Spring 1980

Population Dynamics of Small Mammals in two Plant Communities of the Merritt Island National Wildlife Refuge

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POPULATION DYNAMICS OF SMALL MAMMALS IN TWO PLANT COMMUNITIES OF THE MERRITT ISLAND NATIONAL WILDLIFE REFUGE

BY

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B.S., University of Pittsburgh, 1974

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science: Biological Sciences
in the Graduate Studies Program of the College of Natural Sciences
at the University of Central Florida; Orlando, Florida

Spring Quarter
1980

ACKNOWLEDGEMENTS

During the period of this study, many people provided assistance; to them, I express my appreciation.

I am especially indebted to Dr. I. Jack Stout who provided support, guidance, and understanding throughout my research and writing of this thesis. I thank my committee members, Drs. Llewellyn Ehrhart, David Kuhn, Walter Taylor, and Henry Whittier for their criticisms of this thesis.

I thank Ron Bradley, Russell Caldwell, and Mary Keim for their help in the field work.

My parents deserve special acknowledgement for their patience and support.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

INTRODUCTION

Merritt Island National Wildlife Refuge was established in 1963 in cooperation with the National Aeronautics and Space Administration (NASA). The Refuge shares a common boundary with the Kennedy Space Center, Brevard County, Florida.

In 1972 a team of investigators from the University of Central Florida (formerly Florida Technological University), Orlando, Florida, under grants furnished by NASA, began an extensive survey of the flora and fauna of the Refuge to establish baseline data to facilitate assessment of the effects of ongoing aerospace operations and development on and near the Refuge. In 1976 NASA initiated a three-year contract with the University to extend and elaborate on the initial surveys. One segment of this research consisted of establishing four permanent small mammal trapping grids in four plant communities which are representative of a large portion of the Refuge flora. Two of the four grids were established in a flatwoods and a mesic hammock. The small mammals of these communities are primarily herbivores and granivores and thus might be expected to be affected by environmental perturbation of these areas. These animals also serve as prey items to many avian, reptilian, and mammalian predators.

Few studies have been done on population dynamics of Florida small mammals. Layne (1974) sampled a pine flatwoods community in north-central Florida. The only extensive work in a hammock community was reported by Bigler and Jenkins (1975) who sampled two tropical hammocks in south Florida. Ehrhart (1976) reported on three communities found on the Merritt Island National Wildlife Refuge: a flatwoods-marsh, a mixed scrub, and a *Spartina* marsh. The flatwoods study area in the present study partially overlapped with the flatwoods-marsh community sampled by Ehrhart (1976).

My study was intended to add to the existing demographic information concerning Florida small mammals in general and the small mammals of the Merritt Island National Wildlife Refuge in particular.

DESCRIPTION OF THE STUDY AREAS

Wisconsin Village Flatwoods

The study area was located on the east side of Wisconsin Village road approximately 450 m south of route 402 in the northwestern quarter of section 27, R36E, T21S. It was situated almost due south of the Merritt Island Refuge Headquarters building and adjacent to the northwestern terminus of the Space Shuttle runway. The study grid partially overlapped the area studied by Ehrhart (1976) during 1972-1975. The grid was bordered on three sides by sand roads and on the south by a shallow marsh.

Vegetation. Vegetative cover of the study area may be best described as flatwoods without pines. A dense cover of grasses, herbs and shrubs was present. The dominant ground cover plant was wire grass *Aristida stricta*. Smaller woody plants included St. John's wort *Hypericum reductum*, *Gaylussacia dumosa*, and *Vaccinium myrsinites*. Taller shrubs (1-2 m in height) were *Quercus myrtifolia*, *Q. chapmanii*, *Lyonia lucida*, *L. fruticosa*, *Ilex glabra*, *Befaria racemosa*, and *Serenoa repens*. Taller oaks were concentrated in the northern half of the study area. A smaller oak, *Quercus minima*, was also very common. A more detailed quantitative documentation of the vegetation was reported by Stout (1979).

Topography and soils. The topography was generally level. The study area soils were of the Immokalee Sand type described as being dark gray in color, strongly acid in all horizons, poorly drained, with low organic matter content and natural fertility (Huckle et al., 1974). During the period of study no standing water ever appeared on the area even though this soil type is prone to such occurrences, especially during the summer rainy season. However, the marsh located south of the grid was under water after periods of heavy rains.

Weather. The climate of the central Florida east coast is characterized by very hot, wet summers and mild, dry winters. The nearest source of official weather data applicable to the study areas is the National Weather Service at the Kennedy Space Center from which data for previous years were obtained. These data were used to compare with the weather data collected on the study areas.

A weather station was situated on each of the study sites to assess the microclimate of the trapping area. Each of the weather stations consisted of a hygrothermograph (Bendix model 594) housed in a wooden enclosure and a rain-gauge (Sierra Weather Instrument Co.). The hygrothermograph charts were changed once a week and at the same time the amount of rain for the previous week was measured. In addition, two maximum-minimum thermometers (Taylor #5458) were placed on each grid. One was positioned in a shaded area while the other was placed in a relatively open spot. The thermometers were set at the same time that the traps were opened and were read the next morning, thereby providing the high and low temperature for the trap night.

Weekly mean temperatures for the study area are in Figure 1. From the beginning of October 1976 through February 1977, the mean weekly temperatures were well below the average for the previous twelve years. In mid-January 1977 the temperature reached a minimum for the period of study as record low temperatures were observed throughout Florida at that time. Sub-freezing temperatures were recorded on the study area from 18-22 January and on the night the traps were set freezing rain and snow were reported throughout Florida. The low temperature on the study area was $-7.2^{\circ}C$. The temperature was once again below normal from late March through early June 1977 and then was about normal for the remainder of the study.

Relative humidity was monitored on the study area and the weekly means are in Figure 2. The relative humidity was much higher than the monthly norm in the fall of 1976 and again from February through May 1977 and otherwise fluctuated about the norm.

Monthly rainfall for the Wisconsin Village Flatwoods study area is in Table 1. Rainfall in central Florida can be highly variable from one area to another even though there is very little distance between them. Therefore, the validity of the use of the National Weather Service data for comparison may be questionable. Monthly rainfall for December 1976 and September 1977 was substantially greater than the means for the previous twelve years; however this was offset by an unusually dry period from May through August 1977 (normally the wettest period of the year).

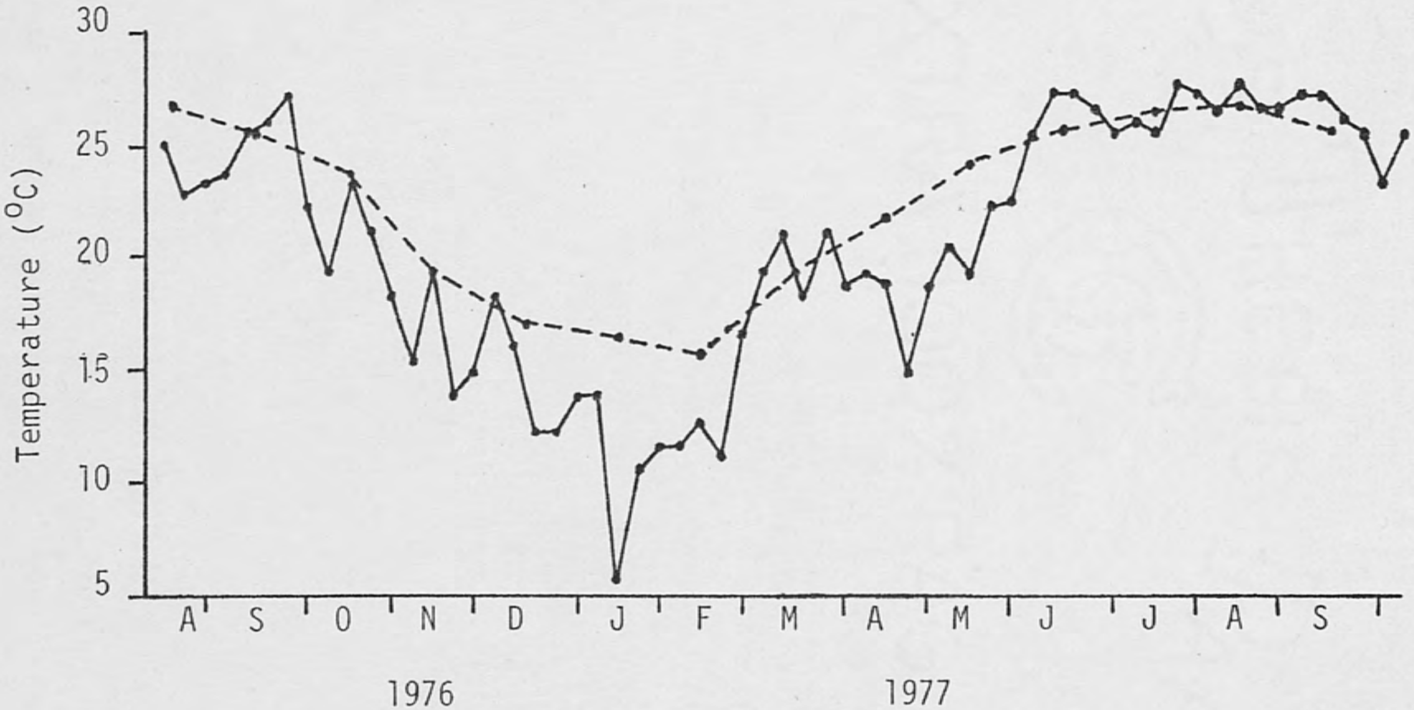

Figure 1. Weekly mean temperature measured in Wisconsin Village Flatwoods grid, August 1976-September 1977. Dashed line indicates mean monthly temperatures from NOAA, National Weather Service, Kennedy Space Center, April 1965 through December 1977.

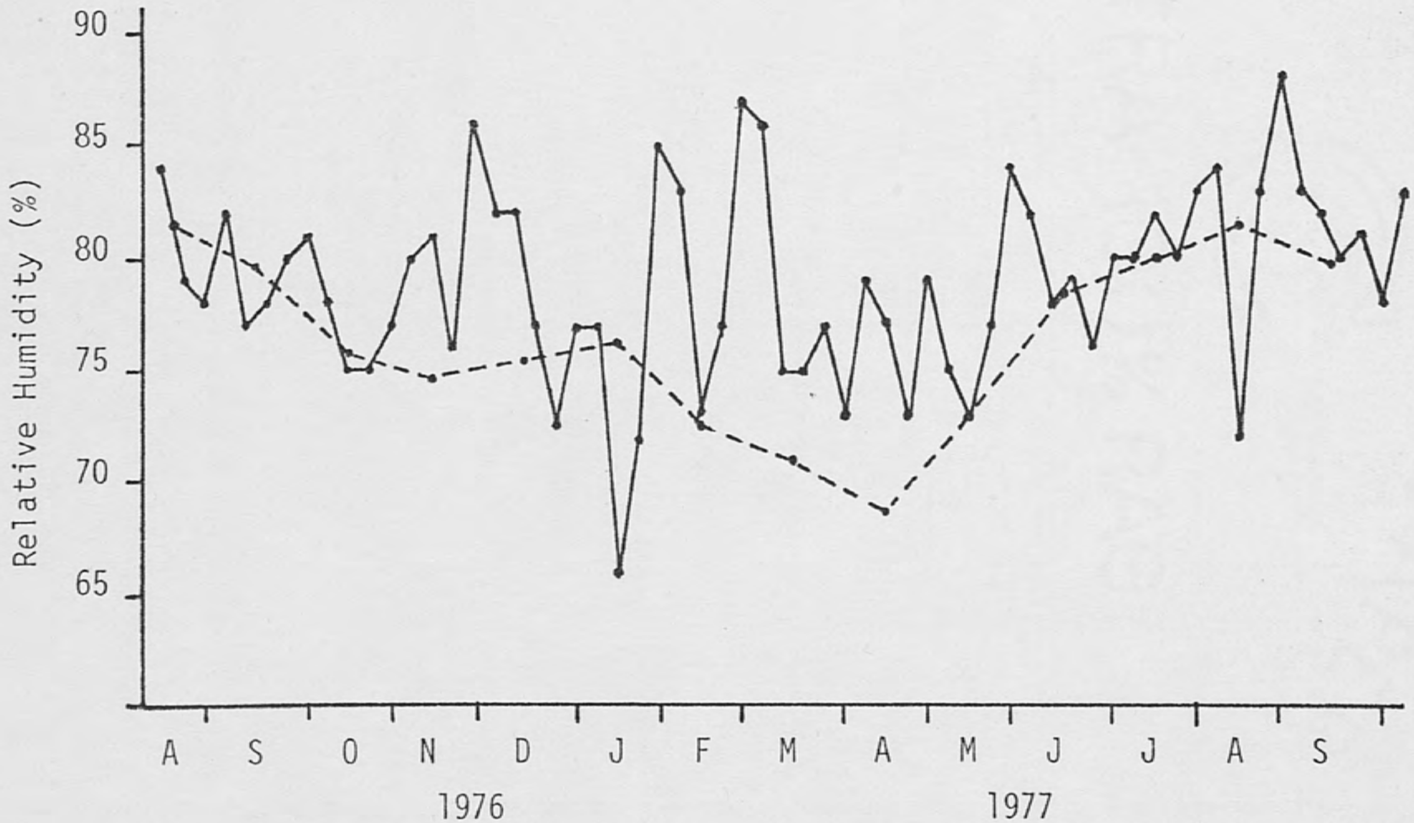

Figure 2. Weekly mean relative humidity (%) measured in Wisconsin Village Flatwoods grid August 1976-September 1977. Dashed line indicates mean monthly relative humidity from NOAA, National Weather Service, Kennedy Space Center, April 1965 through December 1977.

Table 1. Monthly rainfall measured on the Wisconsin Village Flatwoods grid and mean monthly rainfall from the National Weather Service (Kennedy Space Center) for the period April 1965-December 1977. Total for the National Weather Service only includes months for which rainfall was measured on the grid.

Year	Month	Monthly Rainfall Wisconsin Village Flatwoods (cm)	Mean Monthly Rainfall National Weather Service (cm)
1976			
	June	-	22.43
	July	-	13.33
	August (16-31)	7.75	13.69
	September	14.10	12.22
	October	10.90	10.34
	November	3.78	5.54
	December	16.48	5.94
1977			
	January	3.78	4.01
	February	5.16	5.26
	March	2.34	5.49
	April	2.77	2.08
	May	5.79	8.89
	June	7.87	22.43
	July	9.75	13.33
	August	7.14	13.69
	September	22.00	12.22
	Total	119.61	128.28

Happy Hammock

The study area was located on the east side of Happy Creek Road approximately 1.9 km south of route 402 in the northwestern quarter of section 31, R37E, T21S.

Vegetation. Large live oaks, *Quercus virginiana* var. *virginiana*, were scattered throughout the study area and were the major component of the canopy. Other canopy dominants included *Sabal palmetto*, *Quercus laurifolia*, *Acer rubrum*, and *Ulmus americana* var. *floridana*. Subcanopy trees included *Celtis laevigata*, *Morus rubra*, and *Nectandra coricea*. Common shrubs were coffee *Psychotria nervosa* and *P. sulzneri*, *Myrsine guianensis*, and *Ardesia escallonioides*. The herbaceous layer of the hammock was dominated by two species, Boston fern, *Nephrolepis cordifolia*, and Jack-in-the-pulpit, *Arisaema triphyllum*.

The shrub and herbaceous layers were very dense at the outset of the study. However, due to abnormally low temperatures in December 1976 and January 1977, these vegetative layers were decimated and did not recover to any extent through the duration of the study.

Topography and soils. The trapping grid was situated such that all stations were located within the raised terrain of the hammock. This slightly higher ground was composed primarily of soils of the Immokalee sand type, described as being formed in beds of marine sands, permeability is moderate to rapid, organic matter and natural fertility are low, strongly acid, and in most years the water table is within a depth of 25.5 cm for one to two months. The trapping grid was surrounded by lower lying soils of the Anclote series sand type described as having a thick dark-colored surface layer, poorly drained, high in organic matter content and low in natural fertility. In most years the water table is within a depth of 25.5 cm for more than six months and the soil is occasionally flooded two to seven days following heavy rains (Huckle et al., 1974). These low areas were in fact under water from the outset of the study through December 1976 but subsequently were dry until September 1977.

Weather. Weekly mean temperatures for the Happy Hammock study area are in Figure 3. The trends on this area were similar to the Wisconsin Village Flatwoods area; however, the temperatures in the hammock were generally a few degrees higher. As stated previously abnormally low temperatures occurred in late December 1976 and January 1977 which had a drastic effect on the shrub and herb layers of the hammock.

Weekly mean relative humidity was very high and fluctuated dramatically (Figure 4). The mean relative humidity tended to range between 80 and 90% for most of the period of study, exceeding this range in early September and December 1976 and from July through September 1977. Periods of lower relative humidity were recorded in January, February and April 1977.

Monthly rainfall measured in Happy Hammock was considerably less than that recorded in the flatwoods as well as the mean

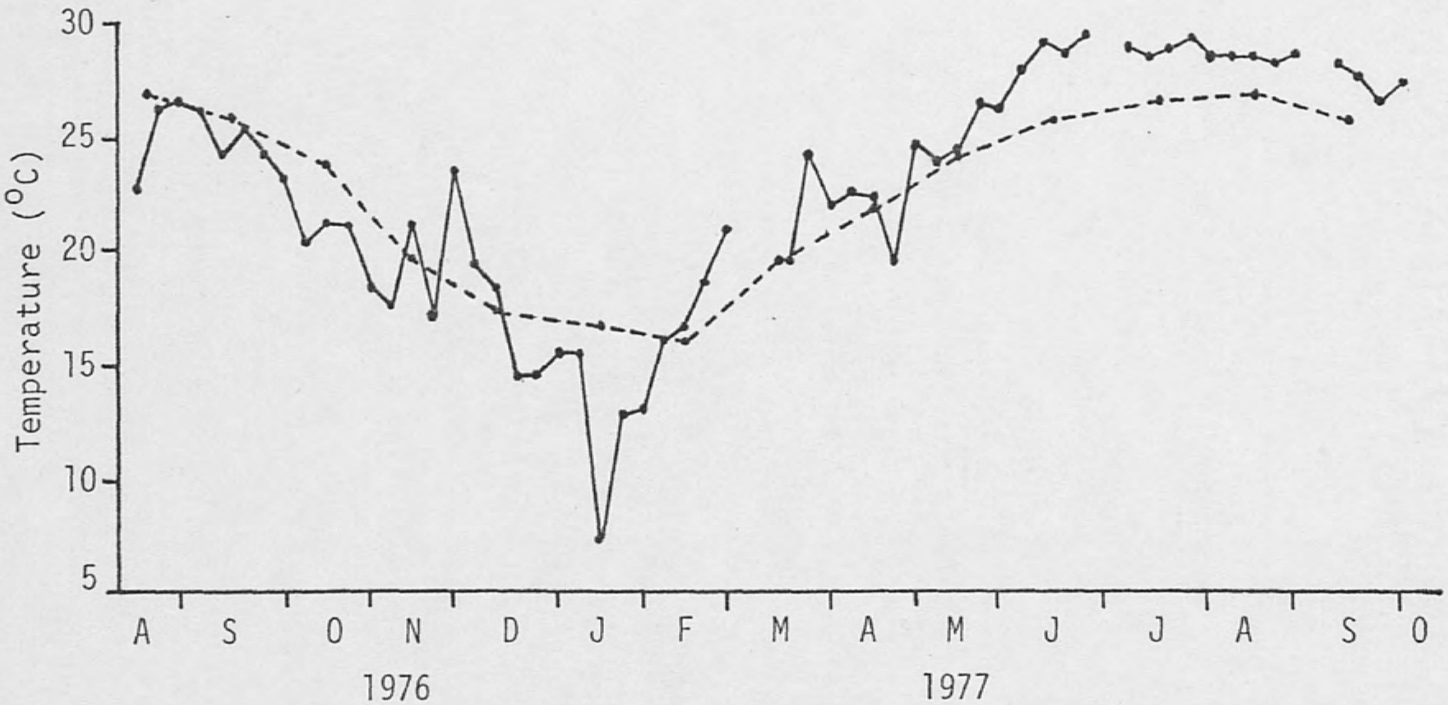

Figure 3. Weekly mean temperature measured in Happy Hammock grid August 1976-September 1977. See Figure 1 for explanation of dashed line.

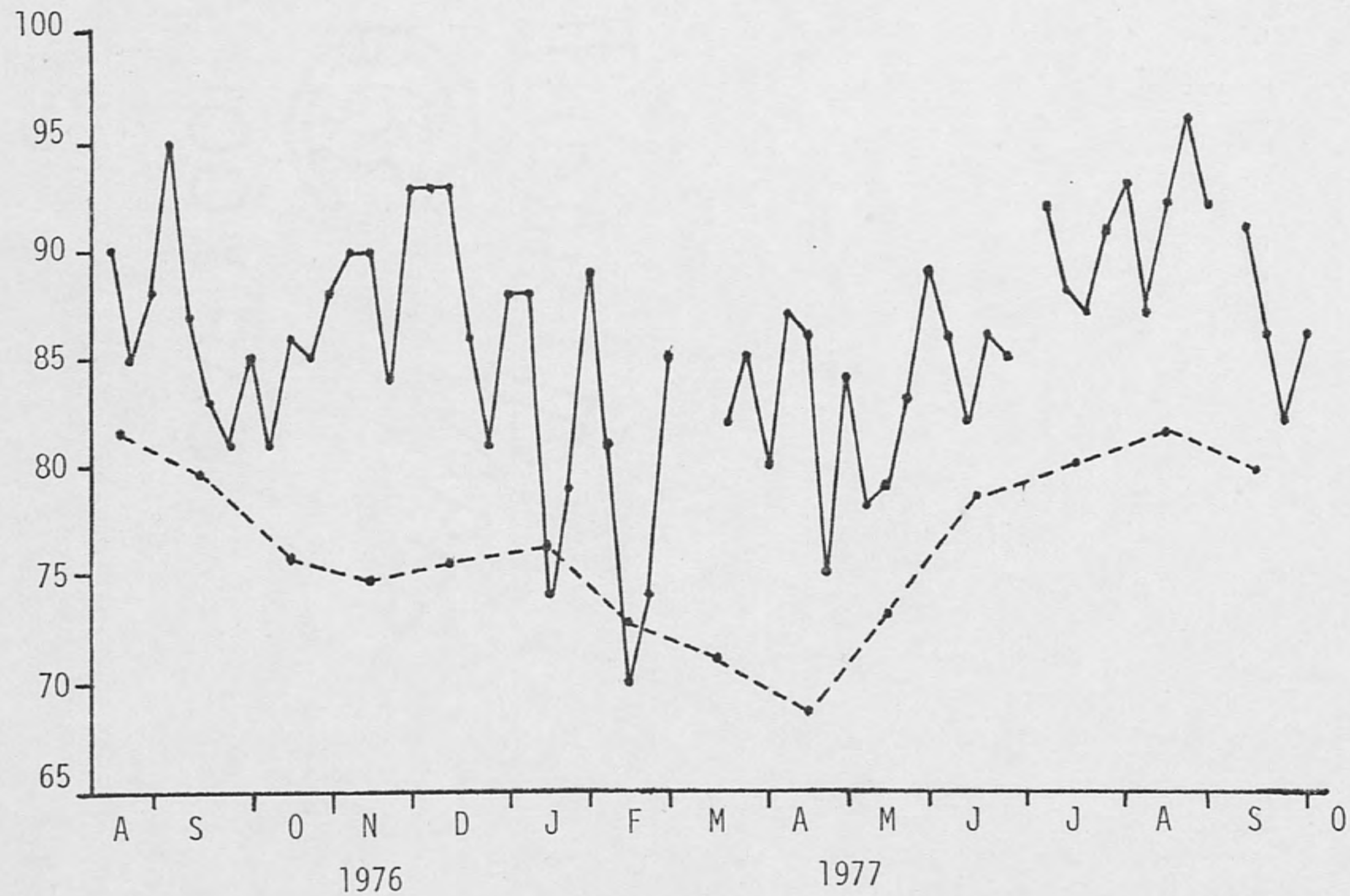

Figure 4. Weekly mean relative humidity measured in Happy Hammock grid August 1976-September 1977. See Figure 2 for explanation of dashed line.

rainfall reported by the National Weather Service (Table 2). Rainfall in the hammock generally followed the same trends as in the flatwoods when compared to the twelve-year monthly means. Abnormally heavy rainfall was recorded in December 1976 and September 1977 while lower than average rainfall was measured in November 1976 and in March, May, June and August 1977. In June, normally the wettest month (22.43 cm), a meager 6.93 cm of rain were recorded.

