Seasonal Molt in the White-footed Mouse *Peromyscus leucopus*[1]

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Abstract

White-footed mice were snaptrapped in and around Louisville, Kentucky, from July 1973 to July 1974 to study seasonal molt of wild adults. Previous investigators assumed that these mice molt seasonally, but it has been unknown whether or not 1 or more molts occurred each year or just how the molts coincided with the reproductive cycle.

The 94 adult specimens taken during the study indicate that there is, in fact, 1 seasonal molt each year and that it occurs in October, November, and December. Those months coincide approximately with the nonbreeding period and the short photoperiod. The actual pattern of new hair growth in adults resembles that of the juvenile molt.

Introduction

Mice of the genus *Peromyscus* have been some of the most extensively studied small mammals, and pelage and molting phenomena have been described in a number of species. Like many mammals, *Peromyscus* grows and molts 2 coats of hair before adulthood is reached. There is no standard nomenclature to describe such pelage changes as there is for the various avian plumages. In order of appearance after birth, the pelages and their subsequent molts will hereafter be termed (1) juvenile pelage (molt) and (2) subadult pelage (molt). They also are commonly referred to as maturational or developmental pelages (molts).

At maturity, the adult pelage must be shed periodically and be replaced if it is to continue to fulfill adequately its various functions. The adult pelages and molts have not been investigated as thoroughly in *Peromyscus* as have the developmental pelages. But it has been well shown that many other adult mammals exhibit seasonal moltings controlled by photoperiod through its effect on the pituitary (Ling 1970).

It is generally assumed that adult *Peromyscus* undergo seasonal pelage changes, but there have been few specific investigations of the subject. Since hair growth cycles seem to be established early in life and subsequent cycles may in fact repeat those early events, it is important to be familiar with the developmental molts. King (1968) presented a short comparative survey of the developmental molts for the genus, but gave no information for seasonal molts.

Gottschang (1956:517–519) gave a specific description of juvenile molt in *P. leucopus noveboracensis*. New rufous fur first begins to grow in a small patch or in a narrow line slightly dorsal and anterior to the hind leg. This narrow line of new hair growth moves forward, and about the time it reaches the front legs, a small patch of new hair appears on the shoulders. The shoulder patch and lateral stripe then enlarge until they meet, thus forming a continuous line along the side that separates the white ventral fur from the dark mouse gray of the rest of the back. The lateral rufous stripes continue to increase in width while a cinnamon rufous patch appears on each cheek just beneath the eye. The eye patch enlarges to replace all the gray on the sides of the face. By then, the lateral rufous stripe has extended from the hind leg back to the base of the tail. The juvenile gray fur down the center of the back is then replaced by rufous adult fur. The last juvenile fur to be replaced is either that at the very base of the tail or that across the top of the shoulders and between the ears. Males and females exhibit the same molting pattern (Fig. 1).

