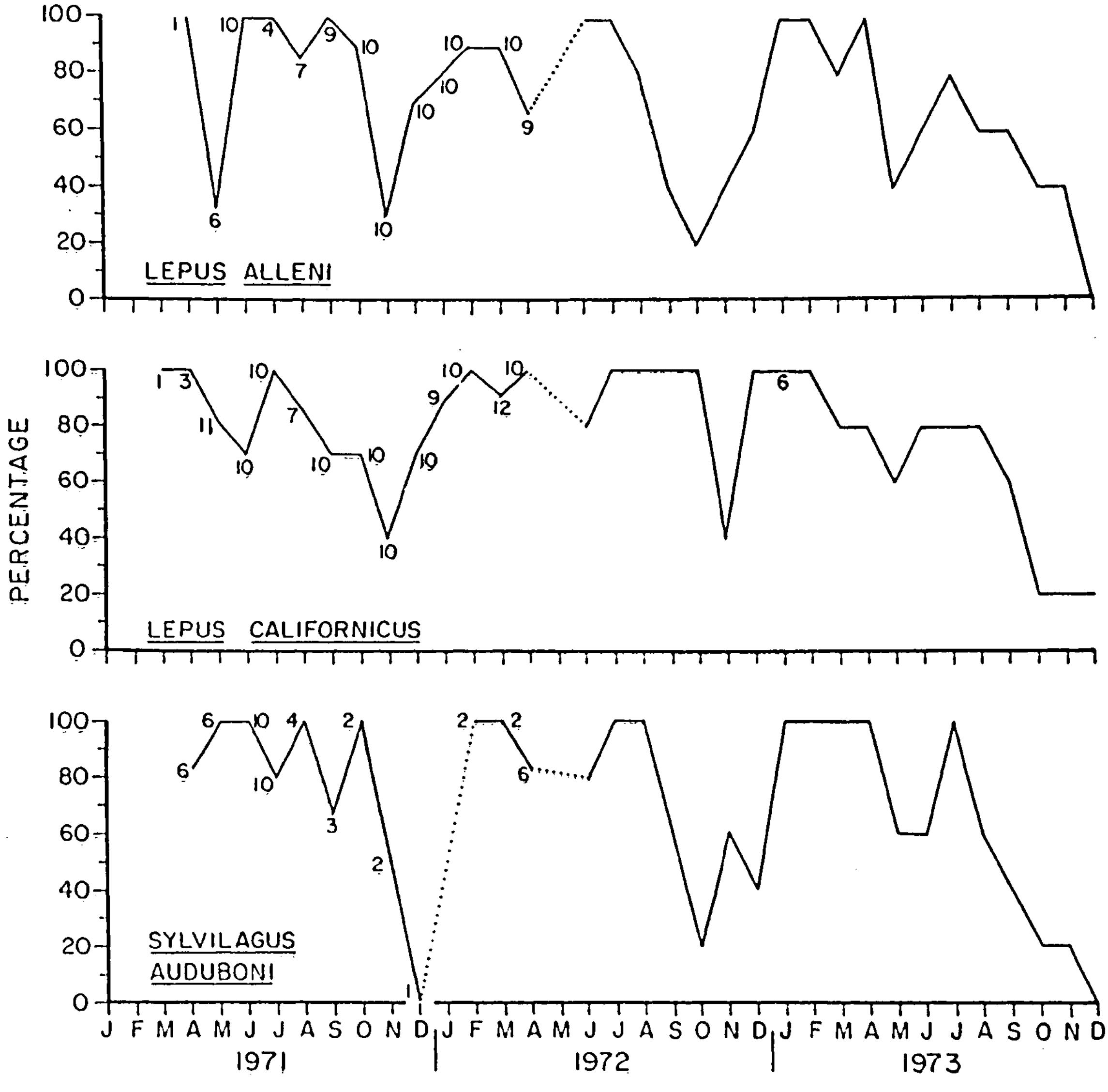

Figure 4. The percentage of reproductively active females collected in the Avra Valley, Arizona -- The number of individuals examined each month was five except where otherwise noted. Females pregnant or lactating were considered reproductively active.

during the January-February-March period and again in the July-August period. By inspection of Figure 4, 20 per cent appears to be the normal basal rate of reproductive activity in all three species during this study.

The comparison of the corpora lutea/fetus ratios shown in Figure 3 and the per cent of reproductively active females shown in Figure 4 confirms the assumption that those females with corpora lutea in their ovaries but with no discernible fetuses were probably in the preimplant stage of pregnancy. That is, the higher corpora lutea/fetus ratios were within the periods of highest breeding activity or within those periods immediately preceding the peaks of activity.

The above periods of high and low reproductive activity are also seen in the mean, paired testes weights of adult males in the collection. These means are presented in Figure 5. The period of high activity, here indicated by the heavier testes weights, is during the January-February-March period with a secondary peak in the late summer and the period of low activity occurring in October-November-December.

Figures 6, 7, and 8 present the conception dates of the pregnant females of *Sylvilagus auduboni*, *Lepus californicus*, and *Lepus alleni*, respectively. These dates were calculated by aging the fetuses and back-dating from the collection dates. Those females having no discernible

