POLSKA AKADEMIA NAUK — ZAKŁAD BADANIA SSAKÓW

ACTA THERIOLOGICA

VOL. VIII, 8: 125—135. BIAŁOWIEŻA 15.X.1964

Stanisław BOROWSKI

Moult of Shrews (*Sorex* L.) under Laboratory Conditions

Linka ryjówek (*Sorex* L.) w hodowli laboratoryjnej

[With 2 Tables & 1 Fig.]

I INTRODUCTION

Shrews belong to small mammals which are hard to keep in the laboratory. The basic problems concerning the rearing of these animals have not been solved as yet.

The attempts of Dehnel (1952) were crowned with success, for he managed to persuade the specimens of *Sorex araneus* L. kept in cages to copulate and produce offspring. He made a number of observations on the pregnancy, birth and nursing of the young in the nest.

Other authors (Dunayeva, 1955; Crowcroft, 1956, 1957) also tried to keep shrews under laboratory conditions, but their achievements can hardly be called the rearing in the full sense of the word.

Dehnel resumed his trials of laboratory raising in the Mammals Research Institute, Polish Academy of Sciences, in 1956. The 2-year raising of shrews allowed him to make numerous remarks on the biology of these animals. The purpose of the observations was, among other things, to obtain information on the changing of hair in shrews and the effect of laboratory conditions, above all the length of day, on the rate and time of moult.

II. LABORATORY MATERIAL

The laboratory material consisted of 168 shrews (140 specimens of *Sorex araneus* Linnaeus, 1758, 26 of *S. minutus* Linnaeus, 1766, and 2 of *S. caecutiens* Laxman, 1788) captured alive in the Białowieża National Park from December 22, 1956 to December 22, 1958. The animals were kept in wooden cages, 15×40×30 cm in dimensions, and fed a mixture of beef hearts, liver, spleen, and lungs in the ground form with a contingent admixture of crushed yeast and vitamins A and C twice a day, similarly to the regimen adopted by Wolska (1952). Germinating seeds of spruce and barley were added occasionally. The cages were placed in three rooms, in which the relative humidity of air ranged between 60 and 80%. The temperature and length of daylight were maintained at the level of the long summer day (18 hrs. at a temperature of 10—18° C) or the short winter day with 3—6 hrs. of daylight at an ambient temperature from 8 to about 0° C (only exceptionally down to —3° C, when some of the cages with shrews were exposed to slight night frost). These extreme periods were separated by 18- to 45-day transition periods, the conditions being changed gradually from the long day to the short one or reversely. Four fluorescent lamps with a total power of 160 W (ca 150 luxes) were placed above the cages. The time of lighting was controlled automatically by a clockwork. Observations of changes in the coat were carried out by me, personally, every other day.

The survival rate of shrews in the laboratory was very low. Only 50% of the animals lived longer than 1 month, and 1.8% longer than a year. One specimen, which lived 400 days in captivity, changing its hair 3 times during this period, was an exception.

III. CHANGING OF HAIR

1. Autumn Moult

In the laboratory the course of the autumn moult in young specimens was generally the same as has already been described on the basis of the materials collected in the field (Dehnel, 1949; Borowski, 1952; Crowcroft, 1956, 1957). In the laboratory, however, the process was protracted and lasted from 15 (No. 127) to 41 days (No.130). In sporadic cases there were interruptions of moulting and the complete change of the coat took 44 days (No. 128). The average duration of the autumn moult in the laboratory was 27.0 days (Table 1); the process was observed in about 90% of the shrews (Fig. 1, Table 2).

During the growth of new hair the skin softens, thickens, and blackens, which is well seen after parting the hair aside. When the winter hair reaches a length of 8—10 mm, the skin becomes light and thin again (Borowski, in preparation). Slight deviations from the course of growth of the winter hair, revealed by the occurrence of "wave moult", were observed in two specimens. During this moult the hair grows over a 2—3 mm belt of the black skin. The black belt of growing hair passes from the sacral region anterad and ventrad.

2. Spring Moult

Generally speaking, the spring moult in the laboratory had the same course as the autumn moult, i.e., it began in the dorsal portion of body to extend over the flanks and, finally, over the belly. Only specimens Nos. 13 and 29 of *S. minutus* began to moult on the belly and ended on the back, just as it is usual with shrews in the wild in spring. The spring moult lasts much shorter than the autumn one (Table 1), it may even be completed in 5 (*S.minutus* No. 6) to 15 days (*S. minutus* No. 29). The average duration of the spring moult was 13.6 days in *S. araneus* (Table 1) and 10.6 days in *S. minutus*. The spring moult was observed in more than 90% of the shrews.

