ACTIVITY OF THE EASTERN WOOD RAT, (NEOTOMA FLORIDANA OSAGENSIS), AS INFLUENCED BY ENVIRONMENTAL CONDITIONS

by 544

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TABLE OF CONTENTS

INTRODUCTION

Ecology can be defined as the study of the relationship between an organism and its environment. This environment includes both biotic and abiotic components. Generally, whenever these components are studied they are considered in terms of the limits that they impose on the species, population or community. The attributes of any of these entities are directly or indirectly dependent on the activity of the individual organism. It is for this reason that activity and its regulation are primary concerns of ecology.

Although the general ecology of the eastern wood rat (*Neotoma floridana osagensis*) has been described (Rainey, 1956), little has been said concerning environmental influence on the activity of wood rats except that they are nocturnal. Therefore, this study was initiated in an effort to obtain more specific information about the habits of these animals.

Two hypotheses were stated in approaching this problem, firstly that activity is not evenly distributed throughout the night and secondly that activity is not randomly distributed with respect to time and environmental conditions. These hypotheses led to a third which stated that some factor or combination of factors must influence activity. The purpose of this study was to determine what these factors might be. In essence, it was an attempt to answer the questions of when and under what conditions wood rats are active; and conversely when and under what conditions activity was inhibited.

The activity of organisms in their natural environments has been studied in many ways. The most direct of these methods employs observations made in the tradition of the classical naturalist. For the most part these studies have been confined to diurnal observations of the organism itself or to examination of the evidence left by organisms that were not actually observed. It is for this reason that knowledge of the activity of nocturnal organisms is lacking.

With the advent of biomechanization, information could be gathered without the necessity of constant surveillance of the organism. The thermocouple (Baldwin and Kendeigh, 1927) and the itograph of Kendeigh and Baldwin (1930) and Kendeigh (1952) have been used to study the nesting activity of birds. Behney (1936) has used the itograph to study the activity of forest deer mice (Peromyscus leucopus). More recently photoelectric cells have been used as a triggering device for recording activity. Loveless et al. (1963) used photoelectric cells to record activity patterns of mule deer (Odocoileus hemionus) in Colorado. As pointed out by Kendeigh (1952) these mechanical recording devices should never entirely replace direct observations because they do not adequately describe the type of activity taking place. Some progress was made in this area by the developement of automatic camera devices by Pearson (1959) and Dodge and Snyder (1960). These devices have been used by Pearson (1960 a and b) and Osterberg (1962) to provide a photographic record of the activity of small rodents. Wiley (1967) has used this device to record the activity of wood rats (Neotoma floridana) in western Kansas.

These instrumental techniques, though valuable in certain aspects of the study of activity, have the disadvantage of not being able to follow the animal. More recently biotelemetric methods have come into widespread use (Sanderson, 1966), but this equipment is expensive and usually does not provide first hand knowledge of the type of activity being recorded.

Nocturnal activity may be studied directly with the aid of artificial lights if these lights do not disturb the animal. Southern, Watson and Chitty (1946) observed and photographed wild rats (Rattus norvegicus) feeding under infrared light. Visible red light enabled Southern (1955) to observe tawny owl (Strix aluco) nesting activity and predation on wood mice (Apodemus sylvaticus). He also reported that both badgers and foxes were red blind. Finley (1959) described the use of visible red light to observe various nocturnal animals. Red filters were incorporated in the previously mentioned camera devices so as not to disturb the animals. Rainey (1956:559), Finley (1958:334) and Wiley (1967) have used red lights to observe wood rats.

Until recently, most activity studies have been orientated towards behavioral patterns, dispersal movements and home range of a species. Activity in relation to environmental factors has not been studied extensively, while population studies based on the number of captures per unit of effort have assumed that activity, and therefore, trapping or hunting success, was independent of environmental conditions. In 1950 Buss and Harbert observed that the occurrence and arrival of mule deer at a salt lick was related to moon phase. Kendeigh (1952) discussed the variations in nesting activities of birds as they were related to the time of day, day of the nesting process, and other environmental factors. Bider (1961) surveyed tracks of the hare (Lepus americanus) in snow and correlated their movements with wind, light and temperature. Gentry and Odum (1957), Sidorowicz (1960) and Gentry et al. (1966) have studied the influence of weather on the capture of small mammals. The relationship between activity patterns of prairie dogs (Cynomys) and environmental factors has been shown by Tileston and Lechleitner (1966). A similar relationship in ground squirrels (Citellus) has been found by Bradley (1967).

Poole (1940), Vorhies and Taylor (1940), Murphy (1952), Rainey (1956) and Finley (1959) have briefly commented on the influence of some environmental factors on the activity of wood rats. Wiley (1967) studied summer activity patterns of wood rats and found them to be related to time and moon phase.

MATERIALS AND METHODS

Study area

The study area (Fig. 1, Plate I) was located on the east half of the NE quarter of section 20 in T9S; R7E approximately eight miles northwest of Manhattan, Riley Co., Kansas. It consisted of 80 acres of heavily grazed rangeland on rocky soil with elevations ranging from 1240 to 1370 feet. Approximately 23 percent of the area was covered with dense brush or trees with the balance of the area being predominantly short grasses and forbs (Fig. 2, Plate II). The brush areas were located principally along the dry stream beds and ravines with some patches being associated with the limestone outcrippings along the top of the hills. Wood rats living on the area were confined to these regions of dense woody vegetation. In order to assess this habitat the frequency of woody plant species was determined on 35 circular plots with radii of one meter. Each plot was centered on a typical nest that was found to be occupied during the study. The results of this analysis (Table 1, Appendix I) showed that the brushy areas in which wood rats built their nests were composed mainly of Red-Osier Dogwood (Cornus stolonifers) Michx, Coral Berry (Symphicarpos orbiculatus) Moench, American Elm (Ulmus americana) L., Missouri Gooseberry (Ribes missourienses) Nutt., and Fragrant Sumac (Rhus aromatica var. serotina) (Greene) Rehd. Other wildlife indicative of this habitat and frequently seen on the area were the cottontail rabbit (Sylvilagus floridanus) and the bobwhite quail (Colinus virginianus).

Trapping and marking

Live trapping was conducted regularly between 25 September and 21 December 1966 and between 16 March and 1 July 1967. Five traps of the type described by Fitch (1950) were set nightly near wood rat houses or runways and baited with a mixture of shelled corn and chicken scratch. After capture, rats were anesthetized with ether, measured and examined for signs of molt, breeding condition and ectoparasites. Each rat had its ears clipped for permanent identification and was given a soft vinyl collar to which a unique pattern of Scotchlite tape had been applied for field identification. These patterns were similar to those described by Ealey and Dunnet (1956). As soon as the rat recovered from the effects of the ether, it was released.

Nocturnal observations

Wood rats were observed at night with the aid of the red light apparatus described below. Both the observer and light apparatus were positioned at distances ranging from 10 to 60, but usually 25 feet from the nest. The observation station was specifically chosen to afford the least obstructed view of the nest and its surrounding area. The light was focused primarily on the nest entrances, with frequent scanning of the runways and places where the rat was most likely to be seen. The primary objective in choosing the observation station and scanning pattern was to see as much activity as possible. All observations reported in this study were made between 30 September 1966 and 17 May 1967. Data concerning activity and environmental conditions were recorded over several hours and later separated into 15 minute periods for statistical treatment.

Red light apparatus.—Preliminary observations were made in Sept. 1966 using a 5 cell flash light which had a disk of red acetate held between the rim and face of the lamp. Data reported in this study were obtained using a 6-volt automobile headlamp, also having red acetate as a filter (Fig. 3, Plate II). The headlamp with its protective metal rim and back was fitted snugly inside a 20 inch section of inner tube so that the face of the lamp was lined up with a circular opening (4" diameter) in the center of the tube. Sheets of red acetate 8 x 9 inches were inserted between the inner tube and the face of the lamp. The open ends of the tube were held behind the lamp by large safety pins. This assembly was attached to a tripod by means of wires and a T shaped piece of sheet metal. Once mounted the light could be rotated both horizontally and vertically or held stationary by tightening the clamps on the tripod. This light was powered by a 6-volt storage battery and therefore was portable, silent and rechargeable.

Two types of red acetate were used during this study. A Cary 14 recording spectrophotometer was used to determine the quality of the light emitted from the apparatus described above using single and double sheets of both types of red acetate as a filter. Table 2 (Appendix I) shows the range and peak wavelengths emitted by these materials. A double sheet of the impure red material was used for most of the study, but the pure red material was found to be superior when it was tried.

In order to test the wood rat's perception of red light ten individuals from a laboratory colony were tested in a shuttle box apparatus of the type described by Warner (1932). It is primarily used to test an animal's ability to learn to avoid punishment by responding to a stimulus. The rats were placed in the shuttle box for a series of 25 trials each day for 7 or more consecutive days. The shuttle box was equipped with a plexiglass window so that the response of the rats to the light stimulus could be observed. The intensity of the stimuli and intertrial periods was determined by a Weston Master IV light meter.

Recording activity.—The amount of activity was recorded in terms of: 1) the number of times a rat was observed during the 15 minute period; 2) the total time (in seconds) that the rat was observed outside of the nest; and 3) the total distance the rat was observed to travel during the same time period. These three factors will be referred to in the future as activity indicators and will be abbreviated as trips, time and distance. In order to facilitate the estimation of distance traveled a ten food grid was marked with surveyor flags and a map was drawn for each of the nests being observed. Any brief sightings of the rat were recorded as 5 second observations. The type of activity was recorded whenever it could be determined. In order to obtain other indications of the activity the number of rats seen during the intervals between observation periods was noted along with the amount of noise made by other rats during the observation period.

Environmental conditions.—Temperature and humidity were continuously recorded on a Taylor hydrothermograph, housed in a standard weather shelter placed on the ground in the study area. At times when this instrument was inoperational records of the U. S. Weather Bureau in Manhattan were used. The tracings for Manhattan were similar to those obtained on the study area when both could be compared.

Records of barometric pressure were also obtained from the U. S. Weather Bureau located in Cardwell Hall on campus. This building is at an elevation of approximately 1080 feet above sea level. Since normal pressure at sea level is 29.92 inches of mercury and this is reduced by .1 inch mercury for every 100 foot rise in elevation the normal barometric pressure for Cardwell Hall is approximately 28.84 inches of mercury. The portion of the study area where most of the observations were made had elevations ranging from 1250 to 1300 ft., therefore, the actual barometric pressure on the area was approximately .2 in. of mercury lower those obtained from the weather bureau.

A table giving the approximate time of sunrise and sunset in Manhattan was also obtained from the weather bureau. Using this table observation periods could be considered in terms of the number of hours after sunset and before sunrise. The twilight hours were further divided into quarter hours because these were the periods during which the environment changes most rapidly. Total length of the dark period rounded to the nearest hour was also derived from this table.

Moon phase was obtained from a graphic time table of the heavens published by the Maryland Academy of Sciences (1966, 1967). When the moon was below the horizon or hidden by clouds it was considered as "no moon."

Those environmental conditions which could not be recorded on instruments or found in reference tables were noted in the field during the observation period. These included the general level of illumination, altitude of the moon above the horizon, amount of cloud cover, precipitation, moisture condition of the ground, relative strength of the wind, amount of background noise and miscellaneous factors such as the proximity of predators, lightning or meteor showers. The time and date of each observation was also noted.

Seasons were defined on the basis of temperature. If the number of hours below freezing during each 24 hour period from noon to noon are graphed as in Fig. 4, the winter months appear as a succession of cold spells with intervening warm periods. The cold season should logically begin and end with a prolonged cold spell, while the intervening period should include most of the other cold spells and have a high percentage of days as well as total time below freezing. For this study the cold season was defined as that period having 60 percent of the total time below freezing and a minimum of 85 percent of the days having at least one hour below freezing. Figure 5 shows the percentage of hours and days that had temperatures below 32° F. during periods that were selected by examining Fig. 4. The dates of 27 November 1966 and 24 February 1967 were chosen as the boundaries of the cold season because they best fit the criteria outlined above.

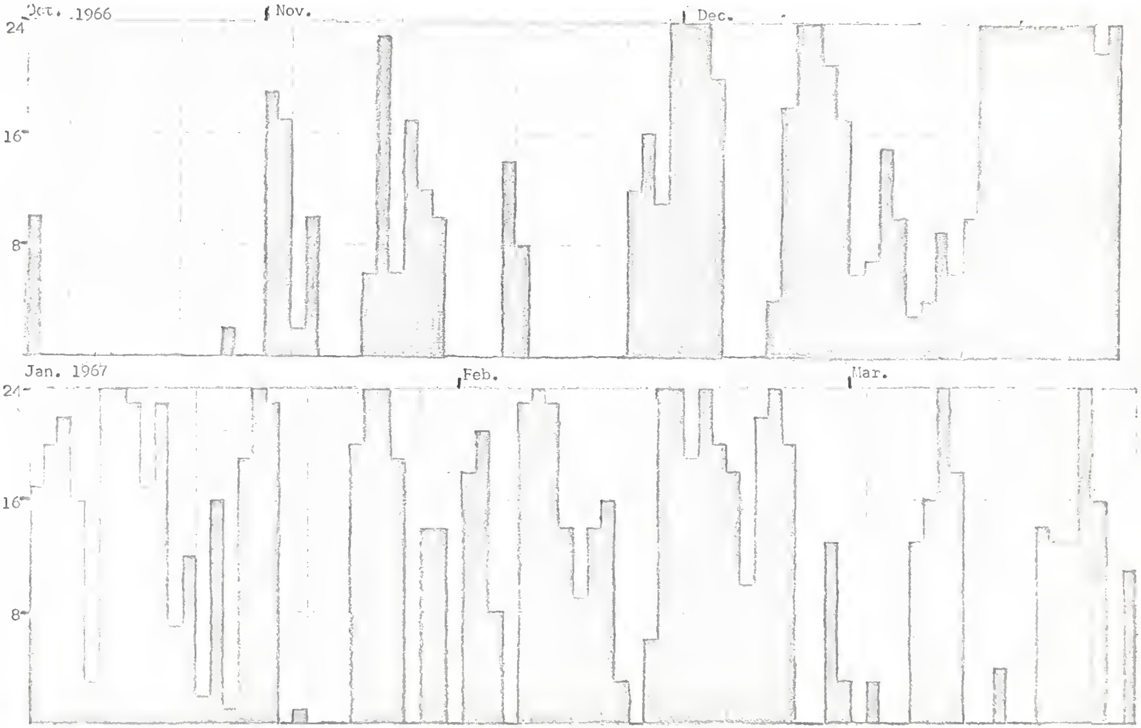

Fig. 4 - Number of hours below freezing in a 24 hr. period from noon to noon.

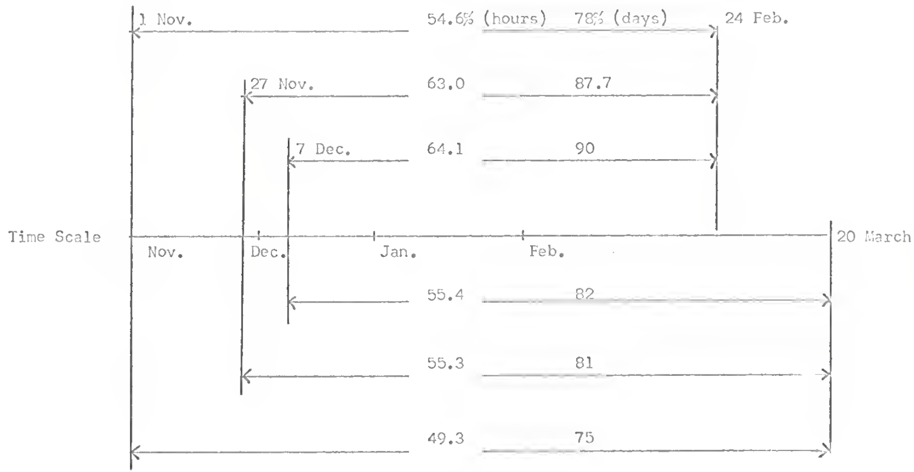

Fig. 5—Time intervals that were considered in selection of the cold period after inspection of Fig. 4. The percent of total hours below freezing and the percent of days with at least one hour below freezing are shown within each of these time periods.

Available cover was assessed by frequent inspection of the study area. Notation was made of the date by which most of the leaves had fallen from the deciduous plants and the date by which most of the plants had begun to leaf out. Food availability was considered to have also corresponded with these dates. Figures 6 and 7 (Plate III) show the condition of the vegetation in October and February.