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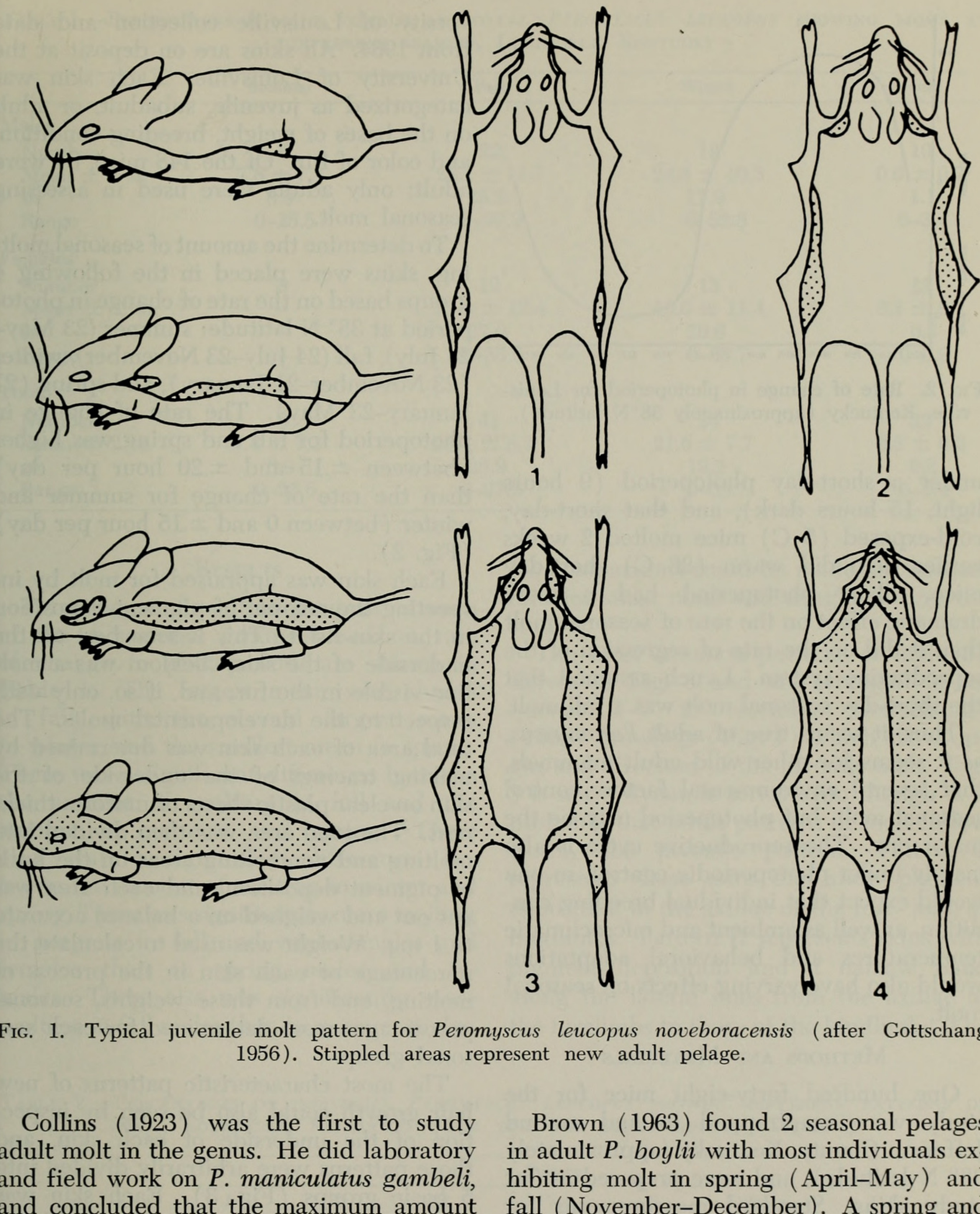

FIG. 1. Typical juvenile molt pattern for *Peromyscus leucopus noveboracensis* (after Gottschang 1956). Stippled areas represent new adult pelage.

Collins (1923) was the first to study adult molt in the genus. He did laboratory and field work on *P. maniculatus gambeli*, and concluded that the maximum amount of molting occurred in fall and early winter (September through December). "The most obvious characteristic of the seasonal molts is the absence of sharply defined molting periods. . . . Specimens may be found undergoing some change of pelage any month of the year." (Collins 1923:64, 66).

Brown (1963) found 2 seasonal pelages in adult *P. boylii* with most individuals exhibiting molt in spring (April–May) and fall (November–December). A spring and fall molt were also characteristic of *Ochrotomys nuttalli* (Linzey and Linzey 1967).