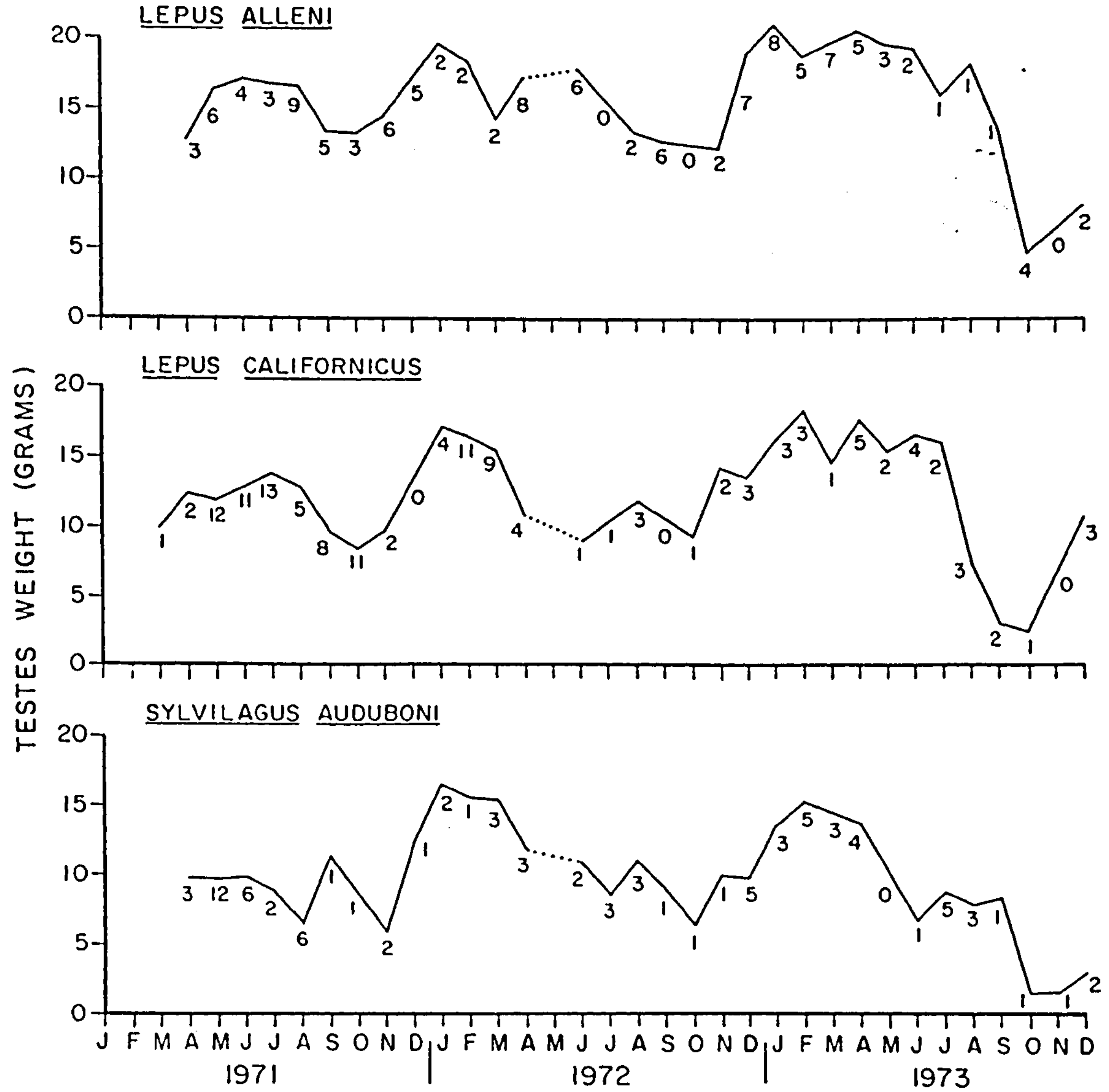

Figure 5. The mean paired testes weights (grams) of adult males collected in the Avra Valley, Arizona.

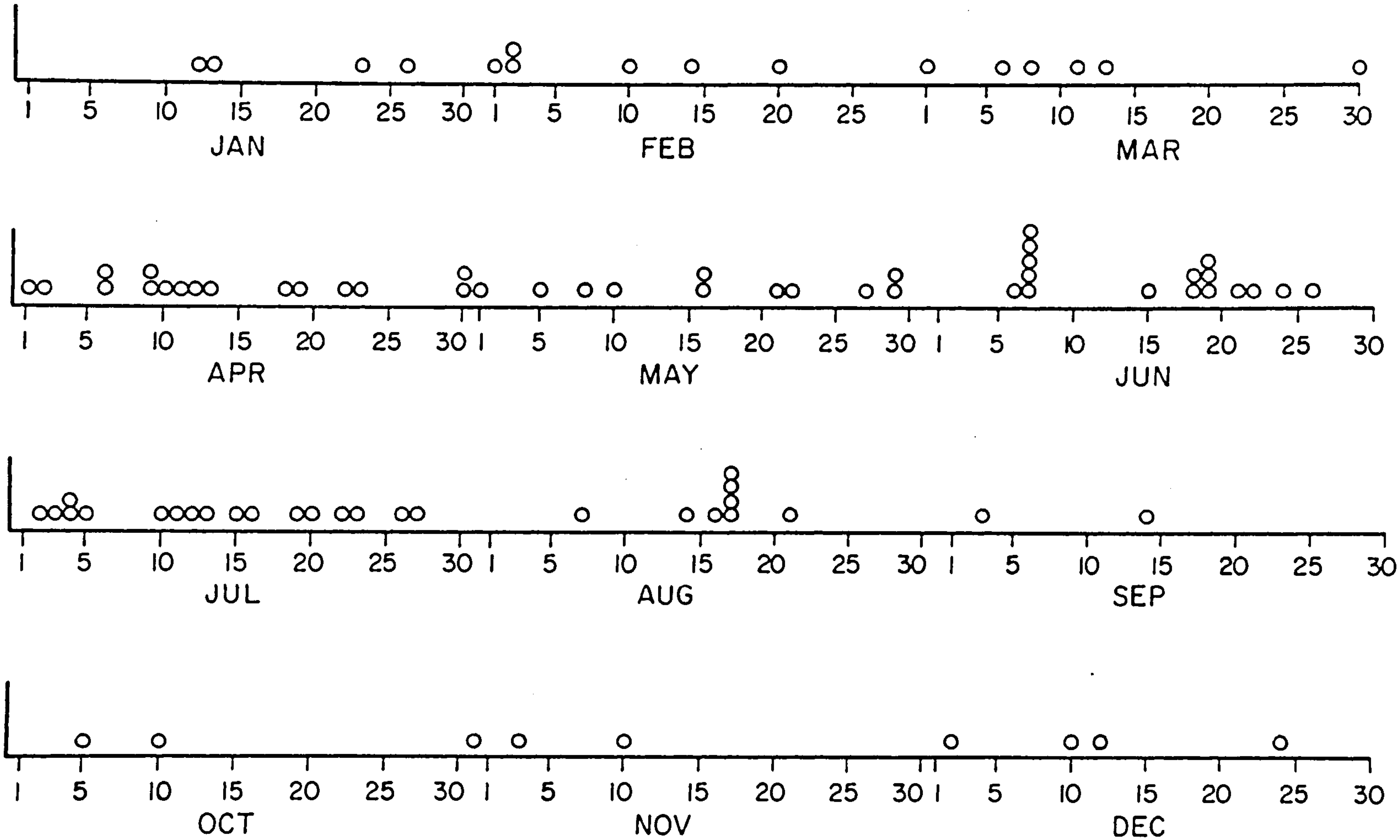

Figure 6. The conception dates of Sylvilagus audubonі from 23 April 1971 through 31 December 1973 -- No collections were made during May, 1972.

