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THE ROLE OF ENVIRONMENTAL FACTORS IN HIBERNATION OF WOODCHUCKS (*MARMOTA MONAX*)[1]

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Abstract. Laboratory experiments, based on knowledge of the natural environment, have been conducted to determine the role of various factors in the entrance into and emergence from hibernation. Woodchucks, captured in the wild were kept in rooms at several temperatures or in coolers at 6°C. They were fed or deprived according to the experimental program. Experiments showed that woodchucks deprived of food and kept at 6°C became torpid but woodchucks fed at 6°C did not. Some woodchucks deprived of food at 20°C became lethargic in winter. Minor disturbances in the laboratory do not arouse woodchucks. Woodchucks that eat when aroused do not become torpid again unless again deprived. Thin woodchucks become torpid as readily as fat ones. The latency of torpidity varies with season, being short (a week) in December and March and long (a month) in summer. The woodchuck has bouts of torpor that are short (4 to 5 days) at first but become longer (10 to 12 days). The arousal bouts last 2 to 3 days. Hibernation in nature lasts 3 to 4 months although presumably the woodchuck is torpid for only 2 months. In the laboratory woodchucks may remain in hibernation (alternating bouts of torpor and arousal) up to 8 months. The stimulus for final arousal was not determined. Emergence from the burrow at Chambersburg, Pennsylvania occurred between January 29 and 8 February in 8 years. The date had no relation to local weather. Woodchucks exposed to very low temperatures (—20°C) aroused promptly.

Although the woodchuck has been famous for centuries as a hibernator and weather prophet, the factors that induce entrance into hibernation in the fall and emergence from hibernation in the spring are not understood. Members of the genus *Marmota* have been studied for many years in North America and in Europe where several species occur. Most of the studies have been experimental, taking animals from nature into buildings and keeping them under a variety of environmental conditions, usually including cold to stimulate hibernation. The purpose of the present paper is to report the results of experiments that were designed from a knowledge of natural conditions. By this orientation, problems of hibernation in woodchucks have been considered that are related to the conditions occurring in nature. Data about the natural conditions will be presented in connection with the experimental results.

It is desirable to define the terms used in this paper. Wherever possible, the accepted definitions are maintained. We can easily define terms by following the woodchucks through their annual cycle. In spring (February) the adults *emerge* from their burrows in full breeding condition and produce young in April. In the fall (November) they *immerge* into their burrows to begin the *hibernation period* (which lasts till *emergence*). After a time of *latency* (lapse of time) the woodchuck becomes *torpid* (enters a condition of *torpidity*) for several days, spontaneously *arouses* and returns to torpidity. The *duration* of each phase of *torpidity* is longer than the *duration* of each phase of *arousal*. (The term dormant is

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often used for torpid.) So far as known woodchucks do not *estivate* (become torpid in summer).

A review of the literature on the natural conditions of hibernation can be brief because so little has been published. Hamilton (1934) described life history features of woodchucks in New York, Grizzel (1955) in Maryland and de Vos and Gillespie (1960) in Ontario. However, extensive literature (in Russian) exists on the many species of woodchucks and squirrels in Asia, but tends to be anecdotal or oriented to problems such as control of plague. The largely physiological literature is adequately and recently reviewed by Kayser (1957) and the three symposia on hibernation (Lyman and Dawe 1960, Suomalainen 1964, Fisher in press). These papers include occasional references to the natural environment of woodchucks and many descriptions of physiological features of woodchucks and other species.

The data obtained under natural conditions have been described in several studies (Snyder, Davis and Christian 1961, Snyder and Christian 1960) and the metabolic cycle has been documented by laboratory research (Bailey 1965). The present discussion will draw upon these studies for a description of the hibernation sequence.

The squirrel family Sciuridae includes many hibernators. The genus *Marmota* has 3 species in North America and 11 in Europe and Asia. The genus *Citellus* (including *Spermophilus*) has about 42 species in North America, Europe and Asia. Many of the species hibernate and have been studied in the laboratory (see symposia). However, only a few papers mention natural conditions or relate the physiological findings to the life history. Members of other families of rodents (*Zapodidae, Gliridae*) hibernate and some have been studied.