A few important factors which affected measurement of rainfall must be considered. The rain-gauge in Happy Hammock was not in an open sky situation, whereas the one in the flatwoods was, and therefore the amount of rainfall measured in the hammock would be expected to be less than that in the flatwoods. The vegetative canopy in the hammock would effectively reduce the amount of rain throughfall; however, it would also serve to retard the amount of evaporative moisture loss from the hammock.

Table 2. Monthly rainfall measured on the Happy Hammock grid and monthly mean rainfall from the National Weather Service (Kennedy Space Center) for the period April 1965-December 1977. Total for the National Weather Service only includes months for which rainfall was meausred on the grid.

Year	Month	Monthly Rainfall Happy Hammock (cm)	Mean Monthly Rainfall National Weather Service (cm)
1976			
	June	-	22.43
	July	-	13.33
	August (16-31)	6.45	13.69
	September	12.64	12.22
	October	11.68	10.34
	November	3.45	5.54
	December	10.97	5.94
1977			
	January	3.61	4.01
	February	4.04	5.26
	March	1.85	5.49
	April	2.31	2.08
	May	2.41	8.89
	June	6.93	22.43
	July	12.32	13.33
	August	6.35	13.69
	September	16.10	12.22
	Total	101.11	128.28

METHODS

Two permanent study grids were layed-out in June 1976. The Wisconsin Village Flatwoods grid encompassed an area of 1.44 ha and consisted of 64 trapping stations spaced at 15 m-intervals. The grid was situated such that the eight columns of stations had a north-south orientation and the eight rows an east-west orientation. During periods of high trap success (defined as greater than 50% of the traps capturing animals), 56 additional stations (half-stations) were located along the eight columns equidistant (7.5 m) from two consecutive rows, i.e., station A-1.5 between A-1 and A-2. Half-stations were used from September 1976 through September 1977, excluding June. In addition to the study grid a series of eight assessment lines of three stations per line was layed-out extending from the edge of the grid (Smith et al., 1971). These lines were 45 m long with a 15 m-interval between stations. Traps were opened on the assessment lines one night per month on the same night as the grid from February through September 1977.

The Happy Hammock grid encompassed an area of 1.12 ha and due to the fact that many peripheral sections of this mesic hammock were covered with up to 61 cm of water in the summer months, it was necessary for the grid to have an irregular configuration. The grid consisted of nine columns of stations with an east-west orientation. There were two columns of four stations, three of five stations, one of six stations, and three of seven stations, for a total of 50 stations. To assess the extent to which the small mammals of the hammock utilized tree trunks in their pattern of movements, 25 of the trapping stations were randomly selected to also have "up traps." At each station with an "up trap" a Sherman trap was placed on a wooden platform with a roof which had been nailed to the tree nearest to the trapping station at a height of 1.5 m. A series of eight assessment lines extending from the grid was used to trap one night per month on the same night as the grid from February through September 1977. Each line extended 45 m from the edge of the grid with three stations per line at 15 m intervals.

Ten wooden nest boxes (Jackson, 1963) were placed within the section of the hammock located across a road from the study area. Boxes were attached to trees at a height of approximately 1.5 m in two lines with an interval between boxes of approximately 20 m. Nest boxes were checked for their contents once a month at the same time that the traps were checked on the grid. Small mammals in the nest boxes were processed in the same manner as those caught in the traps.

Traps were set on the study grids one night per month from June 1976 through September 1977. One large Sherman live-trap (7.62 cm x 7.62 cm x 22.86 cm) was positioned within one meter of the stake marking each station. Traps were set in the late afternoon, baited with oat flakes and then checked the following morning. The initial time each small mammal was captured a numbered monel ear tag (Salt Lake Stamp Co.) was secured to each animal's right ear. Animals were processed in the field and the following data were recorded on a standard form: station number, species, tag number, sex, number of plantar pads on the hind foot (mice only), reproductive condition, hind foot length, body weight, pelage condition (mice only), ectoparasite burden (type and quantity), overall condition, and miscellaneous notes. Reproductive condition of males was classified as to whether the testes were abdominal, scrotal, or in an intermediate position. Females were checked for condition of the vagina (perforate or imperforate), the vulva (inactive, turgid, cornified or membraneous, closed with a copulatory plug, or bloody), the teats (small, large, or hairless and pigmented), pubic symphysis (closed, notched, or open), and finally they were checked for pregnancy. Body weights were taken with 50, 100, or 300 g Pesola spring balances. Pelage condition of mice was categorized into three classes: juvenile, totally gray; subadult, molting but with some gray remaining; and adult, no gray remaining. A minimum estimate of ectoparasites was ascertained. Individual ticks and larvae of botflies were counted. The number of fleas was estimated as none, 1-5, and greater than 5. Mites were simply noted as being present or absent. Chiggers were classified as none, 1-50, or greater than 50. Condition of the captured animals was noted as good or poor.

Numerical estimates (minimum number known to be alive, MNA) of small mammals present on the study areas were based on the number of individuals actually caught plus those taken both in earlier and subsequent trapping periods using the calendar of captures method (Petrusewicz & Andrzejewski, 1962), or more recently referred to as the enumeration method (Hilborn et al., 1976). Densities were calculated using the area of the grid and the MNA for the purpose of comparison to work reported in the literature.

Trappability of small mammals was calculated by dividing the number of individuals caught in a trapping period by the number of individuals known to be alive during that period (Krebs, 1966). The percentage of months of residence including months skipped between captures, that individuals of a given species actually appeared in traps was also used as an index of trappability (Layne, 1974). Only animals trapped two or more months were used in these calculations.

Spatial activity patterns of small mammals captured four or more times were quantified through calculation of the mean distance between successive captures (Brant, 1962).

Survival rates for each trapping interval were calculated by species as the number of marked animals released at time "t" divided into the number of marked animals recaptured in the next sample period (t + 1). Changes in survival rate were analyzed for correlation with population MNA, phase of population growth, and seasonal weather patterns.

RESULTS

Total Capture

Wisconsin Village Flatwoods.--Total trapping effort on the study grid amounted to 1,816 trap nights in which 695 total captures were made yielding a trap success of 38%. Three hundred fourteen individuals of five species were live-trapped and recaptured 381 times on the grid (Table 3). The cotton rat (*Sigmodon hispidus*) was the principal species appearing in traps and accounted for 82.8% of the original captures and 70.9% of the recaptures. The other species captured were *Peromyscus gossypinus*, *Peromyscus floridanus*, *Oryzomys palustris*, and *Ochrotomys nuttalli*.

Table 3. Species distribution of captures and recaptures on the Wisconsin Village grid.

	Original Captures		Recaptures	
	Number	Percent	Number	Percent
Sigmodon hispidus	260	82.8	270	70.9
Peromyscus gossypinus	32	10.2	65	17.0
Peromyscus floridanus	10	3.2	38	10.0
Oryzomys palustris	8	2.5	1	0.3
Ochrotomys nuttalli	4	1.3	7	1.8
Totals	314		381	

Happy Hammock.--Total trapping effort of the study grid consisted of 1,275 trap nights in which 344 total captures were made for a trap success of 27%. One hundred forty-seven individuals of three species were live-trapped on the grid and recaptured 197 times. The cotton mouse was the primary species, accounting for 91% of the original captures and 98.5% of the recaptures. The other species trapped were *Sigmodon hispidus* (6) and *Ochrotomys nuttalli* (7). None of the cotton rats was recaptured and three of the golden mice were recaptured once. Gray squirrels were frequently seen in the hammock but were never captured.

Four hundred twenty-five of the total trap nights were "up traps." Forty-six captures were made in these traps, 39 which were cotton mice and 7 were golden mice. This accounted for 13.4% of the total captures. The seven captures of golden mice were 70% of the total (10) for that species on the study grid. The "up traps" accounted for 11.9% of the captures of cotton mice.

Trappability

Wisconsin Village Flatwoods.--One hundred eight cotton rats appearing two or more months on the study grid were trapped in 256 (87.0%) months out of 294. Eighty-seven of these individuals had no gaps in their trapping record; 11 missed one month; 2 two months; and 8 three or more months. The trappability of cotton rats was greater than 80% in all months except July 1977 (Figure 5). Twenty-seven cotton mice were captured during 58 (81.69%) out of 71 months. Seven Florida mice were trapped in 33 (94.28%) out of 35 months. Five of these had no gaps in their trapping record and two had a gap

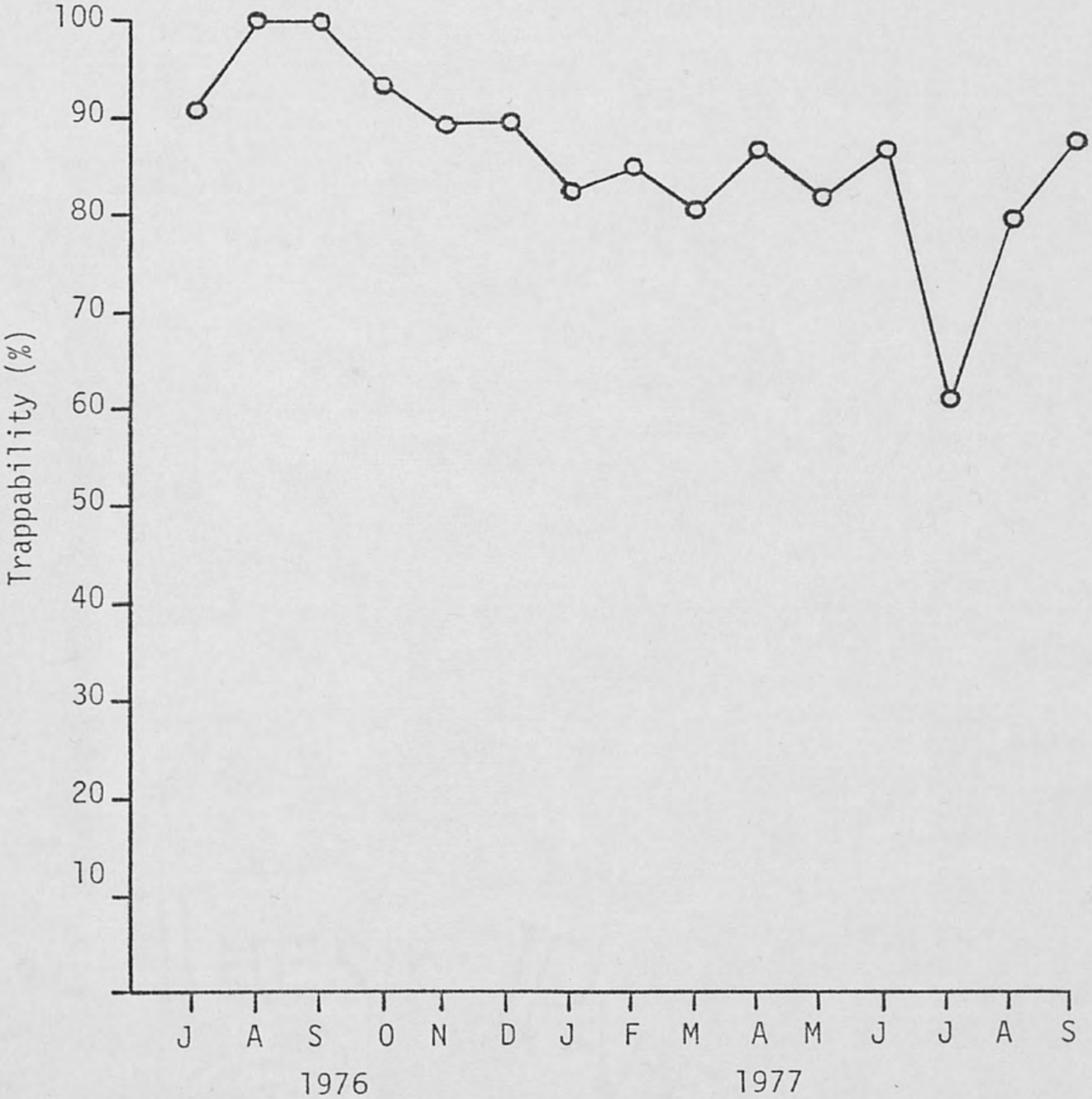

Figure 5. Trappability of cotton rats on the Wisconsin Village Flatwoods grid.

of one month. Three golden mice were trapped in six (60%) out of ten months.

These trappability figures do not take into account captures made on the assessment lines. Of the individuals involved in the calculations four cotton rats were trapped on assessment lines as were two cotton mice and one Florida mouse.

Happy Hammock.--Eighty cotton mice appearing two or more months on the study grid were trapped in 192 (72.18%) months out of 266. Thirty-nine of these individuals had no gap in their trap records; 19 missed one month; 9 missed two months; and 13 three or more months. Nine of the cotton mice that had discontinuous trapping records on the grid were captured on the assessment lines. The monthly trend in trappability of cotton mice varied dramatically (Figure 6). The percentage of known resident individuals that were actually caught was highest in October and December 1976 and September 1977 and was lowest in November and January. From February through July 1977 the trappability consistently ranged between 66 and 82%.

Minimum Number Alive

Wisconsin Village Flatwoods.--The population of cotton rats fluctuated during the 16 months of study. The number steadily increased from 14 individuals in June 1976 to a peak of 89 in November (Figure 7). From December 1976 through March a dramatic decline occurred which was equal to that of the previous summer. The population level remained stable throughout the spring and

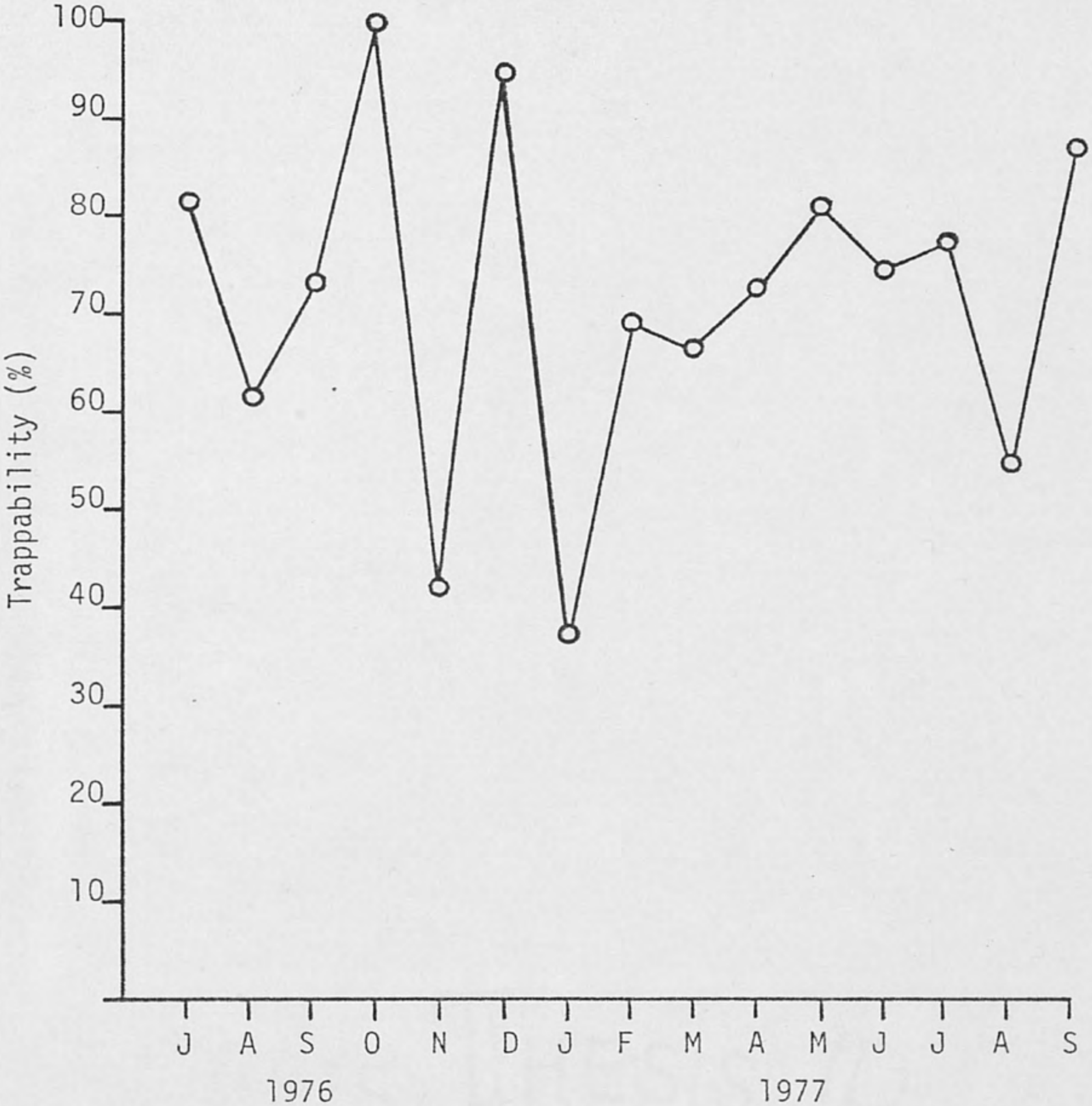

Figure 6. Trappability of cotton mice on the Happy Hammock grid.

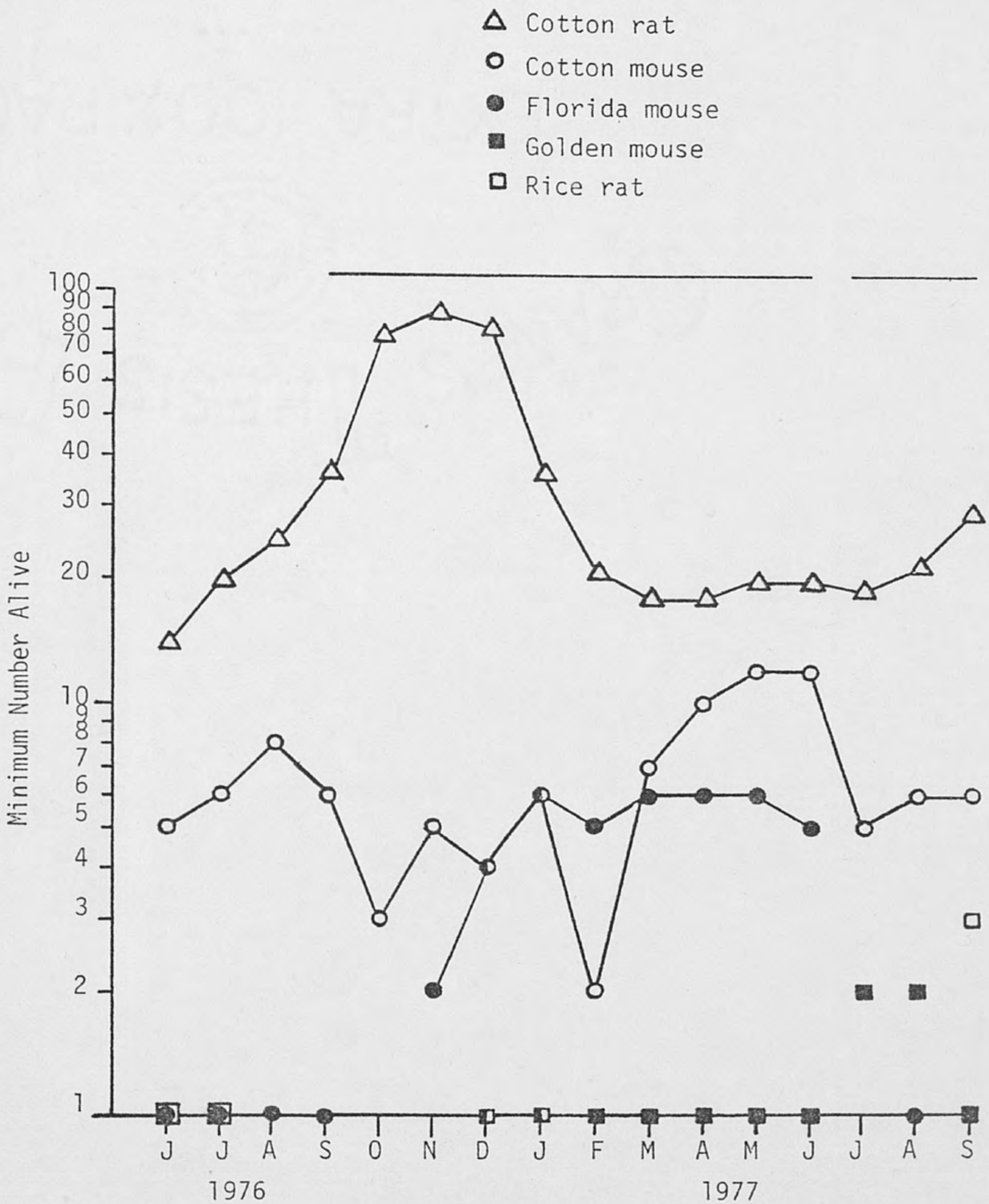

Figure 7. Minimum number of individuals known to be alive on the Wisconsin Village Flatwoods grid. Solid line indicates periods when traps were doubled.

summer of 1977 and again began to increase in September. A small population of cotton mice was apparent throughout the study and reached its highest level in April, May, and June 1977. Numbers of Florida mice increased in November and December 1976 and remained stable (5-6) from January through June 1977. Subsequently, one Florida mouse was known to be alive in August while none was observed in July or September. Individual rice rats were intermittently captured and one or two golden mice were known to be alive from December 1976 through September 1977.

Happy Hammock.--Cotton mice were the only small mammal known to permanently inhabit the hammock. The number steadily increased through the initial summer and then fluctuated between 24 and 37 individuals through the fall and winter months (Figure 8). The population reached a maximum of 43 in March 1977 which was followed by a gradual decline to 11 individuals in August 1977. Golden mice occurred in low numbers (1-3) in December 1976 and in May through August 1977. Captures (6) of individual cotton rats were made in June, October, and December 1976.

Density

Wisconsin Village Flatwoods.--Cotton rat density increased steadily from 9.7 per ha in the initial trapping period to a maximum of 61.8 per ha in November 1976 (Figure 9). Subsequently their density declined through March 1977 and remained between 15.3 per ha and 12.5 per ha through August 1977. A slight increase in cotton rat density occurred in September 1977 to 20.1 per ha.