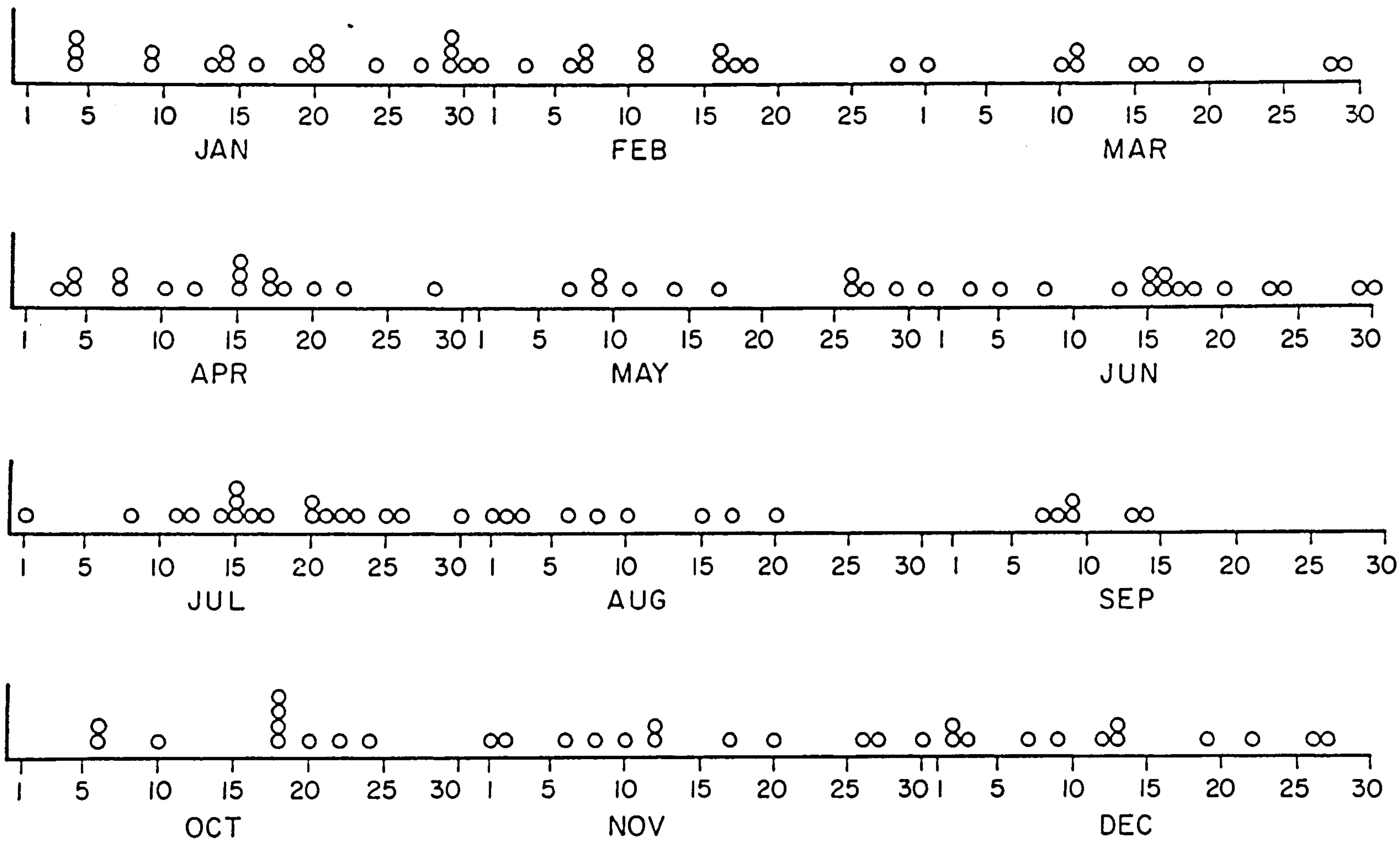

Figure 7. The conception dates of Lepus californicus from 29 March 1971 through 31 December 1973 -- No collections were made during May, 1972.

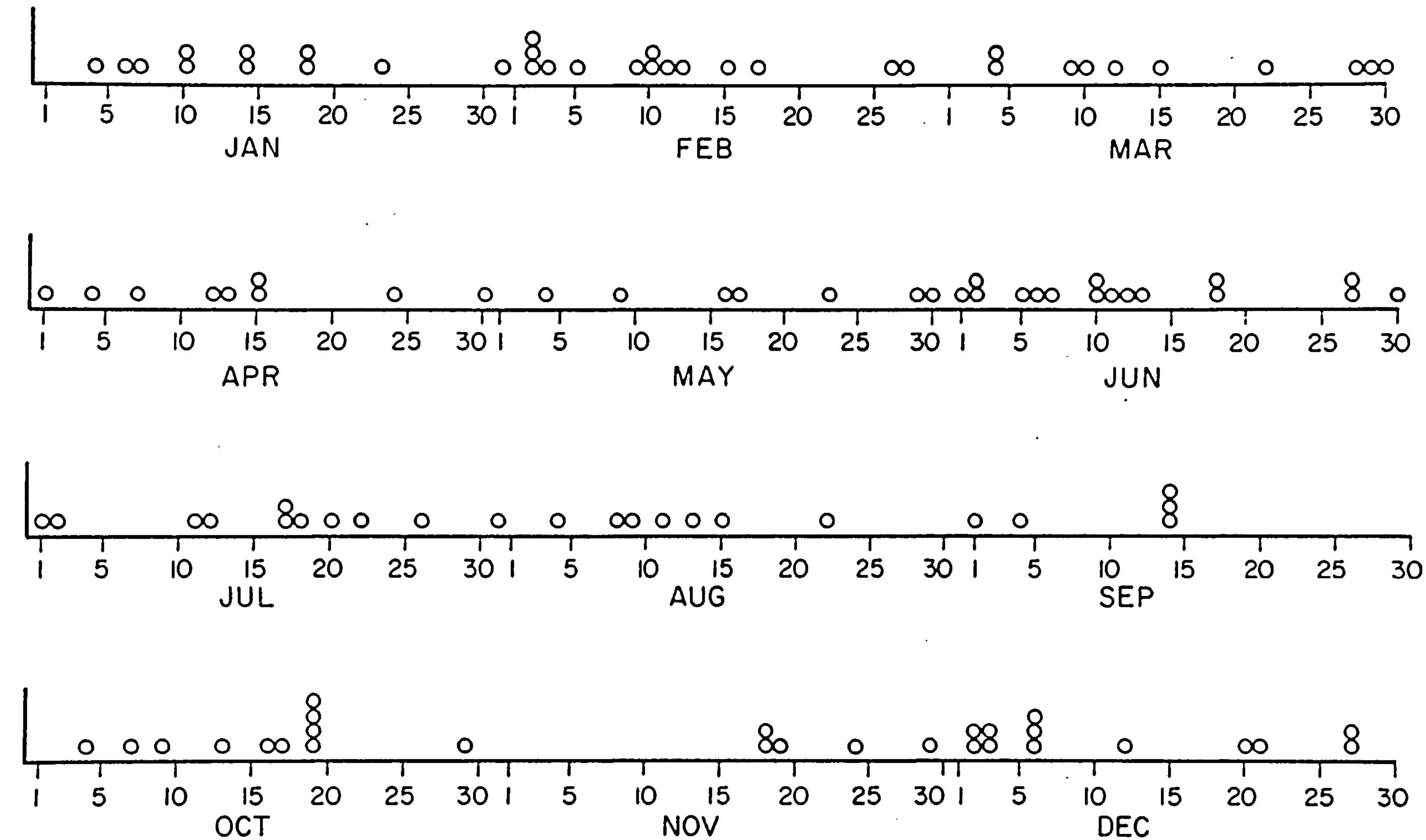

Figure 8. The conception dates of <u>Lepus alleni</u> from 28 April 1971 through 31 December 1973 -- No collections were made during May, 1972.

fetuses and no signs of a recent parturition yet whose ovaries contained corpora lutea were classed in the pre-implantation stage (following the previously discussed criteria) and the fetuses arbitrarily assigned an age of 6 days as the embryo is visibly implanted on about the seventh day in the domestic rabbit (Lechleitner 1959).

No evidence of synchrony was found. Also note that the conception dates reconfirm the periods of high and low reproductive activity mentioned above.

The conception dates extend the previously reported breeding season of the cottontails from January through August (Sowls 1957) to January through December and of both species of jackrabbits from December through September (Vorhies and Taylor 1933) to January through December.

Assuming the number of corpora lutea arising from follicles which shed no ova or more than one ovum to be a very small percentage of the total, the corpora lutea counts were taken as accurate indicators of the number of ova produced. The resulting annual mean ovulation rates are given in Table 4. These means were calculated as the ova per ovulating female with non-pregnant females being excluded.

The annual mean litter sizes presented in Table 5 were calculated from all litters, regardless of age. As this allows no adjustment for prenatal mortality, these estimates are possibly high. In order to determine the magnitude of any possible error introduced with this method,

Table 4. Annual mean ovulation rates (± one standard error of the mean) -- The results of Student's t tests are also given.

	Sylvilagus auduboni	
1971	2.78 ± 0.14	
		df = 63, t = 1.7528, p > .05
1972	3.17 ± 0.18	
		df = 58, t = 1.9505, p > .05
1973	3.68 ± 0.19	
	Lepus californicus	
1971	2.34 ± 0.12	
		df = 118, t = 1.7915, p > .05
1972	2.68 ± 0.14	
		df = 89, t = 2.4322, p < .02
1973	3.31 ± 0.23	
	Lepus alleni	
1971	2.21 ± 0.14	
		df = 97, t = 0.1491, p > .80
1972	2.24 ± 0.14	
		df = 74, t = 3.0588, p < .01
1973	3.00 ± 0.21	

Table 5. Annual mean litter sizes (± one standard error of the mean) -- The results of Student's t tests are also given.