Treatment of Data

The information from each 15 minute observation period was punched on a separate IBM data processing card. These cards were initially sorted to determine the distribution of environmental factors and activity records. Some of the data had to be lumped in order to gain meaningful results from the computer analyses. The categories of environmental factors and their ranges of conditions that were used in this analysis are listed in Appendix II. The activity levels within each of the three primary activity indicators (trips, time and distance) are given in Appendix III. In addition to these variables the computer analysis also included a factor dealing with the type of activity observed and each of the 4 secondary activity indicators (Appendix III).

A program for the IBM 360 computer was written by Dr. Young Koh of the Statistics Dept. at Kansas State University. This program instructed the computer to print out a matrix showing contingency tables, i.e. the number of observations in each variable when compared to every other variable. Chi-Square values were computed for each of these tables. An additional two tables for each set of variables were printed to show the percentage of total observations in each row that were in each column and the percentage of total observations in each column that were in each row.

In preparing the results of this study the Chi-Square values were used to determine whether or not there was a significant relationship between the two variables being tested. The null hypothesis in each case was stated as H_0: Activity as measured by (trips, time or distance) was independent of the environmental factor being considered. All Chi-Square tests were made at the 95% level unless otherwise stated. If the null hypothesis was rejected in favor of the alternate hypothesis that there was a significant relationship between the two variables being tested, activity profiles were drawn in order to determine what this relationship was. If the factor could not be shown to have a significant influence, activity profiles were drawn to show the apparent trends.

These activity profiles, figures 10 through 40 were derived from the percentage tables that were printed by the computer, and can best be described in terms of the hypothetical drawing shown in Fig. 8. Three activity profiles, corresponding to the three primary activity indicators (trips, time and distance), were drawn for each environmental factor studied (Appendix II). The range of conditions that were considered in each factor were listed on the horizontal axis of the profile (A,B,C,D and E in Fig. 8). The lines AA' and EE' or imaginary lines BB', CC' and DD' represent 100 percent of the observations that were made while that particular (A,B,C,D or E) environmental condition prevailed. The horizontal lines FF', GG', HH' and II' represent, from highest to lowest, the four activity levels (Appendix III) within each activity indicator. The line BP represents the percentage of the total observations made under condition B that had enough activity to be classified in level FF'. The line PQ represents the percentage of observations made under condition B that had activity classified in level GG'. Similarly, QR and RS represent the percentages of observations in the next activity levels of HH' and II' respectively. The area above line II' represents the percentage of observations in each condition that had no activity. From this hypothetical activity profile it can clearly be seen that activity as measured by indicator Z, was highest while condition B of environmental factor X prevailed.

The decisions made regarding the influence of environmental factors on the activity of wood rats were based on interpretation of the Chi-Square tests, activity profiles and notations made during the field observations.

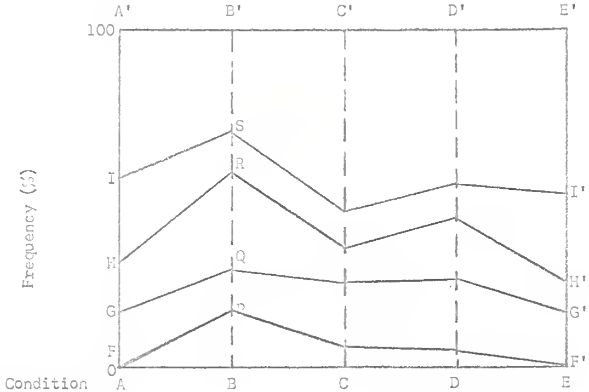

Fig. 8—Hypothetical activity profile showing the relationship between activity indicator Z and environmental factor X.

RESULTS

Trapping and Marking

During the fall trapping period, 57 nests were surveyed in 400 trap nights resulting in 85 captures involving 32 rats. Twelve of these were males and 20 were females. None of the rats were juveniles.

The distribution of the nests on the area is given in Fig. 9 Those nests which were trapped and subsequently used in the population estimates are denoted on the map.

For reasons discussed later the best indication of the population levels was believed to be the percentage of nests that were occupied. The overall trapping results indicated that 56.1 percent of the 57 nests were occupied, however, there was evidence that there were some rats present that were not being trapped. Therefore, the population estimate was based on results from small relatively isolated groups of nests for which the number of occupied nests was known. There were 36 nests in these groups and 26 (72.2 percent) were occupied.

During the spring trapping period 108 nests were surveyed in 501 trap nights resulting in 54 captures of 30 rats, 8 males, 13 females and 9 juveniles. Three of the young were males and 6 were females. Only 10 of the original 32 rats were captured in the spring. Nine of these retained their collars.

One of the nests trapped in the fall was destroyed during the winter by pond excavating operations. The estimate of the spring population based on 35 of the nests used in the reliable fall estimate was 40 percent occupancy (14 rats). The estimate based on 56 of the nests trapped in the fall was 37.5 percent (21 rats) while the estimate based on all of the nests trapped in the spring was only 27.7 percent.

Interspecific Relationships

Commensals and Competitors.—Cottontails (Sylvilagus floridanus) were frequently flushed from wood rat houses during the field work. The white-footed mouse (Peromyscus leucopus) was also often seen in and around wood rat houses. The incidence of mouse occupation increased in late winter and spring when the wood rat population was falling. On several occasions five-lined skinks (Eumeces fasciatus) took refuge in wood rat houses. Harvest mice (Reithrodontomys megalotus) were often observed at night. One short-tailed shrew (Blarina brevicauda) was seen during the observations and one cotton rat (Sigmodon hispidus) was trapped on the area in the spring.

Predators.—Coyotes (Canis latrans) were frequently seen or heard on the study area. At noon on 5 November 1966 a coyote was observed searching near a large wood rat nest under a fallen tree. The coyote made no attempt to destroy the nest but continued to search the brush and dry stream bed in the vicinity for about 15 minutes before wandering off the area through a wooded ravine. It seemed most likely that this sort of behavior would more often be rewarded by flushing a cottontail from the nest than a wood rat.

On 18 May 1966 a 6 foot pilot black snake (Elaphe obsoleta) was seen sunning itself near a brush pile that contained a wood rat nest. When the snake was disturbed it crawled into one of the entrances of the nest.

Excavations appearing to be those of a badger (Taxidea taxus) were frequently found on the slopes near rock outcroppings where wood rat runways were present. At 3:15 A.M. on 25 October 1966 a badger was seen coming around the side of a hill towards a wooded ravine containing six wood rat nests. The moon had just set. The sky was overcast. It was very dark and several rats were active in the ravine. The badger wandered to within three feet of the base of the red light and seemed more concerned about sniffing likely spots where rodents might be found than about the red light. At this point the badger was intentionally frightened and ambled over the top of the hill. No wood rat activity was noted during the time that the badger was near but noise was heard in the ravine three minutes after it had left.

A spotted skunk (Spilogale putorius) was seen during several observation periods. At 1:24 A.M. on 11 November 1966 a spotted skunk was seen crossing the dirt road to approach a wood rat nest at the base of a fallen tree. It was a calm, clear, dark night and wood rats were active. The skunk was not disturbed by the red light and after investigating the nest at the base of the tree it went 60 feet parallel with the road to the tree overhanging a large nest. The light was moved to a point perpendicular to and within 15 feet of this tree. The skunk went out on this horizontal tree and sniffed at a scat station belonging to the rat that occupied the nest below. A rat down on the ground made noise and the skunk quickly turned to stare at it. The skunk then came off the tree, down the incline, around the nest below and dissappeared on the far side of the nest at 1:32 A.M. Soon after, the rat began making many short trips in and out of the various nest entrances frequently pausing on the top of the nest. At 1:58 A.M. the rat ran out of the far side of the nest, then back in. For 15 seconds there was noise on that side of the nest, then there was a sudden rustling sound and the skunk appeared at the far side of the nest. The skunk held its head up several times and seemed to be swallowing something. At 2:01 the skunk wandered slowly towards a third nest 70 feet away, and at 2:02 the rat was seen running up to the overhanging tree and then cautiously down to the nest. The skunk had apparently caught and eaten some other prey, probably a Peromyscus, in the nest. At 2:52 the skunk was seen at another nest 50 feet from the nest where it had caught something. At this time it was slowly leaving the nest and passed two other nests as it went out of sight. Inspection of nest where the skunk had spent 26 minutes revealed that a large corridor had been excavated along the far side of the nest at ground level. Several other nests have also been found gutted in this way. Fitch and Rainey (1956) state that the spotted skunk may be an important enemy of wood rats but they found no records in the literature of these skunks preying on wood rats.

In addition to these predators, barred owls (Strix varia) were commonly seen and heard on the study area. One dead horned owl (Bubo virginianus) was found on the area and a feral cat (Felis domesticus) was seen near one nest. Red tailed hawks (Buteo jamaicensis) were frequently seen on the area during the day but were probably not important as predators of wood rats.

Parasites.—A thorough examination for parasites was not conducted, however, information concerning some ectoparasites of wood rats was recorded during this investigation. Many of the rats had fleas of undertermined species and several had orange ear mites.

Warbles (larvae of the Cuterebra fly) were found infecting 5.8 percent (3 of 52) of the rats trapped in this study. One adult female had a warble under her chin on 5 and 12 December 1966. A young female 80 - 100 days old had two warbles under her throat on 26 and 30 June 1967. An adult female had a warble under her neck on 1 July 1967.

Three ticks (Dermacentor sp.) were found on the muzzle of a large male trapped on 20 May 1967. A young female approximately 50 days old had one tick in her ear on 6 June 1967. The female that had a warble on 1 July 1967 also had a tick in her ear at this time.

Shuttle box experiments

Because of apparatus failure and the small number of rats tested no quantative statement could be made regarding the wood rat's visual perception.

However, some specific statements concerning the results of these experiments can be made at this time. One rat was frightened by the change from intertrial darkness to the stimulus of 16 ft. candles of white light. This rat failed to learn while another rat tested under the same circumstances learned to avoid the shock by jumping when the light came on. Two rats learned to respond to the change from intertrial darkness to the stimulùs of 2.8 ft. candles of red light. One of these was receiving an auditory cue. When the intertrial period was given an illumination of 1.2 ft. candles of white light, one rat learned to respond to a stimulus of an intensity increase to 17.2 ft. candles of white light while the one given a stimulus of increase to 5.2 ft. candles of red light failed to learn. When the intensity of the white stimulus was lowered to 1.8 ft. candles (an increase of .6 ft. candles over the intertrial period) one rat failed to learn and was repeatedly shocked. With the same intertrial intensity of 1.2 ft. candles one rat given a stimulus of 1.6 ft. candles (increase of .4 ft. candles) showed incomplete learning. Two rats given change from darkness of .6 ft. candles of white and .4 ft. candles of red as a stimulus both learned to avoid being shocked.

Activity

Nocturnal observations resulted in a record of wood rat activity for 538 fifteen minute periods distributed over a wide range of environmental conditions. The distribution of these periods with respect to time is given in Appendix II. Some activity was observed under all types of environmental conditions surveyed, however, there were wide discrepencies between the amounts of activity observed under different conditions. These differences will be examined in the following paragraphs. The results of the Chi-Square tests are summarized in Table 3 (Appendix I). Activity profiles

(Figs. 10 through 40) are shown for all environmental factors studied. Although some of these factors could not be shown to have a significant influence on activity, trends in activity patterns were often apparent. Too few data were collected for the secondary activity indicators to provide meaningful analyses.

ANNUAL PATTERN Month.—The Chi-Square tests for all three activity indicators showed that activity was not independent of the month during the period of study (September through May). As can be seen in the activity profiles (Fig. 10), high levels of activity were observed in September and November. Activity then dropped throughout the winter months to a low point in March. Activity increased in April but there was not enough evidence gathered in May to support this trend.

Season.—The trend exhibited by the activity profiles based on months of the year was also evident in the graphs of seasonal activity. These seasons based on temperature may be more biologically significant than calendar periods. The Chi-Square values for the tests comparing the three activity indicators with the season were significant. The graphs in Fig. 11 show that activity levels were highest during the precold period and slightly lower during the cold period than in the post cold period. The difference in this seasonal activity was predominantly due to the increased activity at the highest intensity levels during the precold period while the lower activity levels remained relatively constant during all three seasons possibly suggesting a minimum amount of activity necessary for the survival of the organism.

Cover.—Most of the leaves had fallen from the deciduous trees by 1 Nov. 1966. New leaves had sprouted on most of these plants by 1 April 1967. Activity as measured by trips and time was independent of the amount of cover and the null hypothesis of independence was rejected in the test comparing distance.

Figure 12 shows the activity profiles for this factor. Their was a peak in the graph of distance traveled while the leaves were still on the trees in the fall.

Length of dark period.—Activity as measured by all three indicators was found to be independent of the length of the dark period at the 95% level, but trips and distance were significant at the 90% level. Figure 13 shows that there was a trend towards slightly higher activity on nights with 12 and 14 hours of darkness.

DIEL PATTERN. Because of the changes in photoperiod during the study the diel pattern was considered in relation to the sun rather than clock time. Activity was compared to time in terms of hours after sunset until midnight (Figs. 14 and 15) and hours before sunrise after midnight (Figs. 16 and 17). Because of the discrepencies caused by the changing photoperiod it would not be valid to compare the hours after sunset through the night until sunrise. Since the hours near midnight are relatively equal in illumination and temperature etc. this was chosen as the point where the discrepency would be least important. The numbers in the graphs represent the end (before midnight) or the beginning (after midnight) of one hour periods rounded to the nearest 15 minutes with the first hour in Figs. 14 and 15 beginning at sunset and the last hour in Figs. 16 and 17 ending at sunrise. The first and last hour is also broken down into 15 minute periods because this is the time interval during which the most changes in the environment occur.

Time relative to sunset.—The Chi-Square tests showed that the number of trips was related to the hour after sunset but time and distance were independent. The number of observations in the first hour was too small to be tested separately with any accuracy but the strongly apparent trend in activity can be seen in Figs. 14 and 15. Activity was extremely low during the first 15 minutes after sunset but rapidly increased to a peak during the second hour after sunset. There was a sharp drop during the third hour after sunset and then a gradual rise to a lesser peak during the sixth hour.

Time relative to sunrise.—Activity was found to be independent of the hours before sunrise when measured by trips and time. A relationship was found, however, in the test involving distance. Again there were too few observations to statistically compare the 15 minute periods of the last hour before sunrise.

The activity profiles for the hours before sunrise (Figs. 16 and 17) show that there was a slight increase in activity during the seventh hour before sunrise immediately followed by a decrease and gradual rise to a peak between one and two hours before sunrise. There was very little activity during the last half hour before sunrise and none during the last 15 minutes. By comparing Figs. 14 and 15 with 16 and 17 it can be seen that there was considerably less activity during the last hour before sunrise than during the first hour after sunset.

In comparing activity in the P.M. with that in the A.M. it was found that overall there was less activity in the A.M. and that this difference was significant when time and distance were tested but not when trips were considered.

ILLUMINATION. Basically there are three periods of illumination to consider. They are the rapidly changing illuminations of sunset and sunrise and the darker relatively stable night. Activity was found to be independent of the basic types of illumination when the three activity indicators were tested but as was shown before, activity levels were substantially lower at sunrise then at other parts of the night (Fig. 18). Within each of these periods illumination varied greatly and so did activity.

Sunset.—Generally on clear nights the first 15 minutes after sunset are still very light. This is followed by 15 minutes of twilight when the sky is getting dimmer but it is still possible to see easily. During the next 15 minutes, dusk, the sky is becoming darker and it is difficult to see without lights. In the final 15 minutes of the first hour after sunset it is dark enough so that illumination from the moon and stars predominates. These progressive levels of illumination do not always strictly correspond to time because of variations in cloud cover.

When activity was plotted against the four levels of sunset illumination described above (Fig. 19) it was found that there was no activity in the first period and that activity according to all three indicators increased as illumination decreased. There were too few samples in each category to make a meaningful Chi-Square test.

Sunrise.—At sunrise the illumination increased with dawn or first noticeable light at about one hour before sunrise. During the next 15 minutes the landscape is dimly illuminated and the stars begin to fade. Twilight begins about one half hour before sunrise and features on the ground such as rocks and trees can be clearly distinguished. During the last 15 minutes before sunrise the illumination level is almost equivalent to daylight.

As can be seen from the graphs in Fig. 20, activity was relatively low during the sunrise illumination levels. As the light increased activity rapidly decreased and subsequently stopped at twilight. No Chi-Square tests were conducted for this factor.

Night illumination.—Nighttime presents a less dramatic change than the two transition periods just described but still includes a wide variety of illumination levels. These variations are primarily due to differences in cloud cover, moon phase, and angle of the moon above the horizon. The continuous series of night illumination levels was divided into the following groups for treatment of data: dark, dim, light, bright and bright with shadows.