Table 1.

The duration of moult of *S. araneus* L. and *S. minutus* L. in the laboratory (the number of actually moulting animals is given for each particular group).

Moult	Time of moult in days:								No. of animals	Avg.
	5 10	11–15	16–20	21–25	26–30	31–35	36–40	41–45		
S. araneus										
Autumn	1	1		6	1	5	1	1	19	27.0
Spring	7	5	4	3					19	13.6
Old-age moult	1	1	2	1					5	15.9
S. minutus Spring	3	2							5	10 6

In most cases the five-membered spring hair (n=14) or the fourmembered summer hair (n=6) grew after the spring moult in the laboratory, but in 4 shrews (*S. minutus* No. 6 and *S. araneus* Nos. 59, 79, and 130) the spring moult produced the six-membered winter hair again. Specimen No. 59 died in the final phase of moulting and No. 79 lost its life owing to an unknown cause in its winter coat in less than 2 weeks after the moult. Instead, shrews Nos. 6 and 130 underwent the first reduction of hair according to the scheme described in my earlier work (B o r o w s k i, 1952).

3. The Reduction of Hair

The phenomen of hair reduction occurred in 6 laboratory specimens (*S. minutus* Nos. 3 and 6 and *S. araneus* Nos. 39, 40, 117, and 130). In specimens Nos. 6 and 130 the reduction of the newly-grown winter hair started immediately after the spring moult, the skin being quite light. It lasted 12 days in *S. minutus* No. 6 and 10 days in *S. araneus* No. 130. In

this last specimen the process got inhibited and after a nearly one-month interval it revived just before the autumn moult and lasted for 5 days more. As a result the winter hair of both specimens was shortened by 1 member and assumed the form of the 5-membered spring hair. No other reduction of hair was observed in these animals.

In specimen No. 3 the reduction of hair took place on the belly and lasted for 13 days. It was followed by the 9-day normal spring moult on the back, accompanied by changes in the skin.

Shrews Nos. 39, 40, and 117 showed evident reduction only in the region of the lateral glands, and then No. 39 moulted but on the back, No. 40 all over the body, while No. 117 died in the winter coat with patches of shorter, reduced hair near the lateral glands.

It should be added that owing to the observations made every other day, it was possible to trace the course and rate of the reductive changes clearly on the same specimens. The general direction of changes agreed with the data obtained from studies of animals in natural field conditions (Borowski, 1952), where these changes were observed in a statical manner on the material derived from collections.

During the reduction of hair the skin is light and the longer hair is delimited distinctly from the shorter one, the limit moving uniformly from the inguinal region on to the belly, flanks and back (reduction I, from 6 members to 5 members) or reversely (reduction II, from 5 members to 4 members) (Borowski, 1952). No growth of new hair accompanies this phenomenon. Therefore it cannot be associated with the wave moult, which involves clear-cut changes in the skin, occurring over the area of a narrow belt shifting in conformity with the direction of the moult. However, I failed to observe the mechanism of hair reduction.

The foregoing data indicate the possibility of the occurrence of hair reduction after a normal spring moult followed by the re-growth of the six-membered winter hair.

4. Old-Age Changes in Hair

Changes in hair, such as its falling out or rubbing off in places which do not undergo moulting, then on the ear conchs, tail, and feet, are regarded among other things as a sign of ageing of the shrew. Dehnel (1949) and Borowski & Dehnel (1952) considered these symptoms to be one of the convenient criteria facilitating the distinction of two basic age groups of shrews: the young adults and old adults which have lived through the winter. The description of changes in hair like that is also given by Dunayeva (1955). The process of the so-called old-age moult, too, is a sign of the advanced age of a shrew (Dehnel, 1949; Borowski, 1963).

The falling out of hair on the ear conchs is the first sign of ageing. In the laboratory it took place as early as the beginning of March, usually from several to some dozen days after the appearance of the lateral glands.

The tail gets bald by the rubbing away of hair. In the laboratory this may occur just after the ears have lost their hair, mostly in July and August.

The falling out of hair on the feet often coincides with that on the tail (Nos. 40 and 45). Both these phenomena depend absolutely on the age of the shrew and occur, first of all, in the oldest animals, at least one year of age.