	Sylvilagus audubonі	
1971	2.55 ± 0.18	
		df = 49, t = 0.0344, p > .90
1972	2.54 ± 0.23	
		df = 51, t = 2.1694, p < .05
1973	3.29 ± 0.24	
	Lepus californicus	
1971	1.98 ± 0.12	
		df = 89, t = 2.6742, p < .01
1972	2.48 ± 0.13	
		df = 77, t = 1.8692, p > .05
1973	2.94 ± 0.22	
	Lepus alleni	
1971	1.94 ± 0.17	
		df = 75, t = 0.0415, p > .90
1972	1.93 ± 0.16	
		df = 62, t = 3.1161, p < .01
1973	2.86 ± 0.26	

mean litter sizes were computed over the entire study using first half term litters and last half term litters. The mean litter sizes (± one standard error of the mean) calculated by each method are given below. Also shown are the results of Student's t tests performed on the first half term and last half term means of each species.

Species	First Half Term Litters	Last Half Term Litters
Sylvilagus audubони	2.74 ± 0.19	2.90 ± 0.18
	$t = 0.6219$ df = 78 $p > .50$	
Lepus californicus	2.34 ± 0.14	2.54 ± 0.13
	$t = 1.0340$ df = 119 $p > .30$	
Lepus alleni	1.84 ± 0.14	2.44 ± 0.16
	$t = 2.7333$ df = 96 $p < .01$	

As evidenced by the values for t and the associated probabilities, there are no significant differences between the means computed by these methods for *Sylvilagus audubonі* and *Lepus californicus*.

The significant difference between the means for *Lepus alleni* is not reasonable as the mean litter size based on the last half term litters is larger than the mean based on the first half term litters. This difference could arise from the lack of a sound, definitive aging technique for the fetuses of this species. The aging criteria utilized for the *Lepus alleni* fetuses were developed for the snowshoe hare, *Lepus americanus*. As the length of gestation in the *Lepus alleni* is not known, the gestation period of the *Lepus californicus*, 44 days, was applied. Sizes of the *Lepus californicus* and *Lepus alleni* fetuses judged to be full term indicate that the *Lepus alleni* has a longer gestation period than 44 days. Using aging criteria based on a shorter gestation period to age the *Lepus alleni* fetuses would tend to bias the division of the gestation period in favor of the latter half. I believe this bias is responsible for the difference seen here. However, further investigation into the length of gestation of the *Lepus alleni* is needed to confirm this opinion. Based on the Student's t tests and the above reasoning, the annual means in Table 5 are accepted as presented.

Density

The monthly estimates of population density on the upper bajada study area were quite variable. The source of this variation was not easily identifiable nor was it thought to be constant. The experience of the observer, his mental alertness, and physical well-being during the census all had an effect on the outcome. The flushing behavior of the rabbits, possibly influenced by the time of day, the weather, or the breeding season, was also a cause of variation in the census results.

Changeable as the monthly estimates were, the annual estimates were surprisingly consistent. The Lepus californicus annual means plus or minus one standard error of the mean, expressed as rabbits per 40.5 hectares (100 acres), were: 1971, 2.66 ± 0.75; 1972, 3.27 ± 1.26; 1973, 2.76 ± 0.52. The estimated population density for this species over the entire study period was 2.88 ± 0.46 rabbits per 40.5 hectares. The annual means for the Sylvilagus auduboni were: 1971, 3.38 ± 1.53; 1972, 3.27 ± 0.57; 1973, 3.16 ± 1.03. The overall density was computed at 3.24 ± 0.53 rabbits per 40.5 hectares.

The annual density for 1973 and the overall density for the Sylvilagus auduboni were figured after discarding the monthly estimates for May and July of 1973. These high density levels resulted when obviously very young rabbits flushed close to the observer in the thick vegetation at the bottom of a deep wash. While the monthly densities arrived at using these data might be acceptable estimates of the populations encountered in that habitat type, they can hardly be representative of the entire study area.

An indication that the above estimates of density may be too high is found in the results of two drive censuses conducted on the study area in March and October of 1973. These results are shown in Figure 9 along with the monthly strip census results. While the drive census results displayed a similarity to the strip census results

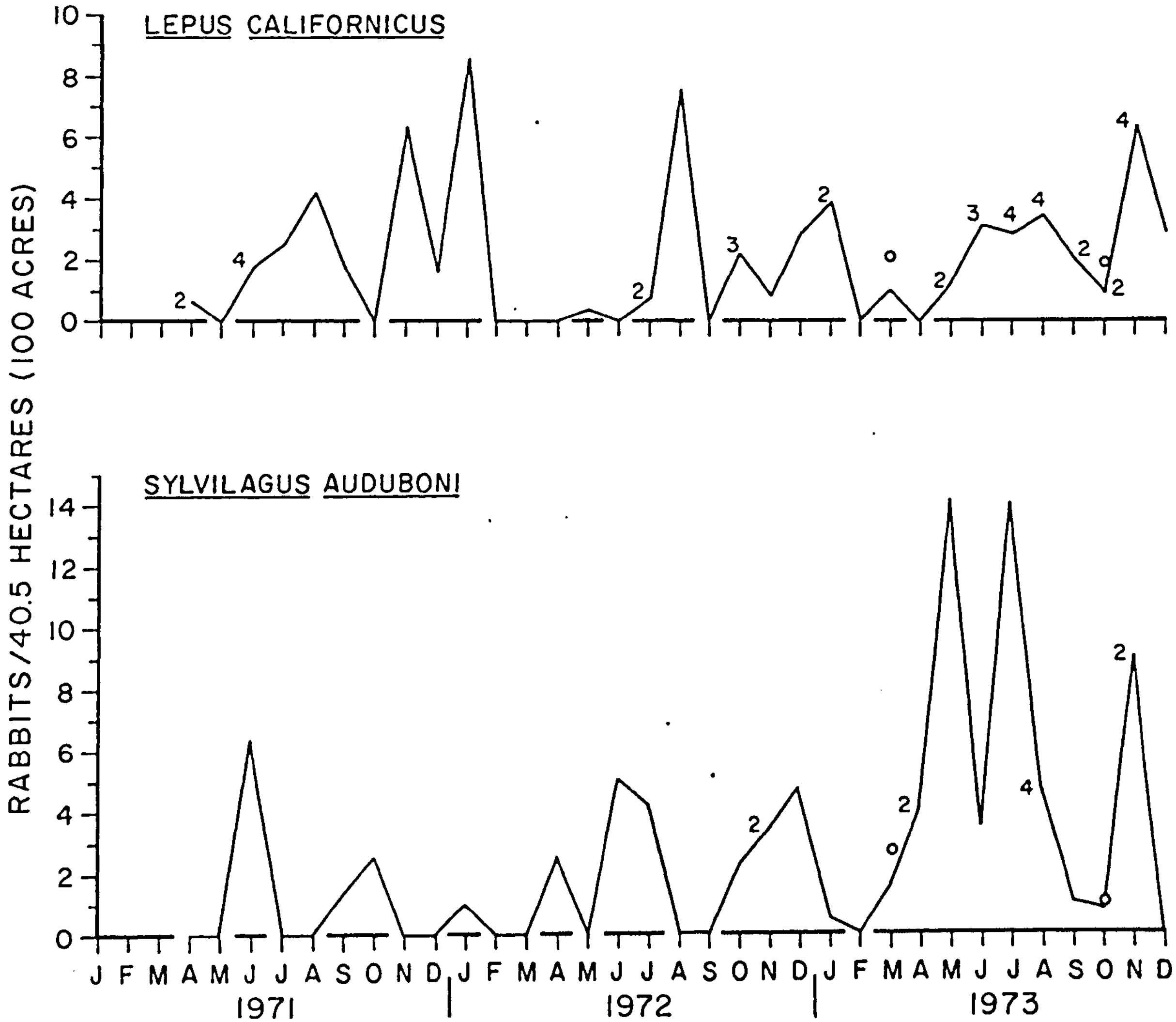

Figure 9. The monthly census results from the upper bajada study area -- All estimates are based on sightings of single animals unless otherwise indicated. The results of drive censuses conducted in March and October, 1973 are shown by open circles.