The Chi-Square tests comparing evening illumination with activity showed that a significant relationship existed for all three indicators. This relationship between illumination and activity is shown in Fig. 21. Activity was high when there was very little illumination. As illumination increased, activity became lower. It should be noted that although the peak is higher under dim conditions there were no samples with large amounts of activity. The last column in these graphs should be considered as a special case since the general level of illumination was bright but the area immediately around the nest was in dark shadows because of heavy vegetation or the contour of the land in relation to the angle of the moon.

The primary contributing factor of evening illumination is the moon. Both the surface area of the moon available for reflection and the angle of the moon above the horizon change constantly producing corresponding changes in the amount of illumination received at any given point on the earth. Delicate instruments can record these changes (Callahan, 1964), but for the purposes of this study the data had to be lumped for meaningful treatment. Changes in size of the reflective surface of the moon could be noted daily but illumination levels did not change greatly from night to night.

Moon phase.—The moon was designated as full (12-20 days since new moon), half moon (5-11 and 21-26 days), and no moon (may have been hidden by clouds). The crescent moon was inadvertently not observed since it usually rose near sunrise and set near sunset.

The Chi-Square tests showed trips (90% level), and time to be related to moon phase but activity as indicated by distance was independent. Figure 22 shows that activity was higher when there was no moon and lower when the moon was full.

Moon altitude.—The illumination received from the moon is also related to the altitude of the moon. The sky is noticeably darker when the moon is less than 30 degrees above the horizon. In the tests comparing activity with altitude of the moon in 15 degree intervals a significant relationship was found for all three indicators. The activity profiles with respect to moon angle are shown in Figs. 23 and 24. In addition to the expected peaks when the moon was near the horizon, it was also found that activity was lower while the moon was setting. After re-examining the data it was found that more than 70% of the observations made in each category of the setting moon were made after midnight.

Moon altitude (grouped).—In order to eliminate the influence of time on the relationship of activity to moon angle, the rising and setting observations were combined and similar altitudes were lumped together. The results of this operation appear in Fig. 25. It can be clearly seen that activity was highest when the moon was just above the horizon and slightly, but nearly consistently, lower when the moon was at its zenith than in an intermediary position. The fact that there was more activity with a low moon than with no moon would infer that the rats prefer some illumination to complete darkness. The null hypotheses of all three Chi-Square tests for moon altitude grouped in this manner were rejected.

Moon phase and altitude combined.—Having established the relationship of activity to moon phase and angle separately, it was desirable to know what influence they exerted when they were combined. Here again a significant relationship was found for all three indicators. The graphs in Fig. 26 show that there was some activity during all observation periods in which there was a half moon less than 30 degrees above the horizon. There was also high activity (almost 70% of the samples) when the full moon was below 30 degrees. Very little activity took place when the full moon was 75 or more degrees above the horizon. Activity levels during other combinations of moon phase and angle were fairly, but not entirely, consistent with these results.

It must be emphasized here that the moon is not the only determining factor of illumination. The amount of light that reaches the earth from the moon, stars and planets can be greatly influenced by the amount and type of cloud cover which prevails.

Cloud cover.—For the purpose of this study sky conditions were classified as: clear, mist or fog, haze, thin clouds, partly cloudy (less than 50%), partly cloudy (more than 50%) and 100% overcast. A significant Chi-Square value was calculated for the test of distance. Activity as measured by trips and time was significant at the 90% level. The activity profiles for this environmental factor are shown in Fig. 27. Activity was highest when there were thin clouds present or when the sky had less than 50% cloud cover. No moon was present during 95% of the observations in this last category.

Thirty-five percent of the observations having thin clouds were dark while 26% were dim and another 26% were light. None of these observations were bright. The low activity during haze periods could be related to illumination which was bright during 40% of these observations and light during 24%. The moon was visible during 66% of the haze periods and in all of these observations it was at least 30 degrees above the horizon and usually full. No moon was recorded during mist or fog periods, but these conditions should be considered as a special case bordering on precipitation.

METEOROLOGICAL FACTORS. Temperature.—The tests were made using the following categories: 0-9, 10-19, 20-32, 33-39, 40-49, 50-59, 60-69, 70-79 and 80-89 degrees F. Test statistics for trips and distance were significant at the 95% level while time was significant at the 90% level. The relationship between temperature and activity is shown in Figs. 28 and 29. Activity gradually increased as temperature increased. Figure 30 shows that there was considerably less activity when the temperature was below freezing.

Humidity.—Readings below 40 percent were lumped together while those above 40 percent were grouped in intervals of 10 percent. Activity as indicated by trips and time was found to be independent of humidity. The test comparing distance, however, indicated that activity was not independent of humidity. This was believed to be a false conclusion since as can be seen in Fig. 31 all three activity profiles for humidity were similar. The slight peaks at 40-49% and 80-89% will be discussed later.

Precipitation.—A significant relationship could only be found for trips and precipitation at the 90% level, although as is shown in Fig. 32 activity was consistently lower during periods of precipitation. Based on notes made in the field, it appeared that snow flurries and intermittened light rain impeded activity very little. However, heavy mist, rain or sleet caused a drastic reduction in the amount of activity and any rats that were seen were running rapidly. During heavy snow falls, rats were frequently seen inside nest entrances but made only one short trip per hour.

Ground condition.—The condition of the ground is related to the combined effects of temperature, humidity and precipitation. For example, visible frost was formed whenever the temperature dropped below 20 degrees coincident with high humidity at the ground level. Moisture in varying amounts was observed on the ground during or after rain. These amounts ranged from dampness to saturation and in some instances the ground was only in the process of getting wet during the observation period. Because of the small number of samples in each case they all had to be combined into a single category. Likewise frost periods had to be combined with periods during which snow was on the ground.

When activity was tested against these three categories the Chi-Square values for trips was significant at the 90% level while the statistic for distance was significant at the usual 95% level. The test statistic for time was not significant. The graphs in Fig. 33 show that there was slightly less activity when the ground was wet and considerably less when there was frost or snow present. Field observations further revealed that if activity took place while snow was on the ground it was confined to branches and areas on the nest without snow while the snow covered ground was avoided. Tracks believed to be those of wood rats were seen on snow but the number of traceable routes indicated that activity was far below the amount normally observed during even shorter time periods without snow.

Barometric pressure.—Changes in weather are reflected in both the level and action of the barometer. For the purposes of this study readings from the barograph were rounded to the nearest tenth of an inch while the trend was classified as steady, rising, falling or fluctuating. During this study readings were observed to range from 28.2 to 29.3 inches of mercury. In the initial test the lowest three readings were grouped together because of their infrequent occurrence. In addition, since the normal barometric pressure for this elevation is 28.84, therefore, readings of 28.8 and 28.9 were combined. The Chi-Square test contained 36 categories for this factor. The results of these tests showed activity (trips and distance) to be related to barometric pressure. In an effort to more clearly define this relationship tests were made on level and action of the barometer independently but no relationship was found. Another test was made after classifying readings as low, normal or high while still considering the action of the barometer. The independence of trips and time was accepted while distance was barely rejected.

The graphs in Figs. 34 and 35 show that activity levels varied considerably with respect to barometric pressure. The least activity occurred when the barometer was normal and falling while the most occurred when the barometer was normal and fluctuating. Activity was fairly consistently high when pressure was rising and low when pressure was either high or low and fluctuating. Activity was higher when pressure was low and rising then when it was high and rising. There was also a slight increase when the pressure was high but falling.

Wind.—No equipment was available for recording wind direction and velocity but on a relative basis the wind was classified as light, strong or absent. The Chi-Square test indicated that activity was independent of the amount of wind, however, the graphs in Fig. 36 show there was considerably less activity when the wind was strong. It is believed that a significant relationship may be found if instruments were used to record wind velocity.

Noise.—One of the major results of wind is noise. The amount of noise produced by a given amount of wind is related to cover, season, dryness of the fallen leaves and precipitation. Like the wind, noise was classified on a relative basis of none, little, and much. The tests indicated that activity (trips and time) was independent of noise but distance was related at the 90% level. Figure 37 indicates that activity was lowest when the noise was greatest. It was observed that the rats were easily "spooked" by gusts of wind that caused leaves to fall or rustle on the ground.

Previous temperature.—Observations were classified as to whether the previous nights overall temperature was the same, lower or higher than the overall temperature of the night on which the activity was recorded. The Chi-Square tests indicated that activity was related to previous temperature, but the graphs (Fig. 38) indicate that the trends were inconsistent even though total activity was lower when the previous nights temperature was higher.

Previous illumination.—The previous nights illumination was classified as the same, brighter or darker than the illumination on the night that activity was recorded. The Chi-Square tests showed that except for distance (90% level), activity was independent of previous illumination, but the graphs in Fig. 39 show that activity was higher on a night following a night that had had brighter illumination.

DISCUSSION

Population Estimates

The method of expressing population estimates in terms of the percentage of nests that were occupied was believed to be superior to the usual methods of giving estimates in terms of rats/acre or rats/unit effort. These accepted methods could not be used because of the irregularity of wood rat habitat and the disproportionate trapping effort made necessary by the need for repeated recapture of the rats that were being observed. Spencer (1941) stated that den counts are a reasonably simple and accurate method of determining the population per acre. Vestal (1938), Monson and Kessler (1940), Murphy (1952), Hanson (1957), Box (1959) and Vogl (1967) have based estimates of wood rat populations on the percentage of occupied nests. Linsdale and Tevis (1951) reported on population changes of N. fuscipes as reflected by nest occupancy over a long period of time. The use of the percentage method can be justified by the fact that no more than one rat occupied each nest, unless it is a female rearing young. Since the nests remain intact for a number of years (Linsdale and Tevis, 1956) the number of nests can be used as a relatively constant indicator of the potential for a specific area to support wood rats. Box (1959) and Vogl (1967) have used den densities to compare the capacity of different plant communities or associations to support wood rats. When the population is high the pressure increases so that almost all of the nests are occupied by different rats.

The fall and spring estimates based on the same 35 nests can be compared directly demonstrating that there was almost a 50 percent decline in population over the winter. It is not known whether the fall estimate of 72.2% is representative of the whole area. However, it would appear that the population level for the entire area was fairly high in the fall and that rats from the untrapped periferal areas moved into the central area when rats in that area were killed by the collars. It was impossible to determine how many of the 22 rats not recaptured in the spring were killed by the collars and how many died of other causes. Trapping in a hedgerow situation in the spring revealed that only 58.8% of the 17 nests were occupied while there was still an abundance of food. It is believed that an undisturbed population on the study area would have been somewhat below 58.8% in the spring. The rats lost over the winter were quickly being replaced by young. The trapping did not indicate the full extent of this replacement since rats younger than 35 days could not be held in the traps.

Activity

In beginning this discussion it would be well to examine the basic hypotheses which led to the undertaking of this study. First it was postulated that activity is not evenly distributed throughout the night. This statement was rather easily substantiated by making a very few observations in the field. It was found that there were wide variations in the levels of activity observed under different circumstances.

This led to consideration of the second postulate that activity was not randomly distributed with respect to time and environmental conditions. This statement was not as easily proven as the first. A large number of samples was required in order to test the hypothesis that activity was independent of any given environmental condition. Considering the number of times that this hypothesis was rejected it is safe to assume that activity was certainly not always random with respect to environmental circumstances.

If these two hypotheses are accepted then it follows that some factor or combination of factors must influence activity. These factors will be discussed in detail but since the validity of these results depends in part upon the validity of certain assumptions made regarding procedure, it is advantageous to examine those assumptions at this time.

First and most important, this was a study comparing the relative activity of these wood rats under different conditions. Using the methods previously described even with the attitude of trying to observe as much activity as possible it would be pretentious to conclude that the total activity of these rats was observed during every observation period. This would be impossible since the beam of light used only illuminated a small percentage of the total area available to be observed. In addition from any given vantage point the entire nest and surrounding area was not visible. Precautions were taken so that variations in vantage points and immediate habitat around each nest would be unbiased with respect to the environmental conditions that were studied. In practice this aim was aided by the policy of limiting the number of observation stations and careful selection for the best possible vantage point of each nest. Those nests with the best vantage point were repeatedly watched under the whole range of environmental conditions being studied.

Taking these factors into account it is valid to assume that the same percentage of total available activity was observed under all conditions. The only exception to this statement occurring when no activity took place but this source of bias would only tend towards the acceptance of the null hypothesis of independence because it lessened the differential between active and inactive periods.

Another factor to be considered was the number of rats available to be observed from any one vantage point. The amount of activity available to be observed increased with the number of rats living within the area being observed, therefore, the chance of spotting activity increased with the number of rats. This was somewhat offset by the fact that the light could only scan one unit of area at any given moment. Comparison could not be made on a per rat basis since it could not always be determined with certainty how many rats were within the observed area but remained in their nests during the observation period. In reality only a small percentage of samples were thought to be based on the activity of more than one rat and these were assumed to be randomly distributed with respect to environmental conditions.

A potentially far greater source of error was present in the possibility of observing a nest without a rat. The chance of this occurring increased as the population decreased but it is believed that this error was kept to a minimum because of the following precautions. The nests most frequently watched were repeatedly retrapped to confirm occupancy. Nests that were known to be occupied in the immediate past were watched more frequently. Several different nests were usually watched during each observation session. These changes of vantage point and nests were made more frequently if activity was not being observed.

For the purposes of this study it was assumed that all rats were typical. It is believed that this assumption is not entirely correct since variations in activity due to sex and age are to be expected. Because of the marking system used, positive identification of the individual being observed was difficult. A system of marking based on broad classes of sex and age would have been preferable, but this information still would have to be ignored unless a large number of samples were available. There may also be individual variations in the rat's disposition to be active, but techniques would have to be refined in order to determine this.

Finally there is the possibility that the rats were influenced by the presence of an observer or the type of red light being used. The amount of disturbance caused by these factors was difficult to assess. Based on careful consideration of the field observations I believe it is valid to assume that the effects of these factors were minimal and equal under all conditions.

Although there has been much controversey on the subject of color perception it is believed that nocturnal animals are insensitive to light at the red end of the spectrum (Walls, 1942). This theory is based on the fact that the retina of most nocturnal animals is made up primarily if not entirely of rods. Rhodopsin, the visual pigment associated with rods, is red and therefore reflects red light, while it absorbs and is broken down by light of shorter wavelengths. Stimulation of the optic nerve results from this break down of the visual pigment.

Perception of light is dependent on both wavelength and intensity. Theoretically there is some point on the spectrum beyond which rats are unable to perceive light at any intensity. It is suspected that this point is well within the limits of human visual perception since humans are adapted to a primarily diurnal environment.

Observations of rats in the shuttle box experiments indicated that the rats were frightened by the white light which possibly inhibited the learning process while even though it appeared that they could perceive the red light or sudden change in intensity under those conditions they were less disturbed and learned easily. This learning to avoid the red light or the intensity change occurred under a stress situation which they were not being subjected to in the field. As previously mentioned, red light has successfully been used to observe wood rats and other nocturnal animals in the past.

The primary criteria for determining whether or not a factor influenced activity were the Chi-Square tests of independence. However, as Snedecor (1956:25) points out, the Chi-Square test should not be used as the sole criteria for making a decision. This decision should be based on the total information available. In this case the activity profiles clearly point out any existing trends. Usually these results are in accord with the Chi-Square tests but if they are not other factors such as choice of categories or the proportion of samples in each category must be considered.

MECHANISM OF ENVIRONMENTAL INFLUENCE. If we accept the theory that environmental factors do influence activity then it is interesting to speculate about the mechanism through which this control manifests itself. First we must consider why the organism is active. Activity is the means of carrying on the normal functions of the organism enabling it to survive. Generally these can be classified as feeding or gathering food, finding or providing shelter, eliminating waste materials, defending itself or a territory and reproducing. All of these activities must be performed while evading predators.

Richter (1927) observed that the white rat in an environment that provided no external stimulation exhibited periodic (every 2 hours) increases in activity. He was able to demonstrate a correlation between this periodic activity and the cyclic recurrence of stomach contractions and thus was able to establish that these hunger contractions stimulate the organism to activity. He further found that activity in the female rat, on an activity wheel, increased from less than 1 mile to 8 or 10 miles every fourth day just prior to ovulation. Other cyclic phenomena observed in the rats were their drinking at regular intervals of 2½ hrs., urination every 2 hrs., and defecation every 5 hrs.

These findings imply that the primary stimulus for an organism to engage in each of these activities is endogenously determined. These activities are also regulated by the organisms evolutionarily developed capacity to go without food, endure the physical environment (heat, cold, precipitation), wariness (of predators), patience (the converse of desire to be active), and preference for one situation over another. Richter (1927) found that in cages where the animal had many different diversions the frequency of its eating period was reduced. Therefore, the activity of an organism may be viewed as a balance between endogenous stimuli and exogenous environmental factors. This balance has been developed through the process of evolution to the point most favorable for the organism. Thus, the survival of an organism has depended in large part on its ability to either suppress its desires during potentially harmful environmental situations or alter its behavior so that these desires could be safely saitiated. Selection has been made for the behavior, sensory apparatus and motor capabilities that best enable the organism to satisfy its endogenous desires without contact with the portion of the external environment that is most detrimental to it.