Lynch (1973) used adult *P. leucopus* in his laboratory study of the effects of changing photoperiod and temperature on the seasonal molts and reproductive system. He found that the seasonal molt and gonadal regression were exhibited only by mice

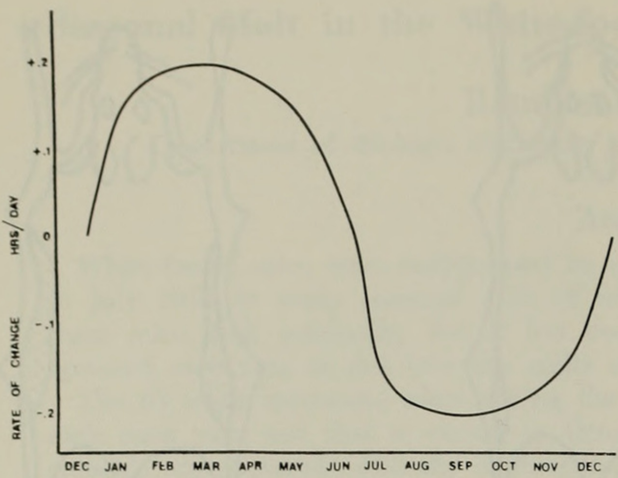

FIG. 2. Rate of change in photoperiod for Louisville, Kentucky (approximately 38°N latitude).

under a short-day photoperiod (9 hours light, 15 hours dark), and that short-day, cold-exposed (5 C) mice molted 2 weeks earlier than did warm (26 C) short-day mice. Short photoperiod had a more dramatic effect on the rate of seasonal molt than it did on the rate of regression of the reproductive system. Lynch assumed that the short-day seasonal molt was a fall molt.

Thus, it seems true of adult *Peromyscus*, as it seems for other wild adult mammals, that several environmental factors control seasonal molt, but photoperiod may be the major one. The reproductive cycle is also mainly under photoperiodic control, so one would expect that individual breeding condition, as well as ambient and microclimatic temperatures and behavioral adaptations would also have varying effects on seasonal molt.

METHODS AND MATERIALS

One hundred forty-eight mice for the study were snaptrapped in and around Jefferson County, Kentucky (approximately 38° N latitude), and were prepared as flat study skins. Standard measurements for each animal at the time of skinning included: lengths of tail, hind foot, and ear, and total length, total weight, size and position of testes, and notation of pregnancy or lactation. The adrenal glands were measured and preserved. Most specimens were collected between July 1973 and July 1974, although several skins were from the University of Louisville collection and date from 1964. All skins are on deposit at the University of Louisville. Each skin was categorized as juvenile, subadult, or adult on the bases of weight, breeding condition, and color of fur. Of the 148 mice, 94 were adult; only adults were used in assessing seasonal molt.

To determine the amount of seasonal molting, skins were placed in the following 4 groups based on the rate of change in photoperiod at 38° N latitude: summer (23 May–24 July), fall (24 July–23 November), winter (23 November–21 January), and spring (21 January–23 May). The rate of change in photoperiod for fall and spring was higher (between ±.15 and ±.20 hour per day) than the rate of change for summer and winter (between 0 and ±.15 hour per day) (Fig. 2).

Each skin was appraised for molt by inspecting the amount of pigment deposition in the skin itself. This is seen best on the underside of the skin. Seldom was a molt line visible in the fur, and, if so, only with respect to the developmental molts. The total area of each skin was determined by making tracings of the underside of the skin on clear plastic sheets of uniform thickness. The total area was then divided into molting and nonmolting areas on the basis of pigment deposition, and each area was cut out and weighed on a balance accurate to 1 mg. Weight was used to calculate the percentage of each skin in the process of molting, and from those weights, seasonal percentages were determined for each seasonal group.

The most characteristic patterns of new hair growth could also be seen by inspection of the underside of each skin, and those patterns were arbitrarily divided into 5 basic groups (Fig. 3). Each skin was categorized as Pattern I, II, III, IV, V, No Molt, or Diffuse Molt. The percentages of individuals in each category then could be calculated for summer, fall, winter, and spring.

Size of adrenal glands was recorded for 66 mice, and mean seasonal size was determined.

