Microclimatic Measurements and Use of Artificial Shelter by Confined Cottontails[1]

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Abstract

Five adult cottontails *(Sylvilagus floridanus mearnsii)* held in each of four 50 x 50-foot outdoor pens were located each day in their daytime resting places. They used five shelter types replicated in the pens. In two pens an artificial den system was used more than all other types together. For 1,298 total resting locations in all pens, 47 per cent were in the den systems alone, the remainder being in the other 4 shelter types. Adult females dominated all den chambers and reduced total incidence of den use by other individuals. Temperatures in the den chamber fluctuated less, were higher in winter and lower in summer than those in surface shelters and for true air temperature. Soil temperatures fluctuated less than those in the den chamber at corresponding depths. One rabbit warmed the immediate ambient temperature where it rested in the den but not that at 15 inches distant. Relative humidity in the den chamber increased, when a rabbit entered and rested there during the day, and dropped when the rabbit left at evening, a cycle diametrically opposed to that aboveground.

The cottontail rabbit is a primary small game species for a large number of people who use it for recreation and food. Its requirements for continued production are worth knowing especially as a basis for its management. Although cottontails may appear to thrive on an assortment of environmental conditions, some conditions are preferred over others at some times.

Cottontails capably use many kinds of natural and artificial shelter aboveground. Their use of natural burrows is also well-known. Trautman (*in* Trippensee, 10) noticed the holing-up behavior of cottontails when snow covered the ground and temperatures dropped below 20°F. He also observed that females tended to use holes more than males. Gerstell (3) related that of 878 rabbits taken by hunters on 3 consecutive days only 21% were females. It appeared that the majority of female rabbits were underground, whereas most of the male population remained in aboveground forms. Other studies (1, 6) show the relationship between the cottontail and woodchuck (*Marmota monax*) burrows. Woodchuck holes seem to be the most important form of underground cover used by cottontails. Allen (1) pointed out that, although rabbits appeared to be more abundant in areas dotted with woodchuck holes, the holes alone did not increase rabbit density.

From a study by Smith (8), whose main objective was to determine how weather changes influence cottontail behavior, we have temperature data related to the use of various shelters by cottontails. A part of that study was to correlate temperature (and in one case relative

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humidity) data with use of artificial shelters by confined rabbits, which is reported here.

Materials and Methods

Wild cottontail rabbits were kept in a 200 x 140-foot outdoor enclosure on the Purdue Wildlife Area located about 7 miles west of West Lafayette, Indiana. Ground predators were excluded by a 5-foot fence of 3-inch diamond-mesh wire overlain by 1-inch wire netting. Hardware cloth (0.5-inch mesh) was buried 12 inches below the surface and extended 12 inches above the surface at the base of the fence. A nylon net covered the top of the enclosure to protect against hawks and owls. The main enclosure was subdivided into 50-foot-square pens, and four used in this study were each stocked with two male and three female adult cottontails.

About 90% of the vegetation within the enclosure was Kentucky bluegrass (*Poa pratensis*) and bird's-foot trefoil (*Lotus corniculatus*). The remaining vegetation was made up of native species. Frequent mowing kept the vegetation uniformly short for good observation. The rabbits grazed extensively on the broad-leafed plants, with bird's-foot trefoil being the least preferred species. Purina Rabbit Chow was always available, and corn and apples were fed intermittently throughout the year. Water and artificial shelter were provided in each pen.

Observations were made from a 10 x 6 x 6-foot hide atop a 12-foot tower adjacent to the enclosure. For individual identification, the rabbits were marked in each ear with a colored, plastic tag (Rototag, Nasco, Ft. Atkinson, Wis.) visible up to 100 feet. The tags appeared to have no effect on the cottontails' behavior. In addition to the Rototags, 16 rabbits were marked with a distinct fur dye pattern.

Five artificial shelters were provided in each pen. Four shelters were placed on the surface and the other, a wooden construction, was buried in the ground. The underground den was a 15 x 15 x 36-inch exterior plywood box buried 30 inches into the ground. Six inches of the box extended above the surface. Wood tunnels, 4 x 4-inch x 9-foot, slanted from opposite sides at the base of the box to the surface. Two lids to the box made the structure dark and watertight. The floor of the tunnels and the den chamber were open to the soil. The box rested on 12 inches of gravel to prevent flooding.