Shrews for example, because of their small size, have a high metabolic rate and therefore require large amounts of food, which must be acquired through almost constant activity (Morrison et al., 1957). Selection for fossorial habits in this organism has enabled it to fulfill these requirements. In wood rats, selection for nest building, food gathering and storing and defence of these posessions have been of great importance in the evolution and survival of this species. Linsdale and Tevis (1951:645) state that food stores help N. fuscipes to avoid unfavorable conditions that may arise outside.

The range of a species is ultimately limited to the range of environmental factors the organism can endure while still carrying on its normal functions. This range can be extended if an organism has more time available in which to carry out its necessary activities than it actually needs. Necessary activities in this case being defined as those which fulfill the needs of the organism as decribed above. This leads to the supposition that these activities are performed in only a portion of the time available and this portion is determined by the immediate environmental factors. If it is proposed that all activities are necessary since evolution has eliminated all unnecessary activity, then sitting in the nest when rest is not needed may be considered of survival value because it keeps the organism out of an unfavorable environmental situation. These circumstances, although they may not in every instance lead to the immediate death of the organism may, if habitually entered into, lessen its chances for survival. Linsdale and Tevis (1951:643) state of N. fuscipes that "on many rainy or moonlit nights some rats do not venture out."

These considerations are the basis for the theory that activity may be inhibited by unfavorable environmental factors and consequently there is a corresponding release or increase in activity when conditions again become more favorable. A good example of this type of mechanism was found in the setting of the moon. If activity had been inhibited for the greater part of the night by a bright moon, the level of activity would begin to rise as the moon neared the horizon and a noticeable increase occurs just after the moon sets. This is also true though less dramatic if a bright moon rose several hours after sunset. Further ramifications of this theory will be considered after the specific influence of the other environmental factors has been discussed.

SPECIFIC INFLUENCES. Nocturnality.—In any prey species living within its range the prerequisite for survival is the evasion or avoidance of predators while carrying on other necessary functions. Night may be considered the most favorable time for a prey species to be active if it has evolved a tolerance for the other conditions (temperature, humidity, etc.) that prevail during this time. Although most predatory species are also active at night the darkness facilitates the elusive capabilities of the prey. The almost exclusively nocturnal habits of wood rats are well documented. From this it may be inferred that the primary factor influencing the activity of wood rats is wariness of predators.

Annual pattern.—Although the entire annual cycle has not been considered in this study it appeared that there would be two peaks in the annual pattern of wood rat activity. The greater of these two occurred in the fall. During this period the rats were experiencing the greatest amounts of available fresh food and overhead cover in conjunction with photoperiods between 12 and 14 hours of darkness. It is fairly certain that the high amounts of activity observed at this time are reflective of the wood rats habit of gathering and storing food for the winter. Rainey (1956:576 and 577) stated, "The drive that compels woodrats to store food in quantity usually does not commence until in September or October. . . The urge to store food dominates all other activities once the drive has begun." Some of the factors which may have initiated this activity are increasing length of dark period, appearance of the type of food that is permanently stored, changes in palatability of vegetation, the occurrence of freezing temperatures and decreasing amounts of foliage on the plants. It is difficult to speculate at this time which of these factors is actually responsible for the initiation of food gathering activities on a large scale.

Activity declined during the winter months (Fig. 10). Cover in the form of leaves on the plants disappeared approximately one month before the onset of the cold period but high levels of activity continued until the cold period (Figs. 11 and 12). Since cover normally restricts the movements of wood rats (Rainey, 1956), it might be speculated that this extension of high activity was due to the drive to gather food and the fact that a large part of early November, particularly the sunsets, was moonless or had the first phases of the moon setting in early evening.

The decline in activity during the cold period was probably due in large extent to the adverse climatological conditions of this period. The facts that cover was sparce and the supply of available food was also dwindling may have influenced the cessation of food gathering on a large scale. It was also observed that during this period the runways deteriorated. This deterioration may have been brought about either by disuse or weathering effects. It seemed likely that precipitation and frost began the deterioration which in turn led to less extensive use by the rats. There was evidence that the rats were heavily dependent on the runway system for navigational and perhaps security reasons. Rats that were released from traps usually wandered aimlessly until they crossed a runway at which time they would run rapidly and directly toward a nest; hesitating only at the entrance if the nest was occupied by another rat.

The increase in activity in the spring was probably brought on largely by the availability of fresh food and the release from the inhibitions of bad weather. Part of this increase was probably also due to the search for reproductive partners and as was observed in the laboratory, the hoarding of food by pregnant females. Summer activity, though not observed, might be expected to be higher than spring but lower than autumn.

The possibility that the influence of other environemntal factors can be modified by season has been shown by other investigators. These papers will be cited in later discussion. Teleston and Lechleitner (1966) noted that only 50 percent of a population of black-tail prairie dogs (Cynomys ludovicianus) was active above ground during peak periods of activity occurring between December and March while 95-100% of the population was active during peak periods in the summer months. They also noted that no activity took place for several days during winter if adverse weather prevailed.

Daily Pattern.—The daily activity cycle was ultimately determined by the sun. The presence of direct sunlight precluded activity while the indirect illumination of sunset and sunrise had an inhibitory effect. Poole (1940) stated that activity of N. floridana magister in the hills of Pennsylvania commensed one half hour after sunset and continued until just before daylight. Spencer (1941) found that N. albigula in the Sonoran desert emerged promptly at sunset, reached peak activity within the first two hours and by midnight were again quiescent. He also found a second period of less intense activity during the three hours before sunrise. Trapping conducted by Murphy (1952) indicated that N. floridana were active during the early hours of darkness but not enough evidence was gathered to tell if they were equally active during all hours of the night. The study by Wiley (1967) indicated that in the summer wood rats become active 30 minutes before total darkness and continue foraging until approximately 30 minutes before sunrise.

Some activity was observed during the first 15 minutes after sunset but the largest burst of activity occurred 30 minutes or more after sunset, (Figs. 14 and 15). The second hour after sunset (the first full hour of darkness) had the most activity. This peak in activity can be interpreted as a hunger response which manifests itself after the organism has been released from the inhibitory effect of sunlight. Vestal (1938) stated that wood rat nests usually contain a temporary food store that is accumulated and consumed in a 24 hour period. He further stated that most of the fresh food in the nests is eaten by late afternoon. After these initial needs were satisfied, activity subsided in the third hour after sunset and generally remained at low levels until the last full hour of darkness before sunrise (Figs. 16 and 17). Activity at this time is advantageous in that it is the last opportunity to carry on normal functions before daylight.

This type of bimodal activity pattern has also been found in deer mice, Peromyscus leucopus (Behney, 1936); cotton rats, Sigmodon hispidus (Calhoun, 1945); kangaroo rats, Dipodomys merriami (Reynolds, 1960); and harvest mice, Reithrodontomys megalotis (Pearson, 1960). Calhoun (1945) experimenting with cotton rats under conditions of light, dark and reversed photoperiod concluded that this rhythm was endogenous but affected by light. Behney (1936) found that deer mice will exhibit diurnal activity in tunnels under snow cover or during hunger.

The activity levels observed during the night were probably determined by individual differences in the length of active and inactive periods. Activity as observed in the field came in spurts of one or more trips with inactive periods in between ranging from a few minutes to more than an hour depending on other conditions. Rainey (1956) observed rats alternating in periods of active foraging, eating from the food store and resting in the nest. These periods of feeding in the nest lasted up to 10 minutes and were sometimes repeated within the hour.

The lesser peaks observed at six hours after sunset and seven hours before sunrise probably occurred because the periodic preferences of most rats may have coincided at these times. The possibility that hunger may recur several hours after the initial feeding burst should also be considered. Poole (1940) also noted a peak in activity near midnight. The fact that Wiley (1967) did not note this peak during summer observations may indicate the effect of long winter nights.

The fact that there was less activity after midnight suggests that most of the necessary functions are performed before that time and activity after that is opportunistic. Wiley (1967) found that 75 percent of their activity occurred before midnight and 54 percent of this amount occurred between 8:30 - 10:30 P.M.

This daily activity pattern may be influenced to varying degrees by other environmental factors. It is most likely that these factors have their greatest effect after the initial activity period has been completed although it is not inconceivable that even this period could be modified if the conditions are severe enough. Rainey (1956) reports observing a rat remaining in its nest until 10:30 one night while it was raining but this same nest was empty at 11:30, after the rain had stopped. Generally it may be stated that the peak in activity soon after sunset is the most dominant factor of the nocturnal activity pattern.

MODIFYING FACTORS. Illumination.—The most important in terms of frequency of occurrence of these modifying factors was illumination. The fact that activity was inversely related to the amount of light supports the theory that it is advantageous for a prey species to remain unseen. The greatest manifestation of this theory is afforded under conditions where the prey can remain in shadows and still be able to watch for predators in the brightly moonlit surroundings. This idea may account for the high amount of activity observed while bright illumination and shadows prevailed (Fig. 21). The peak under dim illumination may, as mentioned before, indicate that the rats prefer some illumination over complete darkness. No distinction was made between totally dark periods and periods where there was only illumination from the stars. These latter periods were relatively dark when compared to moonlit nights but were still lighter than overcast nights. Dark observations included periods of precipitation which may have lowered the activity levels of this category.

Illumination is primarily a function of moon phase and angle as modified by cloud cover. The evidence presented indicates that when there is a moon present, its altitude above the horizon exerted an important effect on wood rat activity in that if it was less than 30 degrees, activity was increased; but at altitudes above 30 degrees the moon uniformly inhibited activity (Fig. 25). It was also found that a full moon had more of an inhibitory effect than a half moon, (Fig. 22) particularly when it was at higher altitudes (Fig. 26). Furthermore, rats preferred to be active when the moon was masked by a uniform layer of thin clouds (Fig. 27). Blair (1951) found that when no moon was present their was no difference in captures of Peromyscus polionotus on clear or cloudy nights but during half to full moon phases captures were much lower on clear nights than when the moon was obscured by clouds.

These factors were determined without consideration of other possible influencing factors. Further investigation revealed that the initial high activity period during the second hour after sunset (Figs. 14 and 15) was apparently not as inhibited by the moon as other times (Figs. 26 and 40). However, in those samples where the moon was present during this time period activity was lower indicating there was some modifying effect. Twelve percent of the observations made at this time had a half moon higher than 60 degrees and 15 percent had a full moon lower than 30 degrees. Activity during these periods was higher than during other time periods having these moon classes but lower than when no moon was present. The highest activity while a moon was present occurred while a full moon was at the horizon.

Pearson (1960 a and b) found that Microtus californicus and Reithrodontomys megalotis tended to be less active on full moon nights when compared to moonless nights. However, he also found a significant tendency for the harvest mice to ba active during those portions of the same night that had illumination from a halfmoon. No allowance was made for cloud cover. When activity was plotted against daily moon phase the only increase was found at no moon. Gentry et al. (1966), in studying the effects of weather on the capture of small mammals, found that the greatest number of captures of cotton rats and total species on the area was made on cloudy nights. Blair (1951) found that live trap captures of Peromyscus polionotus leucocephalus on beaches were reduced on moonlight nights and he concluded, "the degree of illumination by the moon was the most important factor governing the amount of activity on a given night." Blair (1943) had found that activity of P. maniculatus blandus decreased as the intensity of artificial light was increased from 0 to 1.45 foot candles.

Finley (1959) observed that wood rats were shy of moonlight and in a personal communication he indicated that the few animals seen on moonlit nights were usually seen running in moon-shadow situations. Wiley (1967) found wood rat activity to be lower on nights when the moon was full or nearly so and higher on nights of new and quarter moon phases. He suggested that moonlight might only effect activity when the intensity reaches a "determinate" point. This idea is supported by the evidence which I have presented.

Meteorological.—These factors cannot be considered so much in terms of evasion of predators, but more in terms of the physical well being or endurance of the organism. Perhaps it is best to approach this problem by assuming that there is some "normal" level of activity that would occur if environmental conditions were continuously at optium levels for survival of the rats and equal with respect to preference. Then, since the environment is not static, it would be desirable to list those conditions which may decrease or prevent activity.

In considering these factors it is well to remember the homeostatic value of the wood rat nest and the advantages of having large quantities of food stored in the nest. Rainey (1956), comments in detail on the value of these factors to the survival of the individual and extensive range of the genus. He also comments on the phylogenetic origin of the genus and the evolution of this exoadaptive (hereditary adjustment to the external environment) behaviorism.

The first meteorological factor to be examined was temperature. Sidorowicz (1960) found that capture of small rodents in Poland were related to daily maximum and minimum temperatures. Bradley (1967) demonstrated that ground squirrels (Citellus leucurus) favored a temperature range of 15-30°C and their daily activity pattern varied seasonally to coincide as nearly as possible with optimum temperatures. Tileston and Lechleitner (1966) found that the diurnal bimodal activity pattern exhibited by both black and white tailed prairie dogs (Cynomys ludovicianus and C. leucurus) in summer was related to temperature and in winter this pattern changes to a solitary peak coincident with midday high temperature for C. ludovicianus while C. leucurus remained inactive throughout the winter.

The Chi-Square tests and activity profiles (Figs. 28, 29 and 30) showed, as might be expected, that wood rats spend less time out of their nests when the temperature is low. Murphy (1952) stated that wood rats apparently stay within their shelters on extremely cold nights. With the amount and type of information available it is difficult to say more than this regarding this important factor.

First the numerical values given to the temperatures are arbitrary with respect to the zone of thermal neutrality and critical temperature of wood rats. Secondly, it would be advantageous to compare temperatures within each seasonal period to find out if, for instance, there was more activity at 50 degrees during the cold period than during the precold or warm periods. Thirdly, the daily temperature cycle may cause modification of the importance of any given temperature by time. This phenomenom would have its greatest effect around sunset when the temperature is falling rapidly while activity is on the increase. With the evidence currently available it seems likely that temperature as an inhibiting factor during this transition period is subordinate to time relative to the sunset. However, it must be pointed out here that during the second hour after sunset 9 of 37 observations without a moon present had no activity and five of these had temperatures below freezing. Vorhies and Taylor (1940) stated of wood rats in Arizona that "trapping experience indicates greater activity during the early hours of the night, especially during the colder seasons when the night temperature falls rapidly." Lastly, temperature should be considered on the basis of relative discomfort caused by a given temperature in combination with the wind, humidity, precipitation and duration of exposure. Wind chill factors, dampness or condition of pelage could have a great deal of influence on the discomfort or survival of the organism. Hart *et al*. (1961) has shown that newborn caribou (*Rangifer tarandus*) when exposed to cold temperatures (1.5°C), high wind (26 mph) and precipitation for 5.5 hours became hypothermic and died. Many more samples would have been needed to properly study the effects on wood rats of all of these possible combinations involving temperature.

Activity was found to be independent of humidity, however, the graphs in Fig. 31 show peaks at 40-49 and 80-89%. It is believed that this apparent relationship is due to other factors. First, the daily cycle of relative humidity is roughly converse to that of temperature. Therefore, humidity is low during the day but rises rapidly at sunset to a high during the night. Most of the observations that were made while the humidity was less than 40% took place during the first 45 minutes after sunset while activity was low. It was further found that most of the observations that were made while the humidity was between 40 and 49% took place during the latter part of the first, the second and probably the beginning of the third hour after sunset when activity was normally high. None of the observations made at this humidity took place after midnight.

There was a decline in activity when the humidity was above 90%. This was probably due to the indirect affect of humidity as a factor of precipitation or frost. The peak in activity at 80-89% could possibly be explained by the proximity of this humidity to precipitation or the subsequent release from the inhibitory effects of frost.

Although no significant relationship could be shown for precipitation, it was believed that this was due to a type II error (accepting the null hypothesis when it is false). This error was believed to be caused by the disproportionate number of samples in each of the two categories. Activity in some cases was limited by other factors when there was no precipitation. Furthermore, conditions ranging from snow-flurries, mist or light rain to heavy snow and heavy rain were lumped in one category for the tests but differential effects were noted in the field. In spite of these factors activity was still much lower during precipitation (Fig. 32).

Heretofore most studies relating activity to precipitation have used the criterion of a trace or more of precipitation in a 24 hour period. Sidorowicz (1960) reported that the capture of small rodents in a Polish forest was increased on days with heavy rainfall. Pearson (1960 b) found no significant difference in the activity of Reithrodontomys on rainy and rainless nights but he found (1960 a) the activity of Microtus californicus to be significantly ($P < .10$) higher on rainy nights based on a 24 hour period. Gentry et al. (1966) found the type of weather to be significant ($P < .05$) for the capture of cotton rats and total mammals. They had an average number of captures when it rained during a 12 hour period, less when it was clear and most when it was cloudy.