Methods

All of the field work was done on the Letterkenny Ordnance Depot, which is a tract of some 8,000 acres near Chambersburg in southcentral Pennsylvania at latitude 40° 01′ and longitude 77° 44′. (For more details see Snyder, Davis, and Christian, 1961.) The woodchucks were captured alive in box traps and either tagged with metal clips in the ear and released or brought to the laboratory. In the laboratory the animals had a natural length of day and a rather variable temperature. Some woodchucks were also kept in an unheated barn where daylength was natural. In addition, a walk-in cooler on the Ordnance Depot was used for experiments. In 1964 at State College, Pa., a cooler and windowless rooms became available where woodchucks were kept at 16 hr length of day. The cooler was maintained at 6°C, the room at 20°C.

The decision to keep the cooler at 6°C was based on the temperature of the soil immediately adjacent to the winter hibernating dens of woodchucks dug out in December and January. To obtain these data, burrows were opened and a thermometer was inserted into the soil immediately adjacent to the den of the animal.

Woodchucks were considered torpid if they curled up, head between their hind legs, in their box and did not move when first touched. An aroused woodchuck is alert and active.

The food was dog chow prepared in blocks about 3 cm long and 1 cm wide. The woodchucks usually held a block in their hands and sat up to feed. In nature woodchucks eat green vegetation either grass, or herbs. Water was given in a pan in the cage.

Results and Discussion

A. *Factors initiating torpor*

1. Temperature and food. The first set of experiments dealt with the role of temperature and of food. The two factors will be discussed together since they appear to act jointly. In a preliminary experiment 8 woodchucks were placed in cages on 11 October 1962. Two had food and water, 2 had food only, 2 had water only, and 2 had neither. The temperature varied between 15 and 25°C. None became torpid in 40 days. Since these results suggested that woodchucks at summer temperatures do not become torpid, a more comprehensive experiment was conducted. Thirty-two animals were brought into captivity on 23 June 1964. Half of the animals were kept at 6°C, and the other half at 20°C. The day length was 16 hr. No woodchuck had entered hibernation by October 23. Food and water were then removed from half of the woodchucks in each group. None of the animals at 20°C had become torpid by 19 February, 1965, and hence the experiment was ended. At 6°C, the animals deprived of food became torpid, whereas none of the 5 having food became torpid.

The conclusion from these experiments is that woodchucks will become torpid when deprived of food and kept at low temperature. Possibly in some cases an animal becomes torpid when only one of these conditions is present.

Torpidity can be obtained in almost any month of the year. For example, 16 woodchucks under natural conditions were fed till August 14 when all were placed at 6°C and at 0.5 to 2.0 hours photoperiod. Half were deprived of food and water. Of the eight animals without food, three died and the others became torpid between September 14 and October 6, long before the normal date of torpidity (November). None of the 8 given food had become torpid before 20 February when the experiment ended. While in our experience, only woodchucks deprived of food became torpid, it should be noted that ground squirrels become torpid when food is present (Jameson 1964) although the possibility exists that it was not eaten. For several species of *Citellus* (Nikitin, Zuichenko, and Chernikin 1963, Pengelley 1964) deprivation of food results in torpor. A rodent of another family (Heteromyidae) hibernates at once when food is removed (Bartholomew and MacMillen 1961, Clayton 1964).

It perhaps would be worthwhile to investigate the possibility that animals at low temperature with food but without water might become torpid. The one test of this aspect did not indicate that deprivation of water alone at low temperature would result in torpidity. We have not considered a supply of water important since in nature woodchucks obtain their water from plants, puddles, or dew more or less accidentally. Depending on the weather the supply either dries up in the fall with the vegetation or continues to be available from dew or rain. Thus, in nature immergence and torpidity are not dependent upon absence of water.