in these months, they are considerably lower than the annual estimates. The 1973 mean based upon the drive censuses for *Lepus californicus* was 2.02 rabbits per 40.5 hectares and the strip census mean was 2.76 rabbits per 40.5 hectares. The 1973 means for the Sylvilagus auduboni were 1.73 rabbits per 40.5 hectares (drive censuses) and 3.16 rabbits per 40.5 hectares (strip censuses).

DISCUSSION

As will be seen by comparing the precipitation figures for the study area in Table 1 with the results from the natural vegetation transect in Figure 2, the response of the warm season grasses to precipitation is very rapid. The warm season forbs displayed a slower response to the end of the drought. The cool season forbs appeared in number during October of 1972. The timing of the appearance and the magnitude of the green-ups in the summer and winter of 1972 were taken as the norm.

With the lack of summer rains in 1973, the warm season grasses were extremely limited in abundance. The warm season forbs were not in evidence in 1973, a drastic departure from 1972. The deficient summer precipitation in 1973 also delayed the appearance of the cool season forbs from October until December.

With the exception of the warm season grasses, which in 1973 displayed a peak abundance only half that of 1972, the above discussion applies to the disturbed as well as the natural transect results. The major difference between the two areas was that of magnitude with the disturbed area supporting a greater number of plants during the droughts. The timing of the green-up appears to be the same for both areas.

Affects of Rainfall and Vegetation on Reproduction

It is obvious from the results of this study that the reproduction of the Sonoran Desert lagomorphs is affected by precipitation. As suggested in the above paragraphs, I believe the affects of rainfall to be expressed through the vegetative response to that rainfall. I also feel that the populations of desert rabbits in the Tucson area are able to take swift advantage of any favorable changes in the normal pattern of precipitation. In support of these conclusions, the changes in the different measurements of reproductive activity taken throughout this study are discussed in the following pages.

Figures 6, 7, and 8 present the combined conception dates for the entire study. While these figures support the extensions of the breeding seasons for the three species of rabbits, they do not show the annual changes encountered. As the study did not commence until March of 1971, the beginning of the breeding seasons for that year could not be determined.

The first conception date for *Sylvilagus audubonі* in 1972 was 01 February. The last conception date of that year was 24 December. In 1973, the year of the heavy winter rains, the first conception was on 12 January, twenty days earlier than the year before. The lack of summer rains in

1973 cut the breeding season short by 129 days as the last conception date that year was 17 August.

For Lepus californicus, the first conception date in 1972 was 04 January and the last date was 27 December. In 1973 the first conception date was again 04 January but the last date fell on 27 November. This November conception was the only one encountered in this species since 02 August when the breeding season appeared to terminate for that year, 147 days earlier than in 1972.

The pattern seen in the breeding season of Lepus californicus was also apparent in Lepus alleni. In 1972 the first conception date was 06 January and the last was 27 December. The first breeding in 1973 occurred on 04 January, virtually no change from the preceding year. However, the breeding was ended in 1973 by 01 September, a difference of 117 days.

Thus, it appears that the inception of breeding is not greatly affected, if at all, by the winter precipitation. However, the lack of breeding in the fall and winter of 1973 seems to be a direct result of the lack of summer rains during that same year.

Figure 4 shows the monthly percentage of females in the collections which were in an actively reproductive state. By inspection, the only obvious feature is the similarity between species. The percentage of reproductively active females is not noticeably different from one year to the next. The paired, adult testes weights presented in Figure 5 follow the same pattern of reproductive activity seen in the females. Here also, the similarity between species is obvious but no annual changes are apparent.

Although the percentage of females breeding in any one year did not seem to alter, the number of young per litter did increase throughout the study. The annual mean litter sizes given in Table 5 show the amount of change from one year to the next. Also presented are the results of the Student's t tests performed to check the significance of the annual variations. The 95 per cent confidence interval was chosen. As indicated by the values of t and the associated probabilities, the changes in litter sizes were not always significant at that level.

In the annual mean ovulation rates (Table 4) a similar pattern to that of the mean litter sizes is seen. In every case there was a significant increase during the study. However, the annual variations were not always large enough to be considered significant.

When evaluating the amount of increase of the annual mean ovulation rates and the mean litter sizes in 1973 over 1972, it is important to take into account the lack of breeding in the fall and winter of 1973 as evidenced by the conception data. In all three species (with the exception of the one *Lepus californicus* mentioned earlier) there were no pregnant females collected in the last quarter of that year. The levels of reproductive activity in Figure 4 are based upon lactating as well as pregnant individuals, so the absence of pregnant females is not seen. As indicated in Figure 4, reproductive activity was taking place during this time, but the lack of any litters meant the average ovulation rates and litter sizes were calculated from the first nine months of the year only. When viewed in this light, the increases of 1973 over 1972 take on more importance.

The improved productivity resulting from the favorable conditions of the winter of 1972-73 was also expressed in the number of rabbits available during the collecting trips. In an attempt to quantify this subjective observation and evaluation, the number of rabbits collected per hour of hunting effort was calculated for each month of the study. These calculations are presented in graphic form in Figure 10.

As shown, the return per hour of hunting increased throughout the study. The annual mean for 1971 was 2.98 ± 0.57 rabbits per hour (mean ± one standard error of the mean). The 1972 annual mean was 4.07 ± 0.25 rabbits per hour. A Student's t test showed no significant difference between these means at the 95 per cent level ($t = 1.8758$, $df = 18$, $p > .05$). In 1973 the annual mean rose to 5.42 ± 0.83 rabbits for every hour of hunting. This was a significant increase over the 1972 mean ($t = 3.5875$, $df = 21$, $p < .01$).