The surface shelters were evenly spaced around the underground den. One type was created with a piece of 3 x 4-foot snow-fence bent into an arch and thatched with straw. A feeding shelter, 10 inches high, 2 feet wide, and 5 feet long, was made of sheet metal bent into an arch and nailed to a wooden frame (Herald Demaree, Jr., pers. comm.). This shelter provided cover and protected the food from precipitation. Three wooden boxes, 4 x 4-inch x 3-foot, placed in the shape of a "Y", provided shelter for several rabbits at the same time. Open to earth at the bottom, these boxes were covered with a piece of plywood and thatched with straw during the winter. The fifth artificial shelter was made of three 6-inch x 3-foot concrete bell-end pipes arranged similarly to the three wooden boxes.

To determine the amount of use for each artificial shelter, a morning inventory of 20 cottontails was conducted intermittently from October 1971 to August 1972. After rabbit activity ceased, at approximately 1000 hours, an observer entered the pens and recorded the location of each animal on a detailed map. Each pen was divided into a grid of 16 blocks. Thus, each of the 20 rabbits could be recorded in one of 21 possible locations, including the five shelters.

Temperature and humidity within the underground chamber were measured at hourly intervals. In addition, temperature measurements were made 1) at two levels within the underground tunnels; and 2) at depths in the soil corresponding to the same depths measured in the burrow chamber and tunnels. Relative humidity measurements were made by suspending a Bendix hygrothermograph so that the bottom of the instrument was at a depth of about 20 inches inside the burrow chamber. The record from this instrument was compared with true air relative humidity, measured with a hygrothermograph housed in a standard shelter mounted 12 inches aboveground. (True air temperature and humidity are temperature and humidity measured in a standard instrument shelter.) Temperature readings were taken with a Honeywell multi-channeled millivolt recorder located in the observation tower. Thermocouple wire of Teflon-coated copper-constantin led from the recorder to points being monitored in the pens and the weather shelter house.

Results and Discussion

The rabbits used all artificial shelters, but favored some more than others. The underground structures were preferred for escape cover as well as for protection from the weather. The rabbits immediately accepted the artificial burrows and showed little fear of the new structures.

Use of Underground *versus* Aboveground Shelters

The den system frequently held three rabbits (one in the chamber and one in each tunnel) without aggressive behavior (Tables 2 and 3). Therefore, the den was limited in the number of animals it could shelter, in contrast to aboveground cover, consisting of four artificial structures and many hundred square feet of vegetation. Total percentage use for all pens shows that underground (chamber and tunnels) use (47%) was nearly equal to surface use (53%) (Table 1). Den use in Pens 1 and 3 was roughly twice that of all other available shelters. The rabbits also used the underground dens continuously in summer (Tables 2 and 3).

Previous studies showed the use of woodchuck burrows by cottontails and emphasized the importance of such shelter during cold winter weather (1, 3, 5). The possible use of natural ground holes by cottontails during summer was not mentioned. In this study, it is probable that much of the artificial burrow use by the confined rabbit population was a function of their confinement in high densities (87 rabbits per acre). We speculate that in the natural environment cottontails benefit from use of burrows in summer as well as winter.

TABLE 1. *Number of times and per cent of total times rabbits were found in each shelter type for period of 13 October 1971 to 6 March 1972.*

			Underground				Surface			
Rabbit	Sex	Observations	Chamber		Tunnels		Artificial (4 types)		Vegetation	
Pen 1										
P1	Fe	61	61%	37	28%	17	3%	2	8%	5
Y1	Fe	60	1%	1	8%	5	72%	44	18%	11
R1	M	61	16%	10	77%	47	0	0	7%	4
G1	M	61	1%	1	18%	11	20%	12	60%	36
W1	M	61	21%	13	77%	47	0	0	1%	1
Total obser.		304	20%	62	42%	127	19%	58	18%	56
Total % use per pen				63%				37%		
Pen 3										
P3	Fe	64	83%	53	17%	11	0	0	0	0
Y3	Fe	65	1%	1	63%	41	11%	7	25%	16
R3	M	67	1%	1	60%	40	15%	10	24%	16
G3	M	65	1%	1	91%	59	1%	1	6%	4
W3	M	67	0%	0	7%	5	34%	23	58%	39
Total obser.		328	17%	56	46%	156	13%	41	23%	75
Total % use per pen				65%				35%		
Pen 4										
P4	Fe	67	85%	57	9%	6	0	0	5%	3
Y4	Fe	67	0	0	10%	7	60%	40	30%	20
R4	M	67	0	0	0	0	36%	24	64%	43
G4	M	67	0	0	1%	1	43%	29	55%	37
W4	M	67	0	0	46%	31	37%	25	16%	11
Total obser.		335	17%	57	13%	45	35%	118	34%	114
Total % use per pen				31%				69%		
Pen 5										
P5	Fe	66	1%	1	38%	25	55%	36	6%	4
Y5	Fe	64	70%	45	25%	16	0	0	5%	3
R5	M	67	7%	1	1%	1	55%	37	42%	28
G5	M	67	0	0	13%	9	54%	36	33%	22
W5	M	67	0	0	15%	10	61%	41	24%	16
Total obser.		331	14%	47	18%	61	45%	150	22%	73
Total % use per pen				33%				67%		
Total % use for all pens				47%				53%		