2. Disturbance. In natural conditions disturbance would rarely affect a woodchuck since it is behind a plugged tunnel 3 m below the surface. However, the role of disturbance in laboratory tests of factors initiating torpor is difficult to assess. To test for the possibility that a decrease in disturbance might permit torpidity at a warm temperature, 16 animals (8 deprived of food) were moved on January 7 from a room where considerable human activity occurred daily to a quiet room where temperature also was 20°C and day length 16 hr. None of the woodchucks became torpid by 20 February. In another experiment some individuals deprived of food at 6°C, were disturbed by handling and others not. The number of days till torpidity for 8 of the former averaged 44.9

and for 11 of the latter averaged 46.3. Other authors (Benedict and Lee 1938, Bartholomew and Hudson 1964) have worried about noise. Our data indicate that mild laboratory disturbances do not interfere with the results of experiments.

3. Feeding. One aspect that needs further clarification is the effect of eating during arousal times. In nature woodchucks, contrary to some other hibernators, do not store food in their burrows and thus cannot feed during arousal. However, consumption of food by woodchucks during arousal might result in permanent arousal. Four animals were offered food when they awoke in December or January. Two of the animals ate food when they aroused in January and did not again become torpid. Two of the animals did not eat food on any of three arousal periods and eventually aroused permanently. In 1965–66 a more comprehensive test was made. In December, 7 woodchucks were placed at 6°C with a 0.5 to 2.0 hr photoperiod and deprived of food and water. At the first arousal, food was given. Four animals were given food continuously and remained aroused; 2 ate up to 200 grams daily. Three animals were fed for only 4 days after arousal and then deprived; all became torpid within a week of deprivation. In another test 5 very thin animals were placed at 6°C. Food was available at arousal but these animals did not eat and returned to torpor in a day. It is concluded that woodchucks that eat do not return to torpor.

4. Fat reserves. An aspect that requires more data is the suggestion that thin animals do not become torpid (Tevis 1955, Jameson and Mead 1964, Kalabukhov 1960, Hoffman 1964). This relation is a possible explanation for the observed autumnal decline in weight of trapped woodchucks (Snyder *et al.* 1961) since, if the fat woodchucks hibernate first, the thinner ones will remain active and available to be captured. However, experimental tests did not confirm the hypothesis. In 1964, 8 animals at 20°C and 8 animals at 6°C (all at 16 hr daylength) were limited to 50 g a day from 4 September to October 23 and to 25 g thereafter. A control group of 8 animals at each temperature was fed ad lib. The woodchucks on restricted diet at 20°C lost 5% of their original weight while those at 6°C lost 23.6%; those fed ad lib. at 20°C lost 2.5% while those at 6°C lost 16.4%. On October 23, food was completely removed from half of each group. The only woodchucks that became torpid were those in the cooler lacking food; the previously fed (fat) woodchucks became torpid as well as the previously restricted (thin).

In December 1965, 5 thin animals that had been deprived of food since early November were placed at 6°C. Their mean weight of 1700 g was close to the average weight (1540 g) at starvation death of 11 woodchucks. All became torpid promptly. It is concluded that thin woodchucks, lacking fat reserves, may become torpid. Emergence or survival in spring, however, is problematical.

It now seems apparent that, in nature, woodchucks lose weight late in the fall even before immergence, since woodchucks in captivity lose weight even at 20°C and ad lib. food. Results from weights of wild woodchucks show irregularities (Snyder *et al.* 1961) since it is difficult to capture in the fall enough animals to get a random sample. More recent data show that woodchucks have ceased gaining weight (Table 1). It is concluded that the amount of reserve of fat does not influence the initiation of torpidity.

TABLE 1. Weights and percentage of males of woodchucks captured in the fall, 1962–64.