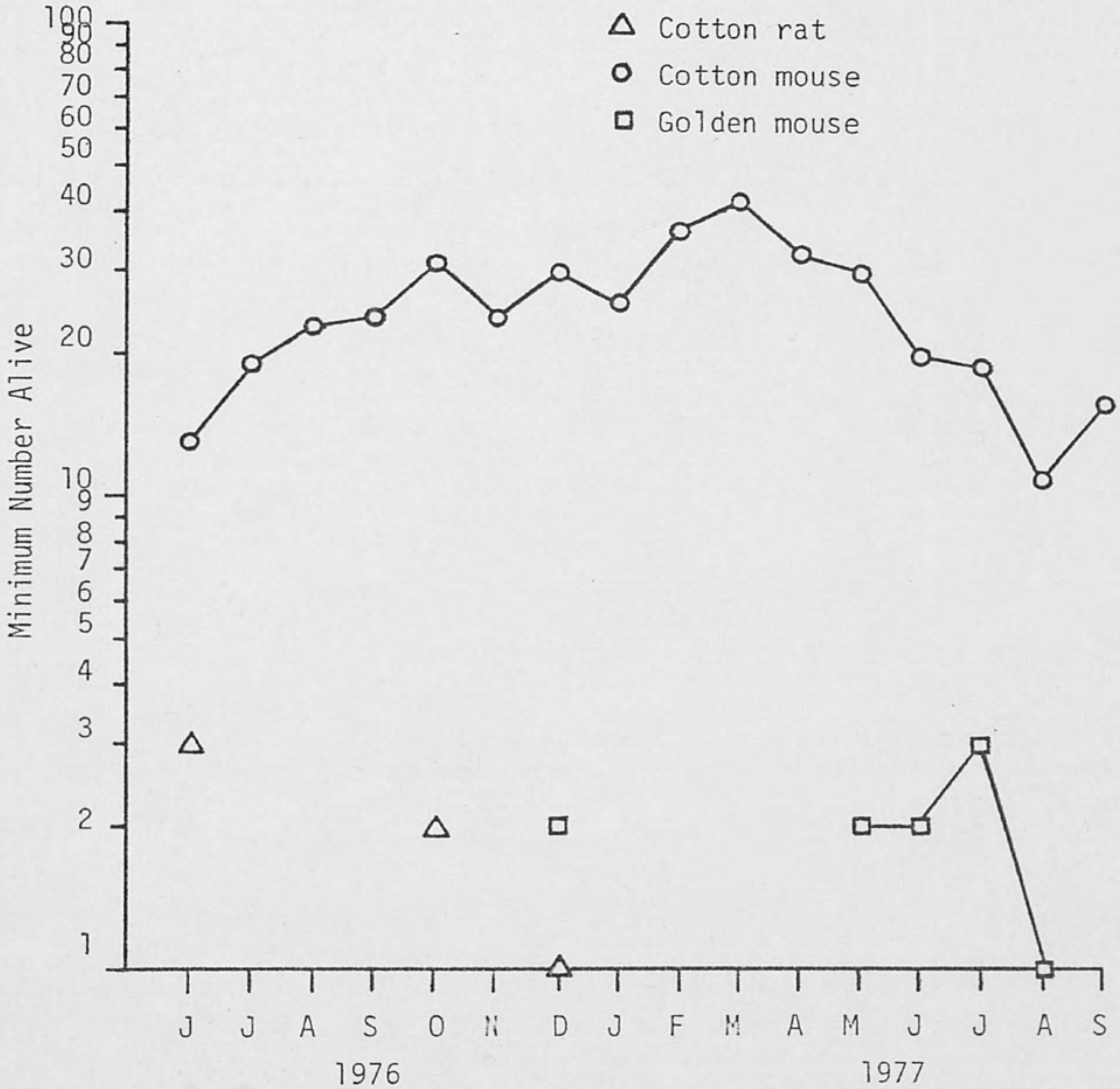

Figure 8. Minimum number of individuals known to be alive on the Happy Hammock grid.

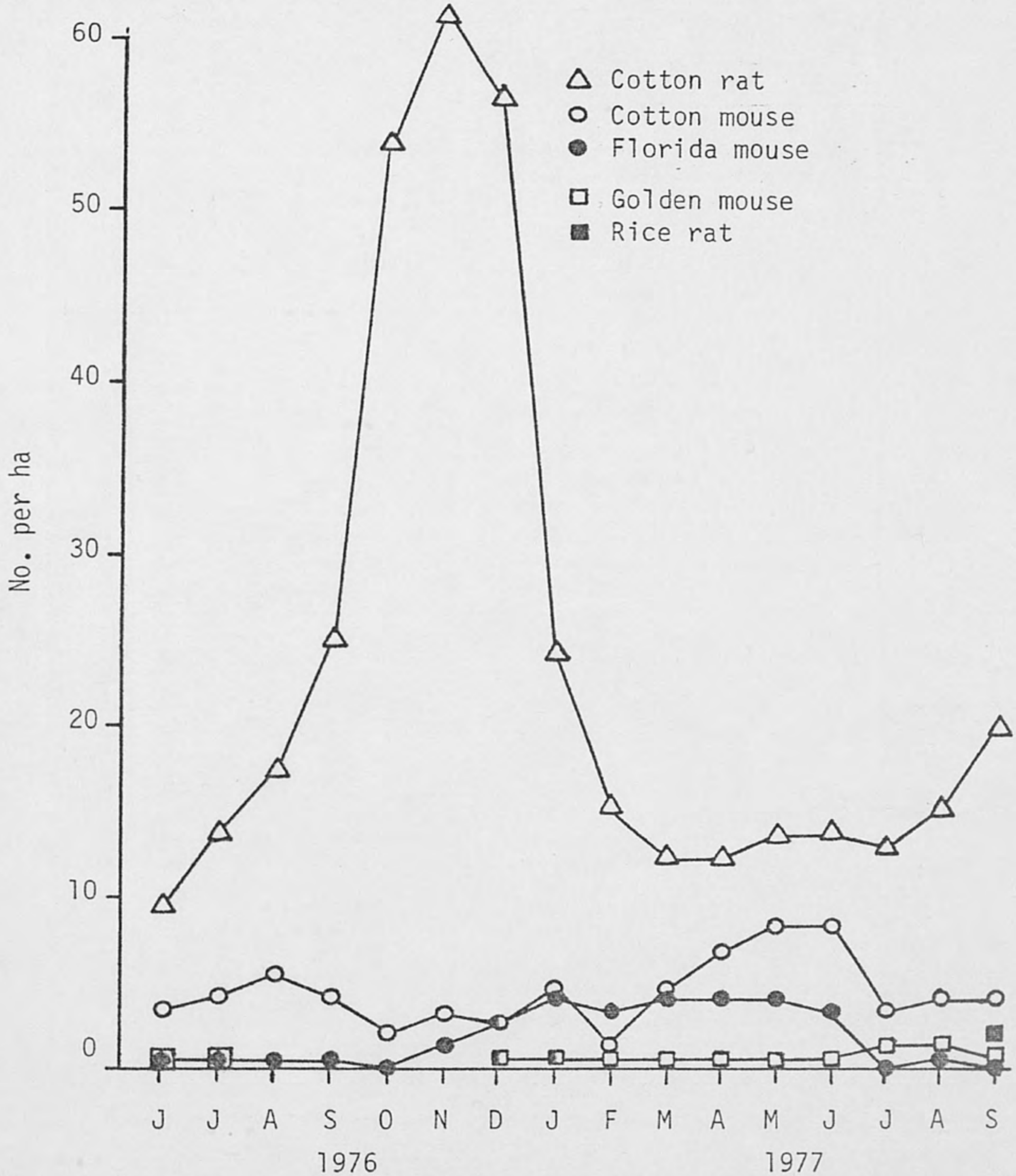

Figure 9. Density of small mammals on the Wisconsin Village Flatwoods grid. Based on 1.44 ha.

Density of cotton mice ranged consistently between 1.4 per ha and 5.6 per ha through most of the period of study (Figure 9). Minimum density occurred in February 1977 and the maximum density was observed in May and June 1977, 8.3 per ha.

Florida mouse density was low throughout the study; however, it began increasing in November 1976 and remained stable from January to June 1977 ranging from 3.5 per ha to 4.2 per ha (Figure 9).

Happy Hammock.--Cotton mouse density increased steadily from 11.5 per ha in June 1976 to 27.5 per ha in October 1976 (Figure 10). In the following three sampling periods the density of cotton mice fluctuated and subsequently strongly increased in February and March 1977 reaching a maximum of 38.2 per ha in March. A decline in density occurred from April through August 1977 when a minimum of 9.8 per ha was observed. This was followed by a slight increase in September 1977.

Survival Rate

Wisconsin Village Flatwoods.--Survival of cotton rats declined over the period of population increase (July-December) in 1976 reaching a minimum for the study in January 1977 (Figure 11). Survival then rose through the winter and spring months reaching the maximum in May 1977. A decline occurred in June and July 1977 which was followed by an increase in August and a slight drop in September. The trend in survival rate was very similar for both males and females ($r = 0.73$, $p < .05$) with the exception of August and December 1976 and June and September 1977.

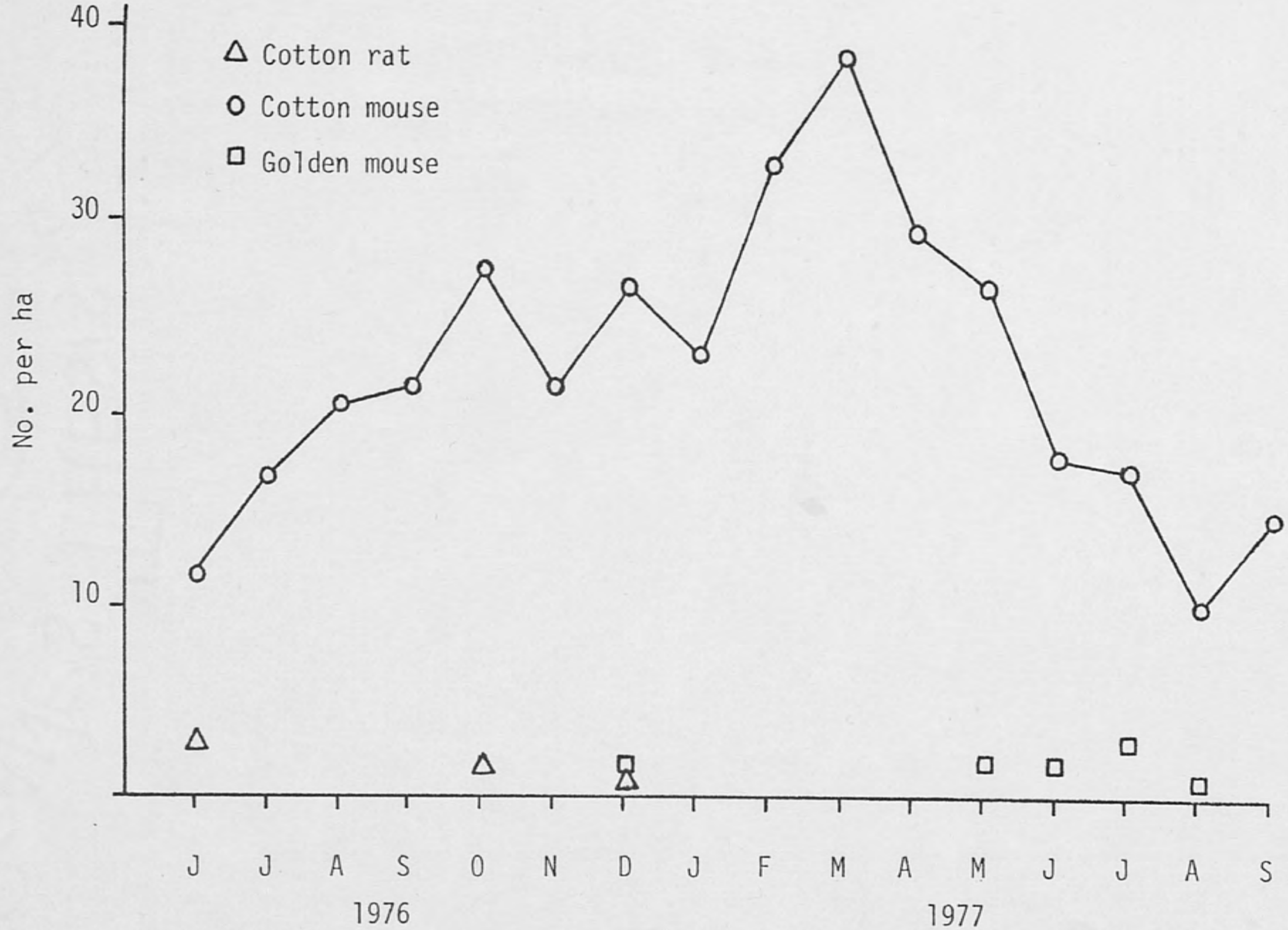

Figure 10. Density of small mammals on the Happy Hammock grid based on 1.125 ha.

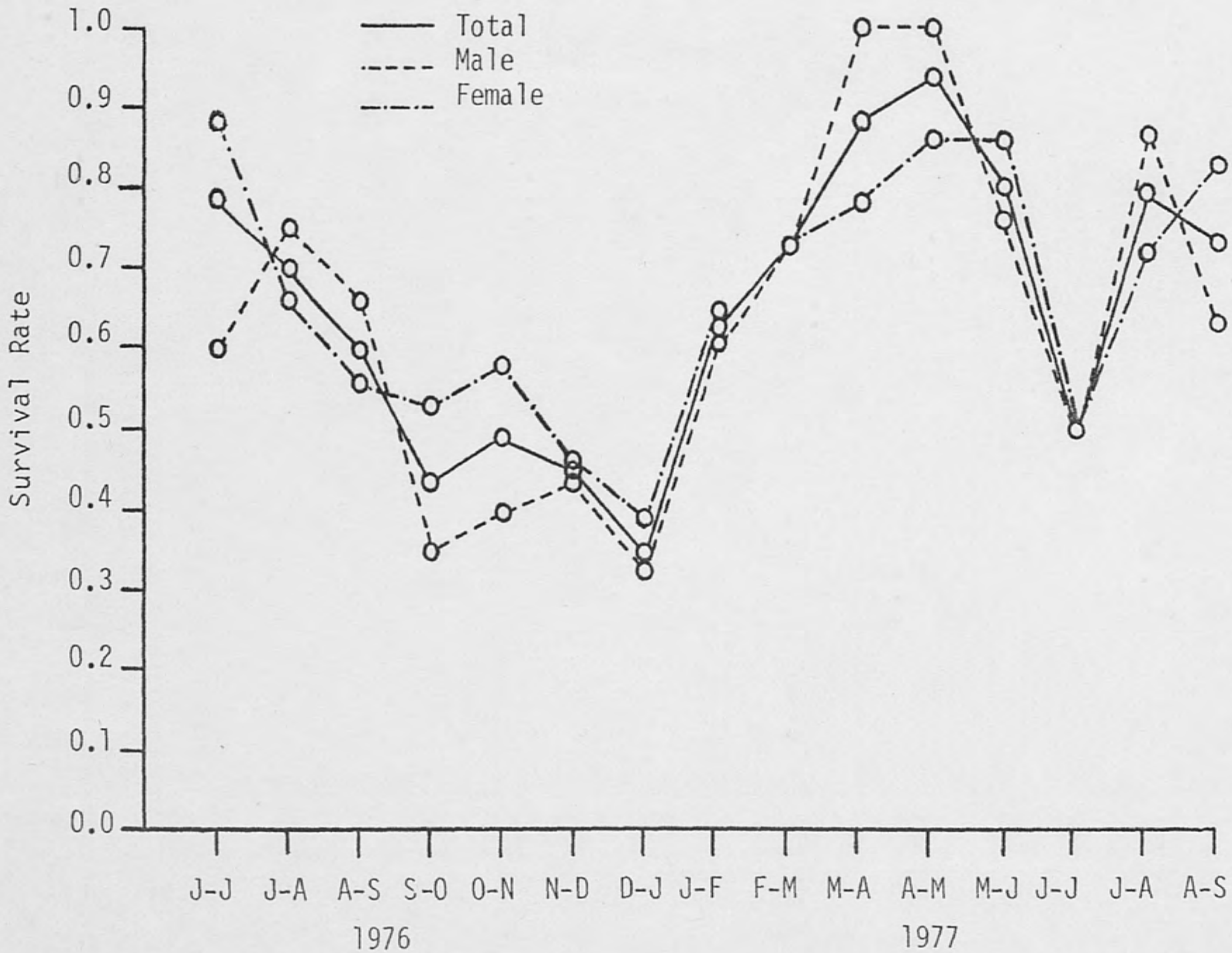

Figure 11. Four-week survival rates of cotton rats on the Wisconsin Village Flatwoods grid.

Four-week survival rate of cotton mice oscillated dramatically throughout the study. No apparent seasonal trends occurred in the population of cotton mice (Figure 12).

The stable population level maintained by Florida mice may be due in part to their high rate of survival from December 1976 through June 1977 (Figure 13). No recaptures of Florida mice were recorded with the exception of one mouse that was recaptured in August 1977 after failing to be caught for 13 months.

Happy Hammock.--The survival rate of cotton mice fluctuated for the first eight months of the study and reached a maximum rate of 0.89 in February 1977 (Figure 14). Through the spring and early summer survival steadily declined to a minimum rate of 0.45 and then climbed again in the final two months of study. The survival rate of males and females was similar with the exception of the October-November trapping interval where survival of males declined dramatically whereas female survival slightly improved.

Trends in Body Weight

Wisconsin Village Flatwoods.--Trends in mean monthly body weights of male and female cotton rats were similar (Figures 15 and 16). Males were heavier than females in all months except November and December 1976. Mean body weights of male cotton rats were significantly greater than those of females captured in July, August, and September 1976 and from April through June 1977 ($p < .05$). Both sexes attained their heaviest mean body weights in July and August 1976 and in August and September 1977. Mean body weights of

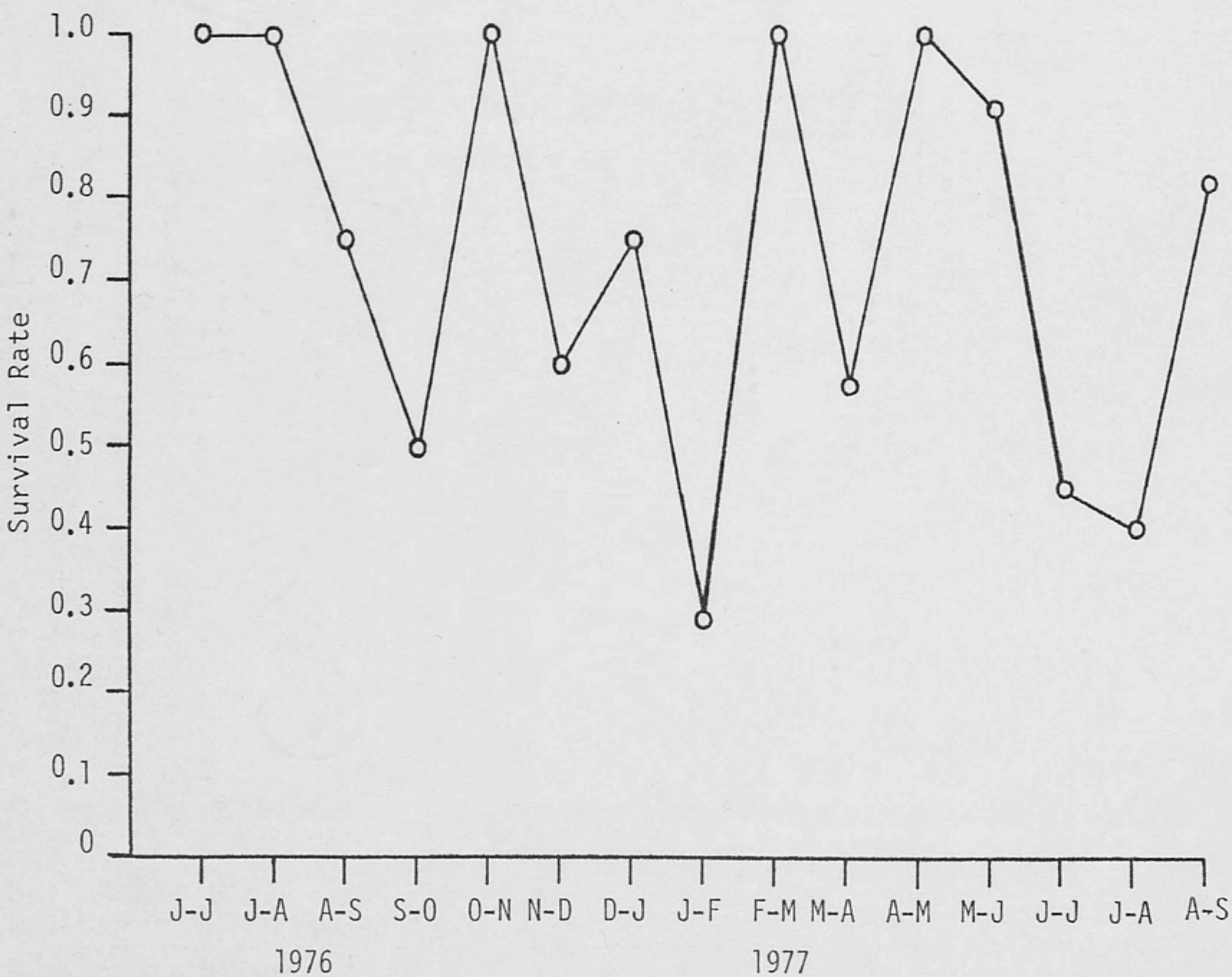

Figure 12. Four-week survival rates of cotton mice on the Wisconsin Village Flatwoods grid.

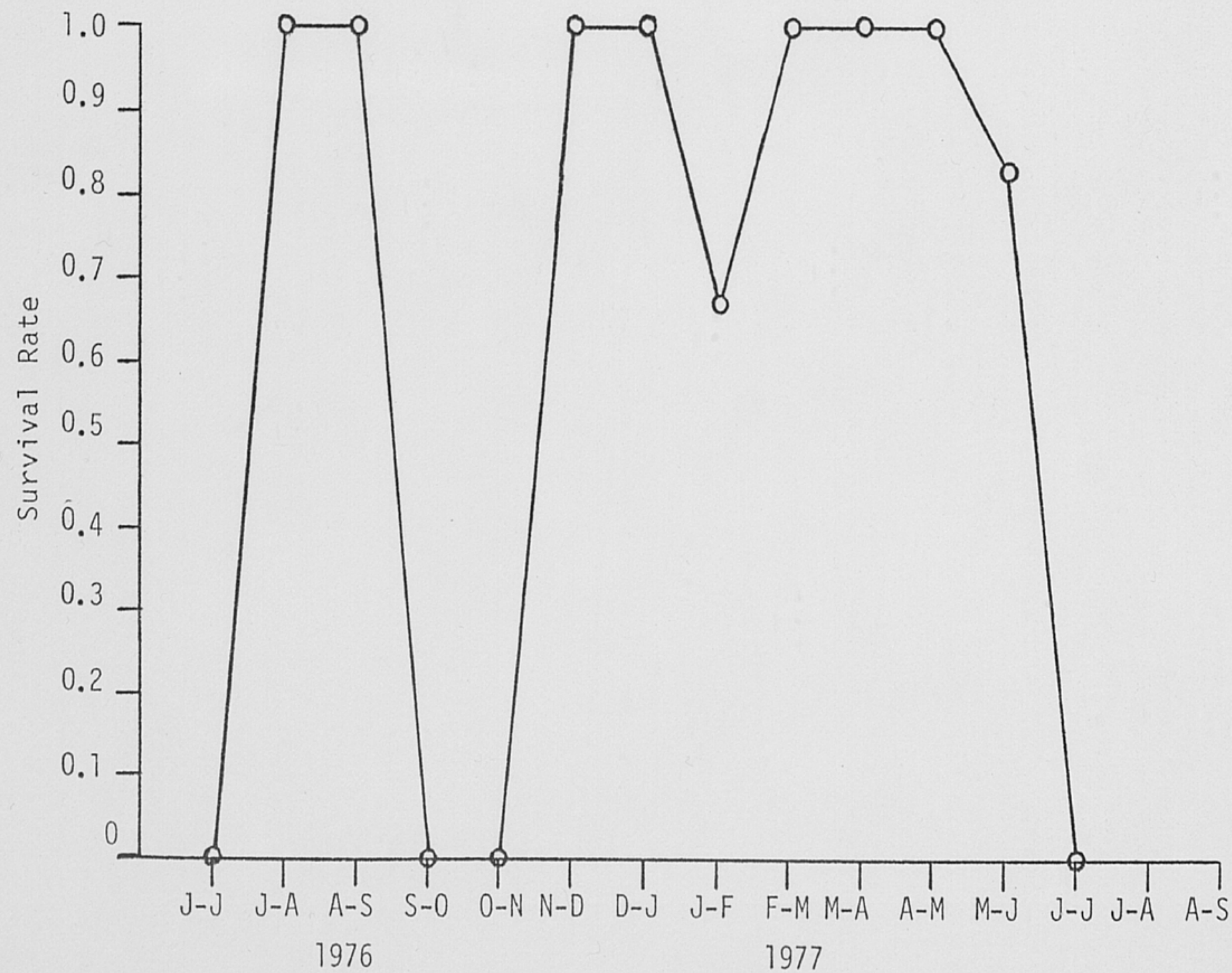

Figure 13. Four-week survival rates of Florida mice on the Wisconsin Village Flatwoods grid.