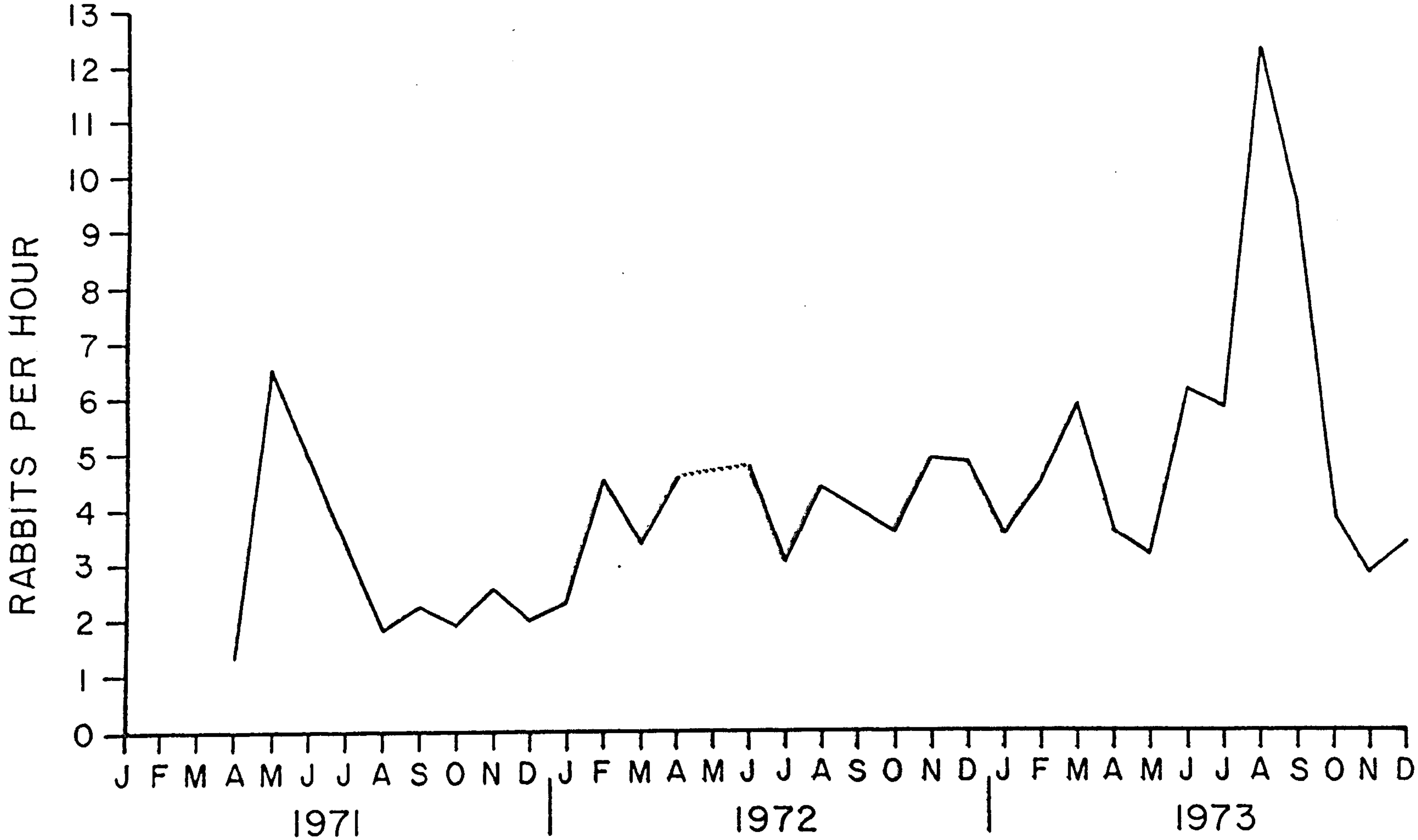

Figure 10. The number of rabbits (all species) collected per hour of hunting effort -- No collections were made during May, 1972.

I recognize the possibility of the increased hunting efficiency resulting from the increased experience of the hunters. However, the mode of hunting had been modified into the most efficient form possible with the given equipment and terrain by the second month of the study (May, 1971). In January, 1972, brighter lights were obtained to use in collecting. These new type lights increased the distance at which rabbits could be seen and thus improved the probability of locating more rabbits. This was the only alteration to the collecting methods made after May of 1971. While the hunters' ability to spot rabbits increased with experience, the drivers' ability to put the shooters in a favorable position remained fairly constant because of the terrain. Therefore, I feel the experince of the hunters added an insignificant amount to the increased hunting efficiency observed.

The largest number of rabbits per hour was collected in August of 1973. During August and September of that year rabbits were seen in irrigated fields for the first time in the entire study. The concentration of rabbits around cultivated crops, brought about by the harsh conditions of that fall, was responsible for an undetermined amount of the increased hunting efficiency.

Notwithstanding the above criticisms of this measurement, I feel the increased number of rabbits collected per hour of hunting effort resulted mainly from the increased productivity discussed earlier.

In addition to improved productivity, the numbers of available rabbits during the collecting trips could have also been increased by the enhanced survival of the young. As an indication of this enhanced juvenile survival, the monthly and annual percentages of juveniles in the collections are shown in Figure 11. Notice the increased proportions of juveniles in the annual populations of all three species during this study.

Thus, the increased productivity, enhanced hunting success, and higher percentages of juveniles in the collections all support the contention that while the above average winter precipitation of 1972-73 did not affect the inception of breeding, the improved range conditions resulting from those rains did raise the level of productivity and the survival of the young.

Density

As was noted in the discussion on hunting efficiency, concentrations of rabbits were observed in and around cultivated crops during August and September of 1973. The attraction of available food and water in times of stress will obviously affect the density of rabbits in the surrounding natural areas. The census routes for this study were located approximately 6.4 kilometers (4 miles) from the