These studies neglect to distinguish between activity during precipitation and the influence of associated conditions on activity immediately prior to or after precipitation. Bradley (1967) observed little ground squirrel activity during periods of cold accompanied by rain or snow. Tileston and Lechleitner (1966) state that all surface activity of prairie dogs ceased during rain or snow.

Vorhies and Taylor (1940) suggested that wood rats were probably less active on wet, cold nights than in drier weather. Murphey (1952) stated that the wood rat apparently stays within its shelter on wet nights. Poole (1940) found that during rainy weather wood rats would often not appear at all. Rainey (1956:559) stated that wood rats were usually more active on dark rainy nights than on clear nights. "Seemingly, this is directly the result of increased darkness." He goes on to say that rats dislike getting wet and forage in slack periods in the rain. The incident of rain inhibiting activity at sunset has previously been cited.

It is difficult to separate the influence of precipitation as it falls on the rat from the influence of its effects on the condition of the ground and environment in general. Bider (1961) concluded that snow on the ground did not impede hares but their movements were restricted to cover during a snow storm. Likewise Tileston and Lechleitner (1966) found that water or snow on the ground only reduced activity of prairie dogs. It is widely believed that wet rats stand little chance of survival and that this chance is diminished by cold temperatures. Hart et al. (1961) have found this to be the case with infant caribou. Two rats that got wet while in traps, died. In view of these facts it seems likely that the rats avoid long exposure to heavy precipitation, but take advantage of the darkness resulting from dense cloud cover. Rats that were observed to be active during precipitation seemed to be hesitant about venturing forth but were probably compeled to do so in order to fulfill some fundamental need. This impression was sustained by the fact that the rats, although seen often at the nest entrances, came out less frequently and ran very rapidly when they did come out.

The degree of saturation of the ground played a large part in limiting wood rat activity during precipitation. When the ground was too saturated for normal travel the rats relied heavily on their arborial routes among the branches and fallen tree trunks. The avoidance of accumulated snow was another factor that strongly affected their behavior and limited their activity. Frost, brought about by a combination of low temperature and high humidity, also inhibited activity to about the same degree as bright moonlight (Fig. 33).

It is difficult to say whether the variations (Figs. 34 and 35) in activity with respect to barometric pressure were random or not. Perhaps the key to this problem is to be found more in the type of activity engaged in rather than the amount. Along these lines the only particularly unusual type of activity noted in this study occurred when rats were observed to be digging frantically in tunnels under their nests. This behavior was observed during 4 periods which included the two samples in which the rat came out of the nest 13 times. Three of these periods took place while the barometer was 28.5 and fluctuating and the fourth took place while the barometer was 28.5 and rising. If these incidents have any significance it would seem to imply that wood rats are sensitive to barometric pressure. Whatever the case may be more study will have to take place before any definite conclusions can be drawn.

Although activity was independent of wind and noise, there was a negative trend at high levels of each (Figs. 36 and 37). Bider (1961) found that high wind was most restrictive on the movements of hares in winter but not in summer. Tileston and Lechleitner (1966) also found that high wind velocities reduced surface activity of prairie dogs. Poole (1940) observed that wood rats in Pennsylvania were not active during an east wind. Wind and noise though related are not entirely identical. The amount of noise produced by a given amount of wind depends on many other factors such as cover, season, leaf litter and precipitation. Only 53% of the observations having strong wind were accompanied by loud noise. When activity was inhibited by these conditions it could probably be attributed to wariness. Finley (1959) observed that wood rats were easily frightened by sounds. Rainey (1956) stated that sudden nearby noises such as rustling of leaves or sticks will cause a wood rat to be on the alert instantly.

OTHER CONSIDERATIONS. It must be emphasized here that the organism is confronted by the total environment while this study has only dealt with some of the individual factors of that environment. Indeed there may be factors of the environment which greatly influence activity but are yet undefined and unstudied. Furthermore the influence of some of these factors in combination may drastically alter the total effect. Likewise the duration and sequence in which changes in each of these factors occur may have an important effect on their control over activity.

Immediate history.—In keeping with the theory that activity is inhibited by unfavorable environmental conditions and that there is a subsequent release or increase in activity when conditions again become more favorable it was found that activity was significantly related to temperatures and appeared to be related to illumination of the previous night (Figs. 38 and 39). The influence of weather change on the capture of small rodents has been dramatically shown by Gentry and Odum (1957) and Gentry et al. (1966). Sidorwicz (1960) stated that "in general the weather over a certain period of several days is the important factor"in the capture of small rodents.

Thus it has been established that activity can be inhibited during certain parts of the same night and from one night to the next. It would be interesting to find out just how many factors can bring about the inhibition of activity over period of several days and if this effect is diminished by prolonged inhibition or in some cases where food is not stored might cause the organism to succumb. As a matter of speculation it is suggested that there may be activity cycles determined by the monthly cycle of the moon as there are cycles governed by the annual cycle of the sun. It should not be overlooked that these cycles may be interruped by the presence of dense cloud cover or influenced by other factors which occur either randomly with respect to the moon phase or seasonally with respect to the sun cycle.

Practical applications.—If enough data were accumulated, a chart showing the cyclic factors of the environment such as Fig. 41 could possibly be used

SUMMARY AND CONCLUSIONS

The nocturnal activity of wood rats (Neotoma floridana osagensis) was observed under field conditions with the aid of red light. Environmental conditions were recorded during these observations. Data were divided into 15 minute samples and analyzed by computer in an attempt to determine whether or not activity was influenced by any of the environmental conditions studied. In this analysis three activity indicators (number of trips, time spent out of the nest and distance traveled) were compared with 25 environmental factors by Chi-Square tests of independence. Graphs were drawn to show any significant relationship or apparent trends that were found.

The wood rat's perception of red light was tested in shuttle box experiments and it was concluded that although they could respond to red light or the change in intensity that it produced they were not overly disturbed by this light in the field.

The trapping program indicated that, based on the percentage of occupied nests, the wood rat population on the area declined from 72.2 percent in the fall of 1966 to 40 percent or less in the spring of 1967. This deficit was being countered by reproductive efforts in the spring of 1967.

The following conclusions regarding the influence of environmental conditions on activity were made from the data presented.

1. Activity was high during the precold period because of the wood rat's drive to store food. This drive was not inhibited by the decrease in cover that resulted from leaffall.
2. The decline in activity during the cold period was probably due to adverse climatological conditions in combination with the absence of cover and dwindling supply of available food.

3. The increase in activity during the post cold period was probably brough on by the release from unfavorable conditions, availability of fresh food and onset of the reproductive processes.

4. The most prominent feature of the daily activity pattern was the burst of activity beginning at 30 minutes after sunset and reaching a peak during the first full hour of darkness. This activity may be interpreted as a hunger response corresponding to the release from the inhibitory effect of sunlight. This peak was less susceptible to the modifying effects of other factors.

5. Lesser peaks were observed near midnight and during the last full hour of darkness before sunrise but most of the total activity for the night occurred before midnight.

6. The most important modifying factor was illumination. Activity was inversely related to illumination.

7. If a moon was present its altitude above the horizon exerted an important effect in that, if it was less than 30 degrees, activity was high, but if it was more than 30 degrees, activity was drastically curtailed. A full moon between 75 and 90 degrees above the horizon had the greatest inhibitory effect.

8. Activity was also significantly related to cloud cover with the highest levels being observed while thin clouds or partially overcast skies prevailed.

9. Activity was directly related to temperature with freezing temperatures apparently having the greatest inhibitory effect.

10. Activity was generally lower during periods of precipitation but varied considerably with type and amount of precipitation.

11. Snow cover or frost resulting from low temperature and high humidity also inhibited activity.

12. Noise resulting from high wind and falling leaves tended to lower activity.

13. Activity was significantly related to the temperature of the previous night.

14. No significant relationship could be demonstrated for relative humidity, barometric pressure, wind or previous night's illumination.

15. Activity may be controlled by the interaction of endogenous stimuli and exogenous environmental conditions.

16. There may be an order of dominance among the various environmental factors that influence activity.

17. It may be possible to predict activity and therefore estimate the annual energy expenditures of a species or population.

18. It is pointed out that home range studies or population estimates based on either captures per unit effort, road kill counts and hunting success may be influenced by environmental conditions since they are dependent on activity.

19. An alternative method of estimating wood rat populations is suggested.

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APPENDIX I

Table 1.—Frequency of woody plants collected within one meter of 35 typical occupied, wood rat nests.

Red-Osier Dogwood	(*Cornus stolonifera*) Michx.	71%
Coral Berry	(*Symphicarpos orbiculatus*) Moench.	63%
American Elm	(*Ulmus americana*) L.	54%
Missouri Gooseberry	(*Ribes missourienses*) Nutt.	46%
Fragrant Sumac	(*Rhus aromatica* var. *serotina*) (Greene) Rehd.	43%
Black Rasberry	(*Rubus occidentalis*) L.	20%
Silverleaf Grape	(*Vitis aestivalis* var. *argentifolia*) (Munson) Fern.	14%
American Hackberry	(*Celtis occidentalis*) L.	11%
Red Cedar	(*Juniperus virginiana*) L.	6%
Bitter Nightshade	(*Solanum dulcamara*) L.	6%
Common Cottonwood	(*Populus deltoides*) Marsh.	3%
Ashleaf Maple	(*Acer negundo*) L.	3%
Smooth Sumac	(*Rhus glabra*) L.	3%

Table 2.—Range and peak wavelengths (millimicrons) emmitted by a 6 volt headlamp with red acetate filters.

type of filter	range of emmision	point of least optical density
light red; single sheet	524-740 332-454	598* 390
light red; double sheet	552-753 337-485	604* 380
dark red; single sheet	582-750	613
dark red; double sheet	595-746	623

* point of least optical density of the two peaks for the same material.

Table 3.—Summary of Chi-Square Tests.

Environmental Condition	Activity Indicator	d.f.	$X^2_{.05}$	Test Statistic	Decision	Figure
Month	Trips	32	46.17	57.65	reject	10
	Time	48	65.12	88.56	reject	
	Distance	48	65.12	93.85	reject	
Season	Trips	8	15.51	28.34	reject	11
	Time	12	21.03	35.88	reject	
	Distance	12	21.03	53.03	reject	
Cover	Trips	8	15.51	8.22	accept	12
	Time	12	21.03	7.60	accept	
	Distance	12	21.03	22.44	reject	
Dark Period	Trips	16	26.30	24.53	accept*	13
	Time	24	36.42	25.77	accept	
	Distance	24	36.42	34.32	accept*	
Hr. after Sunset	Trips	24	36.42	43.65	reject	14 & 15
	Time	36	50.97	36.59	accept	
	Distance	36	50.97	39.10	accept	
Hr. before Sunrise	Trips	28	41.34	30.75	accept	16 & 17
	Time	42	58.10	32.92	accept	
	Distance	42	58.10	64.46	reject	
A.M.-P.M.	Trips	4	9.49	6.83	accept	
	Time	6	12.59	16.58	reject	
	Distance	6	12.59	18.33	reject	
Illumination Grouped	Trips	8	15.51	10.63	accept	18
	Time	12	21.03	9.01	accept	
	Distance	12	21.03	10.54	accept	
Evening Illumination	Trips	16	26.30	58.70	reject	21
	Time	24	36.42	70.07	reject	
	Distance	24	36.42	50.57	reject	
Moon Phase	Trips	8	15.51	15.02	accept*	22
	Time	12	21.03	25.12	reject	
	Distance	12	21.03	18.32	accept	
Angle of Moon	Trips	52	69.82	74.10	reject	23 & 24
	Time	78	99.65	110.08	reject	
	Distance	78	99.65	169.96	reject	
Moon Angle (grouped)	Trips	8	15.51	26.10	reject	25
	Time	12	21.03	32.33	reject	
	Distance	12	21.03	32.64	reject	

* significant at .1 level

Table 8.—(Continued)

Environmental Condition	Activity Indicator	d.f.	$X^2.05$	Test Statistic	Decision	Figure
Moon Phase and Angle (Combined)	Trips	20	31.41	50.05	reject	26
	Time	30	43.77	84.54	reject	
	Distance	30	43.77	64.92	reject	
Cloud Cover	Trips	24	36.42	34.69	accept*	27
	Time	36	50.97	49.45	accept*	
	Distance	36	50.97	65.12	reject	
Temperature	Trips	32	46.17	52.51	reject	28 & 29
	Time	48	65.12	64.75	accept*	
	Distance	48	65.12	70.25	reject	
Temperature (grouped)	Trips	8	15.51	14.90	accept*	30
	Time	12	21.03	21.31	reject	
	Distance	12	21.03	19.50	accept*	
Humidity	Trips	24	36.42	24.59	accept	31
	Time	36	50.97	35.76	accept	
	Distance	36	50.97	55.90	reject	
Precipitation	Trips	4	9.49	8.39	accept*	32
	Time	6	12.59	8.23	accept	
	Distance	6	12.59	7.06	accept	
Ground	Trips	8	15.51	13.66	accept*	33
	Time	12	21.03	18.05	accept	
	Distance	12	21.03	23.62	reject	
Barometric Pressure	Trips	140	168.14	173.63	reject	
	Time	210	240.64	217.78	accept	
	Distance	210	240.64	252.98	reject	
Barometric Pressure (grouped)	Trips	44	60.44	52.69	accept	34 & 35
	Time	66	85.98	70.48	accept	
	Distance	66	85.98	86.13	reject	
Wind	Trips	8	15.51	9.14	accept	36
	Time	12	21.03	9.01	accept	
	Distance	12	21.03	14.06	accept	
Noise	Trips	8	15.51	5.54	accept	37
	Time	12	21.03	11.82	accept	
	Distance	12	21.03	18.81	accept*	
Previous Temperature	Trips	8	15.51	15.72	reject	38
	Time	12	21.03	24.13	reject	
	Distance	12	21.03	24.51	reject	
Previous Illumination	Trips	8	15.51	9.94	accept	39
	Time	12	21.03	16.98	accept	
	Distance	12	21.03	19.60	accept*	

* Significant at .1 level

APPENDIX II

Environmental Factors and Conditions used in the Chi-Square tests and activity profiles.

month
    September 1966 through May 1967

season
    precold - until Nov. 26
    cold - Nov. 27 - Feb. 24
    postcold - after Feb. 24

cover
    until final leaffall - Oct. 31, 1966
    bare branches - Nov. 1, 1966 - Mar. 31, 1967
    spring leaves - April 1, 1967

length of dark period
    10 & 11 hours
    12 "
    13 "
    14 "

time after sunset until midnight	total observation periods in each hour
sunset - 1 hour after	56
1 - 2 " "	61
2 - 3 " "	49
3 - 4 " "	50
4 - 5 " "	48
5 - 6 " "	34
6 - 7 " "	17

first hour after sunset
    sunset - 15 minutes after
    15 - 30 " "
    30 - 45 " "
    45 - 60 " "

time before sunrise (after midnight)	
8 - 7 hours before	9
7 - 6 " "	32
6 - 5 " "	50
5 - 4 " "	40
4 - 3 " "	22
3 - 2 " "	21
2 - 1 " "	27
1 - sunrise "	26

last hour before sunrise
    60 - 45 minutes before
    45 - 30 " "
    30 - 15 " "
    15 - sunrise "

segment of the night
- p.m.
- a.m.

illumination (grouped)
- night
- sunset
- sunrise

sunset illumination
- sunset - very light
- twilight - good visibility
- dusk - artificial light needed
- evening - lunar and stellar illumination predominate

sunrise illumination
- daybreak - first light
- dim light - stars begin to fade
- twilight - land features become distinguishable
- daylight - refracted sunlight

night illumination
- dark - includes starlight
- dim
- light
- bright
- bright with shadows

moon phase
- no moon
- half moon
- full moon - 12th to 20th night of moon cycle

approximate altitude of the moon
- below the horizon
- 0 - degrees above the eastern horizon
- 15 - " " " " "
- 30 - " " " " "
- 45 - " " " " "
- 60 - " " " " "
- 75 - " " " " "
- 90 - degrees above the horizon
- 75 - degrees above the western horizon
- 60 - " " " " "
- 45 - " " " " "
- 30 - " " " " "
- 15 - " " " " "
- 0 - " " " " "

altitude of the moon (grouped)
- below the horizon
- 0 - 15 degrees above either horizon
- 30 - 60 " " " "
- 75 - 90 " " " "

moon phase and altitude combined

half moon ;	0 - 15	degrees	above	either	horizon
" " ;	30 - 60	"	"	"	"
" " ;	75 - 90	"	"	"	"
full moon ;	0 - 15	"	"	"	"
" " ;	30 - 60	"	"	"	"
" " ;	75 - 90	"	"	"	"

cloud cover
- clear
- mist or fog
- haze
- thin clouds
- partially overcast; less than 50%
- partially overcast; more than 50%
- 100% overcast

temperature
- 0 - 9° F.
- 10 - 19° F.
- 20 - 32° F.
- 33 - 39° F.
- 40 - 49° F.
- 50 - 59° F.
- 60 - 69° F.
- 70 - 79° F.
- 80 - 89° F.