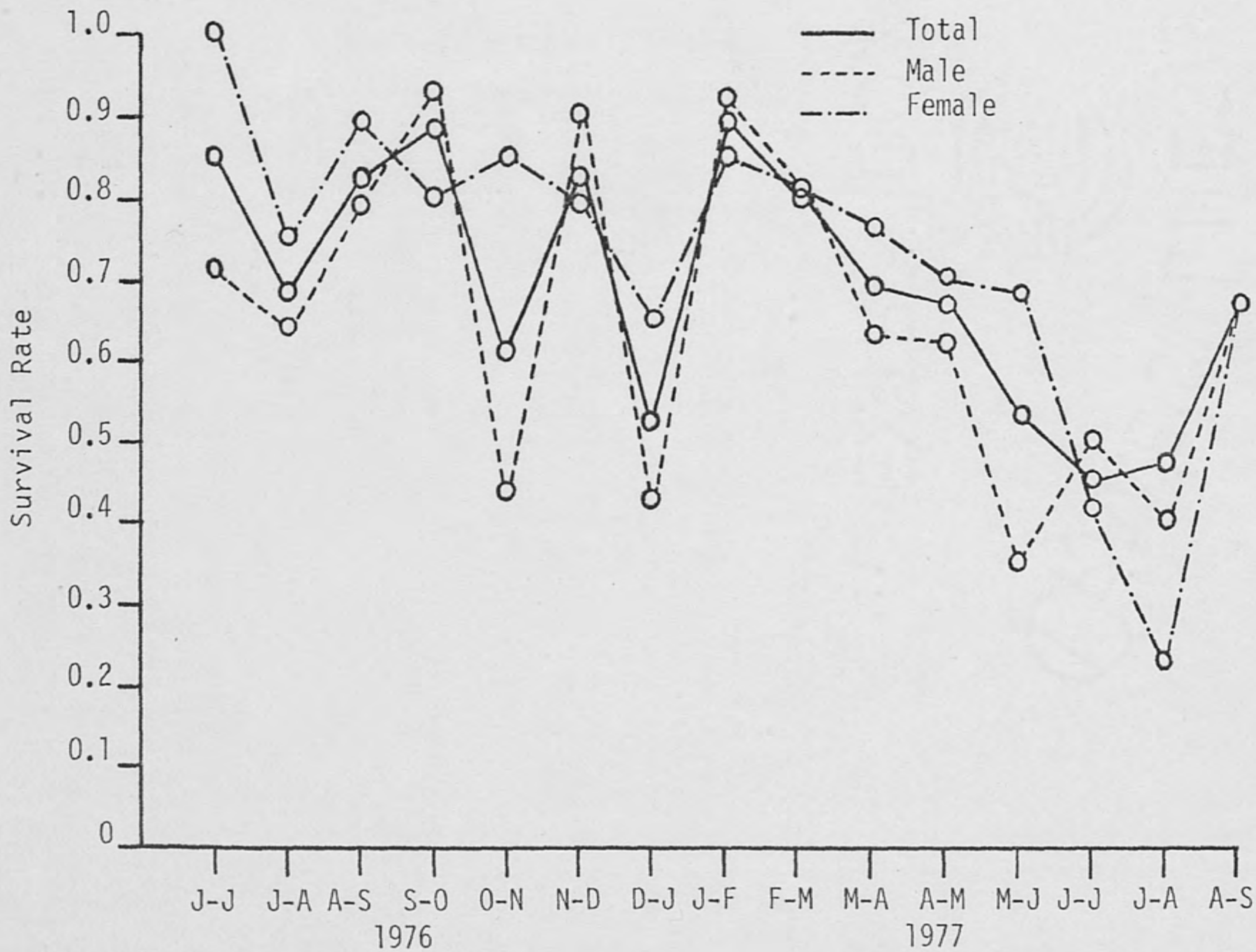

Figure 14. Four-week survival rates of cotton mice on the Happy Hammock grid.

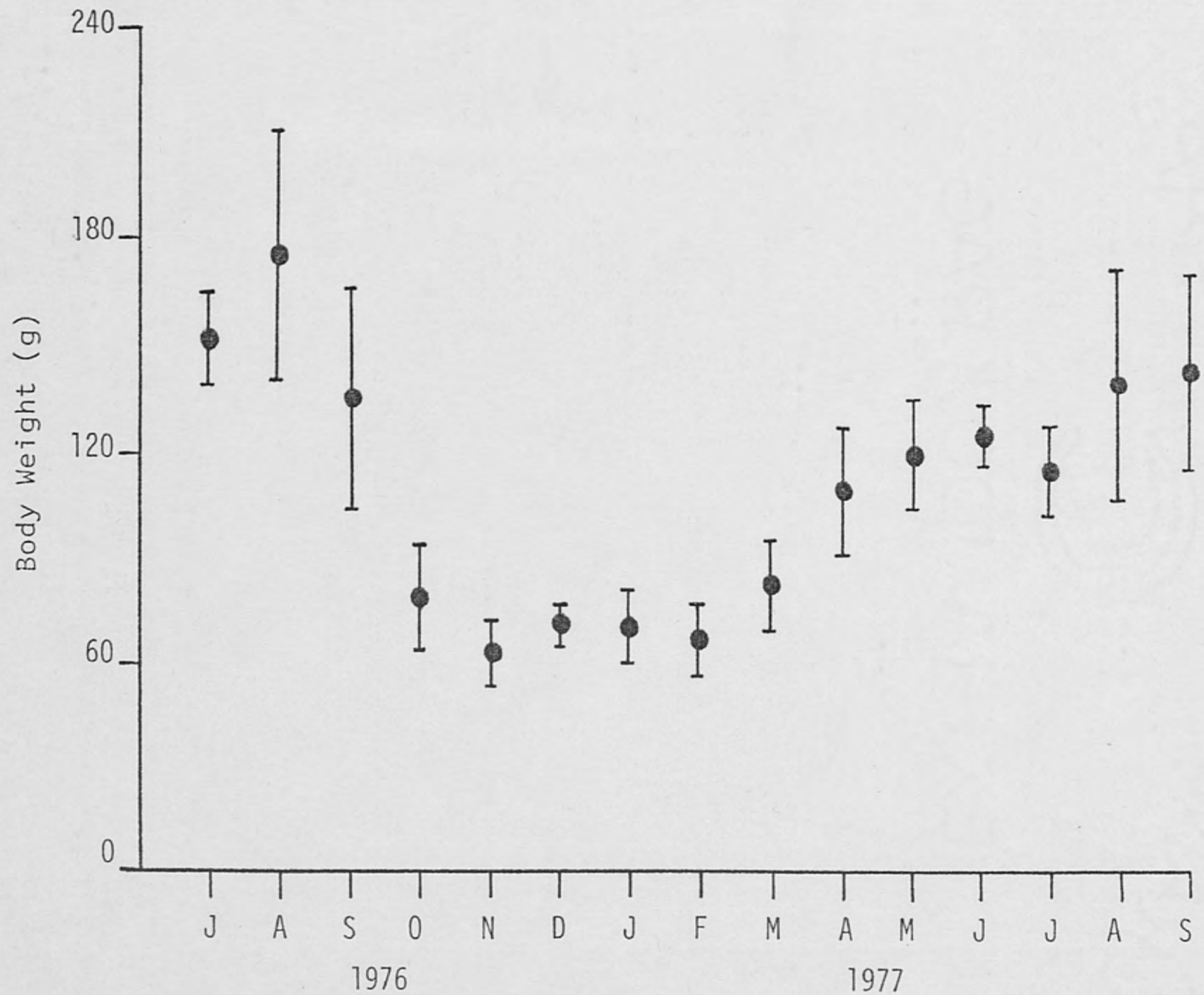

Figure 15. Mean body weights of male cotton rats on the Wisconsin Village Flatwoods grid. Brackets enclose a 95% confidence interval.

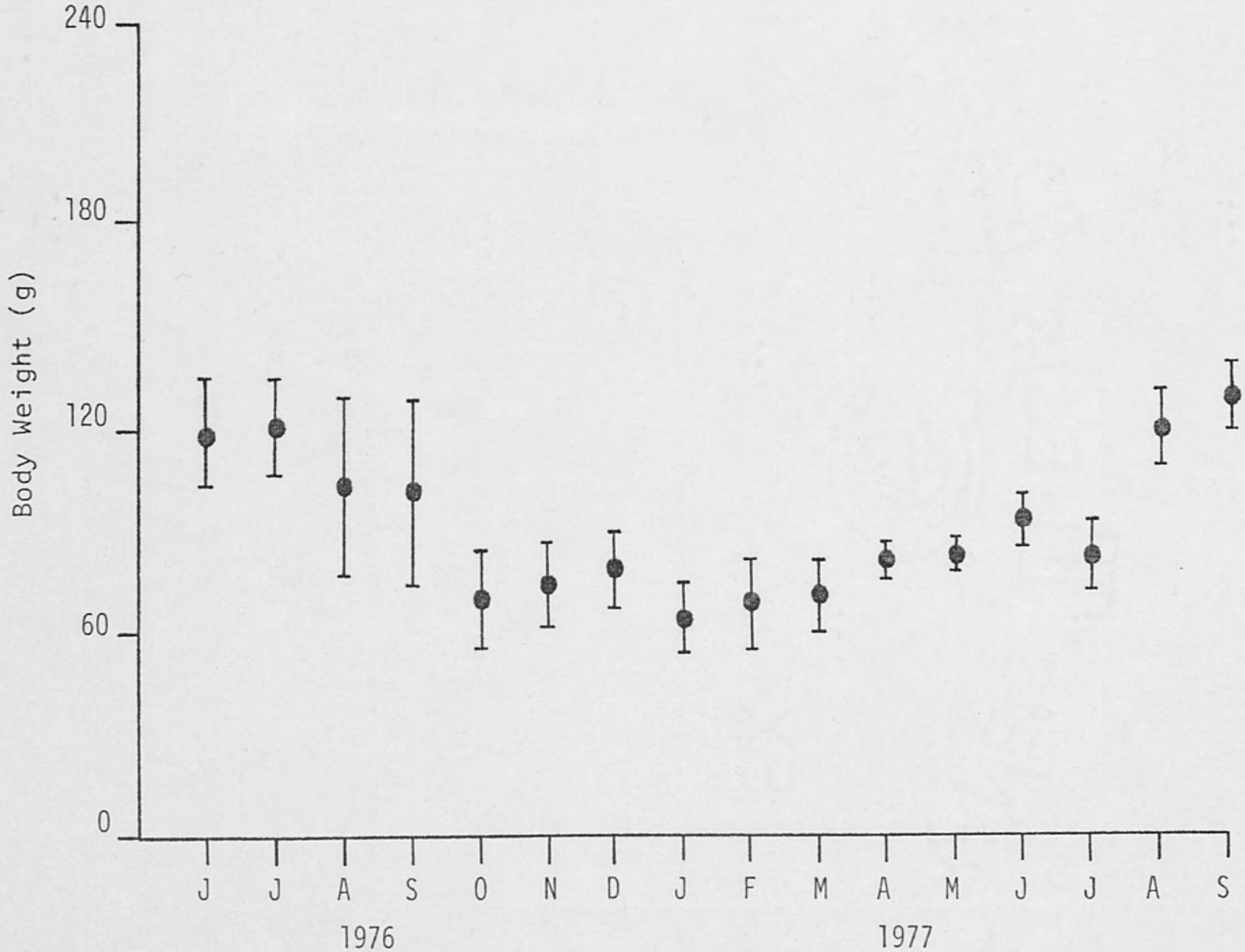

Figure 16. Mean body weights of female cotton rats on the Wisconsin Village Flatwoods grid. Brackets enclose a 95% confidence interval.

both sexes dropped in October 1976 and remained low (60-80 g) throughout the winter months. The drop in mean body weights for both sexes in October and November can be attributed to the appearance of numerous recently weaned juvenile rats in the sample. These young rats as well as older rats generally gained weight through December; however, the cotton rat population as a whole lost weight in January and February. Considering animals that were captured a minimum of five months, females lost an average of 19.6 g and males lost an average of 14.1 g through the two-month period. Mean daily temperatures were substantially below normal during this period. Male body weight subsequently rose through the spring and summer.

Several cotton rats weighing greater than 200 g were captured. These rats were caught in September (three male and three female), October (four male and one female), and November 1976 (one male). No cotton rats of this body weight were seen through the remainder of the study with the exception of a single male in August 1977.

The mean body weight of cotton mice was highest in August and September of 1976 and 1977 (Figure 17). Body weights of cotton mice reached a minimum in December 1976. It then increased through March and remained stable through June 1977.

Mean body weights of Florida mice were tabulated only for November-June 1977 due to inadequate sample size. Florida mice reached their heaviest mean body weight in June 1977 and minimum in January 1977 (Figure 17).

Happy Hammock. Mean body weights of male and female cotton mice were not significantly different in any of the months of study

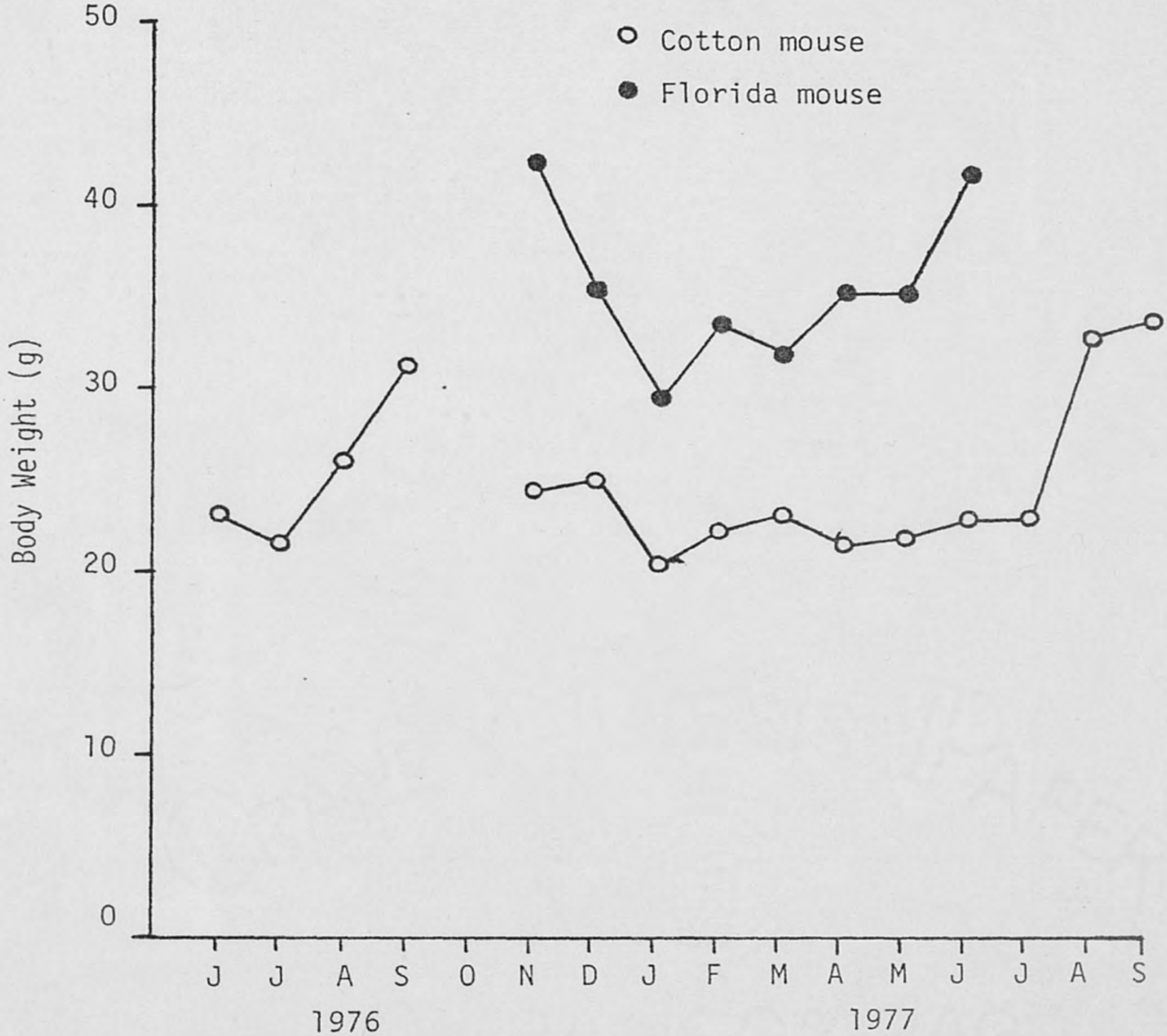

Figure 17. Mean monthly body weight of cotton mice and Florida mice on the Wisconsin Village Flatwoods grid.

(Figures 18 and 19). Mean body weights of males and females increased in the first few months reaching a maximum in September for males and October for females. Male body weights decreased during the next four months and remained stable through April 1977. Mean weights of male cotton mice gradually increased during the summer and in September 1977 had reached the level attained the year before. Subsequent to the October 1976 peak female body weight declined to a minimum in March 1977 which was followed by a series of slight increases and decreases over the remaining months of the study.

Sex Ratio

Wisconsin Village Flatwoods.--Female cotton rats outnumbered males during the initial four months of trapping (Table 4). Males outnumbered females from October through December 1976; however, the sex ratio was 1:1 in January. Female cotton rats were only slightly more abundant in February and March 1977 and again in July, August, and September 1977. The sex ratio did not significantly differ from 50:50 (Chi square test, $p > .05$) at any time through the period of study.

Male cotton mice outnumbered females in most months of trapping except in July and November 1976 and June and September 1977 (Table 5) when females dominated. The sex ratio was equal in December and April and never deviated significantly from 50:50 ($p > .05$).

The sex ratio of Florida mice was equal for six of the 16 months of the study (Table 6) and at no time deviated significantly

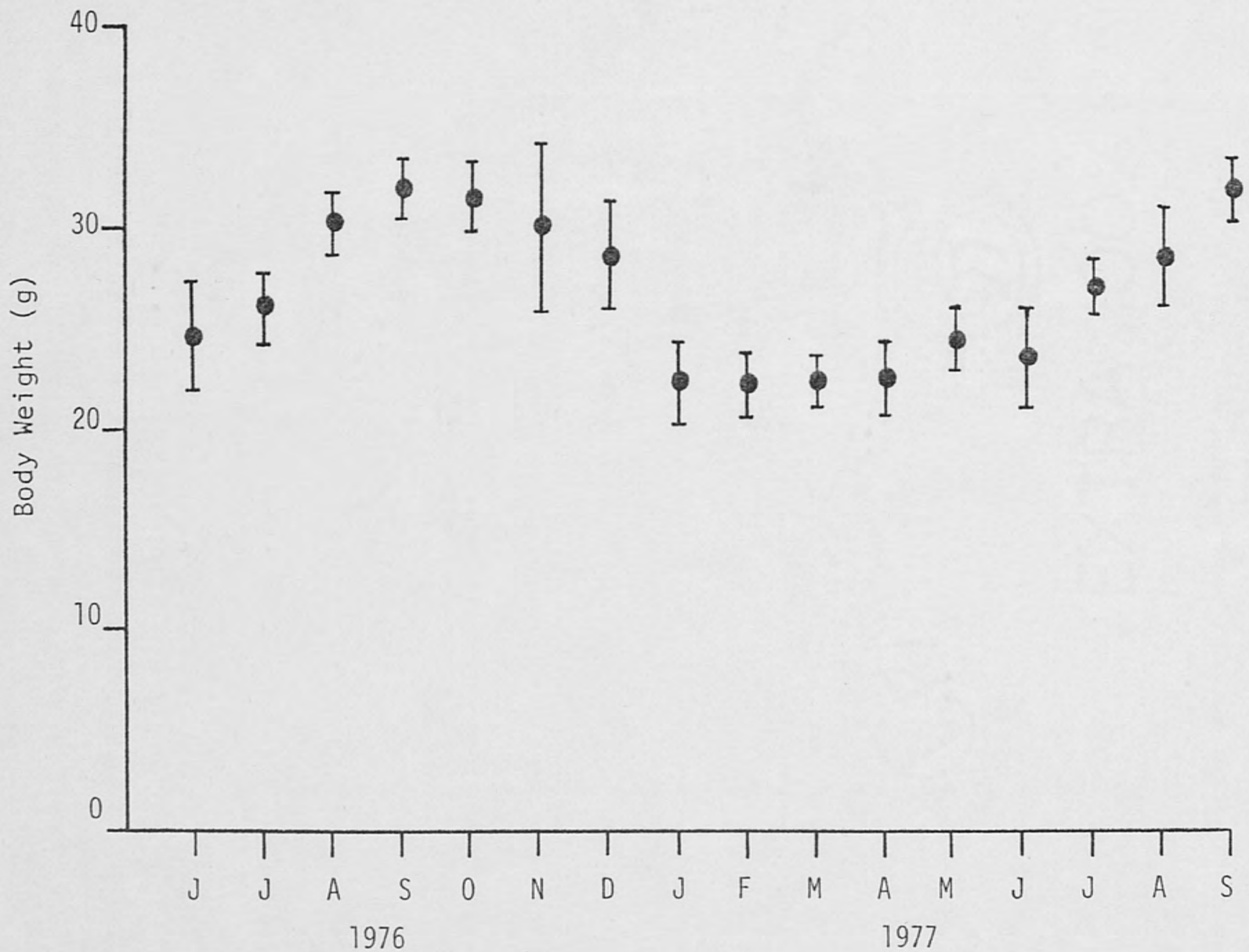

Figure 18. Mean body weights of male cotton mice on the Happy Hammock grid. Brackets enclose a 95% confidence interval.