Rabbit Behavior Relative to Den

Free-ranging female cottontails are more often found underground than males (3, 10). Female rabbits also appear to have a smaller home range than males (2, 4, 7). While we assumed that each of our rabbits used the entire 50-foot-square pen as its range, females clearly dominated the underground den chambers (Table 1). In a companion study, Smith and Frazer (unpublished data) substantiated the empirical observation that undisturbed rabbits habitually use a favorite lying-up spot.

TABLE 2. *Change in female dominance of den chamber in Pen 1.*

Date	North Tunnel	Chamber	South Tunnel
July 18		R1	G1
July 19	W1	G1	P1
July 20	Y1	G1, P1	R1
July 25	Y1, G1[1]		P1, R1
July 26	R1	P1	Y1, G1
July 31	R1	P1	
Aug. 1	Y1	R1	P1
Aug. 2	W1	Y1	P1, R1
Aug. 3	G1, Y1	P1	R1
Aug. 4	P1	R1, Y1	
Aug. 7	R1	P1	W1, Y1
Aug. 8	R1	P1	
Aug. 10		Y1, P1	R1
Aug. 11	W1	Y1	P1, R1
Aug. 18	Y1, G1	P1	R1
Aug. 21	R1	P1, G1	Y1
Aug. 25	G1	Y1	P1, R1
Aug. 28		Y1, R1	P1
Aug. 30		Y1	G1, R1
Sept. 11	G1	Y1	R1

P1=Female; Y1=Female; R1=Male; G1=Male; W1=Male.

[1] Two code numbers indicate 2 rabbits spaced apart.

Marsden and Holler (6) discussed a rigid and fairly linear dominance hierarchy among confined male cottontails. They also reported a clearly established female hierarchy, but emphasized the lack of a rigid and linear dominance relationship as compared to the males. In this study, with respect to the dens, dominant females repelled all

TABLE 3. *Stable female dominance of den chamber in Pen 3.*

Date	North Tunnel	Chamber	South Tunnel
July 18	Y3	P3	
July 19	Y3	P3	G3
July 20	Y3	P3	G3
July 25		P3	G3
July 26	Y3	P3	G3
July 31	W3, G3	P3	Y3
Aug. 1		P3	G3
Aug. 2	W3	P3	G3, Y3
Aug. 3	Y3	P3	G3
Aug. 4	Y3	P3	G3
Aug. 7		P3	
Aug. 8		P3	
Aug. 10	Y3, G3	P3	
Aug. 11		P3	
Aug. 18	W3	P3	Y3
Aug. 21	Y3, G3	P3	
Aug. 25		P3	W3, Y3
Aug. 28	Y3, W3	P3	G3
Aug. 30	Y3	P3	G3
Sept. 11	Y3	P3	G3

P3=Female; Y3=Female; G3=Male; W3=Male.

males as well as subordinate females. Quantities of fur and patches of blood in dens and tunnels occupied by females suggested that the dominant females aggressively defended the chambers, but not the whole system (see above).

Females P1, P3, P4, and Y5 dominated the den chambers in their pens during the winter of 1971-72 (Table 1). Observations made during the summer of 1972 also showed that dominance of females using three of the four chambers remained the same. In Pen 1 the dominance hierarchy associated with the burrow was in a state of turmoil as compared to a stable hierarchy in Pen 3 (Tables 2 and 3). At the time the summer observations were made, the dominant female P1 was almost 3 years old. Perhaps aging decreased her dominance. On 3 September, near the end of the summer observations, P1 was found dead without evident wounds. We immediately replaced her with another female. When the study was terminated on 1 January 1973, female Y1, the original subordinate animal, dominated the chamber.