TABLE 1.—PERCENTAGES OF MALE, FEMALE, AND TOTAL *PEROMYSCUS LEUCOPUS* SHOWING MOLT AT DIFFERENT SEASONS, LOUISVILLE, KENTUCKY

	Summer	Fall	Winter	Spring
Males				
Number	6	22	12	10
Mean ± 2 SE	7.8 ± 7.3	28.1 ± 11.7	24.4 ± 10.3	0.6 ± 0.7
SD	8.9	25.2	17.9	1.1
Range	0–25.5	0–97.9	0–52.8	0–3.4
Females				
Number	0	19	13	12
Mean ± 2 SE	–	22.2 ± 12.4	19.0 ± 11.4	0.1 ± 0.1
SD	–	27.0	20.6	0.3
Range	–	0–85.6	0–68.7	0–0.9
Total				
Number	6	41	25	22
Mean ± 2 SE	7.8 ± 7.3	25.4 ± 8.1	21.6 ± 7.7	0.3 ± 0.3
SD	8.9	25.9	19.2	0.8
Range	0–25.5	0–97.9	0–68.7	0–3.4

RESULTS

Percentages of molt in progress in each of the 4 seasonal groups based on rate of change in photoperiod are shown in Table 1. The largest mean was always in fall, with the second largest mean in winter, and the smallest mean in spring. There was a significant difference between the amount of molting in fall and the amount in summer and spring. There also was a significant difference between the amount of molting in winter and spring. There was significantly more molting in progress in fall and winter males and females than in spring males and females. There also was significantly more molting in fall males than in summer males. No comparisons could be made for summer females since none was caught during the study.

The most common patterns of molt are shown in Fig. 3 and are arranged in sequence I–V to resemble Gottschang's (1956) drawings (Fig. 1) which show origin and direction of the juvenile molt. Fig. 3 is not a dynamic series even though it is probable that adult patterns of molt follow closely the juvenile pattern. Pattern I represents those skins that show pigment deposition in the axillae of the fore- and/or hindlimbs. Pattern II represents skins with pigment deposition and a narrow band along the lateral lines from the axillae of the forelimbs to those of the hindlimbs. The

TABLE 2.—PERCENTAGES OF INDIVIDUAL *PEROMYSCUS LEUCOPUS* SHOWING DIFFERENT PATTERNS OF MOLT, LOUISVILLE, KENTUCKY. (SEE TEXT FOR DESCRIPTION OF PATTERNS)

	Pattern						
	I	II	III	IV	V	Diffuse	Total
Summer	16.6	–	–	–	–	33.3	49.9
Fall	9.7	9.7	19.5	19.5	17.1	–	75.6
Jul–Aug	9.1	9.1	–	9.1	9.1	–	36.6
Oct	–	–	30.0	40.0	20.0	–	90.0
Nov	15.0	15.0	25.0	15.0	20.0	–	90.0
Winter	8.0	16.0	24.0	16.0	8.0	–	72.0
Spring	13.6	–	–	–	4.5	–	18.2