Date	Adult Woodchucks	Mean weight (g)	Standard error (g)	Per cent male
September 11-20	37	3957	132	54.0
September 21-30	26	4205	159	46.2
October 1-10	18	4310	109	50.0
October 11-20	8	4180	256	62.5
October 21-31	8	4210	165	62.5
Total or Mean	97	4172	—	55.0

B. *Maintenance of Torpor*

1. Latency. In nature woodchucks disappear into their burrows about the middle of October. We lack information about the time of initiation of torpor in natural circumstances. Work in the laboratory with caged animals deprived of food and put at a low temperature suggests that initiation of torpor requires several weeks. Woodchucks were placed at 6°C and deprived of food at various times of the year (Table 2). Those placed at 6°C and deprived of food in October became torpid in 20 to 70 days. Similarly, animals deprived of food in November hibernated in 10 to 50 days. Animals fed and kept at natural temperatures (25 to 10°C) soon became torpid when placed in the cooler without food on 29 December. Animals captured in the wild in March, placed at 6°C and deprived of food became torpid rather soon in a number of cases. However, in most instances they died before becoming torpid. In April such animals all died promptly. Animals captured in April, kept in the cooler but fed until 16 June survived in some cases after the food was removed. The latency of the torpidity was rather high. Animals put in the cooler in June, August, and September and deprived of food hibernated, although some of them died before adequate time for entrance into torpidity. None of the animals deprived of food after September died before becoming torpid. These data show that woodchucks, when exposed to appropriate environmental conditions, become torpid after periods as long as 2 months. Animals can become torpid in March if they still have enough fat to survive but the woodchucks tested in April presumably do not have enough fat to live long enough to become torpid. It will be noted (Table 2) that the animals entered torpidity earlier in 1962 than in 1963. A reason for this difference is not apparent. The experiment was done in 1962 and 1963 by two different persons but with the same equipment and presumably under the same conditions.

The reproductive condition of woodchucks appears to have no influence on the occurrence of torpidity although it might affect latency. Woodchucks, like ground squirrels, come into full sexual activity during hibernation. Males have active sperm at emergence and females are ready to ovulate. Thus, woodchucks in February (active gonads) and March (regressing gonads) and in June (inactive gonads) can become torpid. These results contradict statements by several authors (e.g. Hoffman 1964) that seasonal hibernators cannot be forced into hibernation when gonads are maximal or beginning to atrophy.

To see whether a period of time at 6°C but with food would result in a short latency some woodchucks were placed in the cooler in April 1964 and others in June. All were deprived of food on 16 June, 1964. The woodchucks that had been at 6°C since April became torpid later than the others.

TABLE 2. Latency of torpidity of woodchucks, placed at 6°C and deprived of food and water at specified times.

Year	Start at 6°C	Deprived	Day length		Latency (midpoint of days since deprived) 5	15	25	35	45	55	65	75	85
1962	October	October	brief[1]	T	–	–	4	2	1	–	–	–	–
				D	–	–	–	–	–	–	–	–	–
1963	October	October	brief[1]	T	–	–	–	–	7	3	3	–	–
				D	–	–	–	–	–	–	–	–	–
1964	June	October 23	16	T	–	2	1	1	–	2	–	–	–
				D	–	–	–	–	–	–	–	–	–
1962	November	November	brief[1]	T	–	1	8	7	2	–	–	–	–
				D	–	–	–	–	–	–	–	–	–
1963	November	November	brief[1]	T	–	–	–	1	–	1	–	1	–
				D	–	–	–	–	–	–	–	–	–
1965	November	November	brief[1]	T	–	1	3	2	1	1	–	–	–
				D	–	–	–	–	–	–	–	–	–
1964	December 29	December 29	brief[1]	T	3	–	1	–	–	–	–	–	–
				D	1	1	–	–	–	–	–	–	–
1964	March 26	March 26	12	T	–	3	1	1	1	–	–	–	–
				D	–	8	2	2(1)	(1)	–	(1)	–	–
1964	April 17	April 17	12	T	–	–	–	–	–	–	–	–	–
				D	7	–	–	–	–	–	–	–	–
1964	April 20 to 23	April 20-23	brief[1]	T	–	–	–	–	–	–	–	–	–
				D	4	2	1	–	–	–	–	–	–
1964	April 9 to 23	June 16	brief[1]	T	–	–	–	–	–	3	1	–	–
				D	–	–	–	1	–	2(1)	1	(2)	–
1964	June 16	June 16	brief[1]	T	–	–	3	–	–	1	–	–	–
				D	–	1	1	1(1)	(2)	1	–	–	–
1964	August 14	August 14	brief[1]	T	–	–	–	3	1	1	–	–	–
				D	–	–	1	1	–	1	–	–	–
1963	September	September	brief[1]	T	–	–	2	2	3	3	–	–	–
				D	–	–	–	–	–	–	–	–	–
1964	Sept. 17 to 19	Sept. 17-19	breif[1]	T	–	–	4	5	–	–	–	–	–
				D	–	–	–	(1)	–	–	–	–	–