relative humidity
- 0 - 39%
- 40 - 49%
- 50 - 59%
- 60 - 69%
- 70 - 79%
- 80 - 89%
- 90 -100%

precipitation
- none
- mist, light or heavy rain, snow or snow flurries

ground
- dry
- damp or wet
- frost or snow

wind
- none
- light
- strong

noise
- none
- little
- much

barometric pressure

28.2 - 28.7 in. of Hg steady
" " " " " rising
" " " " " falling
" " " " " fluctuating
28.8 - 28.9 in. of Hg steady
" " " " " rising
" " " " " falling
" " " " " fluctuating
29.0 - 29.3 in. of Hg steady
" " " " " rising
" " " " " falling
" " " " " fluctuating

previous nights temperature

same
lower
higher

previous nights illumination

same
brighter
darker

APPENDIX III

Activity Indicators and Activity levels used in the Chi-Square tests and activity profiles.

number of trips*

- 0
- 1
- 2
- 3
- 4 or more

time observed out of the nest (seconds)*

- 0
- 5
- 10 - 19
- 20 - 29 — combined in activity profiles
- 30 - 39
- 40 - 99
- 100 or more

distance traversed (feet)*

- 0
- 1 - 9
- 10 - 19
- 20 - 29 — combined in activity profiles
- 30 - 39
- 50 - 99
- 100 or more

type of activity

- undetermined
- chasing another rat
- placing material on nest
- digging in nest
- resting
- feeding
- evading predator

relative amount of rat noise

- little or none
- occasional
- frequent
- almost constant

number of rats trapped during the entire night

number of rats believed trapped during the observation period

number of rat sightings (other than those being observed)

* primary activity indicators

EXPLANATION OF PLATE I

Fig. 1. Aerial view of the study area. (14" = 1 mile)

PLATE I

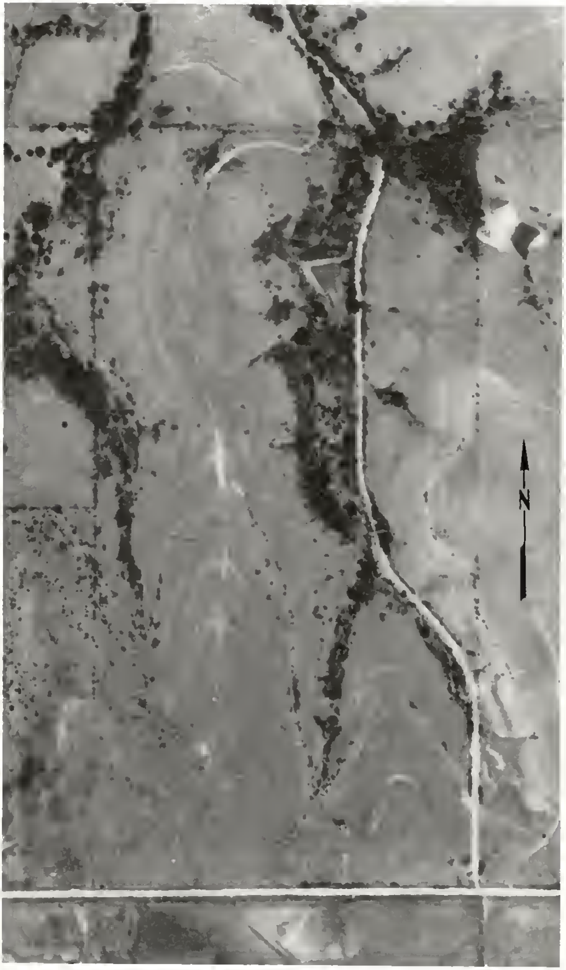


Figure 1

EXPLANATION OF PLATE II

Fig. 2. Typical view of the study area on Oct. 13, 1966, showing the situation of the suitable wood rat habitat with respect to the contour of the land.

Fig. 3. A close view of the red light apparatus used to observe wood rats.

PLATE II

Figure 2

Figure 3

EXPLANATION OF PLATE III

Fig. 6. A view showing the condition of the vegetation on October 10, 1967. Several wood rat nests (not visible) are present in the area shown.

Fig. 7. A view of the same area (as Fig. 6) showing the condition of the vegetation on Feb. 13, 1967.

PLATE III

Figure 6

Figure 7

EXPLANATION OF PLATE IV

Fig. 9. Map of the study area showing the location of wood rat nests. Those marked by solid symbols were used in the population estimates.

PLATE IV

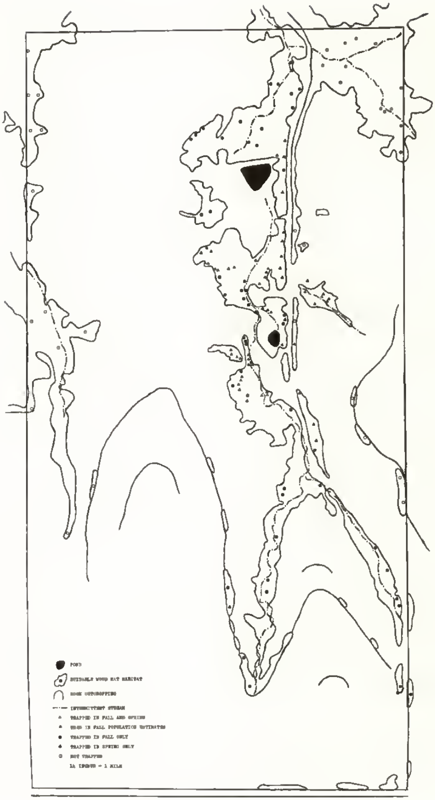


Figure 9

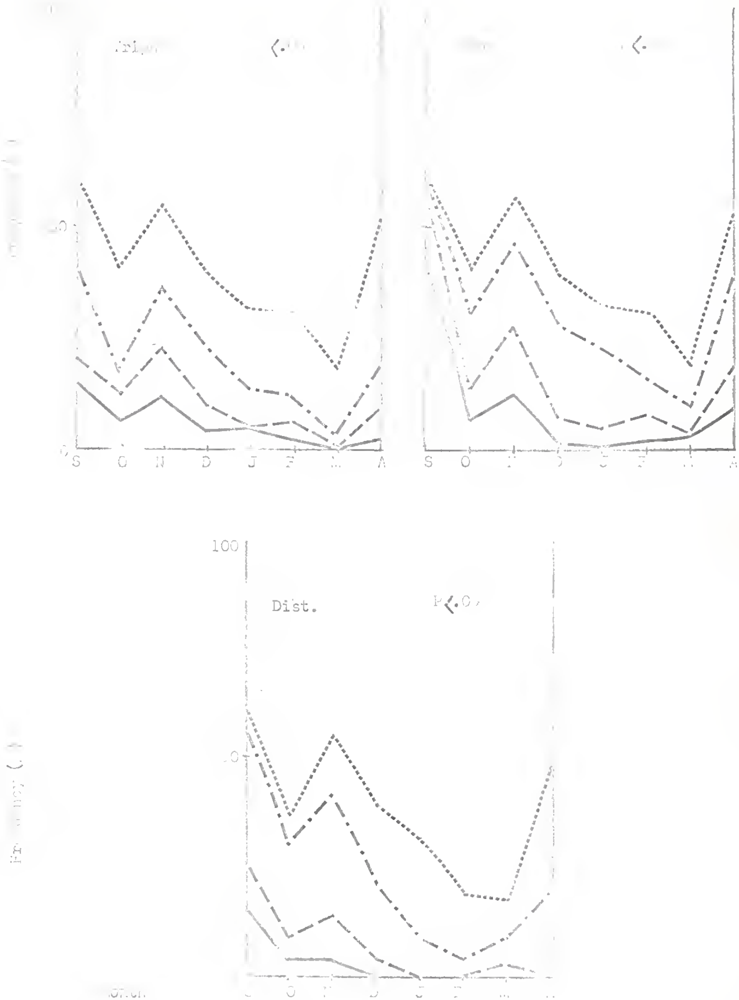


Fig. 10— Relationship of activity to month

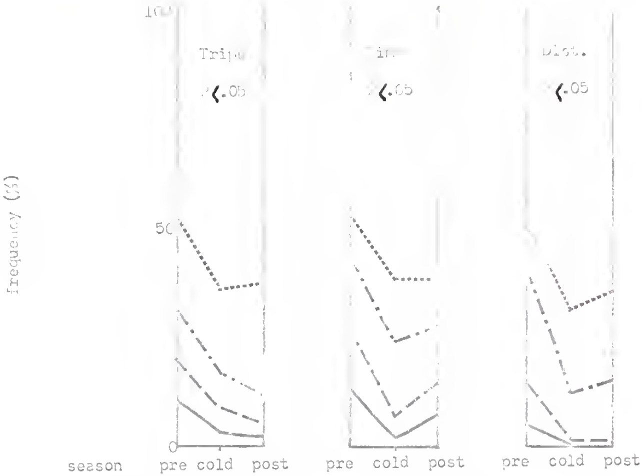


Fig. 11—Relationship of activity to season

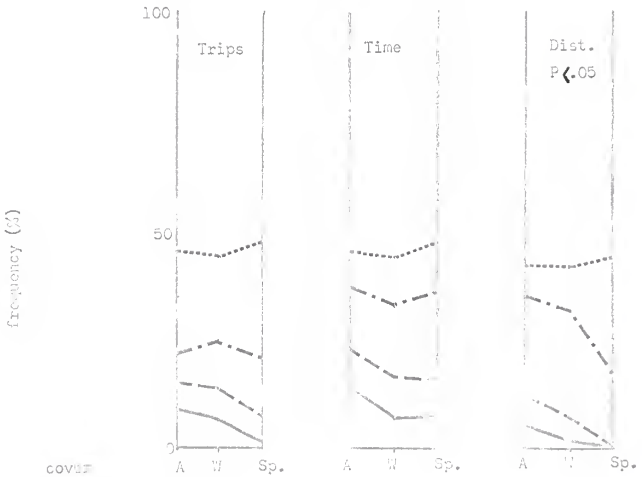
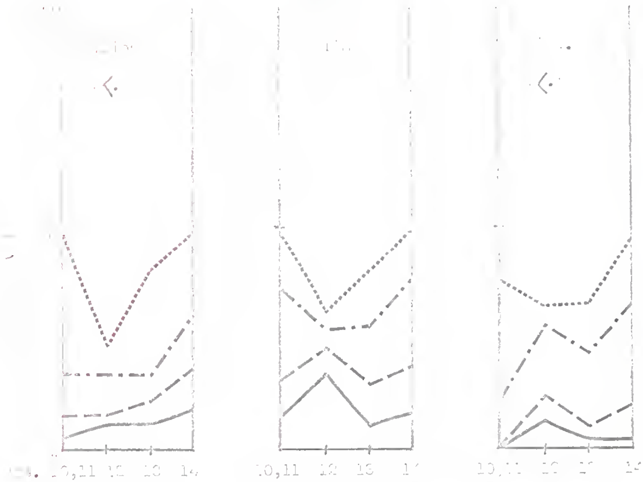


Fig. 12—Relationship of activity to cover



[illegible]

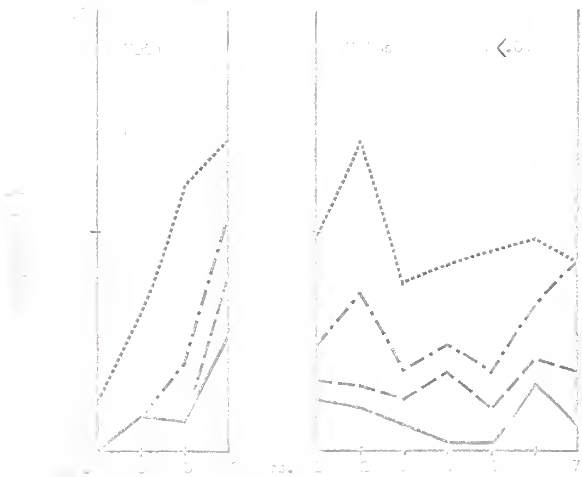


Fig. 14—Relationship [illegible] to [illegible]

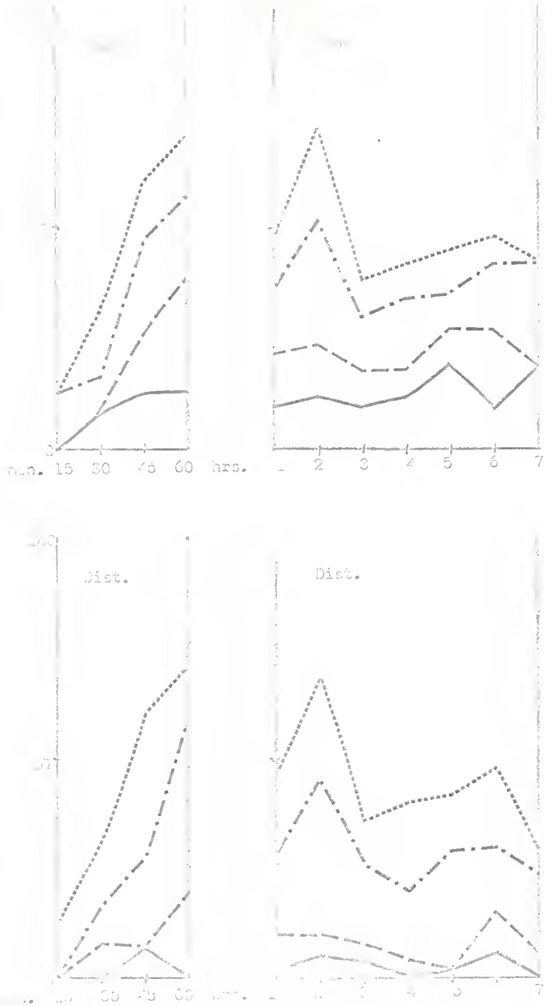
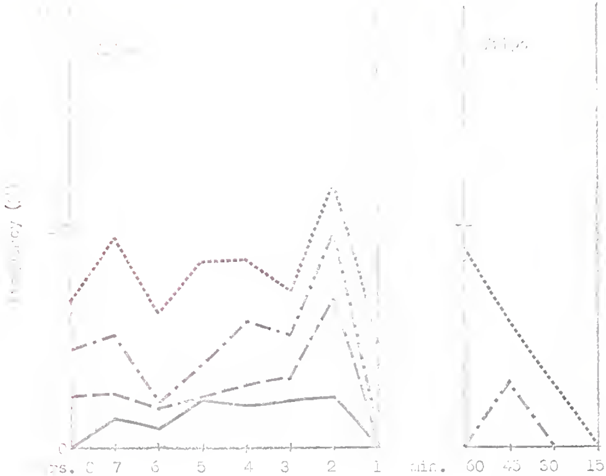


Fig. 10—...al ...ity of activity to time after sunset



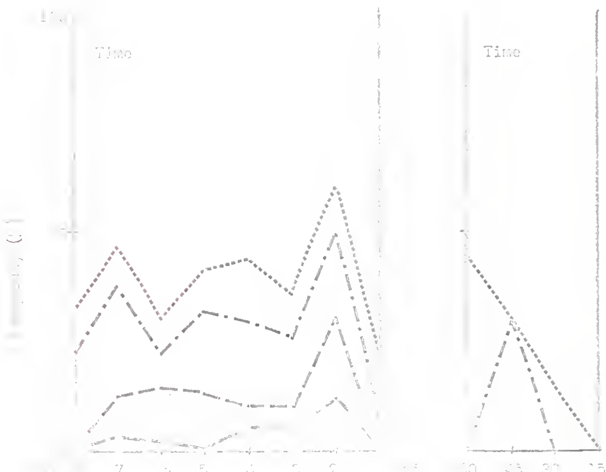
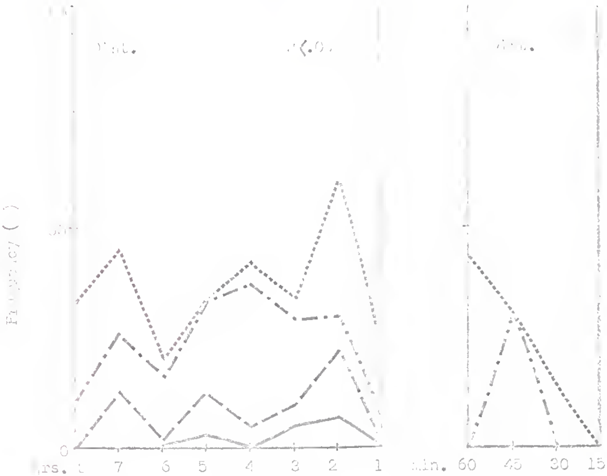
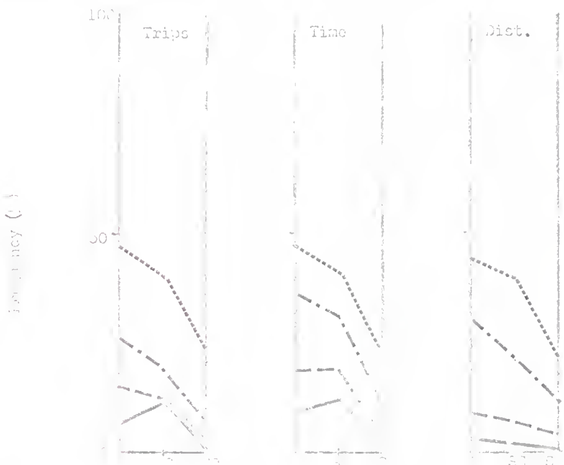