Microclimatology of Artificial Shelters

Temperatures in the burrows and in each artificial shelter were measured and tabulated by Smith from June 1971 to January 1973 (8). His data show the stability of the burrow microclimate on typical summer and winter days. Although there was marked fluctuation in the true air temperature cycles in both seasons, the temperature within the den chamber remained nearly unchanged (Tables 4 and 5). The temperatures within the four surface shelters closely followed that of true air temperature (8). The value of the surface shelters to cottontails probably lies in their ability to protect from wind, precipitation, and direct sunlight, or merely to offer a place to hide. In winter, a strong wind with high relative humidity decreases the effective temperature acting on the animal. In summer, calm conditions with direct sunlight would increase effective temperature on the rabbit. Cottontails no doubt favor those resting places that protect them from stress and help in maintenance of their homiothermic status.

Burrow Microclimate. To make comparisons between true air, burrow, and soil temperatures, temperatures were recorded at three points in the den chamber, two points in the tunnels, and at soil depths corresponding to the points in the chamber (Tables 4 and 5). Table 4 shows the data for a typical fall day, and Table 5 for a winter day.

On 31 October true air temperature fluctuated 30°F while burrow temperatures at 18 inches and 30 inches fluctuated only 7°F and 4°F, respectively. Fluctuations at the lowest point of the tunnel, *i.e.*, 30 inches below the surface, and halfway between there and the surface, were 7°F and 6°F, respectively. Temperature fluctuation at 1-inch soil depth was a spread of 22°F, about one-quarter less than that for true air temperature.

At 18-inch and 30-inch soil depths, the variations were 2 and 1°F, respectively. Although the temperatures in the burrow at 30 inches are similar to those in the soil at the same depth, we attribute any difference to the movement of cold air downward via the double lids and tunnels into the chamber. This implies that a natural den chamber situated above the lowest level of entrance tunnels would aid an animal occupant in heat conservation.

TABLE 4. *Temperature cycles (°F) for a typical fall day on 31 October 1971.*

		Artificial Burrow System							
		Chamber			Tunnel		Depth of Sensor in Soil		
Time	True Air 1 ft. Above Ground	Ground Level	18 in.	30 in.	Lowest Point	Middle	1 in.	18 in.	30 in.
0800	46	57	57	60	60	60	51	60	60
0900	49	59	59	61	60	60	54	60	60
1000	54	60	61	61	61	60	55	60	60
1100	57	60	60	61	61	61	59	60	60
1200	60	61	61	61	61	61	63	61	61
1300	61	62	62	62	62	61	64	61	61
1400	61	62	62	62	61	61	64	61	61
1500	61	62	62	62	61	61	61	60	60
1600	59	62	61	62	61	60	57	60	60
1700	53	62	62	61	61	60	55	60	60
1800	43	60	61	61	60	59	52	60	60
1900	39	58	59	60	59	59	49	60	60
2000	37	57	59	60	58	58	48	60	60
2100	36	56	58	60	57	57	47	60	60
2200	34	55	57	59	57	57	45	60	60
2300	33	54	56	58	57	57	44	60	60
2400	34	52	56	58	56	56	44	60	60
0100	31	51	56	58	56	56	43	60	60
0200	32	51	55	58	55	55	42	60	60
0300	35	50	56	59	56	56	42	60	61
0400	34	50	55	58	55	55	42	60	60
0500	33	49	55	58	55	55	42	60	60
0600	37	49	55	58	56	56	43	60	60
0700	42	50	56	58	57	57	44	59	60

The burrow system showed more temperature variation than the soil, where temperatures were very stable at 18-inch and 30-inch depths. The soil did not cool as much as the burrow chamber. Evidently the wood construction of the den system acts as a channel for air movement while possibly preventing heat transfer from warmer soil to the cavity.

A true air low reading of -14°F was recorded 14 January 1972, while the burrow temperature at the same hour was 44°F warmer. Temperature fluctuations of 27°F true air, 12°F at the bottom of the chamber and 2-3°F in the tunnel, clearly show the heat conservation of the den system.