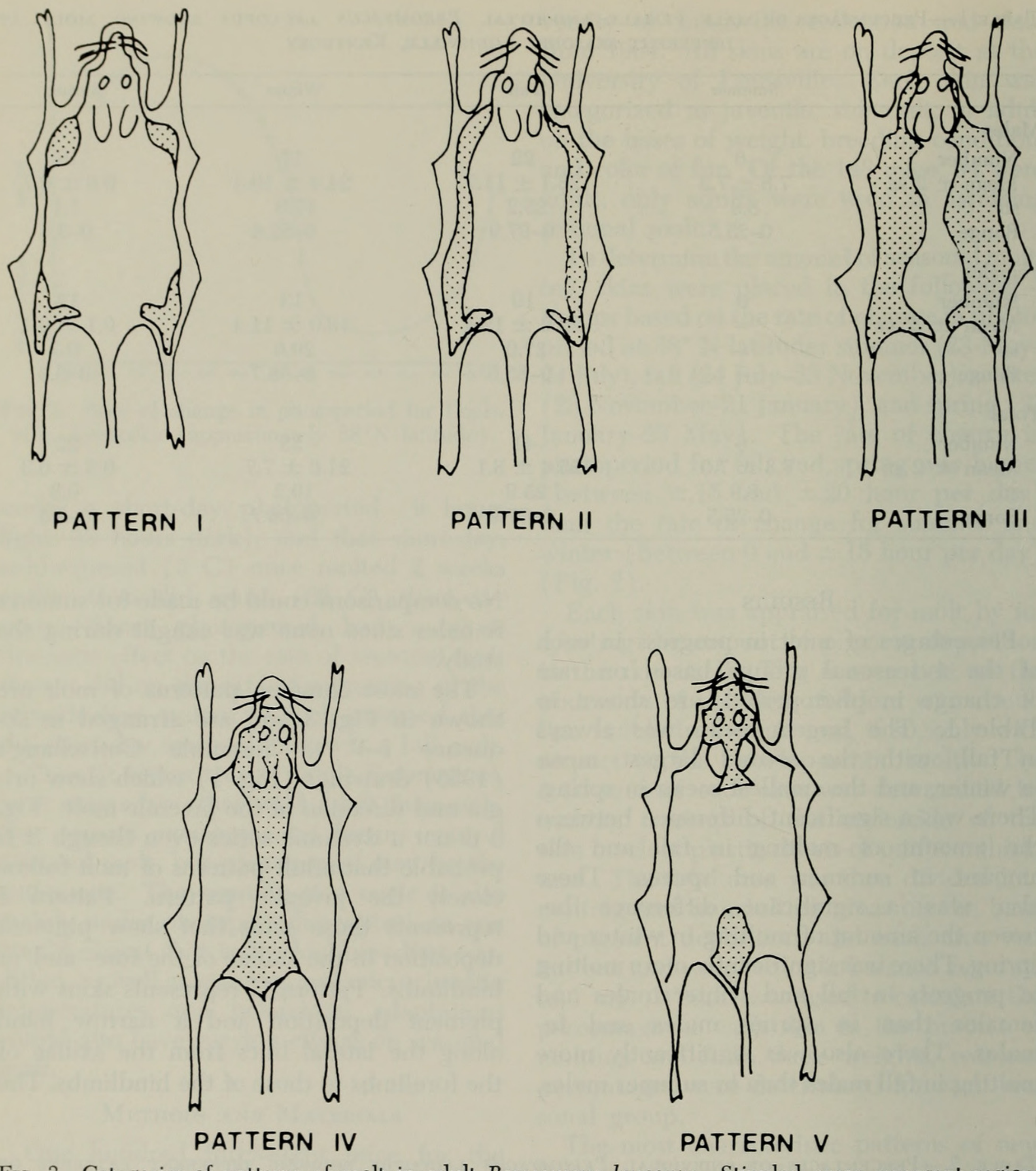

FIG. 3. Categories of patterns of molt in adult *Peromyscus leucopus*. Stippled areas represent regions of new hair growth. See text for explanation of patterns.

third pattern is the most variable in the sequence and symbolizes skins with pigment lines midway up the sides parallel to the lateral lines. Those 2 pigment lines may or may not be connected by pigment deposited across the dorsum. The lines vary greatly in width, and may extend from the lateral line almost to the mdidle of the back. Pattern IV depicts skins with pigment laid down in a single middorsal line from between the eyes to the base of the tail. Pattern V represents skins with pigment on the head (around and between the eyes and ears) and/or at the base of the tail. The pigment deposition represented by each of the 5 patterns is almost always bilaterally symmetrical.