[1]In dark except for short time (0.5-2.0 hours) daily for feeding and cleaning. T refers to woodchucks that became torpid; D to ones that died. Number in parentheses refers to a woodchuck that had become torpid but died.

TABLE 3. Days before torpor by age and sex. In 1963 the woodchucks were deprived in October and in 1962 in November.

Year	Adult male n	Adult male mean	Yearling male n	Yearling male mean	Adult female n	Adult female mean	Yearling female n	Yearling female mean	Total n	Total mean
1963 (Oct.)	5	48.0	0	—	4	56.5	4	47.0	13	50.2
1962 (Nov.)	5	24.2	5	22.8	3	27.0	5	23.0	18	24.2

TABLE 4. Length of torpid and arousal bouts. A bout was tallied for the month in which it began. The woodchucks were kept at 6°C and short (0.5 to 2.0 hour) photoperiod and deprived of food (modified from Bailey 1965).

Month	Woodchucks	Torpid bouts (days) number	Torpid bouts (days) mean	Torpid bouts (days) S.D.	Arousal bouts (days) number	Arousal bouts (days) mean	Arousal bouts (days) S.D.
November	8	14	7.50	6.51	5	1.60	0.87
December	24	64	8.70	4.94	54	2.37	1.26
January	24	60	10.60	3.29	59	1.71	1.08
February	20	34	12.00	4.67	31	2.00	0.83
March	13	28	10.82	4.07	28	2.21	0.61
April	9	17	10.00	3.70	16	2.01	0.61

Although the tests are not extensive, the data in Table 2 do not suggest any difference in latency of torpor for animals kept on short days (0.5 to 2.0 hr) or on long days (12 or 16 hr).

The possibility that differences exist among sexes and ages cannot adequately be explored with the data at hand since only small numbers of animals were available in each test and considerable differences existed in the conditions. However, in 2 experiments some woodchucks are comparable (Table 3). The suggestion (see 1963 data) that adult females require more days before entering torpidity should be explored with an adequate number of individuals in each category.

2. Duration of torpor. The duration of each of the bouts of torpor has been examined for a number of hibernators (Fisher 1964, Jameson 1964, Pengelley and Fisher 1961). For the woodchuck, Bailey (1965) pointed out some of the changes. His data (reanalyzed in Table 4) show that the length of the bout of torpidity increases from November to February but woodchucks remaining in hibernation through March and April continued long periods. Similarly, the duration of the arousal bouts may have increased, although it was more variable. As might be expected the data are more appropriately analyzed according to the order of each bout (Table 5). The length of the bout increases from the first to about the third and then is more or less the same, perhaps declining at the last. A very similar change occurs in *Citellus lateralis* (Jameson 1964). The duration of bouts of torpidity at 16-hr photoperiod may be less than that at 0.5 to 2.0 hours. A few data for 6 woodchucks in early stages of hibernation show short (4.35 day) bouts

TABLE 5. Length of torpid bouts by order.