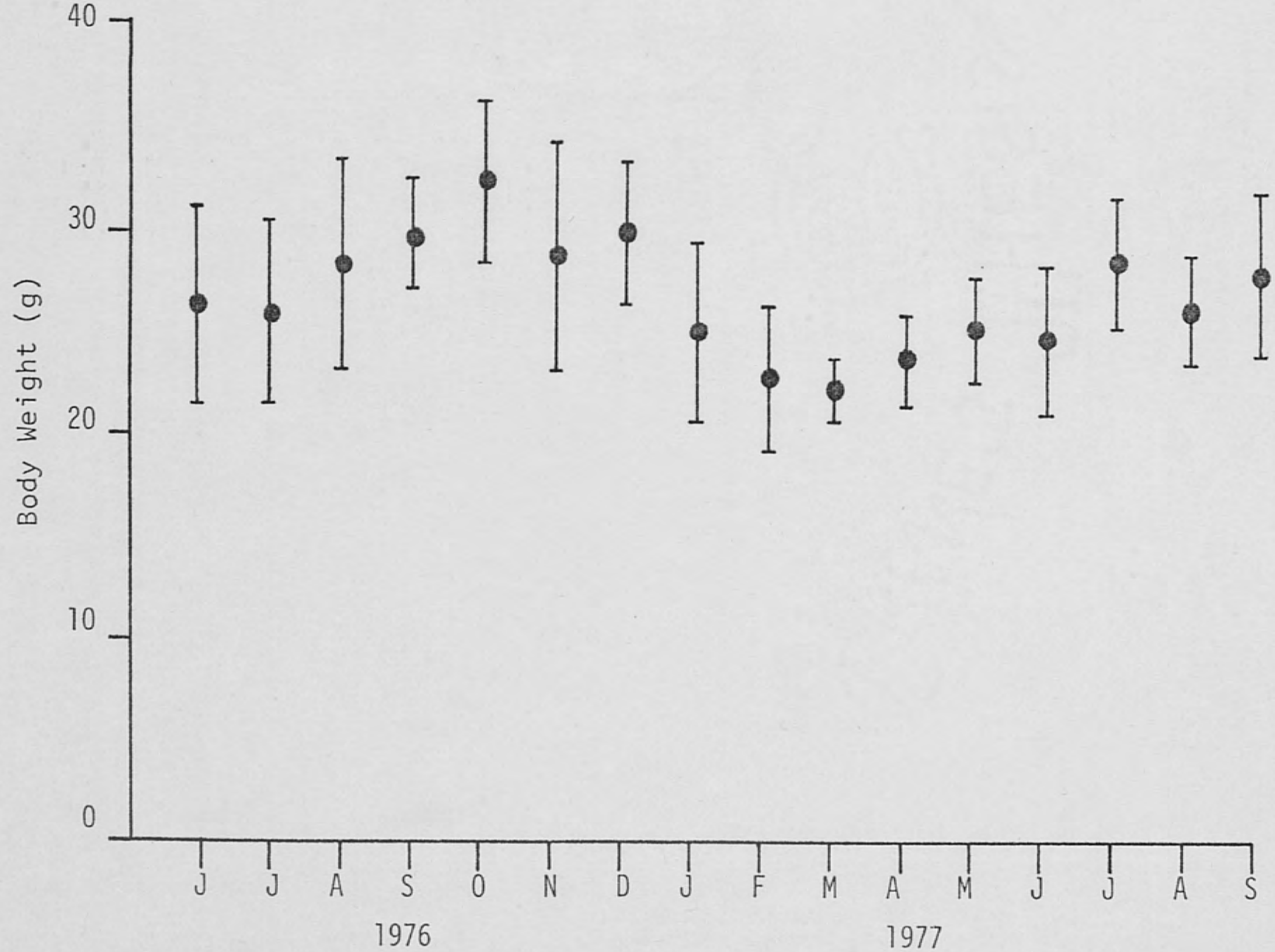

Figure 19. Mean body weights of female cotton mice on the Happy Hammock grid. Brackets enclose a 95% confidence interval.

Table 4. Sex ratio of cotton rats live-trapped on the Wisconsin Village Flatwoods grid.

Year	Month	N	Male	Female	Ratio	Chi-Square Value
1976						
	June	14	5	9	0.55	0.64
	July	19	7	12	0.58	0.84
	August	25	9	16	0.56	1.44
	September	36	17	19	0.89	0.03
	October	77	40	37	1.08	0.05
	November	85	46	39	1.18	0.42
	December	77	45	32	1.41	1.87
1977						
	January	30	15	15	1.00	0.00
	February	19	9	10	0.90	0.00
	March	15	7	8	0.87	0.00
	April	16	9	7	1.28	0.06
	May	17	10	7	1.43	0.24
	June	16	10	6	1.66	0.56
	July	14	6	8	0.75	0.07
	August	20	9	11	0.82	0.05
	September	27	13	14	0.93	0.00

Table 5. Sex ratio of cotton mice live-trapped on the Wisconsin Village Flatwoods grid.

Year	Month	N	Male	Female	Ratio	Chi-Square Value
1976						
	June	5	3	2	1.50	0.00
	July	5	2	3	0.66	0.00
	August	8	5	3	1.66	0.13
	September	5	3	2	1.50	0.00
	October	0	-	-	-	-
	November	5	2	3	0.66	0.00
	December	4	2	2	1.00	0.00
1977						
	January	7	4	3	1.33	0.00
	February	2	2	0	-	0.50
	March	7	4	3	1.33	0.00
	April	8	4	4	1.00	0.00
	May	10	6	4	1.50	0.10
	June	9	4	5	0.80	0.00
	July	4	3	1	3.00	0.13
	August	5	4	1	4.00	0.40
	September	5	2	3	0.66	0.00

Table 6. Sex ratio of Florida mice live-trapped on the Wisconsin Village Flatwoods grid.

Year	Month	N	Male	Female	Ratio	Chi-Square Value
1976						
	June	1	1	0	-	0.00
	July	1	0	1	0.00	0.00
	August	1	0	1	0.00	0.00
	September	1	0	1	0.00	0.00
	October	0	-	-	-	-
	November	2	1	1	1.00	0.00
	December	4	2	2	1.00	0.12
1977						
	January	6	4	2	2.00	1.66
	February	4	1	3	0.33	0.25
	March	6	3	3	1.00	1.66
	April	6	3	3	1.00	1.66
	May	6	3	3	1.00	1.66
	June	4	2	2	1.00	0.25
	July	0	-	-	-	-
	August	1	1	0	-	0.00
	September	0	-	-	-	-

from 50:50.

Four of the nine rice rats and one of the four golden mice captured were males.

Happy Hammock.--Male cotton mice outnumbered females in 10 of the 16 months of study and the sex ratio was equal in only two months (Table 7). Females were more prevalent than males in November 1976 and in January, April, and June 1977. Males outnumbered females 2:1 in August 1976 and September 1977. The cotton mouse sex ratio never deviated significantly from 50:50 (Chi square test, $p > .05$).

Five of the six cotton rats captured were females as were five of the seven golden mice.

Reproduction

Wisconsin Village Flatwoods.--Reproductive activity of cotton rats was largely confined to the summer and fall months. The reproductive status of male cotton rats of breeding age (> 100 g) is summarized in Table 8. All males examined in the initial sample were reproductively active. Activity steadily declined in subsequent months reaching complete inactivity in November 1976. Male cotton rats resumed reproductive activity in April 1977 and from June through September all males had descended testes. Female cotton rats of breeding age (> 100 g) were reproductively active from the outset of the study until January 1977 (Figure 20). The percentage of rats observed to have a perforate vagina was at a maximum through the initial summer of trapping and then steadily decreased through

Table 7. Sex ratio of cotton mice live-trapped on the Happy Hammock grid.

Year	Month	N	Male	Female	Ratio	Chi-Square Value
1976						
	June	13	7	6	1.17	0.00
	July	17	10	7	1.43	0.23
	August	18	12	6	2.00	1.39
	September	19	11	8	1.37	0.21
	October	31	18	13	1.38	0.52
	November	13	5	8	0.62	0.31
	December	29	16	13	1.23	0.14
1977						
	January	16	6	10	0.60	0.56
	February	30	17	13	1.31	0.30
	March	33	17	16	1.06	0.00
	April	25	11	14	0.78	0.16
	May	26	13	13	1.00	0.04
	June	16	7	9	0.78	0.06
	July	17	9	8	1.12	0.03
	August	8	4	4	1.00	0.12
	September	15	10	5	2.00	1.07

Table 8. Reproductive status of adult (> 100 g) male cotton rats on the Wisconsin Village Flatwoods grid. Sample size in parentheses.

Year	Month	Position of Testes in Percent Descended or Intermediate	Abdominal
1976			
	June	100.0(5)	0.0(0)
	July	85.7(6)	14.3(1)
	August	77.8(7)	22.2(2)
	September	81.8(9)	18.2(2)
	October	40.9(9)	59.1(13)
	November	0.0(0)	100.0(21)
	December	0.0(0)	100.0(25)
1977			
	January	0.0(0)	100.0(8)
	February	0.0(0)	100.0(5)
	March	0.0(0)	100.0(7)
	April	14.3(1)	85.7(6)
	May	30.0(3)	70.0(7)
	June	100.0(10)	0.0(0)
	July	100.0(6)	0.0(0)
	August	100.0(8)	0.0(0)
	September	100.0(11)	0.0(0)

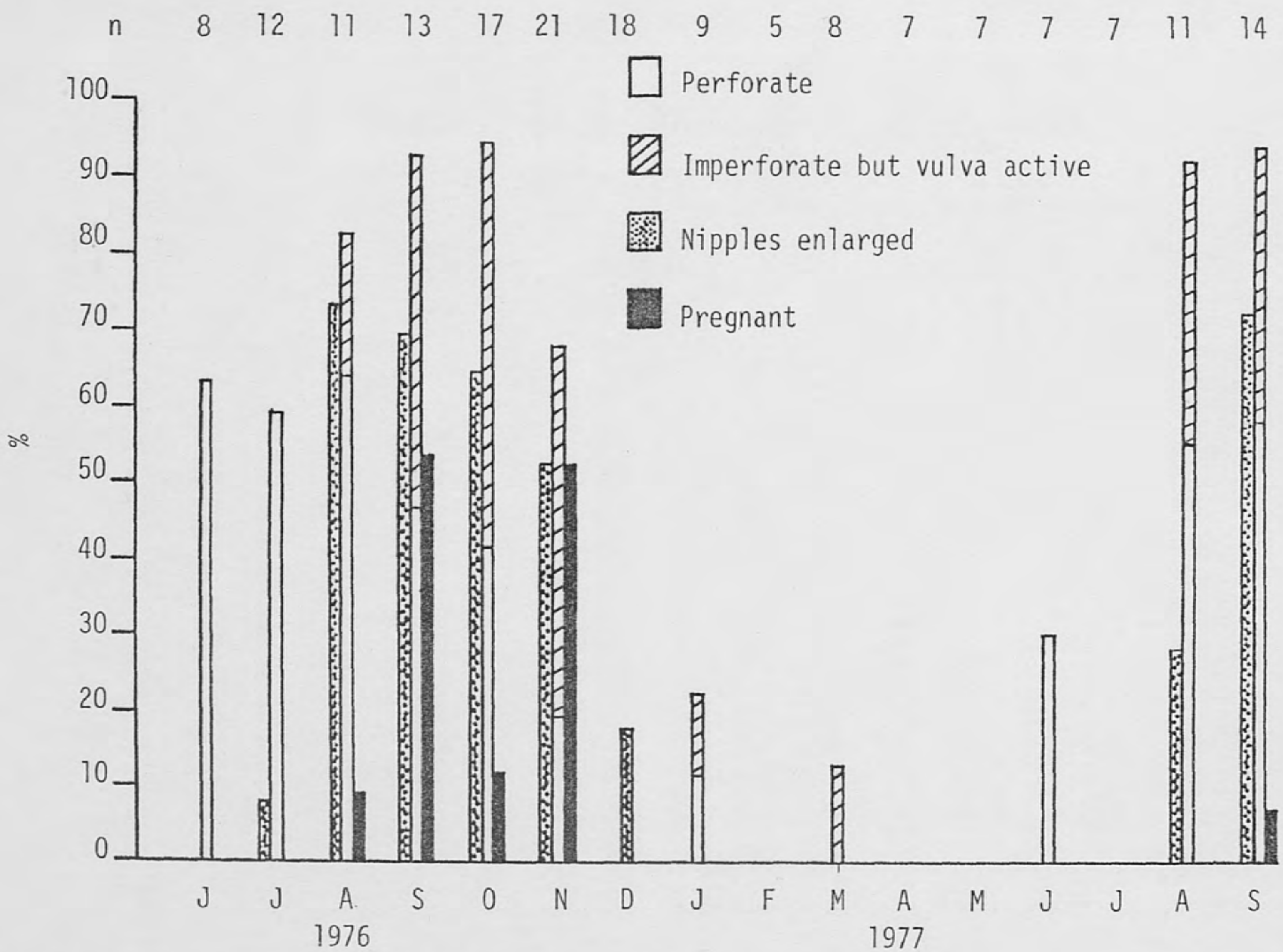

Figure 20. Monthly percentage of adult (>100 g) female cotton rats in reproductive condition on the Wisconsin Village Flatwoods grid.

January 1977. Perforate females did not reappear until June 1977 and in August and September most rats were perforate. The percentage of females apparently nursing young peaked in August 1976 and then gradually declined through December. Females once again appeared to be nursing young in August and September 1977. A small percentage of pregnant rats was recorded in August 1976. The percentage of pregnant females was highest in September and November 1976 and a single pregnancy was noted in September 1977.

In October 1976 a female cotton rat gave birth to six in a trap. The average measurements of the six offspring were: total length, 78.8 mm; tail length, 28 mm; hind foot length, 10.3 mm; and weight, 5.92 g. After the female was processed and released she carried each of her young away individually.

Adult (based on pelage) male cotton mice with descended testes were common in the late summer months of August and September in 1976 and from July through September 1977 (Table 9). However, a few males with descended testes were seen in June and November 1976 and in March, April, and June 1977. Female cotton mice of breeding age (based on pelage) had perforate vaginas in August and September 1977 only (Figure 21). However, cotton mice that were imperforate but had other aspects of vulvar activity were seen from August through January and again from May through July 1977. Evidence of nursing of young was apparent in September, November, and December 1976 and not again until September 1977. Two pregnant cotton mice were examined in September 1976 and one was seen in September 1977.

The reproductive status of male Florida mice is summarized in

Table 9. Reproductive status of adult (based on pelage) male cotton mice on the Wisconsin Village Flatwoods grid. Sample size in parentheses.

Year	Month	Position of Testes in Percent Descended or Intermediate	Abdominal
1976			
	June	33.3(1)	66.7(2)
	July	0.0(0)	100.0(2)
	August	100.0(5)	0.0(0)
	September	100.0(3)	0.0(0)
	October	0.0(0)	0.0(0)
	November	50.0(1)	50.0(1)
	December	0.0(0)	0.0(1)
1977			
	January	0.0(0)	100.0(4)
	February	0.0(0)	100.0(2)
	March	75.0(3)	25.0(1)
	April	50.0(2)	50.0(2)
	May	0.0(0)	100.0(6)
	June	25.0(1)	75.0(3)
	July	100.0(3)	0.0(0)
	August	100.0(4)	0.0(0)
	September	100.0(2)	0.0(0)

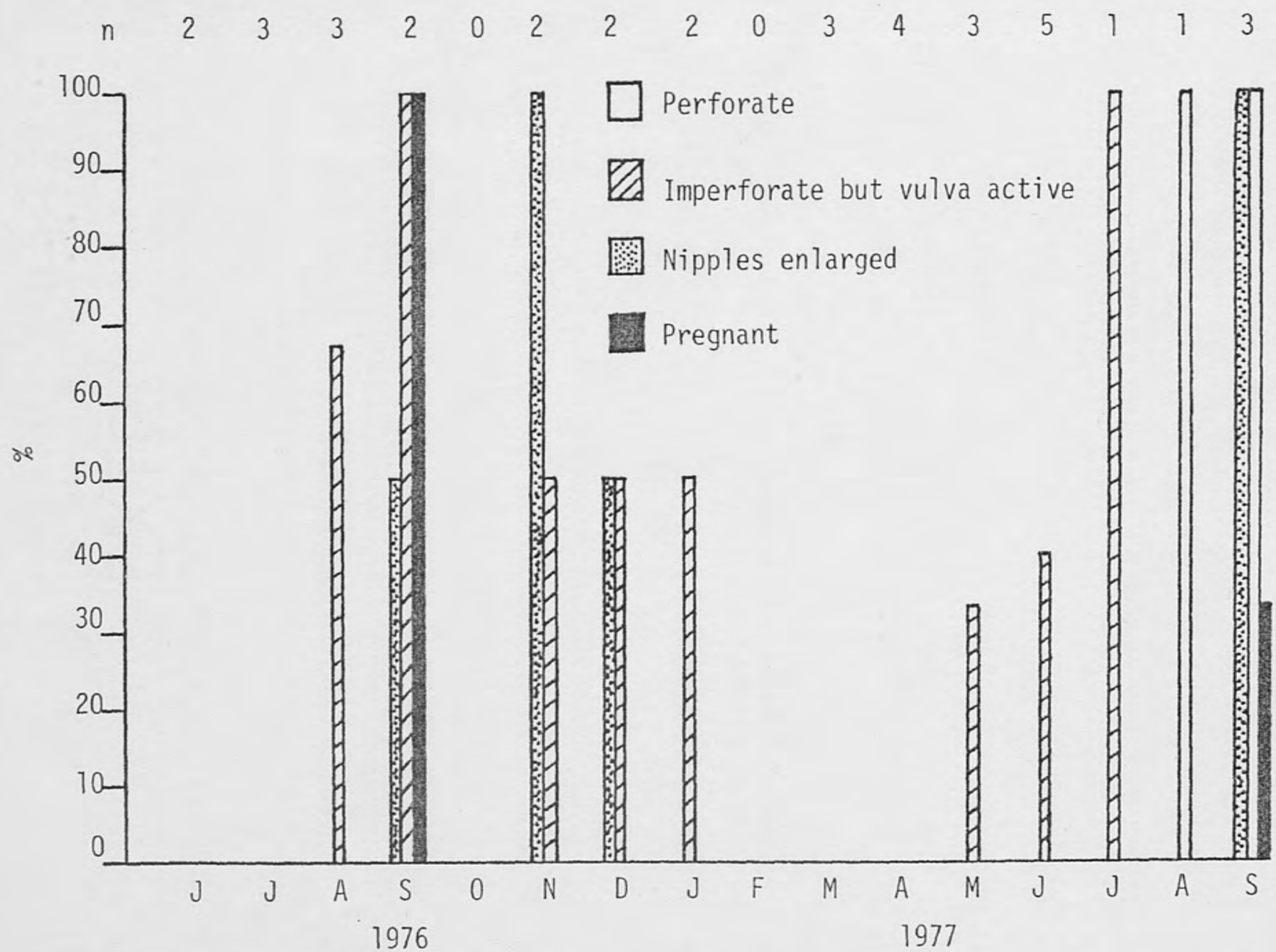

Figure 21. Monthly percentage of adult (based on pelage) female cotton mice in reproductive condition on the Wisconsin Village Flatwoods grid.

Table 10. Of the trapping periods when male Florida mice of breeding age (based on pelage) were captured, January and February 1977 were the only months when no mice appeared to be reproductively active. The small sample of female Florida mice generally reflected the reproductive activity pattern seen for the males (Figure 22). Females were either perforate or had other vulvar activity in August, November, and December 1976 and from March through June 1977. Females apparently were suckling young in September, November, and December 1976 and in March and June 1977. Pregnant Florida mice were seen in November 1976 and again in May and June 1977.

Of the adult male rice rats examined, those with descended testes were seen during July 1976 and June and September 1977. A single adult female rice rat was perforate in September 1977.

A single adult (based on pelage) male golden mouse was reproductively active in July and August 1977 and one female was nursing young in June and August 1977.

Happy Hammock.--Male cotton mice of breeding age (based on pelage) had descended testes in all months of the study except June 1976, January, and April through June 1977 (Table 11). The highest percentages of reproductively active males were seen from August through December 1976 and in August and September 1977. Adult female cotton mice showed some degree of activity in all months except July 1976 (Figure 23). Mice with perforate vaginas were observed in June and December 1976 and again in August and September 1977. Females that were imperforate but had an active vulva were recorded

Table 10. Reproductive status of adult (based on pelage) male Florida mice on the Wisconsin Village Flatwoods grid. Sample size in parentheses.

Year	Month	Position of Testes in Percent Descended or Intermediate	Abdominal
1976			
	June	100.0(1)	0.0(0)
	July	0.0(0)	0.0(0)
	August	0.0(0)	0.0(0)
	September	0.0(0)	0.0(0)
	October	0.0(0)	0.0(0)
	November	100.0(1)	0.0(0)
	December	50.0(1)	50.0(0)
1977			
	January	0.0(0)	100.0(4)
	February	0.0(0)	100.0(1)
	March	33.3(1)	66.7(2)
	April	33.3(1)	66.7(2)
	May	33.3(1)	66.7(2)
	June	50.0(1)	50.0(1)
	July	0.0(0)	0.0(0)
	August	100.0(1)	0.0(0)
	September	0.0(0)	0.0(0)

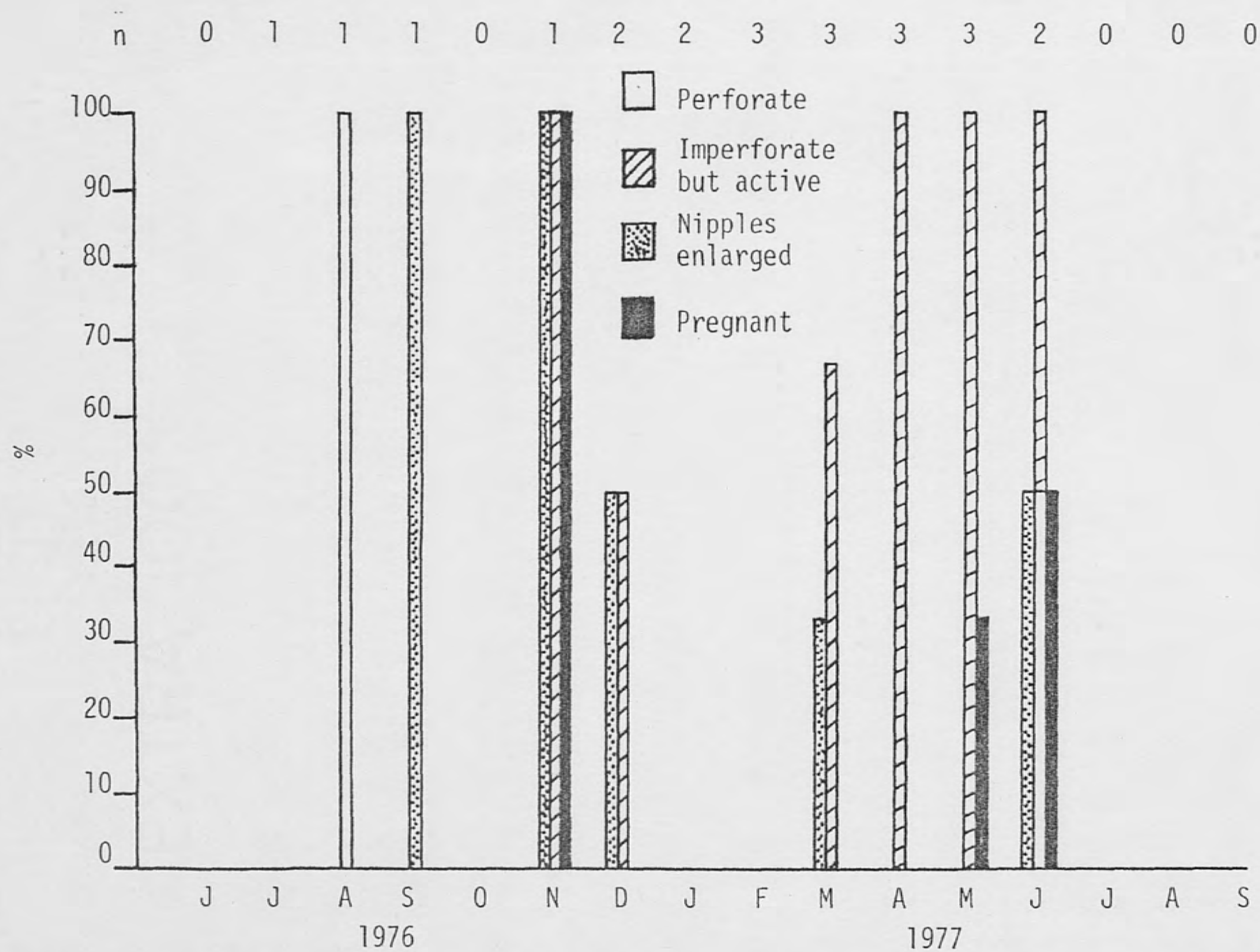

Figure 22. Monthly percentage of adult (based on pelage) female Florida mice in reproductive condition on the Wisconsin Village Flatwoods grid.

Table 11. Reproductive status of adult (based on pelage) male cotton mice on the Happy Hammock grid. Sample size in parentheses.