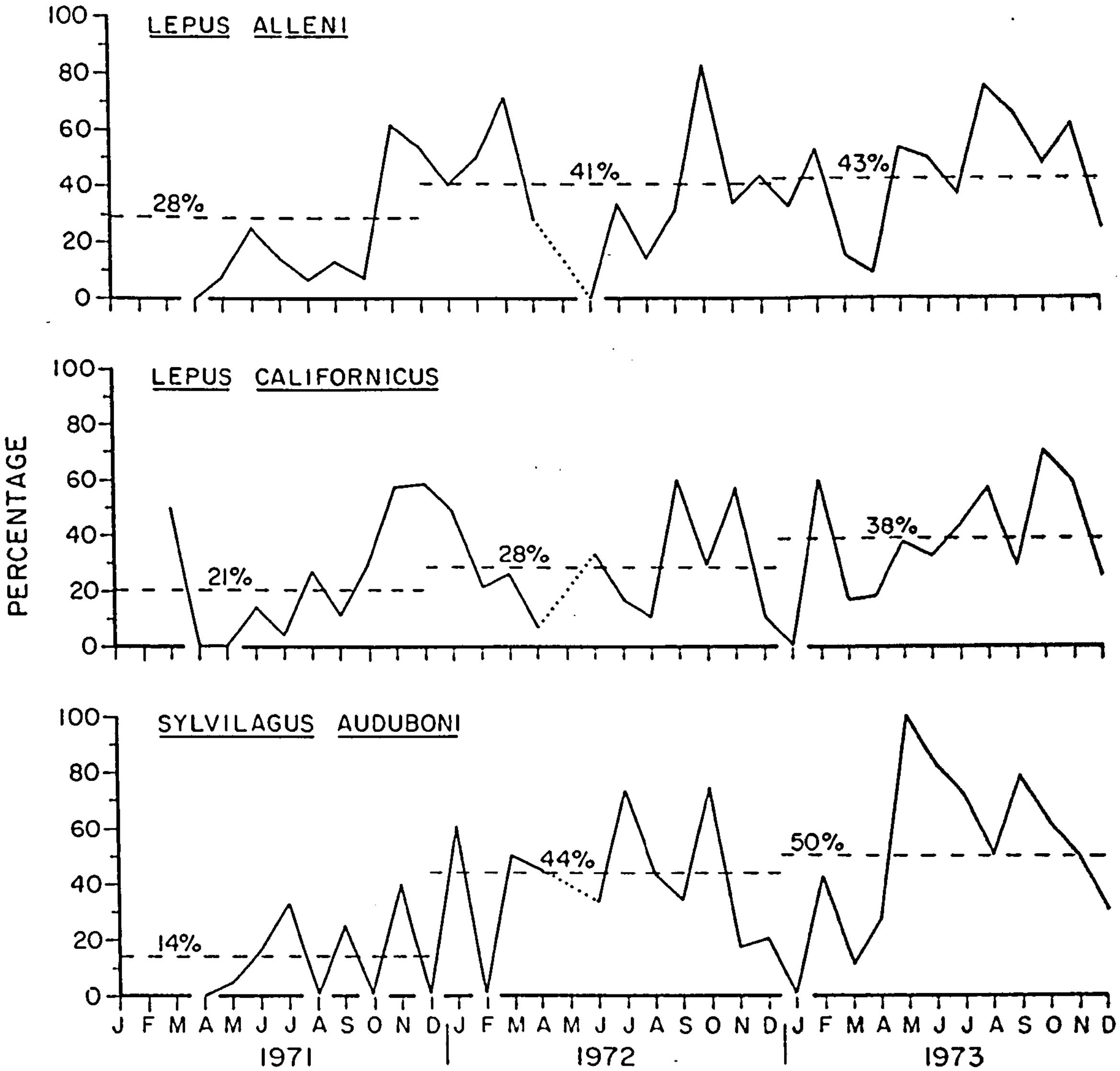

Figure 11. The percentage of juveniles collected in the Avra Valley, Arizona -- No collections were made during May, 1972.

nearest irrigated fields. This interval provided an adequate buffer zone to prevent an influence on the densities computed from the censuses along those routes.

Figure 9 reveals high density levels in the summer months of June, July, and August. These may be the result of influences of the ambient temperature, with the rabbits remaining in their forms longer during the hotter months, allowing the observers to approach closer than in the cooler parts of the year. This behavior could result in shorter flushing distances which produce higher density estimates.

Another possible source of the monthly variation is the time of year in relation to the major breeding periods. The higher density levels in the summer months also coincide with the time of year when the young of the spring breeding begin to appear in the collections. Again in the fall of each year the density levels rise, possibly with the increased numbers of juveniles from both the spring and summer breeding seasons.

Student's t tests performed on the annual mean densities presented earlier showed no significant differences between years for either species. The values obtained in these tests were as follows:

*Sylvilagus audubon*i:

1971-72: $t = 0.0862$, $df = 8$, $p > .90$

1972-73: $t = 0.0896$, $df = 13$, $p > .90$

Lepus californicus:

1971-72: $t = 0.4163$, $df = 12$, $p > .60$

1972-73: $t = 0.4208$, $df = 15$, $p > .60$.

The stability of the annual mean densities on the upper bajada study area produces a contradiction to the major conclusion of this report, that the productivity of the rabbit populations in the Avra Valley underwent significant changes as a result of varying annual precipitation. If that conclusion is correct, why were there no measurable increases in the population densities? Two explanations seem apparent.

One explanation is the small sample sizes involved in the density level computations. In only half of the censuses was more than one jackrabbit seen and in less than one fourth of the censuses was more than one cottontail observed.

The low rabbit population in this area and the large monthly fluctuations in the calculated densities indicate that either a more precise census technique is needed for the Sonoran Desert or that the sample size must be greatly increased before much reliance can be placed upon the census results.

A second, and more likely, explanation to the above conflict is the differences between the areas utilized for the collections and the area used for the censuses.

Approximately one half of the monthly collections took place in the lower portions of the valley in areas where agriculture may have had an affect in increasing productivity.

More importantly, the census routes were located on the upper portions of the bajada where man-made disturbances were at a minimum. This distinction is important as I feel the greater amounts of disturbed areas in the lower valley more effectively influence the productivity of the rabbits in the Avra Valley than does the presence of irrigated crops. The disturbed areas in the lower valley are principally in the form of roads and fallow fields. As mentioned in the description of the study area, the edge effects created by these man-made manipulations were the most productive areas for collecting. As evidenced in the results of the vegetative transects, these areas supported more plant species which were more persistent during periods of drought.

With the man-made disturbances on the upper bajada at a minimum, the carrying capacity of this area is more likely to remain at a lower and more constant level than that of the cultivated valley. Here, any surplus population would be lost to higher mortality or forced to emigrate.

APPENDIX A

PLANTS ENCOUNTERED ON THE UNDISTURBED SITE VEGETATION TRANSECT

TREES:

Acacia constricta
Acacia gregii
Cercidium microphyllum
Olneya tesota
Prosopis juliflora

CACTI:

Carnegiea gigantea
Echinocereus fendleri
Ferocactus wislizeni
Opuntia spp.

SHRUBS:

Aloysia wrightii
Aplopappus tenuisectus
Condalia lycioides
Ephedra trifurca
Fouquieria splendens
Franseria deltoidea
Krameria parvifolia
Larrea tridentata
Lycium exsertum
Sphaeralcea emoryi

GRASSES:

Aristida adscensionis
Aristida wrightii
Bouteloua aristidoides
Bouteloua barbata
Bouteloua rothrockii
Muhlenbergia porteri
Schismus arabicus
Tridens pulchellus
Unknown annual grasses
Unknown perennial grasses

FORBS:

Allionia incarnata
Ambrosia psilostachya
Amsinckia intermedia
Astragalus didymocarpus
Astragalus nuttallianus
Bowlesia incana
Chaenactis steviodes
Chorizanthe rigida
Descurainia pinnata
Ditaxis adenophora
Eriastrum diffusum
Eriogonum deflexum
Eriophyllum lanosum
Erodium cicutarium
Erodium texanum
Euphorbia albomarginata
Euphorbia capitellata
Janusia gracilis
Lappula redowskii
Lepidium lasiocarpum
Lesquerella gordoni
Lotus humistratus
Lotus salsuginosus
Lupinus sparsiflorus
Monoptilon bellioides
Phacelia arizonica
Plantago insularis
Plantago purshii
Sphaeralcea coulteri
Thelypodium lasiophyllum
Tribulus terrestris
Unknown forbs

APPENDIX B

PLANTS ENCOUNTERED ON THE DISTURBED SITE VEGETATION TRANSECT

TREES:

Acacia constricta
Acacia greggii
Cercidium floridum
Cercidium microphyllum
Olneya tesota
Prosopis juliflora

CACTI:

Carnegiea gigantea
Ferocactus wislizeni
Opuntia sp.

SHRUBS:

Aplopappus tenuisectus
Aplopappus gracilis
Atriplex canescens
Atriplex elegans
Condalia lycioides
Franseria deltoidea
Larrea tridentata
Lycium exsertum
Sphaeralcea emoryi

GRASSES:

Aristida adscensionis
Aristida wrightii
Bouteloua aristidoides
Bouteloua barbata
Bouteloua rothrockii
Eragrostis lehmanniana
Eragrostis megastachya
Muhlenbergia porteri
Schismus arabicus
Trichachne californica
Tridens pulchellus
Unknown annual grasses
Unknown perennial grasses

FORBS:

Allionia incarnata
Ambrosia psilostachya
Amsinckia intermedia
Asclepias linarea
Astragalus didymocarpus
Astragalus nuttallianus
Bowlesia incana
Calycoseris wrightii
Chaenactis steviodes
Chorizanthe rigida
Cucurbita digitata
Descurainia pinnata
Ditaxis adenophora
Draba cuneifolia
Eriastrum diffusum
Erigeron divergens
Eriogonum deflexum
Eriophyllum lanosum
Erodium cicutarium
Erodium texanum
Eschscholtzia mexicana
Euphorbia albomarginata
Euphorbia capitellata
Janusia gracilis
Lappula redowskii
Lepidium lasiocarpum
Lesquerella gordoni
Lotus humistratus
Lotus salsuginosus