The highest percentage of individuals

TABLE 3.—SIZE (GREATEST LENGTH, MM) OF ADRENAL GLANDS OF ADULT MALE AND FEMALE AND ALL *PEROMYSCUS LEUCOPUS* EACH SEASON, LOUISVILLE, KENTUCKY

	Summer	Fall	Winter	Spring
Males				
Number	4	15	5	9
Mean ± 2 SE	3.5 ± 0.3	2.5 ± 0.3	2.7 ± 0.2	2.7 ± 0.3
SD	0.4	0.7	0.3	0.4
Range	3.2–3.8	1.5–3.8	2.4–3.0	2.2–3.5
Females				
Number	0	15	6	12
Mean ± 2 SE	–	2.9 ± 0.3	2.3 ± 22.0	2.3 ± 18.0
SD	–	0.6	0.3	0.3
Range	–	2.4–4.0	2.0–2.7	2.0–2.9
Total				
Number	4	30	11	21
Mean ± 2 SE	3.5 ± 0.3	2.7 ± 0.4	2.5 ± 0.9	2.5 ± 0.2
SD	0.4	0.7	0.3	0.4
Range	3.2–3.8	1.5–4.0	2.0–3.0	2.0–3.5

showed molt in fall (75.6%) and winter (72%), while the lowest percentage was in spring (18.2%) (Table 2). When the fall group was broken down into 3 subgroups, the percentages were highest in October and November (both 90%). Winter was represented by mice caught only in December. So, October, November, and December were the months with the highest percentages of individuals showing molt.

Sizes of adrenal glands for the 4 seasons are shown in Table 3. Adrenal glands in summer are significantly larger than at any other time of year, and the male adrenal gland is significantly larger in summer than in fall, winter, or spring. No females were collected in summer during the study, but the females did have significantly larger adrenal glands in fall than in winter or spring.

DISCUSSION

Although some adult *P. leucopus* can be found in the process of molting at any time of year, there is but 1 annual molt. It occurs in fall and winter (specifically October, November, and December) when the rate of decrease in photoperiod is greatest. But those months do not coincide exactly with the greatest rate of change in the fall photoperiod between 24 July and 23 November. That time lag fits in with the general nature of hormonal control; hormone levels build up slowly in the bloodstream and must reach a certain critical level before stimulating any physiological changes.

It is also known that *P. leucopus*, from approximately the same locality as the present study group, are in breeding condition all months except November, December, and January (Thane Robinson pers. comm.). This is essentially in agreement with the findings of Burt (1940) and Whitaker (1940) at Ann Arbor, Michigan, who reported that few young were produced in November and none in December, January, or February. Most litters were produced in April, May, and June. A slump occurred in July, but production was up again in August, September, and October.

Since Hayward (1965) has shown that *P. maniculatus* does not need to grow a warm winter coat, the fact that the nonbreeding months overlap the months of the annual molt probably is no coincidence. October, November, and December must represent the most energetically feasible time of the year to molt with respect to the reproductive cycle.

These findings agree with Osgood's

(1909) belief that *Peromyscus* undergoes only 1 seasonal molt in the fall and with Collins's (1923) field study which showed a fall molt (October and November) in *P. maniculatus*. Brown (1963) and Lynch (1973) are the only investigators who attempted to relate adult molting to photoperiod and the reproductive cycle. *P. boylii* apparently has 2 seasonal molts (fall and spring) that coincide with the ends of breeding periods. Laboratory reared *P. leucopus* come out of breeding condition and exhibit molting when exposed to short photoperiod, but the seasonal timing of the molt in wild white-footed mice has not been determined previously.

Adult *P. leucopus* do adhere to definite patterns of new hair growth and those patterns resemble those of the juvenile molt (Table 2). Only in the summer group did any individuals exhibit molt with a diffuse pattern.

Just how size of adrenal glands relates to seasonal molting is not known. But adrenal gland size is a known indicator of the amount of environmental stress in small mammals, and stress probably can modify the effects of a major environmental cue like photoperiod.

The present study helps confirm the belief that photoperiod is the major environmental cue to trigger seasonal molt in wild adult *P. leucopus*, as it is in many other wild animals. Also, it shows how tightly linked are the 2 energy costly events of reproduction and new hair growth. Other less important factors probably modify the main environmental cue so that some individuals may be found molting at any time of year. Only 1 seasonal molt was typical of *P. leucopus* at 38° N latitude, but depending on the latitude and the breeding cycle, there may be 2 seasonal molts per year, as there are in *P. boylii* and *Ochrotomys nuttalli*.

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