Year	Month	Position of Testes in Percent Descended or Intermediate	Abdominal
1976			
	June	0.0(0)	100.0(7)
	July	10.0(1)	90.0(9)
	August	83.3(10)	16.7(2)
	September	100.0(11)	0.0(0)
	October	100.0(17)	0.0(0)
	November	80.0(4)	20.0(1)
	December	87.5(14)	12.5(2)
1977			
	January	0.0(0)	100.0(6)
	February	11.8(2)	88.2(15)
	March	11.8(2)	88.2(15)
	April	0.0(0)	100.0(11)
	May	0.0(0)	100.0(13)
	June	0.0(0)	100.0(7)
	July	14.3(1)	85.7(6)
	August	75.0(3)	25.0(1)
	September	100.0(10)	0.0(0)

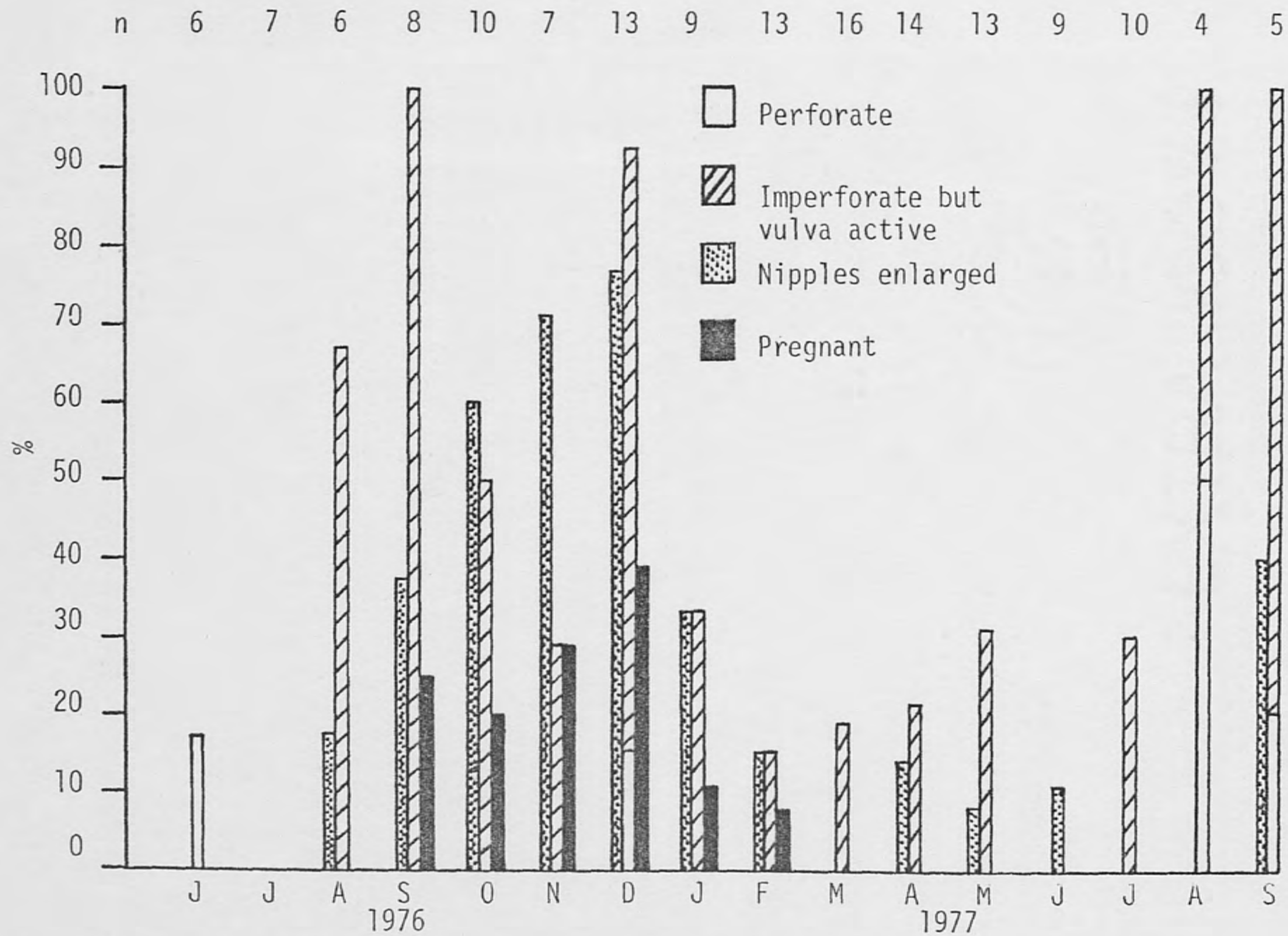

Figure 23. Monthly percentage of adult (based on pelage) female cotton mice in reproductive condition on the Happy Hammock grid.

in all months of the study except June and July 1976 and June 1977. The percentage of mice suckling young steadily increased from August through December 1976 and then decreased through June 1977. In September 1977 two females were apparently nursing young. Pregnant cotton mice were seen from September 1976 through February 1977 with the highest percentage occurring in December.

Of the adult female golden mice examined, reproductively active ones were observed in December 1976 and in May through July 1977. A single male caught in September 1977 had descended testes.

Age Structure

Wisconsin Village Flatwoods. The age structure of cotton rats (based on weight classes) is summarized in Figure 24. The percentage of adult rats was greater than 80% in June 1976. Thereafter the adult segment of the population steadily decreased through February 1977 reaching a minimum of 5.2%. From March through September adults made up an increasingly greater proportion of the population reaching a maximum of 88.9% in September 1977. The percentage of juveniles in the population was small at the outset of the sampling but steadily increased from August through November 1976 reaching a maximum of 57%. They continued to compose between 44 and 48% of the cotton rats from December through February. Few juvenile rats were seen from March through September 1977. Subadult cotton rats were a relatively small segment of the population from July through November 1976. From December through April (73.3%) subadults made up an increasingly larger segment of the population and continued to

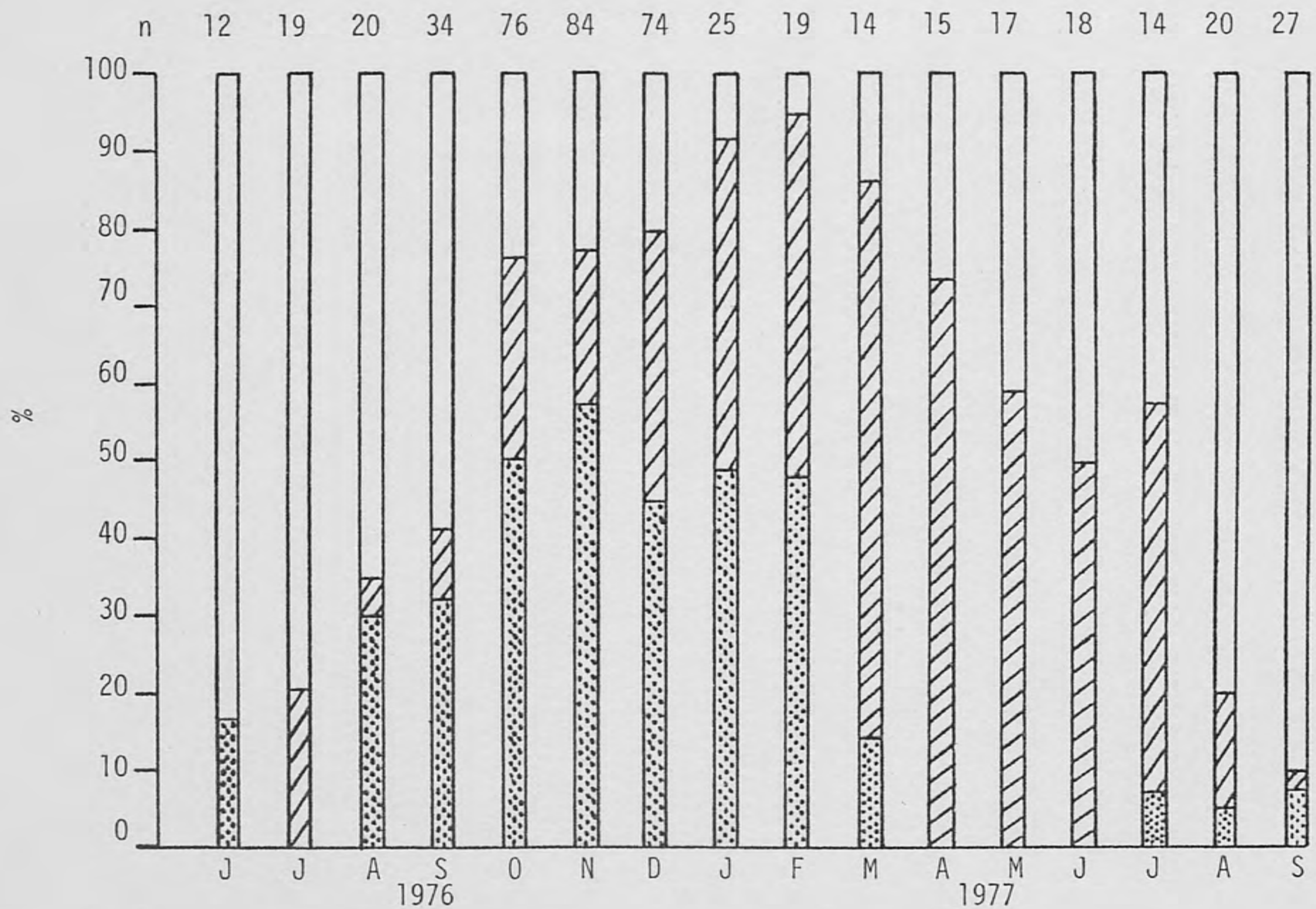

Figure 24. Age structure of cotton rats based on weight classes: 0-60 g, juvenile (stippled); 61-100 g, subadult (diagonal); greater than 100 g, adult (open), on the Wisconsin Village Flatwoods grid.

make up greater than 50% of the rats captured through July 1977.

Based on pelage, the trappable cotton mouse population was predominantly adult throughout the study (Table 12). Single juvenile cotton mice were caught in November 1976 and January 1977. Single subadult mice were seen in June, July, November, and December 1976 and in January and March 1977.

The majority of Florida mice captured during the study were adults (Table 13). No juveniles were trapped; however, subadult mice were present from December 1976 through April 1977.

Based on the weight criteria used by Negus, Gould, and Chipman (1961), all of the rice rats captured were adults (greater than 55 g) with the exception of a single juvenile rat in December and a subadult in January.

All golden mice examined were adults.

Happy Hammock.--The cotton mouse population was predominantly adult throughout the period of study (Figure 25). A small percentage of juveniles was seen in October, November, and January. Subadult mice were most prevalent in July 1976 and from November through March 1977. Single subadult mice were trapped from April through June 1977.

All cotton rats captured were adults as were the golden mice.

Movements

Wisconsin Village Flatwoods.--Male and female cotton rats differed significantly ($t = 2.13$, $p < .05$) in the average distance between successive captures (Table 14). Fourteen males traveled an

Table 12. Age structure of cotton mice, based on pelage. Data are from the Wisconsin Village Flatwoods grid. Sample size in parentheses.

		Pelage Class in Percent		
Year	Month	Juvenile	Subadult	Adult
1976				
	June	0.0(0)	20.0(1)	80.0(4)
	July	0.0(0)	20.0(1)	80.0(4)
	August	0.0(0)	0.0(0)	100.0(8)
	September	0.0(0)	0.0(0)	100.0(5)
	October	0.0(0)	0.0(0)	0.0(0)
	November	25.0(1)	25.0(1)	50.0(2)
	December	0.0(0)	25.0(1)	75.0(3)
1977				
	January	14.2(1)	14.2(1)	71.6(5)
	February	0.0(0)	0.0(0)	100.0(2)
	March	0.0(0)	14.2(1)	85.8(6)
	April	0.0(0)	0.0(0)	100.0(8)
	May	0.0(0)	0.0(0)	100.0(0)
	June	0.0(0)	0.0(0)	100.0(9)
	July	0.0(0)	0.0(0)	100.0(4)
	August	0.0(0)	0.0(0)	100.0(5)
	September	0.0(0)	0.0(0)	100.0(5)

Table 13. Age structure of Florida mice, based on pelage. Data are from the Wisconsin Village Flatwoods grid. Sample size in parentheses.

Year	Month	Pelage Class in Percent Juvenile	Subadult	Adult
1976				
	June	0.0(0)	0.0(0)	100.0(1)
	July	0.0(0)	0.0(0)	100.0(1)
	August	0.0(0)	0.0(0)	100.0(1)
	September	0.0(0)	0.0(0)	100.0(1)
	October	0.0(0)	0.0(0)	0.0(0)
	November	0.0(0)	0.0(0)	100.0(1)
	December	0.0(0)	25.0(1)	75.0(3)
1977				
	January	0.0(0)	66.7(2)	33.3(1)
	February	0.0(0)	25.0(1)	75.0(3)
	March	0.0(0)	33.2(2)	66.7(4)
	April	0.0(0)	16.7(1)	83.3(5)
	May	0.0(0)	0.0(0)	100.0(6)
	June	0.0(0)	0.0(0)	100.0(3)
	July	0.0(0)	0.0(0)	0.0(0)
	August	0.0(0)	0.0(0)	100.0(1)
	September	0.0(0)	0.0(0)	0.0(0)

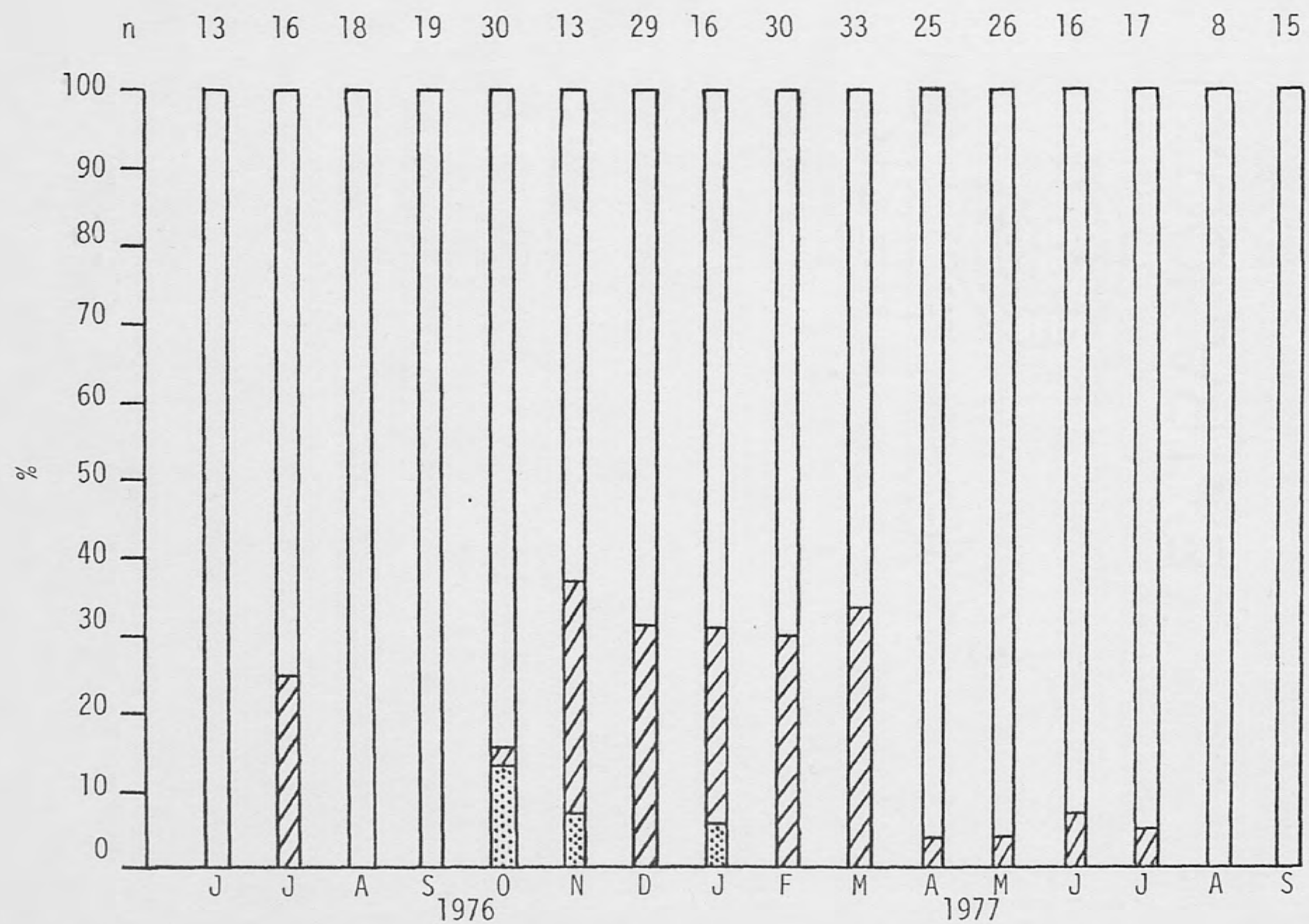

Figure 25. Age structure of cotton mice, based on pelage, juveniles (stippled), subadults (diagonal), adults (open), on the Happy Hammock grid.

Table 14. Mean distance (meters) between successive recaptures of small mammals from the Wisconsin Village Flatwoods grid. Individuals included in the calculations were captured four or more times. Sample size in parentheses.

Species	Male	Female
Sigmodon hispidus	34.5(14)*	26.8(17)
Peromyscus gossypinus	51.5(6)**	32.6(5)
Peromyscus floridanus	50.0(3)***	45.0(3)

*t = 2.13, df = 29, $p < .05$

**t = 1.51, df = 9, $p < .20$

***t = 0.20, df = 4, NS

average of 34.5 m (range, 18-57 m), whereas 17 females averaged 26.8 m (range, 14-43 m). The number of successive recaptures of an individual apparently had no effect on the average distance calculated for that animal.

Six male cotton mice traversed an average of 51.5 m (range, 27-82 m), while five females traveled an average of 32.6 m (range, 10-62 m). The difference between the sex was not significant (Table 14).

The average distance between successive recaptures of Florida mice was 50.0 m (range, 35-79 m) for three males and 45.0 m (range, 19-83 m) for three females. The difference was not significant (Table 14).

A single golden mouse recaptured five times had an average distance between successive recaptures of 68 m.

Happy Hammock.--The average distance between successive recaptures of 13 male cotton mice was 33.5 m (range, 9-58 m), while 15 females averaged 23.9 m (range, 9-57 m). The sexes did not differ significantly in recapture distance ($t = 1.70$, $p < .20$).

Assessment Lines

Wisconsin Village Flatwoods.--The total trapping effort on the assessment lines amounted to 192 trap nights in which 71 total captures were made producing a trap success of 37%. Forty-eight individuals of five species were live-trapped and recaptured 23 times. Of the small mammals captured the cotton rat (21) and the cotton mouse (20) were the species most often seen. The other species trapped were the Florida mouse (2), the golden mouse (1), and the rice rat (4).

Eleven of the cotton rats and nine of the cotton mice that were captured on the assessment lines were also trapped on the study grid either previous to or subsequent to their capture outside of the grid. Additionally one Florida mouse, one golden mouse, and two rice rats were captured on both the study grid and the assessment lines.

If the eight assessment lines of three trapping stations are visualized as three concentric square bands, certain patterns of small mammal captures are revealed. Of the cotton rats and cotton mice captured on the assessment lines, 77.8% of those captured at the trapping stations nearest to the study grid were also trapped on the grid. The rats and mice caught on the other two bands of traps had nearly the same frequency of captures on the grid (30.4% for the intermediate band and 29.2% for the most distant band of traps from the grid). Of the cotton rats trapped on the band of assessment lines nearest to the grid, 71.4% were also caught on the grid. On the intermediate and most distant bands of traps only 30.8 and 41.7% of the rats trapped were also caught on the grid. Eighty-two percent of the cotton mice captured on the first band of assessment line traps were also caught on the grid. Cotton mice caught on the second and third bands of traps that were also captured on the grid were 30.0 and 16.7%, respectively.

Examination of the various demographic parameters that were considered for the small mammals captured on the study grid revealed essentially no differences between animals caught on the assessment lines and those trapped on the grid.

Happy Hammock.--The trapping effort on the assessment lines consisted of 192 trap nights in which a total of 100 captures was made yielding a trap success of 52%. Sixty-seven individuals of four species were live-trapped and recaptured 32 times. The cotton mouse was the predominant species (64), while single captures were made of a golden mouse, a cotton rat and a Florida mouse.

Twenty-nine of the cotton mice captured in the assessment line traps were also trapped on the study grid. Looking at the assessment lines as three concentric bands of trap stations revealed that 57% of the cotton mice captured in the traps nearest to the study grid were also trapped on the grid while the figure was 41 and 43% for the intermediate and most distant bands, respectively.

Examination of the various demographic parameters measured for the cotton mice captured on the assessment lines revealed trends very similar to those for animals captured on the study grid.

Nest Boxes

A total of 13 cotton mice was found in the wooden nest boxes located in the section of hammock across Happy Creek Road from the study grid. All of the nest box inhabitants were observed during the January-April 1977 period with the exception of a single mouse observed in July 1977. In January four cotton mice were found in a single nest box in a spherical nest constructed of fibers from *Sabal palmetto*. No attempt was made to process these mice. In February two cotton mice, a subadult male and an adult female, were found in the same nest box and were processed. The male mouse was subsequently found inhabiting another one of the nest boxes in March, April, and July. Two other mice were found inhabiting different boxes in February and one male was successfully processed while the other mouse escaped. In March three of the nest boxes contained the palm fiber nesting material but no mice; however, two other boxes were inhabited by individual mice, one of which escaped and the other was a recapture. Two individuals, a male and a female, were found in separate boxes and were successfully processed.

Almost all of the mice found in the nest boxes had constructed spherical nests of palm fibers. However, a few mice were observed in the boxes devoid of nesting material. Six of ten nest boxes were utilized by mice or contained nests. An attempt was made to examine the nests as thoroughly as possible without destroying them. No food items were observed in the nest boxes.

Habitat Utilization

Wisconsin Village Flatwoods. All stations on the trapping grid were utilized by the small mammals, as evidenced by captures, with the exception of one station. No apparent reason for avoidance of that station could be determined. Cotton rats appeared to have utilized the entire area encompassed by the study grid with no apparent predilection for any segment of the habitat. Cotton mice and Florida mice showed a distinct preference for certain areas of the grid. Cotton mice were captured 61 times in the 42 perimeter stations, whereas only 39 mice were trapped in the 78 inner traps. Therefore, 61% of the cotton mice captured were caught in 35% of the traps. Florida mice exhibited quite a different bias. Sixty-six percent of the Florida mice captured were trapped at stations in the northwest quadrant of the grid and 84% were trapped in the northern half.

Happy Hammock.--Cotton mice were captured throughout the study grid in both the traps on the ground and the "up traps." Golden mice were captured predominantly in the "up traps."

Ectoparasite Burden

Wisconsin Village Flatwoods.--Cotton rats were infested by ticks, fleas, mites, chiggers, and botflies (Table 15). Ticks were observed in all months of study and were most abundant in October 1976 (1.15/rat) and August 1977 (0.70/rat). Fleas were also present throughout the study. The heaviest flea infestation occurred in February 1977 when 74% of the rats examined had fleas and 58% had greater than five fleas per rat. Mites were seen on cotton rats in all months except June through August 1976 and August 1977 reaching their greatest abundance in December 1976 and June 1977. Cotton rats had chiggers primarily during the late summer and early fall months of 1976 and 1977. Botfly larvae were seen protruding from two rats in October 1976.

Cotton mice had a relatively light ectoparasite burden (Table 16). Ticks occurred almost exclusively on the pinnae and were most abundant in November and December 1976 and February 1977 (1.50/mouse).

Table 15. Ectoparasite burden of cotton rats live-trapped on the Wisconsin Village Flatwoods grid.