Order	Woodchucks	Means (days)
First	24	4.21
Second	24	8.42
Third	24	11.38
Fourth	23	10.26
Fifth	23	12.04
Sixth	23	10.91
Seventh	19	10.26
Eighth	14	13.57
Ninth	13	10.54
Tenth	9	12.33
Eleventh	8	9.87
Twelfth	5	11.80

but the reason may be that most were first or second periods of torpor.

3. Duration of hibernation. The duration of hibernation period in nature was examined by observing the length of time a burrow was closed. In 1963 during October and November woodchuck burrows were plugged with dirt or cotton and examined daily. At first the holes remained closed only for several days. The data show that the average time in the hole in October and November for 52 burrows was 4.59 days (S.D. = 3.04). Then the burrows remained closed till spring. The average interval in the burrow for 28 woodchucks was 103.8 days (S.D. = 13.6). The woodchuck probably was not torpid for at least a week or more at the start of this period. In the spring the same procedure showed that the average return to burrows for 21 woodchucks was 3.57 days (S.D. = 2.54). A suggestion that males remain active later in the fall than do females is present in data from trapping (Table 1).

Adult male woodchucks emerge in the first part of February, the adult females and yearling males in the last half of February and the yearling females in the first part of March (Snyder *et al.* 1961, Bailey and Davis 1965). Additional data are presented in Table 6. If we assume that very few woodchucks become torpid before December 1, then the maximum length of hibernation period would be 1 December to March 15 (105 days). However, at 6°C without food and on photoperiod of 0.5 to 2.0 hr woodchucks showed long periods of hibernation. Natural arousal occurred in 9 animals within a period of 3 months but three woodchucks aroused naturally after as much as 5 months of hibernation. Also 4 woodchucks were artificially aroused, one after 6 months of hibernation. From another viewpoint (the time till death) many animals died after a period of 3 months had elapsed. Thus, under the conditions existing in a cooler at 6°C with only brief periods of light, the animals do not necessarily arouse in time to emerge. Furthermore, some animals spend extended periods in hibernation. One animal put into hibernation in August had periods of torpor and arousals for 8 months; another similarly for almost 5 months. Very young woodchucks can become torpid. In late June, 1966 8 male woodchucks, born about April 10, were deprived of food. Four were placed at 6°C and four were placed at natural (15 to 25°C) temperature. The four at 6°C became torpid while the others did not.

The loss of weight before death is related to the number of days of torpidity within the hibernation period. The data (Fig. 1) show that the percentage loss before death is inversely related to the percentage of the hibernation period spent in torpor. Benedict and Lee (1938) list results showing that 117 woodchucks lost an average of 56.6% of their body weight before death at an average of 112 days.

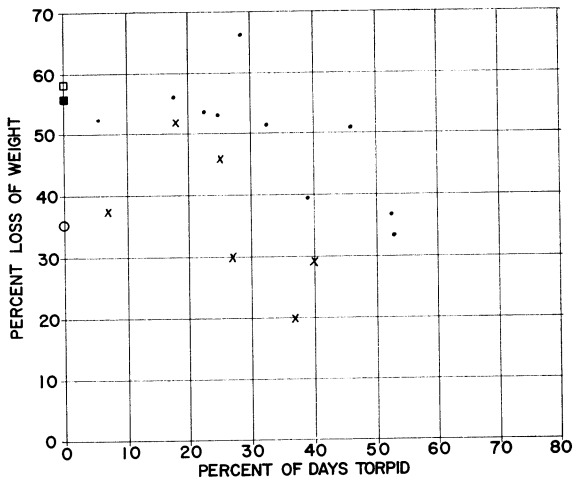

FIG. 1. The relative loss of weight (ordinate) is greater in woodchucks that spend a relatively small proportion (abcissa) of their hibernation period in torpidity. (Crosses refer to animals at 6°C in winter and dots to animals at 6°C in late summer. Open square represents 33 spring animals that died before becoming torpid; closed square is from Benedict and Lee (1938); open circle is for 10 summer animals.)