Fig. 16—Relationship of activity to time before sunrise



. 17—Relationship of activity to time before sunrise



. —Relationship of activity to illumination (grouped)

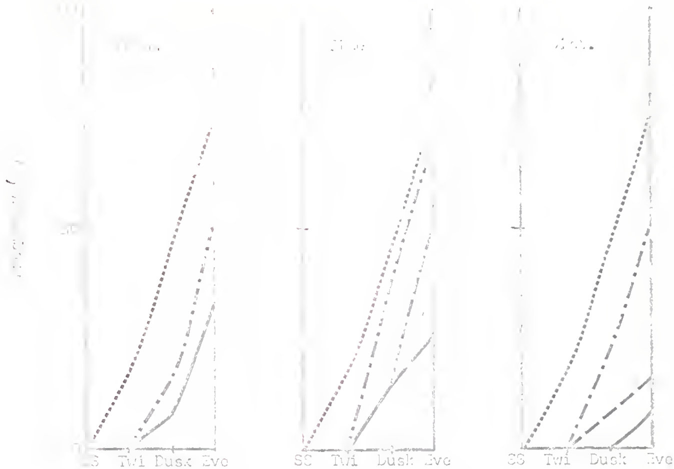


Fig. 19—Relationship of activity to sunset illumination

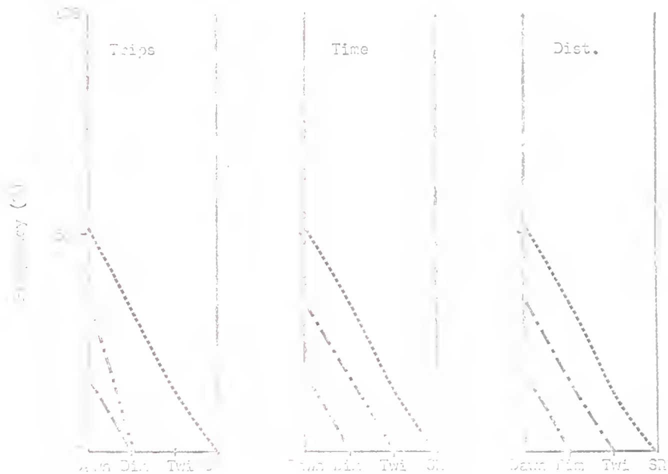


Fig. 20—Relationship of activity to sunrise illumination

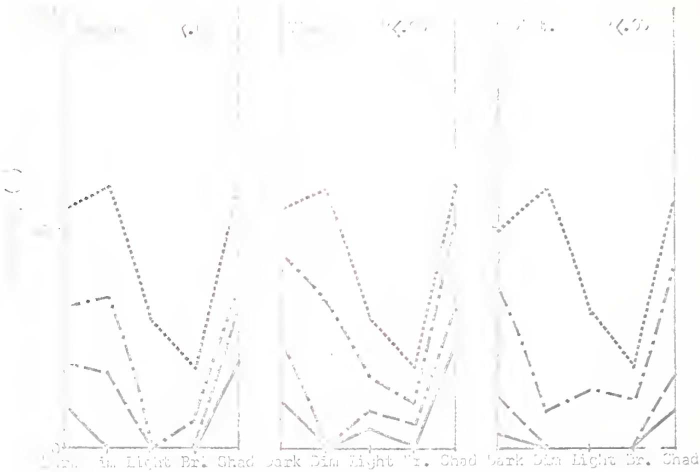


Fig. 21 —Relationship of activity to evening illumination

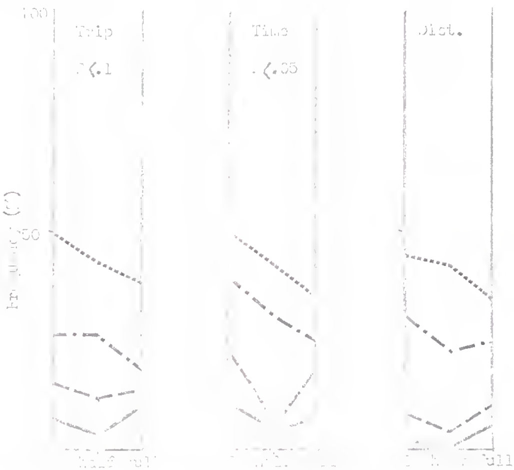
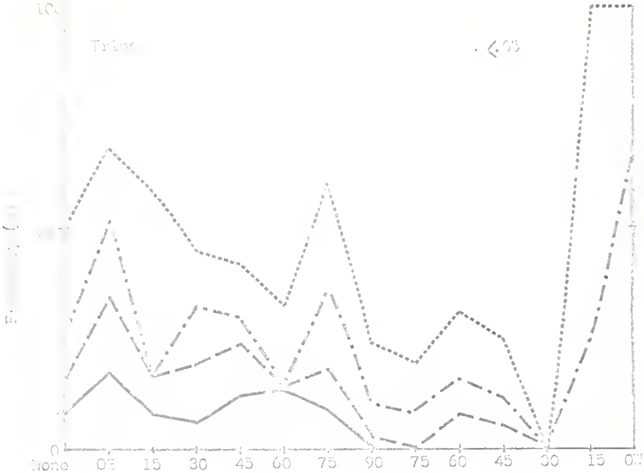


Fig. — Relationship of activity to moon phase



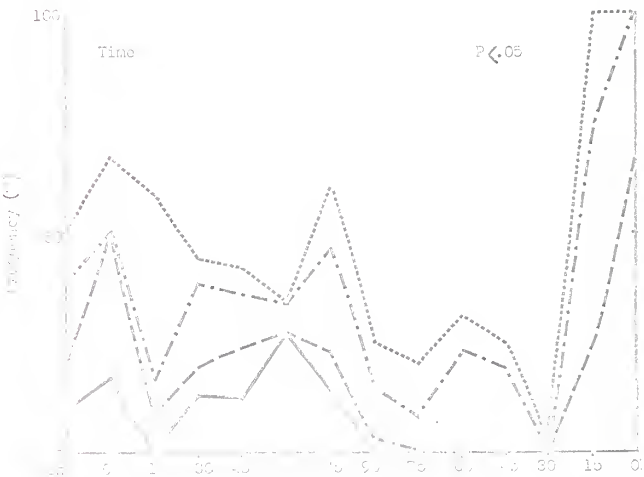


Fig. 23—Relationship of activity to altitude (angle) of the moon

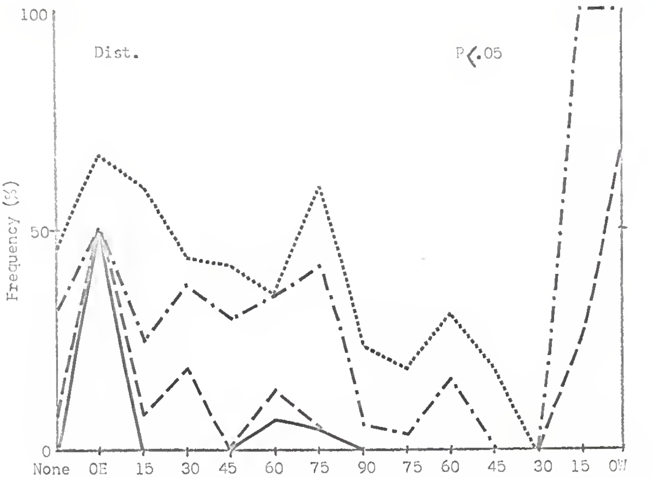


Fig. 24—Relationship of activity to altitude (angle) of the moon

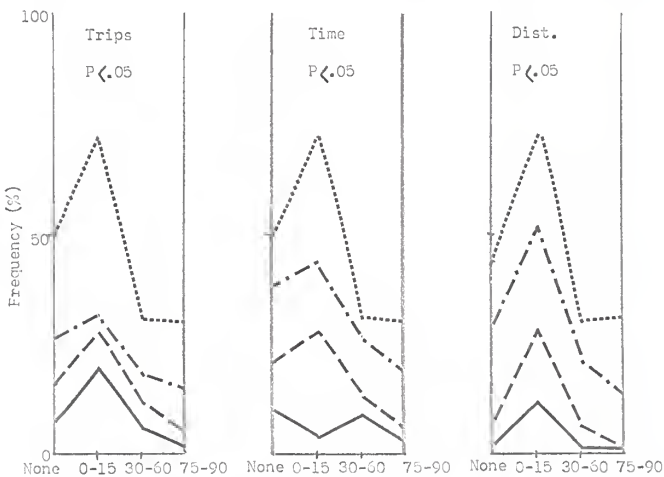


Fig. 25—Relationship of activity to moon altitude (Grouped)

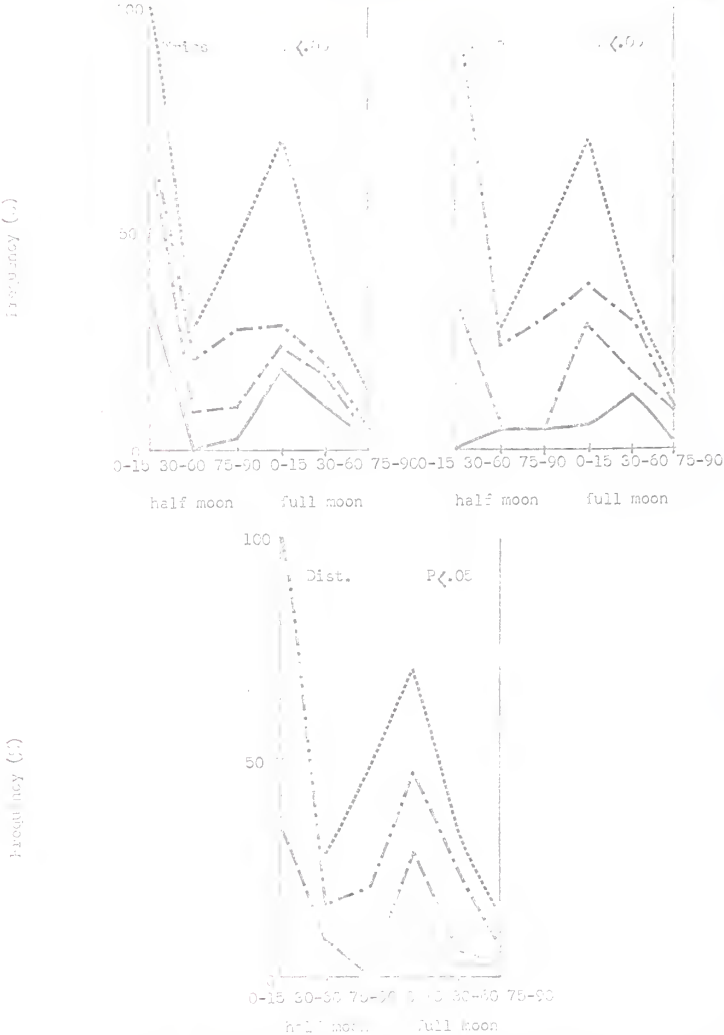
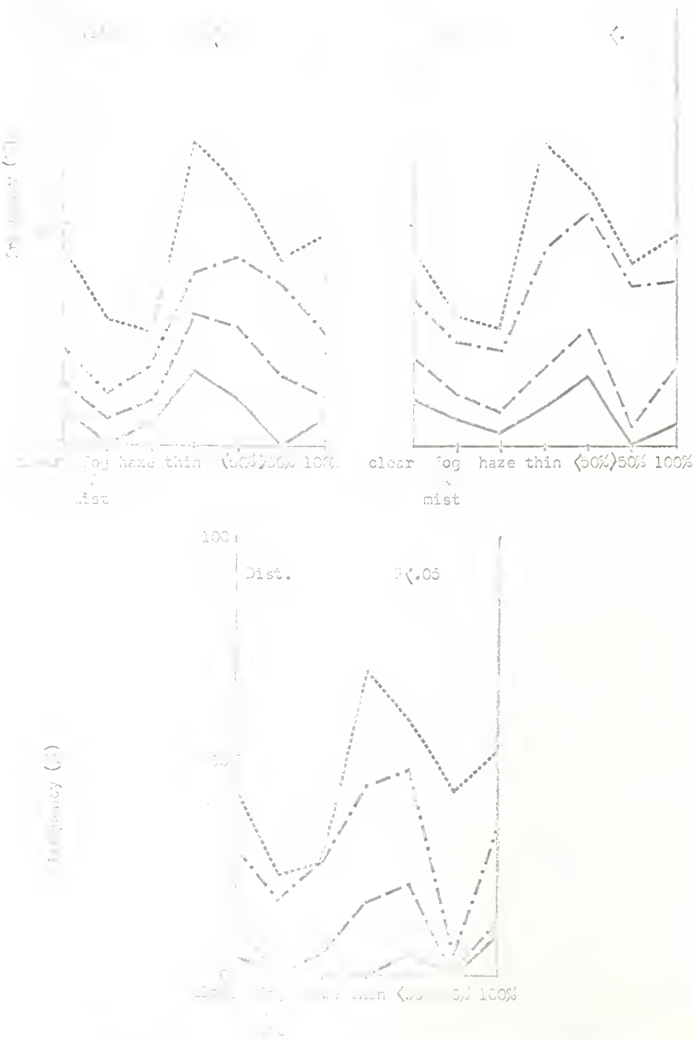


Fig. 16—Relationship of activity to moon phase and angle combined



[illegible] to cloud cover

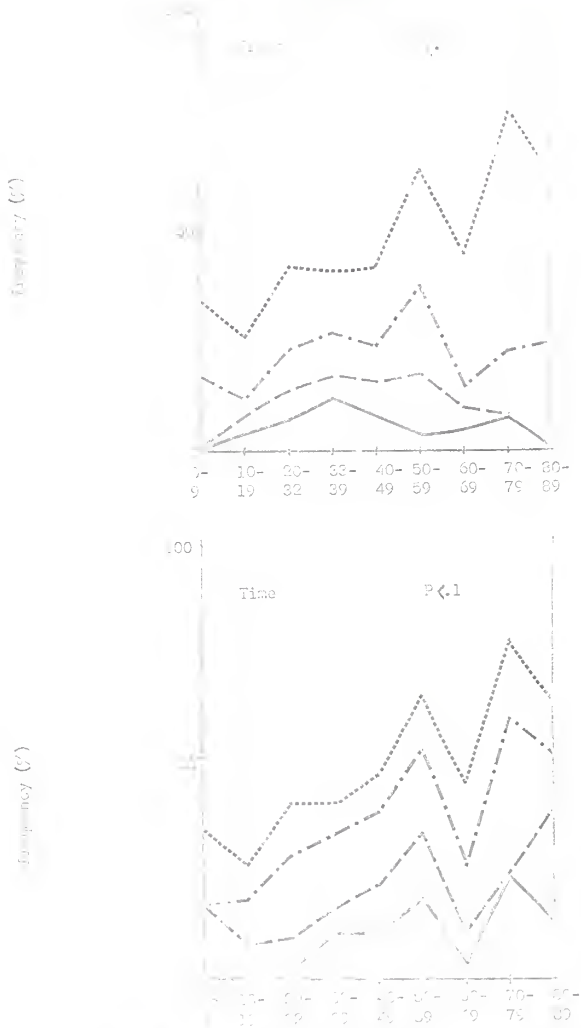


Fig. [illegible] — Relationship of activity to temperature (F.)