Year	Month	No. Examined	Ticks Per Host	Frequency No. of Fleas 1-5	> 5	Presence of Mites	Frequency No. of Chiggers 1-50	> 50	Botflies Per Host
1976									
	June	14	0.14	9	1	0	1	0	0.0
	July	19	0.16	2	0	0	0	0	0.0
	August	25	0.12	5	1	0	4	0	0.0
	September	36	0.17	2	0	12	19	3	0.0
	October	77	1.15	13	0	39	53	3	0.03
	November	85	0.11	26	0	18	7	0	0.0
	December	77	0.13	18	1	31	1	0	0.00
1977									
	January	30	0.07	8	0	1	1	0	0.0
	February	19	0.21	3	11	5	0	0	0.0
	March	15	0.33	5	5	2	0	0	0.0
	April	16	0.06	4	1	3	1	0	0.0
	May	18	0.05	11	0	3	1	0	0.0
	June	39	0.02	14	1	16	6	0	0.0
	July	14	0.14	5	1	3	5	0	0.0
	August	20	0.70	9	1	0	8	5	0.0
	September	27	0.25	5	0	1	9	10	0.0

Table 16. Ectoparasite burden of cotton mice live-trapped on the Wisconsin Village Flatwoods grid.

Year	Month	No. Examined	Ticks Per Host	Frequency No. of Fleas 1-5	> 5	Presence of Mites	Frequency No. of Chiggers 1-50	> 50	Botflies Per Host
1976									
	June	5	0.00	0	0	0	0	0	0.00
	July	5	0.00	0	0	0	0	0	0.00
	August	8	0.00	0	0	0	0	0	0.00
	September	5	0.20	0	0	1	0	0	0.00
	October	0	-	-	-	-	-	-	-
	November	5	0.80	0	0	0	0	0	0.00
	December	4	0.50	0	0	1	0	0	0.00
1977									
	January	7	0.00	0	0	0	0	0	0.00
	February	2	1.50	0	0	0	0	0	0.00
	March	7	0.14	0	0	0	0	0	0.00
	April	8	0.12	0	0	0	0	0	0.00
	May	10	0.00	2	0	0	1	0	0.00
	June	19	0.00	0	0	0	0	0	0.00
	July	4	0.50	0	0	0	0	0	0.00
	August	7	0.28	0	0	0	0	1	0.14
	September	5	0.00	0	0	0	0	0	0.00

Fleas, mites, chiggers, and botfly larvae were seen very infrequently on cotton mice. Single mice were seen with one botfly larva in April, May, and August 1977.

Florida mice were predominantly free of ectoparasites. Individual mice were observed to harbor chiggers in September 1976 and May 1977, a tick in March 1977, and less than five fleas in May 1977.

Happy Hammock.--In comparison to their counterparts in the flatwoods, cotton mice in Happy Hammock harbored a heavy ectoparasite burden (Table 17). Ticks were recorded in all months of study with the exception of the month of July in both years. The highest numbers of ticks occurred in October (8.32/mouse) and November (9.61/mouse) of 1976.

Cotton mice were parasitized by botfly larvae in all months except February, March, and September 1977. Botfly larvae were most prevalent in July, August, and December 1976 and again from April through August 1977. The peak infestations occurred in July of both years (0.58 larva/mouse). There was no significant difference between the sexes in terms of botfly parasitism; however, it appears that this parasitism may have affected external reproductive condition (Table 18). The overwhelming majority of larvae was located in the inguinal area. In 12 instances two larvae were seen on an individual mouse.

Cotton mice experienced no parasitism by mites or chiggers and only three instances of fleas occurred in May 1977.

Table 17. Ectoparasite burden of cotton mice live-trapped on the Happy Hammock grid.

Year	Month	Number Examined	Ticks Per Host	Botfly Larvae Per Host
1976				
	June	13	0.07	0.15
	July	17	0.00	0.58
	August	18	0.55	0.38
	September	19	0.05	0.05
	October	31	8.32	0.06
	November	13	9.61	0.15
	December	29	3.31	0.27
1977				
	January	16	1.18	0.06
	February	30	0.53	0.00
	March	33	0.27	0.00
	April	26	0.19	0.26
	May	26	0.11	0.46
	June	18	0.11	0.50
	July	17	0.00	0.58
	August	8	0.25	0.25
	September	15	1.00	0.00

Table 18. Effect of botfly larvae parasitism on the reproductive status of cotton mice on the Happy Hammock grid. Sample size in parentheses.

		Male		Female	
Year	Month	Not Infected % Active	Infected % Active	Not Infected % Active	Infected % Active
1976					
	June	0.0(7)	0.0(0)	0.0(5)	0.0(1)
	July	25.0(4)	0.0(6)	0.0(4)	0.0(3)
	August	100.0(8)	50.0(4)	75.0(4)	50.0(2)
	September	100.0(10)	100.0(1)	100.0(8)	0.0(0)
	October	94.0(18)	0.0(0)	69.2(13)	100.0(2)
	November	90.0(5)	0.0(0)	60.0(5)	100.0(2)
	December	100.0(11)	60.0(5)	72.7(11)	100.0(2)
1977					
	January	0.0(6)	0.0(0)	33.3(9)	0.0(1)
	February	11.8(17)	0.0(0)	15.4(13)	0.0(0)
	March	11.8(17)	0.0(0)	18.8(16)	0.0(0)
	April	0.0(7)	0.0(4)	27.3(11)	0.0(3)
	May	0.0(7)	0.0(6)	37.5(8)	0.0(5)
	June	0.0(4)	0.0(3)	20.0(5)	0.0(4)
	July	25.0(4)	0.0(5)	50.0(4)	25.0(4)
	August	100.0(3)	0.0(1)	100.0(3)	100.0(1)
	September	100.0(10)	0.0(0)	100.0(5)	0.0(0)

DISCUSSION

Total Capture, Minimum Number Alive, and Density

Small mammal captures in the flatwoods community consisted primarily of three cricetid rodents: *Sigmodon hispidus*, *Peromyscus gossypinus*, and *P. floridanus*. The cotton rat was the dominant rodent species on the study area throughout the sampling period. The cotton mouse and Florida mouse were captured throughout the study and apparently maintained small populations on the area. Two other cricetid rodents, the golden mouse and rice rat, were captured occasionally. The rice rats were most likely transients from the adjacent wetlands.

The cotton rat has been reported from a variety of habitats in Florida; however, all previous work indicates that it most commonly inhabits and reaches its greatest abundance in flatwoods communities (Rand & Host, 1942; Moore, 1946; Barrington, 1949; Pournelle, 1950; Pearson, 1954; Starner, 1956; Arata, 1959; Layne, 1974; and Ehrhart, 1976). Several studies that have reported densities of cotton rats for open grass-forb habitat types in Florida (Layne, 1974; Ehrhart, 1976), Georgia (Provo, 1962; Schnell, 1968), Kansas (Fleharty, Choate, & Mares, 1972; Petryszyn & Fleharty, 1972), Louisiana (Negus, Gould, & Chipman, 1961), Oklahoma (Goertz, 1964), South Carolina (Golley et al., 1965), Tennessee (Howell, 1954), and Texas (Stickel & Stickel, 1949; Raun & Wilks, 1964; Joule &

Cameron, 1975; Cameron, 1977) range from 5 to 47 per ha with an average of 22 per ha. The peak density of cotton rats observed in this study, nearly 62 per ha, far exceeds those previously reported, with the exception of Davis (1958), who estimated an irruption of hundreds of rats per acre in Texas.

The trend in abundance of cotton rats, as indicated by the minimum number known to be alive and the calculated density, increased steadily from June 1976 to a maximum in November and then declined at a rate equal to that seen during the phase of increase. During the period of population increase survival rate was decreasing and the rats were reproductively active. Subsequently the population remained stable and seemed to be on the rise again in the final months of the study. According to Stout (personal communication), who continued to monitor the populations, cotton rat numbers subsequently dropped markedly and did not increase appreciably through June 1979.

Ehrhart (1976) recorded similar fluctuations with peak cotton rat populations observed during the summers of 1972 and 1974 in mixed scrub and flatwoods-marsh communities and during spring 1974 and winter 1975 in a marsh. The flatwoods-marsh study area included all but the northern-most two columns of the flatwoods area reported on here. Thus the data presented here, in conjunction with those of Ehrhart, strongly suggest approximately a two-year cycle of abundance of cotton rats. Odum (1955), who monitored a *Sigmodon* population in Georgia over an 11-year period, reported that maximum abundance occurred in November of every year but one (sampled twice a year, November and May).with three distinct cycles, two of which spanned two years and the other spanned four years. Komarek (1937) witnessed a regular spring decline in the number of cotton rats in four consecutive years in Georgia. Haines (1971) observed peak populations in summer and fall with declining spring populations during a three-year cycle in Texas. Inglis (1955) reported a cotton rat population high in November followed by a winter and spring decline in Texas. Raun and Wilks (1964), Joule and Cameron (1975), and Cameron (1977) reported a two-year cycle for cotton rats in Texas with the former recording peak density in June and the latter in November and December followed by a winter and spring decline. In Tennessee, Dunaway and Kaye (1961b) experienced highest trapping success in summer with winter declines. Briese and Smith (1974) recorded peak captures in January in South Carolina. In Kansas, Petryszyn and Fleharty (1972) and Fleharty, Choate, and Mares (1972) reported an annual cycle of abundance with peak density occurring in autumn followed by a population decline through winter and spring. Sealander and Walker (1955) observed peak captures of cotton rats in November in old fields in Arkansas with no apparent seasonal pattern of fluctuation. Layne (1974) witnessed what he described as "less pronounced population fluctuations" in a flatwoods community in Florida and attributed this to flatwoods providing a more stable environment for *Sigmodon* than grass-forb habitats. His observation is contrary to that of Ehrhart (1976) and this study.

In summary, it appears that cotton rats undergo regular population fluctuations throughout most of their range with peak abundance occurring most often in autumn followed by a winter and spring decline which may be followed by a secondary peak in summer. The duration of cotton rat cycles is not regular and varies from one to four years in length.

Pronounced winter declines or "crashes" of *Sigmodon* have been reported by several investigators. Goertz (1964) noted such a crash in Oklahoma during an abnormally severe winter in 1959-60. Dunaway and Kaye (1961a) and Haines (1971) reported the same phenomenon for cotton rat populations in Tennessee and Texas, respectively, during the same period. Fleharty, Choate, and Mares (1972) studied a cotton rat population in several habitats in Kansas and witnessed a crash that completely decimated the population after a severe winter in 1968. The decline began in November as it had in the previous three years with no cotton rat captures occurring after January. The cotton rat population in the present study also began to decline in November and decreased rapidly through the next few months. However, extremely low temperatures did not occur until January when the population was already decreasing. This is in close agreement with the above cited work and a body of research that has been reported for microtines which strongly documents adverse weather conditions accelerating the fall of declining populations but not being the direct cause. According to Howard (1951), it is unlikely that small mammals in nature die from freezing alone, but when coupled with an insufficient food supply they may succumb from cold weather.

Factors other than weather may have been involved in the winter decline. Schnell (1968) concluded, "When diverse and highly mobile predator populations are present they are more important than food, social interaction, or weather in regulating cotton rat density" (p. 698). No direct evidence of predation was seen in the flatwoods; however, snakes were common on and around the study area. Numerous raptors were observed in close proximity to the grid, and mammalian predators, such as raccoons, skunks, and bobcats, were common throughout the area.

The cotton mouse is ubiquitous in Florida and is often abundant in flatwoods. The cotton mouse population in the flatwoods reached its highest density, 8.3 per ha, in the spring, coincident with the period of low cotton rat abundance. However, it did not appear there was any direct relationship between the population fluctuations of the two species. Ehrhart (1976) observed small cotton mouse populations in three communities on the Merritt Island National Wildlife Refuge and reported a maximum density of 10.4 per ha in the winter in the flatwoods-marsh community. His results did not indicate any apparent seasonal pattern of cotton mouse abundance and there did not appear to be any synchrony among the three populations. The flatwoods cotton mouse population did not resemble the hammock population in terms of abundance with the exception of both populations reaching their peak in March. Further discussion of cotton mouse abundance is provided in connection with the hammock population.

According to Layne (1963) the Florida mouse is restricted in its distribution to a narrow range of xeric communities: sand pine scrub, long leaf pine-turkey oak, slash pine-turkey oak, and scrubby flatwoods. This is supported by the majority of the Florida mice having been caught in the section of the study grid with the best drainage and highest concentration of oaks, which is best described as scrubby flatwoods. The Florida mouse population was stable through the winter and spring and reached a maximum density of 4.2 per ha. Ehrhart (1976) caught a few Florida mice in the section of the flatwoods-marsh where scrub oaks appeared. Additionally, he monitored a small population in a mixed scrub community. He observed a maximum density of 14.1 per ha in the summer of 1972 with no apparent seasonal trend in Florida mouse abundance.

The hammock community was essentially inhabited by a single small mammal species, *Peromyscus gossypinus*. The golden mouse was also present but in very low numbers and in only five months of the study. The gray squirrel was frequently seen running through the trees but was never caught in traps.

Cotton mice have been reported from a variety of habitats. Populations achieve their greatest abundance in lowland hardwood forests, mesic and hydric hammocks, and swamps (Howell, 1921; Dice, 1940; Hamilton, 1943; Barrington, 1949; Ivey, 1959; Pournelle, 1950; Pearson, 1953, 1954; McCarley, 1954, 1963; Kale, 1972; Smith et al., 1974; Bigler & Jenkins, 1975). They have also been reported in xeric hammocks, beach dunes, and pine flatwoods

(Barrington, 1949; Ivey, 1949; Pournelle, 1950; Layne, 1974; Ehrhart, 1976), pine-turkey oak, sand pine scrub (Layne, 1970), mixed pine-hardwood forests (Shadowen, 1963), and mixed scrub and marsh (Ehrhart, 1976).

Maximum density estimates of cotton mice reported are as follows: 6.7 per ha in the timbered region of eastern Texas (McCarley, 1954); 96.6 per ha in wet lowland forests in Tennessee (Calhoun, 1941); 7.2 per ha in Florida pine flatwoods (Layne, 1974); 10.4, 9.4, and 5.5 per ha in flatwoods-marsh, mixed scrub, and marsh habitats, respectively, in east coastal Florida (Ehrhart, 1976); 3.0 per ha in mixed pine-hardwood forests in Louisiana (Shadowen, 1963); and 96 per ha in a south Florida tropical hammock (Bigler & Jenkins, 1975). The peak density reached by the hammock cotton mouse population in this study was 38.2 per ha.

The monthly trends in cotton mouse fluctuations indicated by minimum number alive and the calculated density suggest a cycle of abundance from a low in the initial trapping period to the peak in March followed by a steady decline through August. According to Wolfe and Linzey (1977) cotton mouse populations typically reach a peak in mid- or late winter and are at their lowest in late summer. This observation is substantiated by results reported by McCarley (1954) in Texas, Ehrhart (1976), Bigler and Jenkins (1975), Layne (1974) and this study in Florida, and Shadowen (1963) in Louisiana. Pearson (1953) reported peak numbers in October with low numbers occurring from January through September in Florida. McCarley (1954) concluded that environmental conditions, specifically temperature and available food, are very influential in cotton mouse population regulation. Pearson (1953) suggested a good correlation between the success of acorn production and the level of cotton mouse populations. Smith, Gentry, and Pinder (1974) found no correlation between the success of acorn production and the level of cotton mouse populations. Smith et al. (1974) found no correlation between weather conditions and cotton mouse numbers in South Carolina. The results of this study appear to substantiate the correlation between acorn production and cotton mouse population increase as an acorn crop blanketed the floor of the hammock in the fall of 1976. The severely cold winter apparently did not directly affect the population; however, it had a marked effect on the hammock vegetation killing most of the subcanopy components as well as the herbaceous layer. This decrease in vegetative cover may have made the mice more susceptible to both avian and mammalian predation. According to Stout (personal communication) the cotton mouse population failed to attain the spring 1977 level through the subsequent two years of study and I submit that this was indirectly caused by the change in the structure of the hammock vegetation.

Trappability

Cotton rats were highly trappable. No segment of the population tended to be more trappable than others. Layne (1974) also recorded high cotton rat trappability. It is remarkable that trappability was consistently high in view of the fact that sampling was once a month for a single night. Traps were left in place in the field between trapping periods so animals could remain familiar with them; however, they were only open on the night of sampling. Many investigators have observed that trappability of small mammals generally increases over consecutive nights of trapping. Layne (1974) reported that experienced cotton rats clearly had a higher probability of capture than naive animals. Summerlin and Wolfe (1973) observed that socially dominant cotton rats were more trappable than subordinates and that subordinate animals exhibited less exploratory activity and tended to avoid traps treated with conspecific scent. Joule and Cameron (1974) reported significant differences in body weight and size class between first and second night samples of cotton rats with a preponderance of larger animals in the first night. They concluded that primarily during the period of high reproductive activity relative body weight of the individual influences its temporal trappability. The results of this study are inconsistent with that conclusion as the October and November samples contained high proportions of light weight (less than 60 g) individuals.

The cotton mouse and Florida mouse populations were also highly trappable. Layne (1974) reported a trappability of 67% for cotton mice in the flatwoods. The results of this study exceed that figure substantially. As no other documentation of trappability for these two species could be found it is not known how these results compare to other work.

The cotton mouse population in the hammock had a lower trappability than the flatwoods population. The monthly trappability fluctuated considerably with no apparent seasonal trend; however, greatest stability occurred during the period when numbers were highest.

Survival Rate

The four-week survival rate of cotton rats declined steadily through the period of population increase and rose steadily during the period of decrease. Little difference was noted between males and females. The maximum longevity observed was 12 months. Layne (1974) reported two individuals with a known residence of 14 months and a mean longevity of approximately three months in a Florida flatwoods. Dunaway and Kaye (1961 b) observed few cotton rats present over ten months and one animal present for 403 days. Fleharty et al. (1972) noted average longevity of approximately 53 days with an average rate of turnover of the population of 66% following initial capture. Goertz (1964) reported that disappearance of animals was about equal for both low and high populations. It appears that the majority of young born during the fall failed to overwinter; however, those that were successful continued to thrive through the spring. Factors contributing to low winter survival may have been low temperatures, predation (Schnell, 1968), lack of available food, intraspecific aggression, and parasitism. Survival is a measure of both mortality and emigration and therefore increased dispersal may also have contributed to decreased survival.

Cotton mouse survival in the flatwoods exhibited no seasonal trends and fluctuated widely through the period of study. Maximum longevity observed was seven months. Layne (1974) reported an average longevity of 1.7 months and a maximum of five months. Barrington (1949) reported a male cotton mouse present for 477 days. In Texas, McCarley (1959b) observed two females initially captured as juveniles were recaptured a year later. Pearson (1953) reported a single cotton mouse captured nearly two years after its capture and 28% of a population in a Florida hammock lived over 100 days. In a Florida hammock Bigler and Jenkins (1975) observed 22% of the population survived over a 12-month period. The population turned over completely every 18 to 20 months.

Four-week survival rate of cotton mice in the hammock was generally higher for females than males. The flatwoods and hammock populations were similar in terms of average longevity (3.22 and 3.11 months, respectively); however, several cotton mice in the hammock were present for 12 months. In the hammock population survival appeared to be independent of density; however, during the period of population decline survival rate also steadily declined. The spring decrease in survival rate may have been related to the change that occurred in the vegetative cover in the hammock following the low winter temperatures. The decrease in cover may have increased the vulnerability of the cotton mouse population to predation. Parasitism may have also been a factor that affected cotton mouse survival and is pursued in greater detail in a later section.

Body Weight

Cotton rat body weights followed trends similar to those reported by other investigators. The general trend that has been observed is for mean body weights to be highest in late summer, lowest in the winter, and increasing through the spring and early summer. The low mean body weights in fall and winter were partially due to younger (lighter weight) animals making up a high percentage of the population and the increasing mean body weight through the spring and early summer was due to the growth of these animals. Layne (1974) noted highest mean body weight in September and lowest in February and March. In Texas, Chipman (1966) found a drop in mean body weight from January to March followed by a substantial increase through May. Randolph, Randolph, Mattingly, and Foster (1977) reported an average weight gain of 54.3 g for female cotton rats during the gestation period. Females lost an average of 32.5 g through parturition and subsequently lost 21.6 g during the period of lactation. Significant body weight loss through the winter has also been documented by Dunaway and Kaye (1961a, 1964) in Tennessee, Goertz (1965a) in Oklahoma, Sealander and Walker (1955) in Arkansas, and Ehrhart (1976) in Florida. Fluctuations in the mean body weight of cotton rats have also been associated with population density. Odum (1955), Goertz (1965a), and Cameron (1977) have reported high mean body weights during periods of low density and low mean body weights at high density. In summary, mean body weights of cotton rat populations fluctuate seasonally due to a variety of factors: weather, available food, density, and pregnancy.

The trends in mean body weight of cotton mice were similar in both the flatwoods and the hammock populations. Mean weights for the sexes in both communities were highest in late summer and early fall and lowest during the winter and early spring. Ehrhart (1976) observed similar trends in cotton mouse populations on his flatwoods-marsh and mixed scrub study areas. In two south Florida hammocks, Bigler and Jenkins (1975) observed heavier mean body weights than in this study with the highest mean weights occurring in fall and winter.

Captures of Florida mice were frequent enough for mean body weights to be calculated from December 1976 to June 1977. The heaviest mean weight occurred in June. Ehrhart (1976) reported highest mean weights during summer in two years and in spring in another year in the mixed scrub habitat.

Sex Ratio

During the study a total of 257 individual male and 250 female cotton rats were live-trapped on the Wisconsin Village Flatwoods grid. Seasonal trends were apparent in the sex ratios; however, none of the deviations were significant ($p > .05$). Female cotton rats were predominant in summer months of 1976 while males were more common in the samples from fall and spring. Ehrhart (1976) reported sex ratios favoring males in the scrub and marsh habitats and slightly more females than males (131:151) in the flatwoods;

however, his data did not suggest any seasonal trends. Layne (1974) observed a general tendency for the proportion of males to be higher in winter and early spring and lower in the fall. A higher percentage of males than females has been reported in the samples of several investigators (Komarek, 1937; Erickson, 1949; Stickel & Stickel, 1949; Sealander & Walker, 1955; Hays, 1958; Dunaway & Kaye, 1961; Goertz, 1965 a; Cameron, 1977). In a laboratory study, Meyer and Meyer (1944) observed more males than females among offspring of cotton rats. Dunaway and Kaye (1961 b) observed that more females than males were caught from summer through fall due to greater longevity of females. Sealander and Walker (1955) reported sex ratios favored males in late fall and from January through April and attributed this to males ranging further and being more active than females during these periods. Goertz (1965) concluded that large numbers of male captures reflected greater male home ranges. Layne (1974) concluded that sex ratios favoring females are correlated with breeding activity, an observation which is supported by the results of this study during 1976 but not in 1977. Layne attributed this correlation to increased aggressiveness of breeding females and possibly reduced male movements due to increased social dominance.

The sex ratio of cotton mice on both study areas slightly favored males in the total samples as well as in most of the monthly samples. The sex ratio most strongly favored males in the late summer in both the flatwoods and hammock, corresponding with the period of maximum reproductive activity. Ehrhart (1976) reported sex ratios favoring males for cotton mice in both the flatwoods and scrub habitats. The sex ratio in the flatwoods favored males in all but two sample periods and strongly favored males overall (63:41). Sex ratio information reported for other cotton mouse populations also document excesses of males (Pournelle, 1952; Pearson, 1953; McCarley, 1959a, 1959b; Layne, 1974; Bigler & Jenkins, 1975). In a laboratory study Pournelle (1952) observed a sex ratio of near unity and attributed the high percentage of wild trapped males to greater activity under natural conditions.

The sex ratio of Florida mice was at unity for most monthly samples in the flatwoods and was near unity (21:22) in the total sample. In monthly samples that deviated from unity the sex ratio favored males only twice and females four times. In the mixed scrub habitat Ehrhart (1976) observed more females than males in the total sample and in eight out of 12 sampling periods. Layne (1966) reported that litters of wild and laboratory-bred Florida mice consisted of 51 and 50% males, respectively. The small number of Florida mice captured in each sample makes relating the sex ratio to other population parameters difficult; however, it appears that the presence of male mice in the samples may be related to male reproductive activity.