F. *Emergence from burrow*

The emergence of groundhogs has become legendary, supposedly happening exactly February 2 each year. Consideration of the origin of this legend shows that it developed some 200 years ago in the Pennsylvania Dutch section around Lancaster about 65 miles east of Chambersburg at the same latitude (Reichman 1942). An Old-World legend about the emergence of the badger on Candlemass Day was transferred to the groundhog. To determine the time of emergence a program was set up during 1958 to 1966 for the systematic search of an area of approximately 1,000 acres. Beginning on January 20 the area was carefully examined every day for about a month, recording, of course, the dates of emergence of groundhogs. The weather conditions were variable over this period of time but the first groundhog came out between January 29 and February 9 (Table 7). Analyses of the weather do not indicate that any particular condition immediately preceding emergence was associated with the variability. It is, of course, true that the date of emergence of the first individual is a rather poor estimate of the average date of emergence. Unfortunately, a better statistic, the date by which 50% of the animals have emerged, cannot be calculated since, due to the movements that occur in late February, one cannot determine the total number of woodchucks that emerged.

Other authors have noted the small variability in date of emergence. De Vos and Gillespie (1960) in Ontario (43′ 40″ N) reported first emergences in three years on March 5, 9, and 16. Hamilton (1934) in New York (42′ 30″ N) reported February 21, 22, and 26. The delay northward is about one day for 10 miles or 7 minutes of latitude. Obviously, physiography and altitude will affect this approximation. Anthony (1962) reports that few woodchucks hibernate in Southern Illinois.

TABLE 6. Sex and age of woodchucks captured from 1 February to May 15, 1957 to 1963. Expected number is based on the assumption that in each half-month period the number in each age and sex class would be the same faction as that age and sex class is of the total. Thus, the expectation for adult males is 235/714 = 0.329 for each week; for yearling males it is 97/714 = 0.136; for adult females 232/714 = 0.325; for yearling females 150/714 = 0.211.

	MALES				FEMALES				
	Adults		Yearlings		Adults		Yearlings		
Date	captured	expected	captured	expected	captured	expected	captured	expected	Total
Feb. 1-15	7	2.3	0	1.0	0	2.0	0	1.5	7
Feb. 16-29	34	13.2	1	5.4	4	12.9	1	8.4	40
Mar. 1-15	48	27.3	11	11.3	23	27.0	1	17.5	83
Mar. 16-31	65	58.5	15	24.2	65	58.2	33	37.5	178
Apr. 1-15	44	78.5	39	32.6	86	78.2	70	50.5	239
Apr. 16-30	12	24.0	16	9.9	30	23.7	15	15.3	73
May 1-15	25	30.9	15	12.7	24	30.6	30	19.7	94
Totals	235	234.7	97	97.1	232	232.6	150	150.4	714

TABLE 7. Dates of emergence of first woodchuck and temperature (F) conditions.

			Temperature (F)		
Year	First woodchuck	Temperature	Mean previous 3 days	Trend previous 3 days	Mean 8-10 days before
1958	February 3	23	30.7	36, 39, 27	29.7
1959	February 2	18	31.3	44, 30, 20	30.7
1961	January 30	24	18.7	20, 12, 24	16.3
1962	February 5	42	32.0	24, 28, 44	20.0
1963	February 5	26	23.0	28, 21, 20	19.7
1964	February 3	28	35.0	29, 35, 39	33.0
1965	January 29	20	30.8	30, 32, 29	23.5
1966	February 9	32	24.3	16, 25, 32	10.3

The factors that stimulate emergence are not understood. The temperature in the burrow naturally varies little since it is about 1 m below the surface. The temperatures at the hibernating nest of 4 woodchucks dug out in January were 5, 6, 7, 8°C. Temperatures in one burrow, recorded by a permanently located probe, were constant (Fig. 2). The temperatures in January in 50 burrows (without woodchucks) as measured by insertion of a probe on a long cable averaged 2.5°C (range 1.5 to 5.0°C). The reason the temperature is higher in the nest than in the burrow is at least in part due to the fact that the woodchuck's temperature even while torpid is 6 to 10°C (Bailey 1965).