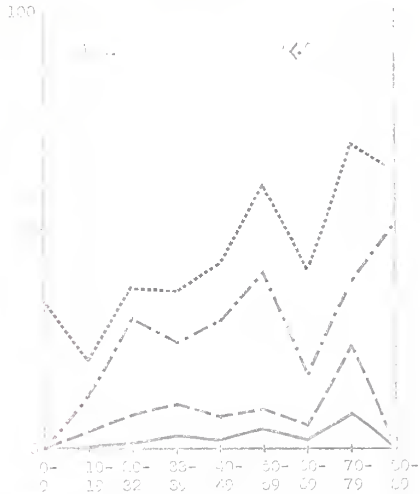
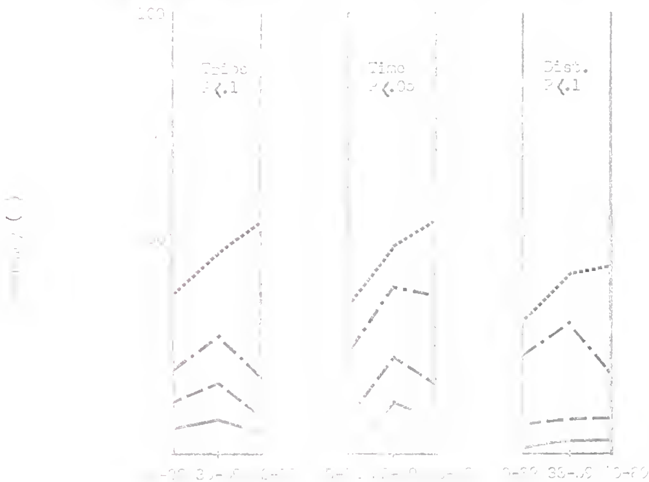
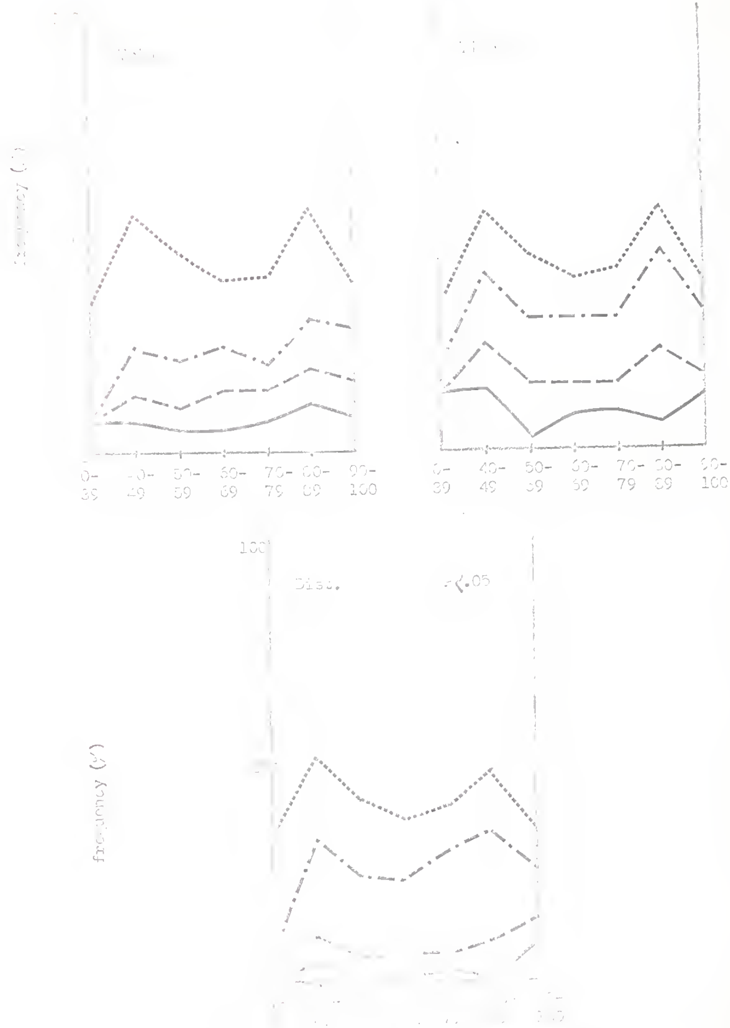


Fig. [illegible]—[illegible]tionship of activity to temperature (F.)



[illegible]


0-
39
40-
49
50-
59
60-
69
70-
79
80-
89
90-
100
100
Disc.
p<.05
frequency (%)

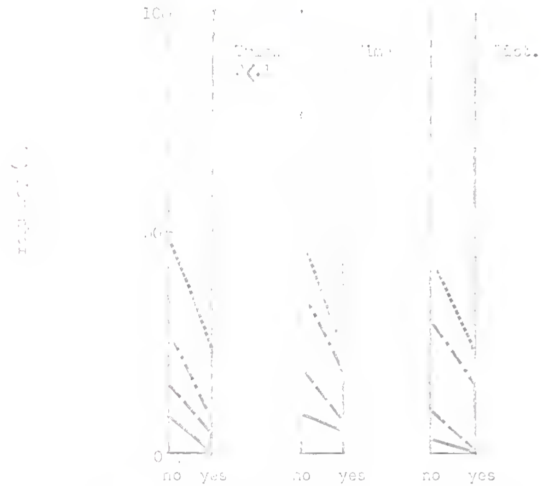


Fig. 32--Relationship of activity to precipitation.

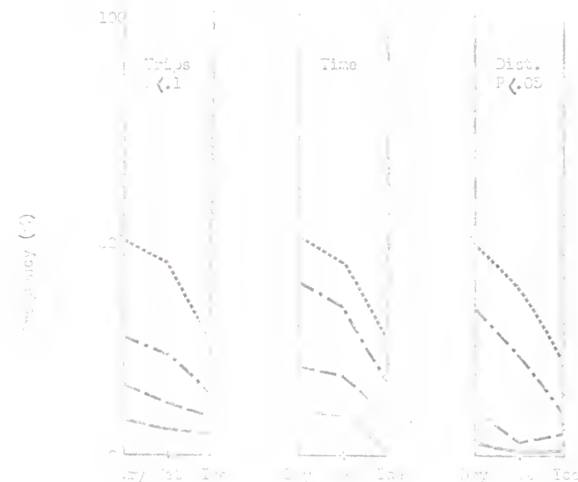
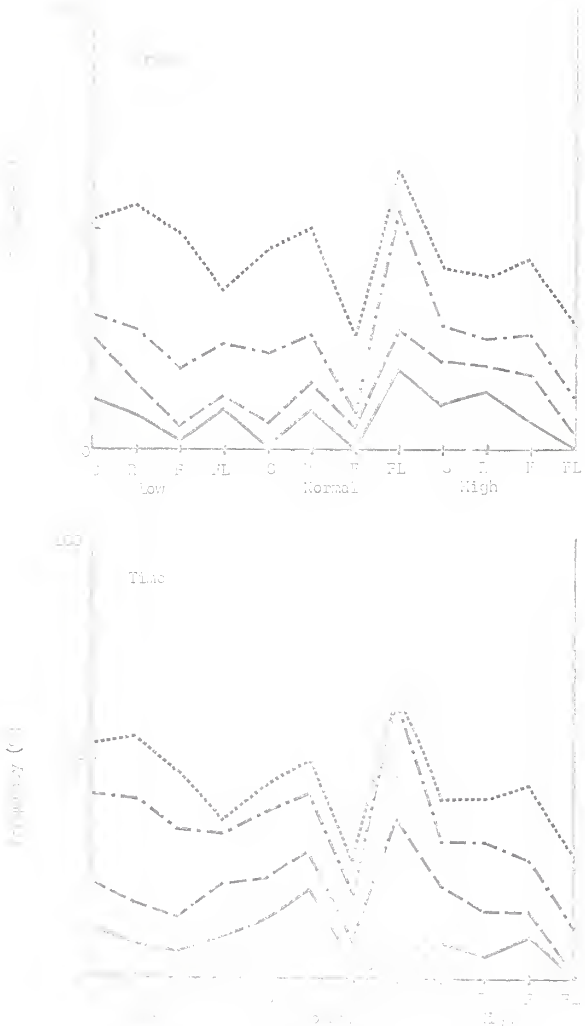


Fig. 33--Relationship of activity to ground condition.



34

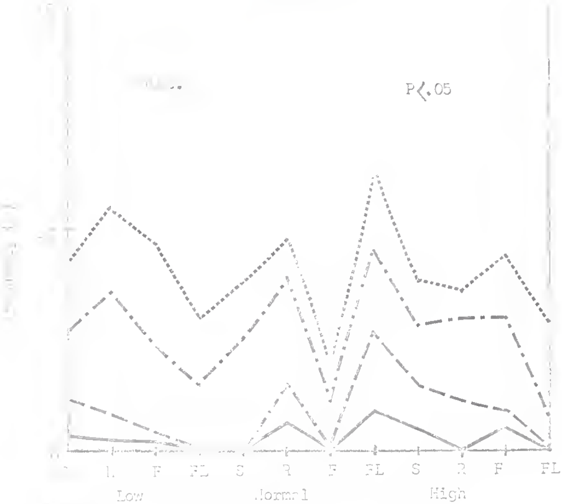


Fig. 35—Relationship of activity to pressure.

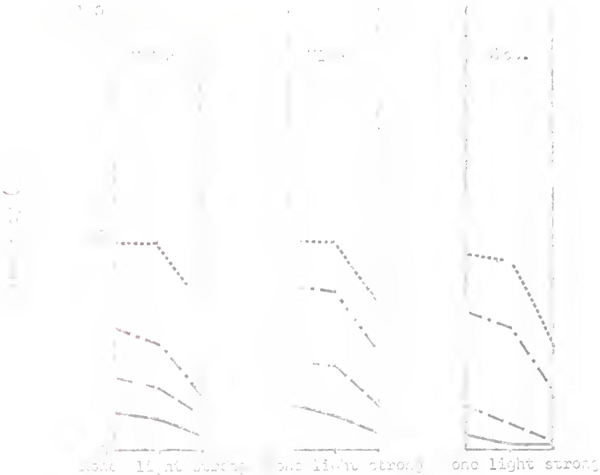
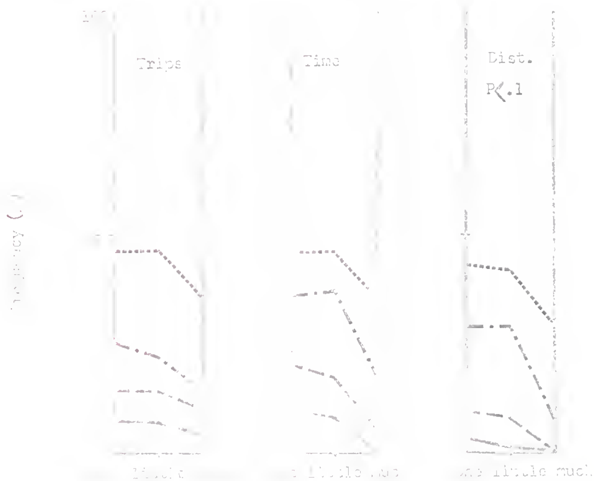


Fig. ... relationship ... activity to wind.



... activity to ...

Fig. [illegible]—Relationship [illegible] activity to previous night's temperature.

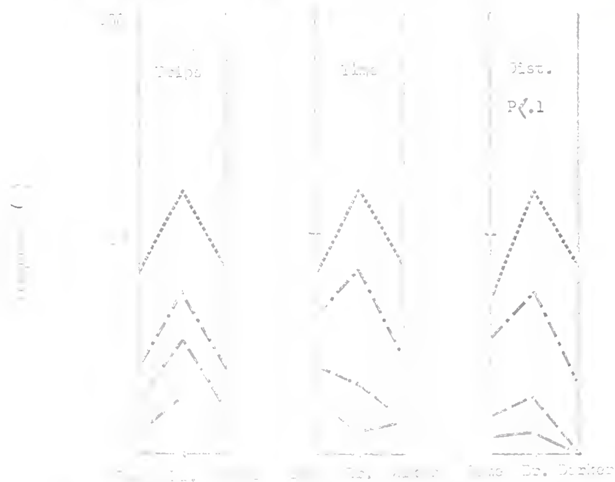


Fig. [illegible]—Relationship of activity to previous night's illumination

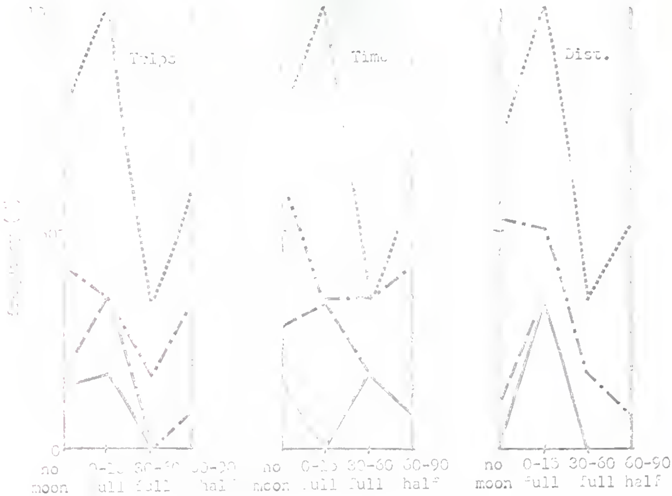


Fig. 40—Activity during the second hour after sunset related to moon phase and angle.

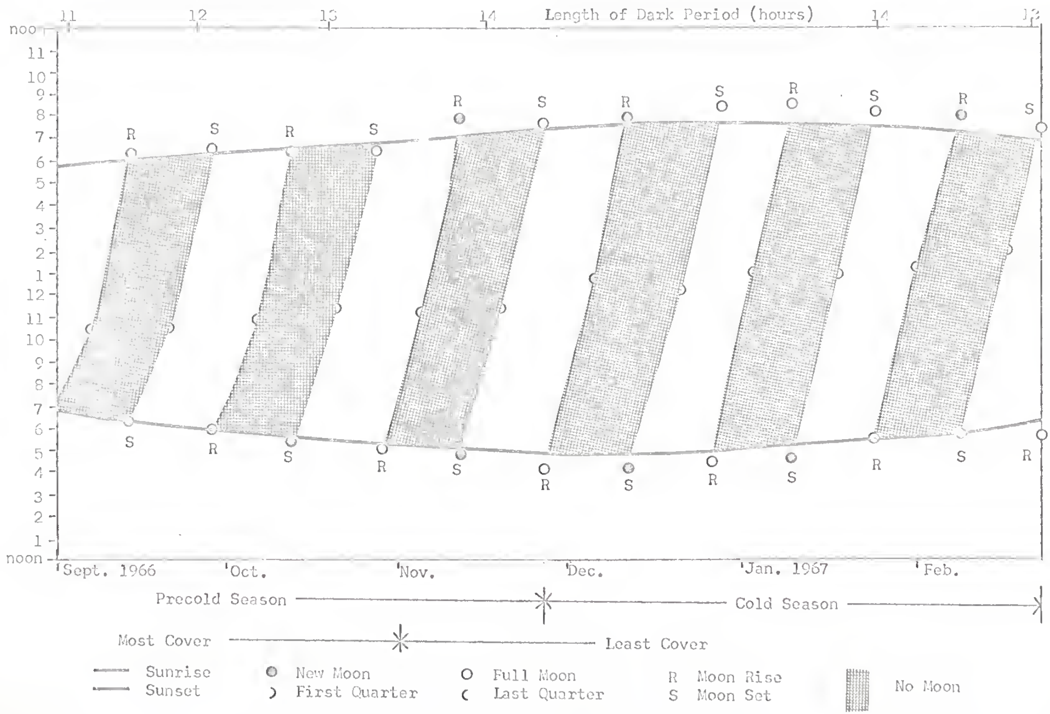


Fig. 41—Cyclic factors of the environment

ACTIVITY OF THE EASTERN WOOD RAT, (NEOTOMA FLORIDANA OSAGENSIS), AS INFLUENCED BY ENVIRONMENTAL CONDITIONS

by

HAROLD WILLIAM KNOCH

B. S., FAIRLEIGH DICKINSON UNIVERSITY, 1965

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Zoology

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1968

The nocturnal activity of wood rats (Neotoma floridana osagensis) was observed under field conditions with the aid of visible red lights. An attempt was made to determine the influence of various environmental factors on the amount of activity observed. Data were divided into 15 minute samples and analyzed by computer. Three activity indicators (number of trips, time spent out of the nest and distance traveled) were compared with 25 environmental factors. Chi-Square tests of independence were made to determine if activity was related to any of these factors. Graphs were drawn to show any significant relationships or apparent trends that were found.

Activity was found to be related to month, season, amount of cover, time relative to sunset and sunrise, illumination, moon phase, altitude of the moon above the horizon, cloud cover, temperature, precipitation, moisture condition of the ground, temperature on the previous night and noise resulting from wind. No relationship could be demonstrated for relative humidity, barometric pressure, wind or previous nights illumination.

It is proposed that activity is controlled by the interaction of endogenous stimuli and exogenous environmental conditions. It is speculated that there may be an order of dominance among the various environmental factors that influence activity. The possibility of predicting activity is discussed and the practical applications of these findings are pointed out.