Reproduction

Reproductive activity of cotton rats was clearly concentrated in the summer and fall as indicated by the position of the testes in male rats and several external characteristics of female activity. These periods of reproductive activity resulted in increases in numbers of cotton rats, and density, and a shift in the age structure to a higher percentage of juvenile rats (< 60 g). Meyer and Meyer (1944) reported animals bred throughout the year in a laboratory colony. Ehrhart (1976) reported that reproduction took place in all seasons of the year in the flatwoods-marsh during 1974 and in all seasons except winter in the mixed scrub as indicated by the appearance of juveniles in the samples. Highest numbers of juveniles were observed in spring and summer. Layne (1974) reported male reproductive activity throughout the year with all adult males being active in all months except January, March, and April. Pregnant or lactating females were seen from April through November and had a distinctly bimodal distribution with the major peak in late summer and fall. In north Florida, Barrington (1949) collected pregnant rats in January, July and November and observed lactating females in February, June, October and December. Pournelle (1950) captured immature cotton rats in a north Florida swamp in May, July, August and October and a single female caught in July was found to be pregnant. Pearson (1954), in a study in northern Florida, reported males with scrotal testes in June, July, August and October. Females were either pregnant or lactating during the same period and in April. In south Florida hammocks, Bigler and Jenkins (1975) found cotton rat breeding to peak from March to May and September to November with very little activity during the summer months. Dunaway and Kaye (1961b) observed reproduction to occur chiefly from

April to October in Tennessee. In Texas, Haines (1961) recorded pregnant cotton rats from February to October with the highest rate of pregnancy in May and June. According to Sealander and Walker (1955) cotton rat reproduction in Arkansas took place from April to December with the major breeding period probably occurring from February or March through July followed by a shorter breeding period in the fall. O'Farrell, Kaufman, Gentry and Smith (1977) reported monthly trends in cotton rat reproductive activity from 1955-1973 in South Carolina. Males were in reproductive condition from spring through early fall, while females exhibited a distinctly bimodal cycle with a prolonged spring period of reproduction and a short fall period. Svihla (1929) reported finding either pregnant females or young during February, April, July, and August in Louisiana. In Oklahoma, Goertz (1965b) observed males with scrotal testes occurred primarily from April through September. Reproductively active females were observed in every month with the least activity occurring in December and January. Pregnant rats were observed in all months except December, January, and March with the highest numbers recorded in May and September. The lack of pregnancies during December and January was attributed to a combination of extremely cold weather and high population density. Odum (1955) observed pregnant females in Georgia during May and November sampling periods with the higher percentages occurring in May.

The results presented here on reproductive activity are in partial agreement with those of other investigators. With the exception of periods of unusually high winter temperatures, winter breeding has rarely been observed in wild cotton rat populations. The results of this study corroborate this observation. Most cotton rat studies indicated a spring peak of reproductive activity. This was not observed in the present study. Weather has been proposed to strongly effect the reproductive cycle of cotton rats and it is possible that the extreme low winter temperatures delayed what normally would have been a spring period of breeding. Additionally, most investigators have reported a lull in reproductive activity in July and August which has been attributed to high temperatures. Except for an apparent lack of female activity in June 1977 high summer temperatures did not appear to diminish cotton rat reproduction.

Reproductive activity of cotton mice in the flatwoods was similar to that of cotton rats with most activity occurring in late summer and fall. Peaks in male activity were observed in August and September of 1976 and 1977 and also in July 1977 and pregnant females appeared in September of 1976 and 1977. The population in the hammock exhibited a similar pattern; however, pregnant mice were seen from September through February and males continued to be active through December. Peaks in mimimum number alive and density of cotton mice occurred after the main period of reproductive activity. In north Florida, Pournelle (1952) observed greatest reproductive activity of the cotton mouse during the late fall and early winter with the highest percentages of pregnancies in November, December, and January. Some pregnant females were seen in all months of the year except June and July. In the same study, males were reported to be reproductively active from August through February with a low ebb in activity from April to August. Pournelle concluded that field and laboratory observations indicated high summer temperatures represented one of the factors influencing the cycle of reproduction of the cotton mouse. Ivey (1949) found evidence of breeding from November through February in north coastal Florida. In north Florida, Barrington (1949) reported reproductively active female cotton mice in all months except July with peak activity occurring from about October through February. Pearson (1954) also reported breeding activity concentrated in the fall and winter months. In a north Florida flatwoods, Layne (1974) observed a pregnant female in January and July and several reproductively active females in February. In south Florida hammocks, Bigler and Jenkins (1975) noted reproductive activity throughout the year with the highest degree of activity occurring in the fall and winter. In South Carolina male cotton mice were most active from April through May and September through November while female activity was distinctly bimodal with peaks in spring and fall (O'Farrell et al., 1977). In eastern Texas, McCarley (1954) observed breeding from September through May with the peak activity occurring during December and January. In southern Alabama, Linzey (1970) recorded females with embryos or placental scars in February, March, May, July, September, and December and males in breeding condition through the same period. In summary, observations concerning cotton mouse reproductive activity including those in this study indicate that breeding takes place throughout most of the year and is most concentrated in fall and early winter.

There has been very little documentation of the reproductive activity of the Florida mouse under natural conditions. Layne (1966) reported a strong seasonal breeding pattern in a north Florida population with a major peak of activity in late summer and fall and a lesser peak in late winter. In the same study, under laboratory conditions, breeding appeared to be less restricted in terms of seasonality. Under laboratory conditions, Dice (1954) reported a single breeding pair that produced a litter every month except May, July, and November. In the mixed scrub habitat on Merritt Island, Ehrhart (1976) sampled juvenile Florida mice in all seasons with the greatest numbers appearing in the fall samples. As the samples of Florida mice in the flatwoods were relatively small, it would be difficult to infer any seasonal patterns of reproductive activity. The only months in which adult mice were observed to have been reproductively inactive were January and February.

Age Structure

Body weight has been used to age cotton rats; however, Chipman (1965) concluded that weight was a poor aging criterion. To compare my data with those from previous works I used body weight. Ehrhart (1976) observed juvenile cotton rats in all seasonal samples in 1974 with the highest percentages appearing in spring and summer in the flatwoods-marsh habitat. A similar trend was reported for the mixed scrub population; however, juveniles did not appear until spring. Layne (1974) reported juveniles composed approximately 30% of the population in June; therefore, the proportion steadily declined through September. A second peak of juveniles occurred in October followed by a continual decrease through February. In South Carolina, O'Farrell et al. (1977) found that the cotton rat population was dominated by adults from February through March with juveniles appearing in samples in greatest numbers in June and October. Correspondingly rats weighing less than 100 g made up an increasingly greater proportion of the sample from April through October. In Arkansas, Sealander and Walker (1955) reported that adults (females > 112 g, males > 139 g) predominated the population in May and June while subadults were present in samples from February through June and again in November. Odum (1955) observed a much higher percentage (76) of nonbreeding juveniles during years of high population density than in low years (55). Additionally adults made up only 6% of the samples at high densities and 15% at low densities. In Texas, Cameron (1977) reported juveniles made up a substantial portion of samples from May through December or January. Adults dominated the samples in April but decreased through December. Subadults were most abundant from December through March. In Kansas, Fleharty et al. (1972) found juveniles in the population samples in all months except May with greatest numbers occurring in September, October, and November. Old adults (> 110 g) were most abundant from May through August. On the same study area Fleharty and Choate (1973) reported increasing numbers of juveniles through the summer months and slowly decreasing numbers in the fall. Adults (subadults in this study) were most common in samples from February through May. In Tennessee, Dunaway and Kaye (1964) observed highest numbers of juveniles in summer and fall and adults were most abundant from April through September. I found that my population was initially predominantly adults. They declined steadily through the fall when juveniles dominated the population. Juveniles continued to make up a large part of the samples through February and a greater percentage of the population was made up of subadults and adults through winter and spring. Adults again made up the vast majority of cotton rats seen in August and September of 1977. My results on age class distribution are congruent with those reported by other investigators.

The age structure (based on pelage characteristics) of the cotton mouse population in both the flatwoods and the hammock was similar with juveniles being present in samples in the fall and early winter and subadults in the summer, fall and winter. Adults made up the bulk of the samples in all months. Pournelle (1952) observed that cotton mice began their first molt from the 34th to the 40th day after birth. As mice are usually weaned by the third or fourth week, it is very probable that young mice were not exposed to capture until they were in subadult pelage. In Texas, McCarley (1954) reported highest percentages of juveniles from November through January and again in May. In south Florida hammocks, Bigler and Jenkins (1975) observed peaks in juveniles and subadults in samples in late winter and early spring. According to O'Farrell et al. (1977), in South Carolina greatest percentages of juveniles appeared in late fall and winter. In southern Alabama, Linzey (1970) recorded juveniles from late fall to late spring. Ehrhart (1976) reported juvenile cotton mice in samples in fall, winter, and spring in the flatwoods-marsh and in fall in the mixed scrub habitat. Subadults were in samples in all seasons in the flatwoods-marsh and all except spring in the mixed scrub. All sample periods were clearly dominated by adult mice (Ehrhart, 1976).

The age structure (based on pelage characteristics) of Florida mice was exclusively adult from May through November and contained subadults from December through April. No juveniles were trapped. In the scrub, Ehrhart (1976) observed juveniles in all seasons with subadults appearing in winter and fall sample periods. Starner (1956) reported juvenile Florida mice during the fall in northern Florida.

Movements

Spatial activity patterns of cotton rats have been reported by several investigators using various methods of measurement (Stickel & Stickel, 1949; Dunaway & Kaye, 1961b; Goertz, 1964; Fleharty & Mares, 1973). Layne (1974) reported average distance between successive captures within a trapping period and throughout trapping periods. Generally males moved greater distances than females and adults moved further than subadults and juveniles. The mean distances between successive recaptures observed in the present study, 34.5 for males and 26.8 for females, appear to be comparable to trends in spatial activity reported by other investigators using various indices of movement patterns; however, comparisons are difficult due to the variety of methods used and habitats studied.

Information on spatial activity of cotton mice has been reported by a number of investigators. Barrington (1949) utilized average distance between successive recaptures and reported values of 101.5 m for males and 32 m for females. When only animals recaptured three or more times were considered (as in this study) the male figure was 231.3 m and females traveled 31.4 m. Pearson (1953) observed an average distance between recaptures of 39.3 m for males and 34.1 m for females. In the same study it was observed that distances between recaptures were shorter under crowded conditions than during periods of low numbers. Pournelle (1950) observed the average distance traveled between captures to be 132.0 m for males and 71.0 m for females. In two hammocks in south Florida, Bigler and Jenkins (1975) reported average distances between recaptures of 23.1 and 34.9 for males and 19.4 and 18.5 for females. Males from the low density population were found to move the greatest distances. Layne (1974) calculated average distance between captures within a trap period, average distance traveled between trapping periods, and minimum home range for cotton mice. All three indices of movements were greater for females than males.

In the present study the mean distance between successive recaptures was larger for males (51.5 m) on both study areas than for females (32.6 m). Furthermore, mice in the flatwoods moved greater average distances (43.0 m) than those in the hammock (28.4 m).

The mean distance between successive recaptures for Florida mice in the flatwoods was similar to that for cotton mice. Male Florida mice moved greater distances (50.5 m) than females (45.0 m). No data were found in the literature regarding movements of Florida mice.

Assessment Lines

Wheeler and Calhoun (1967) first proposed the use of assessment lines to determine the actual area sampled with trapping grids or census lines. Concurrent use of assessment lines and a grid should improve the accuracy of density estimations (Smith et al., 1975). Studies utilizing a variety of assessment line configurations in conjunction with both removal and live trapping have concluded use of assessment lines did improve density estimation and that the best results were obtained with live-trapping (Hagen, Östbye, & Skar, 1973; Swift and Steinhorst, 1976; O'Farrell, Kaufman & Lundahl, 1977; Kaufman et al., 1971).

In this study the assessment line trapping clearly indicated that the area of effect of the trapping grids extended well beyond the grids themselves. The high percentages of animals caught on the assessment lines that were also caught on the grids mandate that an accurate estimation of density could only be ascertained by extending the areas of the study grids to at least include an additional trap site interval (15 m) and quite possibly even further. As the assessment lines used were only three trap stations long (45 m), it is difficult to suggest how far the areas of effect of the study grids reached. However, it is evident from the results presented here in conjunction with those reported by others that any attempt to accurately calculate density of small mammals must utilize the assessment line technique to establish the actual area sampled by the grid.

Ectoparasites

Investigators studying ectoparasites of cotton rats have observed generally heavy infestations of various parasites and that the most influential factors regarding species and abundance are moisture and substrate.(Harkema & Kartman, 1948; Worth, 1950; Morlan, 1952; Smith & Love, 1958). Worth (1950) reported cotton rat ectoparasites in two populations, one in a wet area of south Florida and the other in a drier area on the west coast of Florida. He observed species of mite (2), chigger (3), tick (2), lice (1), and flea (1) infesting cotton rats. A definite annual cycle was observed in the flea, *Polygenis gwyni*, with peak infestations occurring in spring. Cotton rats from the wetter south Florida habitat had more than twice as many ectoparasites as those from the drier habitat. Ehrhart (1976) collected two tick species and one flea species from cotton rats on Merritt Island. Parasites frequently infesting cotton rats studied in southern Georgia by Morlan (1952) were the louse *Hoplopleura hirsuta*, the mite

Haemolaelaps glasgowi, and the flea *Polygenis gwyni*. Peak flea infestations were observed in the spring and summer months, while no apparent seasonal trends were noted for the other species. Larvae and nymphs of the tick, *Dermacentor variabilis*, were collected in most months of the year. In another study in southwest Georgia, Smith and Love (1958) found the following three chief ectoparasites on cotton rats: *Polygenis gwyni*, *Hoplopleura hirsuta*, and the mite *Laelaps glasgowi*. The peak of abundance for *P. gwyni* was during April, May, and June. The mite and louse species were most abundant in late winter and early spring. In a study of cotton rat parasites in Georgia and North Carolina, Harkema and Kartman (1948) reported five species of ectoparasites for the Georgia sample and eight species for the North Carolina rats. Heavy infestations of both *Hoplopleura hirsuta* and the flea *Rhopalopsyllus gwyni* were observed in the Georgia sample. In my study, cotton rats on the flatwoods study area experienced the heaviest ectoparasite burden in October. A high incidence of ticks, fleas, mites, and chiggers coincided with the high cotton rat numbers.

The ectoparasite burdens borne by cotton mice in the two study areas are probably correlated with differences in the two environments. In the flatwoods cotton mice were not parasitized to any degree. Ticks most often were the sole ectoparasite infesting the mice. The cotton mice in the hammock were much more heavily infested with ectoparasites. Both ticks and botfly larvae were very prevalent and exhibited a distinct seasonality in their infestations of cotton mice. Ticks were present in all months of study except July in 1976 and 1977. They reached their greatest frequencies in October and November. In contrast, botfly larvae achieved their greatest degree of infestation of mice in July of both years with increasingly higher frequencies occurring from April through July. The incidence of botfly infections was low in the fall and winter. Ehrhart (1976) found four tick species and two flea species on cotton mice. In Gulf Hammock, Florida, Pearson (1954) noted parasitism of cotton mice by ticks, red bugs, and fly larvae. Infestations by fly larvae occurred in all months but February and March with a peak in June. In two south Florida hammocks, Bigler and Jenkins (1975) recorded heavy parasitism by ticks and botfly larvae. Peak tick infections were observed in April, May, and November, while peak botfly larvae infestations occurred in April and June of one year and January and June in the next year. Worth (1950) reported cotton mice parasitized by mites and ticks (heavily); however, no infestations by botfly larvae were observed.

Parasitism of small mammals by botfly larvae, *Cuterebra* sp., has been reported by many investigators from studies in a variety of habitats (Scott & Snead, 1942; Dalmat, 1943; Test & Test, 1943; Sillman & Smith, 1959; Abbott & Parsons, 1961; Wecker, 1962; Brown, 1965; Clough, 1965; Dunaway, Payne & Story, 1967; Miller & Getz, 1969; Hunter, Sadlier, & Webster, 1972; Smith, 1977; and others). Botfly infections most often occur in the inguinal or abdominal regions of mice; however, they also appear on the dorsum. Multiple infections in a single animal are common. Peak infestations generally occur in summer or fall with most studies reporting low bot parasitism in winter. There is little agreement in the literature on two important facets of botfly larva parasitism. Several modes of entry of the larva into the host have been proposed and demonstrated. Larvae have been reported to enter mice through the mouth, nostrils, and abrasions or wounds in the skin. The second area of bot parasitism open to question involves the effect of the infection on the individual. Bot larvae infections have rarely been reported as directly causing the death of the host; however, it has been suggested as contributing to decreased survival. Several investigators have reported diminished reproductive activity in both sexes because of botfly larvae infestations (Wecker, 1962; Brown, 1965; Clough, 1965; Smith, 1977). Results of the present study suggest a possible correlation between bot infection and decreased sexual activity; however, due to small sample sizes the relationship cannot be proven.

SUMMARY AND CONCLUSIONS

1. Two permanent study grids, located on the east coast of Florida, were live-trapped one night per month for 16 consecutive months from June 1976 through September 1977. *Sigmodon hispidus*, the cotton rat, was the most abundant small mammal on the flatwoods grid, while *Peromyscus gossypinus*, the cotton mouse, was dominant on the hammock grid. The cotton mouse and *Peromyscus floridanus*, the Florida mouse, were secondary components of the small mammal fauna in the flatwoods. *Ochrotomys nuttalli*, the golden mouse, was occasionally caught on both grids and a few *Oryzomys palustris*, rice rats, were seen in the flatwoods.

2. The minimum number of cotton rats known to be alive (MNA) increased steadily, reaching a maximum of 89 individuals in November 1976 and subsequently declined just as steadily through March 1977. The population increased once again in late summer of 1977. The MNA of cotton mice reached a maximum of 12 individuals in May and June 1977 in the flatwoods and 38 in March 1977 in the hammock. The peak MNA (6) of Florida mice occurred in January and from March to May 1977.

3. Trappability was high for the dominant species found in the flatwoods: cotton rats (87.07%), cotton mice (81.69%), and Florida mice (94.28%). On the hammock grid, cotton mice were less trappable (72.1%).

4. Four-week survival rates of cotton rats were inversely proportional to the trends in MNA. Minimum survival occurred in January 1977 coincident with abnormally low temperatures. The declining survival rate through the summer and fall of 1976 was apparently due to the disappearance of newly recruited juvenile rats and old adults.

5. Cotton mice studied on both grids had survival rates that fluctuated widely.

6. The small Florida mouse population in the flatwoods experienced a high rate of survival through most of the study period, particularly from December 1976 through June 1977.

7. Mean monthly changes in body weights of cotton rats were similar for males and females. Both sexes attained their greatest mean body weights in the summers of 1976 and 1977. Minimum mean body weights were reached during the winter of 1977 (January and February) as abnormally cold weather occurred and the rats generally experienced losses in body weight.

8. Cotton mice on both study areas achieved their maximum mean monthly body weight in August, September, and October. Mean body weights of cotton mice generally decreased through the fall months and stabilized through the winter followed by a gradual increase through the spring and summer months.

9. Mean monthly body weights of Florida mice were highest in November 1976 and June 1977 and reached a minimum in January 1977.

10. Sex ratio of cotton rats captured on the flatwoods grid

never deviated significantly from 50:50; however, there were slightly more females captured in the summer months of 1976 and 1977.

11. Male cotton mice outnumbered females throughout most of the months of study on both areas, but at no time deviated significantly from 50:50.

12. The sex ratio of Florida mice was at unity for six of the 13 months this species was captured and at no time deviated significantly from 50:50.

13. The reproductive activity of cotton rats was largely confined to the summer and fall months of 1976 and 1977. Greater than 75% of the adult males examined from June through September 1976 and 100% of those examined from June through September 1977 had descended testes. Female cotton rats similarly showed signs of reproductive activity primarily from June through November 1976 and in August and September 1977.

14. Cotton mice in the flatwoods were reproductively active primarily during July to September. In the hammock the majority of males had descended testes from August through December 1976 and in August and September 1977. Females in the hammock were reproductively active from September 1976 through February 1977 and otherwise experienced some degree of activity in almost all of the months of study.

15. The small number of Florida mice made it difficult to ascertain their reproductive activity; however, it appeared that adult females were pregnant in November 1976 and in May and June 1977.

16. Age structure of the cotton rat population consisted of a high percentage of adults (> 100 g) from July through September 1976 and again in August and September 1977. The percentage of juveniles (< 60 g) in the population increased steadily from August through November 1976 and remained greater than 40% through February 1977. Subadults (61-100 g) composed an increasingly higher proportion of the population from December 1976 through April 1977.

17. The cotton mouse populations in the flatwoods and hammock were predominantly adults in all months of the study; however, juvenile mice were caught in November 1976 and January 1977 in the flatwoods and in October and November 1976 and January 1977 in the hammock.

18. Most of the Florida mice captured were adults; a few subadults were seen from December through April 1977.

19. Male and female cotton rats differed significantly ($p < .05$) in the average distance between successive recaptures, as males traveled an average of 34.5 m, whereas females averaged 26.8 m.

20. In the flatwoods male cotton mice traveled an average of 51.5 m and females traveled an average of 32.6 m between recaptures; however, the difference in movements between the sexes was not significant. In the hammock population, the average distance between successive captures for males was 33.5 m and for females it was 23.9 m. The sexes did not differ significantly ($p > .05$).

21. Male Florida mice averaged 50.0 m between recaptures, while females traveled an average of 45.0 m. The difference was not

significant ($p > .05$).

22. A high percentage of the cotton rats and cotton mice captured on the assessment lines surrounding the Wisconsin Village Flatwoods grid were also caught on the study grid. The highest percentage of interchange occurred with those assessment line traps nearest to the grid indicating that the area of effect of the trapping grid probably extended at least one trap interval beyond the grid.

23. Greater than 40% of the cotton mice captured on the assessment lines extending from the hammock grid were also caught on the study grid. The highest degree of interchange was observed with the trap stations nearest to the grid; however, a relatively high amount also existed with the most distant trap sites. Therefore, it appears that the area of effect of the grid in the hammock extended well beyond the grid itself.

24. A few cotton mice utilized the nest boxes provided in the hammock located away from the hammock study grid. These mice were observed primarily from January through April 1977. Nests in the boxes were spherical and constructed exclusively of palm fibers.

25. Cotton rats were captured at all trap sites on the flatwoods study grid with the exception of one, whereas cotton mice were captured with greatest frequency along the perimeter of the grid. Florida mice were captured most often in the area of the grid containing the densest growth of scrub oaks.

26. On the hammock grid cotton mice were captured in traps on the ground and in elevated traps located throughout the grid.

Golden mice were caught predominantly in the elevated traps.

27. Cotton rats had fleas, ticks, mites, chiggers, and botfly larvae. Ticks were most abundant in October 1976 (1.15/rat) and August 1977 (0.70/rat). The heaviest flea infestation occurred in February 1977 when 74% of the rats examined had fleas.

28. Cotton mice in the flatwoods had a few ectoparasites and were primarily parasitized by ticks. The heavist tick infestation occurred in February 1977 (1.50/mouse). Florida mice were predominantly free of ectoparasites.

29. In the hammock, cotton mice harbored ticks in all months of study except July of 1976 and 1977. The highest numbers of ticks occurred in October (8.32/mouse) and November (9.61/mouse) of 1976. Cotton mice were parasitized by botfly larvae in all months except February, March, and September 1977. Botfly larvae were most prevalent in July, August, and December 1976 and again from April through August 1977. Peak infestations were observed in July of 1976 and 1977 (.58 larva/mouse). Because most parasitic larvae were located inguinally, parasitism may have had an affect on cotton mouse reproductive activity.

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