Lupinus concinnus
Lupinus sparsiflorus
Monoptilon bellioides
Nicotiana trigonophylla
Perizia wrightii
Phacelia arizonica
Phacelia crenulata
Plantago insularis
Plantago purshii
Sisymbrium irio
Solanum elaeagnifolium
Sphaeralcea coulteri
Thelypodium lasiophyllum
Tidestromia lanuginosa
Tribulus terrestris
Unknown forbs

APPENDIX C

PLANT DATA FROM THE UNDISTURBED SITE VEGETATION TRANSECT

	Grasses	Forbs	Shrubs	Trees	Cactus	Bare Ground
			Per Cent Occurrence			
1972						
Jan	27.4	183.8	88.9	17.6	5.2	--
Feb						
Mar	12.9	3.9	87.1	16.6	2.6	20.5
Apr	6.1	1.2	74.4	12.2	4.9	33.0
May						
Jun	47.5	6.3	69.5	15.0	1.3	20.0
Jul	51.2	17.4	81.2	11.3	1.2	18.7
Aug	96.1	3.8	63.8	10.0	5.0	18.7
Sep	108.6	1.2	70.1	16.1	4.9	21.3
Oct	116.3	167.2	56.3	11.2	7.5	3.8
Nov	66.2	269.7	66.3	11.3	1.2	0.0
Dec	33.3	361.0	79.4	16.6	3.8	0.0
			Relative Abundance Index			
1972						
Jan	8.5	56.9	27.5	5.4	1.6	--
Feb						
Mar	9.0	2.7	60.6	11.6	1.8	14.3
Apr	4.6	0.9	56.4	9.2	3.7	25.0
May						
Jun	29.8	3.9	43.5	9.4	0.8	12.5
Jul	28.3	9.6	44.9	6.2	0.7	10.3
Aug	48.7	1.9	32.3	5.1	2.5	9.5
Sep	48.9	0.5	31.5	7.2	2.2	9.6
Oct	32.1	46.1	15.5	3.1	2.1	1.0
Nov	16.0	65.0	16.0	2.7	0.3	0.0
Dec	6.7	73.1	16.1	3.4	0.8	0.0

Plant Data, Undisturbed Site--Continued

	Grasses	Forbs	Shrubs	Trees	Cactus	Bare Ground
			Per Cent Occurrence			
1973						
Jan	54.9	481.1	73.7	8.7	2.5	0.0
Feb	82.0	608.0	90.0	14.0	2.0	0.0
Mar	78.7	707.6	69.9	13.7	0.0	0.0
Apr	47.5	447.5	91.2	6.3	1.2	0.0
May	11.2	3.6	71.2	10.0	3.7	33.8
Jun	9.9	1.2	69.9	17.3	1.2	35.0
Jul	11.2	0.0	74.9	12.5	3.8	31.2
Aug	7.5	0.0	84.9	12.5	0.0	28.7
Sep	2.5	0.0	68.7	13.7	2.4	30.0
Oct	5.0	0.0	58.8	9.9	1.2	35.0
Nov	3.8	0.0	82.4	17.5	3.8	25.0
Dec	6.2	79.9	66.2	8.7	2.4	22.5
			Relative Abundance Index			
1973						
Jan	8.8	77.5	11.9	1.4	0.4	0.0
Feb	10.3	76.4	11.3	1.8	0.2	0.0
Mar	9.0	81.3	8.0	1.6	0.0	0.0
Apr	8.0	75.4	15.4	1.1	0.2	0.0
May	8.4	2.7	53.3	7.5	2.8	25.3
Jun	7.4	0.9	52.0	12.9	0.9	26.0
Jul	8.4	0.0	56.1	9.4	2.8	23.4
Aug	5.6	0.0	63.4	9.4	0.0	21.5
Sep	2.1	0.0	58.6	11.7	2.0	25.6
Oct	4.5	0.0	50.8	9.0	1.1	31.8
Nov	2.9	0.0	62.2	13.2	2.3	18.9
Dec	3.3	43.0	35.6	4.7	1.3	12.1

APPENDIX D

PLANT DATA FROM THE DISTURBED SITE VEGETATION TRANSECT

	Grasses	Forbs	Shrubs	Trees	Cactus	Bare Ground
			Per Cent Occurrence			
1972						
Jan	65.6	322.0	84.3	7.9	0.0	--
Feb						
Mar	21.1	84.4	68.7	16.3	1.3	0.0
Apr	29.5	11.9	55.2	9.4	0.0	37.6
May						
Jun	40.9	18.8	64.1	11.2	1.3	31.0
Jul	66.1	21.2	51.2	6.3	2.4	33.8
Aug	140.7	47.0	62.0	11.4	0.0	19.0
Sep	137.3	36.2	50.0	3.7	0.0	21.3
Oct	158.7	265.1	48.6	8.8	1.2	10.0
Nov	124.9	311.0	56.7	3.7	0.0	3.8
Dec	81.2	377.5	56.3	13.7	0.0	5.0
			Relative Abundance Index			
1972						
Jan	13.7	67.1	17.6	1.6	0.0	--
Feb						
Mar	11.0	44.0	35.8	8.5	0.7	0.0
Apr	20.5	8.3	38.4	6.5	0.0	26.2
May						
Jun	24.4	11.2	38.3	6.7	0.8	18.5
Jul	36.5	11.7	28.3	3.5	1.3	18.7
Aug	50.2	16.8	22.1	4.1	0.0	6.8
Sep	55.2	14.6	20.1	1.5	0.0	8.6
Oct	32.2	53.8	9.9	1.8	0.2	2.0
Nov	25.0	62.2	11.3	0.7	0.0	0.8
Dec	15.2	70.7	10.5	2.6	0.0	0.9

Plant Data, Disturbed Site--Continued

	Grasses	Forbs	Shrubs	Trees	Cactus	Bare Ground
			Per Cent Occurrence			
1973						
Jan	82.4	397.2	53.8	7.4	0.0	6.2
Feb	104.0	576.0	46.0	4.0	0.0	4.0
Mar	103.7	619.8	46.2	6.2	0.0	2.5
Apr	62.5	349.8	52.5	3.9	1.2	8.8
May	40.0	23.8	53.4	3.8	1.2	32.5
Jun	39.9	7.3	52.3	2.4	2.5	33.7
Jul	27.5	4.9	45.0	6.3	0.0	43.7
Aug	15.1	5.0	60.0	7.4	0.0	38.8
Sep	18.6	2.5	48.6	6.1	2.5	47.4
Oct	1.2	0.0	38.6	7.4	1.2	53.8
Nov	4.9	2.4	41.1	4.9	0.0	55.0
Dec	1.2	95.0	47.2	3.7	0.0	17.5
			Relative Abundance Index			
1973						
Jan	15.1	72.6	9.8	1.4	0.0	1.1
Feb	14.2	78.5	6.3	0.5	0.0	0.5
Mar	13.3	79.6	5.9	0.8	0.0	0.3
Apr	13.0	73.1	11.0	0.8	0.2	1.8
May	25.8	15.4	34.5	2.4	0.8	21.0
Jun	28.9	5.3	37.9	1.7	1.8	24.4
Jul	21.6	3.8	35.3	4.9	0.0	34.3
Aug	12.0	4.0	47.5	5.8	0.0	30.7
Sep	14.8	2.0	38.7	4.8	2.0	37.7
Oct	1.2	0.0	37.8	7.2	1.2	52.6
Nov	4.5	2.2	38.0	4.5	0.0	50.8
Dec	0.7	57.7	28.7	2.2	0.0	10.6

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