In an attempt to determine the role of various factors in hibernation, some pens with artificial burrows were constructed. When out of the burrow the woodchucks were exposed to natural temperatures and daylength. The artificial burrow is a box measuring 2 × 2 × 2 feet, large enough for several woodchucks. The woodchucks did not build a nest and the temperature in winter varied from 0 to 7°C, more than occurs in a natural burrow. In the winter of 1964 to 65 no more than 58% of 28 woodchucks were torpid at any of the biweekly inspections. This value is low since about 10 out of 12 should be torpid (see Table 4). The percentage torpid decreased in February to zero. In the winter of 1965 to 66 the same procedure was followed except that some cages had only one woodchuck while others had 4 or 5. The percentage torpid ranged in January from 80 to 100 and was 76 on February 22 when the experiment was ended. Since the woodchucks in groups might have kept each other aroused a comparison was made between the singles and multiples per pen. But the single woodchucks were torpid at only 63% of the inspections while those in groups were torpid at 77% of the inspections ($P = .05$). While it can be said that woodchucks in the pens emerged at the same time as those outside, no understanding of the stimuli has been obtained thus far.

An additional point in the problems of emergence is the reaction of a woodchuck to very low temperatures. It will be remembered that the natural burrow temperature is about 6°C. Under certain circumstances the temperature might go below freezing due to poor location of the nest. It has been reported in the literature many times (Lyman 1948) that woodchucks awake when exposed to temperatures below freezing. However, since a careful examination of this point apparently has not been made, an experiment was designed to compare the duration of torpidity when animals were placed at −20°C. Five woodchucks were hibernating in the cooler at 6°C. The test was to move one of these animals to a freezing cabinet at −20°C. After a few preliminary tests, a routine was set up in which the woodchuck, after a period of torpidity and an arousal in the cooler, was allowed to become torpid for 1 day and then on the second day placed in the freezer. In all 5 cases these animals awoke within 2 hr. Since simply moving the animal from the cooler to the freezer might be responsible for the arousal, each animal was taken (after another period of torpidity and arousal) on the second day of torpor to a refrigerator at 6°C. In 7 trials the woodchuck in the refrigerator was torpid for an average 5.7 days which was the same duration as his alternate periods in the cooler. It is recognized that −20°C is a relatively low temperature, and

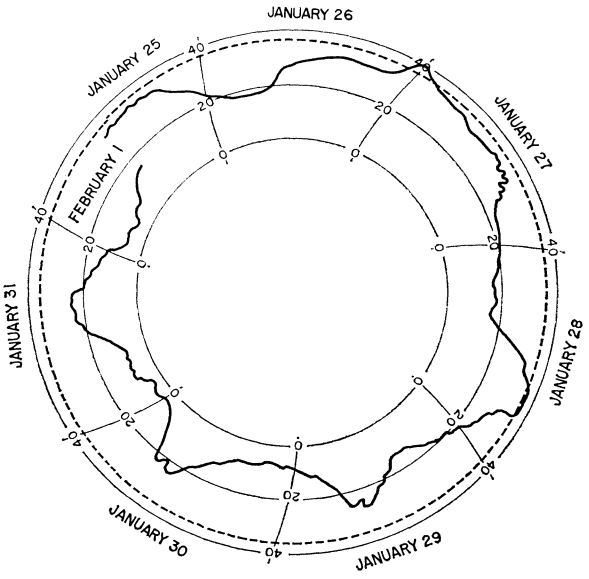

FIG. 2. The temperature (F) in the last week of January measured at ground level (irregular line) and at a depth of 2 feet (dashed line) in an abandoned burrow. Note that after 3 cold days (Jan. 29 to 31) the temperature in the burrow dropped only 2 degrees on February 1.

that tests should be done at more natural temperatures such as −5°C.

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