Modification of Burrow Microclimate. Sunquist (9) reported that in winter the temperature of an occupied skunk den was 8°F higher than in an unoccupied den. In our study, one cottontail had little effect on den temperature. Figure 1 shows a 30-hour temperature cycle recorded in opposite corners at the floor of one chamber. From about

0800 to 1700 hours, the temperature in the southwest corner ranged from 2° to 6°F warmer than the opposite corner. Female P3 habitually rested in the southwest corner of the chamber, about one-half inch from one temperature sensor. At night, when P3 was active aboveground, the two corner temperatures coincided. Although the rabbit warmed the air of the chamber immediately around it, no increase in temperature could be detected 12-15 inches away.

For the period 29 November-6 December 1971, two hygrothermographs simultaneously recorded relative humidity within the den chamber and 1 foot aboveground. The records show that den humidity was influenced by presence or absence of a rabbit (8). On days when precipitation or heavy cloud cover occurred, both den and surface humidities reached and stayed at 100% around the clock. On days without precipitation and with sunshine, relative humidity aboveground decreased to a low of 40% at noon. At the same time, den humidity, which had dropped to 80% during the night, increased to 100%, and started to fall off again about 1700 hours. During three cycles of "drying" days, relative humidity curves for the two locations were more or less completely out of phase.

One explanation is that the artificial den's relative humidity cycle was disturbed by a rabbit known to be or not to be in the chamber.

TABLE 5. *Temperature cycles (°F) for a typical winter day on 14 January 1972.*

		Artificial Burrow System							
		Chamber			Tunnel		Depth of Sensor in Soil		
Time	True Air 1 ft. Above Ground	Ground Level	18 in.	30 in.	Lowest Point	Middle	1 in.	18 in.	30 in.
0800	—3	--	33	35	34	33	34	39	43
0900	8	--	35	37	35	33	34	39	43
1000	12	--	35	38	35	34	34	39	43
1100	13	--	35	39	35	34	34	39	43
1200	12	--	35	39	35	34	34	39	43
1300	11	--	35	39	35	34	34	39	43
1400	8	--	36	39	36	34	34	39	43
1500	6	--	37	39	36	34	34	39	43
1600	4	--	36	40	36	34	34	39	43
1700	1	--	35	40	35	34	34	39	43
1800	—2	--	34	35	34	33	34	39	43
1900	—3	--	34	34	34	33	34	39	43
2000	—4	—	33	34	34	33	34	39	43
2100	—5	--	33	33	33	33	34	39	43
2200	—7	--	32	31	33	32	34	39	43
2300	—8	--	30	30	33	32	34	39	43
2400	—11	--	30	30	33	32	34	39	43
0100	—11	--	30	30	33	32	34	39	43
0200	—11	--	30	29	33	32	34	39	43
0300	—11	--	30	29	33	32	34	39	43
0400	—10	--	30	29	33	32	34	39	43
0500	—10	--	30	29	33	32	34	39	43
0600	—12	--	30	28	33	32	34	39	43
0700	—14	--	30	30	33	32	34	39	43

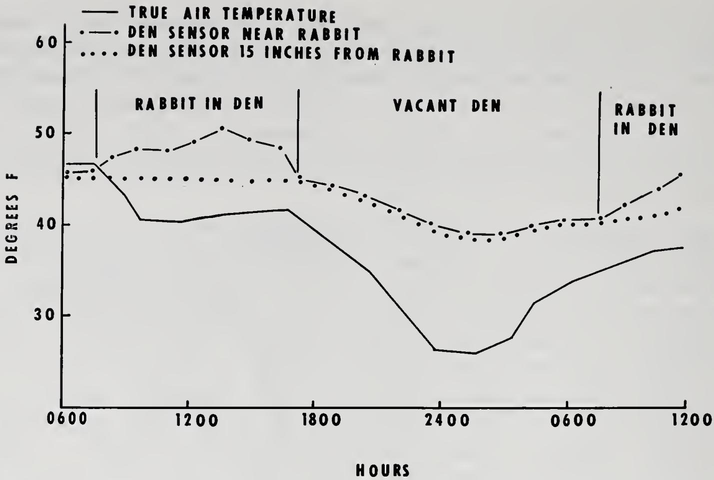

FIGURE 1. *Temperature cycle of 30 hours 24-25 December 1971 showing influence of rabbit on temperature of den chamber.*

Each day at about 1700 hours, when female P3 came aboveground, den humidity dropped. The next morning, when P3 went back into the den, den humidity rose to 100% and remained there as long as the rabbit was in the den. This cycle of humidity records, corresponding to the rabbit's location, was repeated three consecutive days. We believe the respiration of the rabbit in the den, a non-permeable box, caused the increased relative humidity.

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