The old-age moult is the last partial change of hair in the life of the shrew (B o r o w s k i, 1963). In the laboratory it ran in a typical manner, by patches, and was followed by the appearance of the greying hair in specimens Nos. 64 and 99. It is interesting that the old-age moult in specimens Nos. 110 and 130, which had survived the winter, had the course of a normal autumn moult. The summer was replaced all over the body of the animals by the long winter hair. This fact is undoubtedly exceptional and has never been observed in natural conditions (B o r o w s k i, 1963). The abundance of food may have been the direct cause of this phenomenon.

IV. THE EFFECT OF THE LENGTH OF DAY ON THE MOULTING

Many studies made on farm animals show that it is possible to control the processes of moulting by the length of daylight or artificial light to which the animals are exposed.

Two experimental series were carried out for this purpose. Two groups of mammals were used in either series: one placed in the room in which long day was maintained and the other in the room with short day.

In series I of experiments 22 specimens of shrews caught in January and February 1957 were kept in the conditions of long day (the length of daytime was increased up to 18 hours from January 12 to February 1 (Fig. 1, group 1) and 10 specimens in the conditions of short day (group 2). The age of the animals approximated to 7—8 months. The rooms being situated next to each other, the door between them was opened for the time of handling of the shrews and during the day in group 2. The temperature was measured with a week thermograph only in the room of group 1. It was maintained at a level of 5° C up to March 1957, then ranged from 5 to 15° C in April and May to reach about 18—20° C in summer. The humidity was measured with a hair hygrometer and it fluctuated between 60 and 95%. Thus, in this series (I) of experiments the

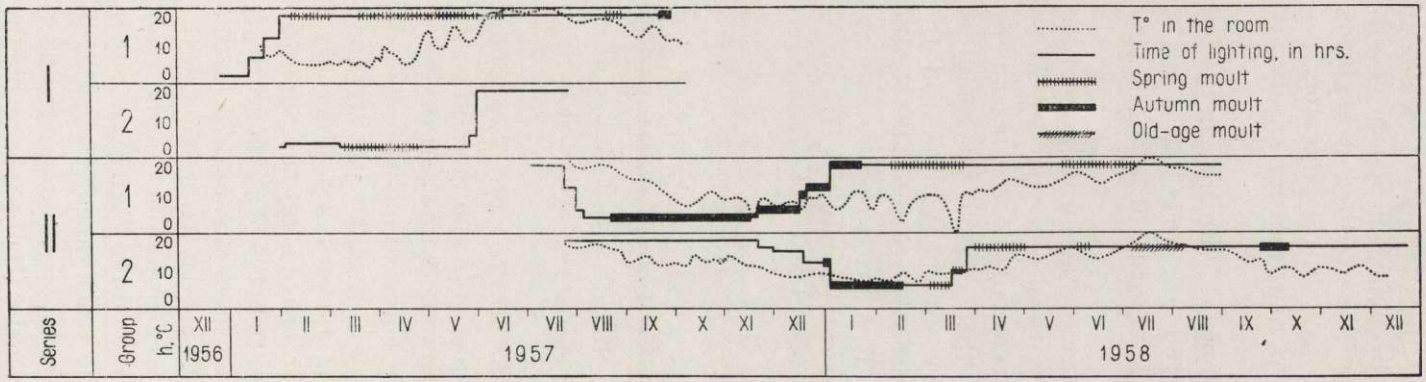

Fig. 1. The effect of the day length on the moult of *Sorex* L. in the laboratory.

Series	Group		1956	1957												1958											
			XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	1	n	1	22	23	18	20	19	27	20	20	5	2													
		in moult			2	2	4	8	1		1		1														
		%			8.7	11.1	20.0	42.1	3.7		5.0		–														
	2	n			10	9	9	6	2	1																	
		in moult				2	2																				
		%				22.2	22.2																				
II	1	n								30	30	28	20	18	17	15	9	8	7	5	5	4	2				
		in moult									2	5	4	3	4	2	1	2		1	2						
		%									6.7	17.9	20.0	16.7	23.5	13.3	11.1	25.0		20.0	40.0						
	2	n								21	21	18	15	13	12	10	7	7	7	5	9	8	6	8	2	1	1
		in moult									7	1				7	1	2	4		1			1	1		
		%									70.0	14.3	28.6	57.0							11.1			12.5	–		

Table 2.

Percentage of shrews moulting in the laboratory (less old-age moult and hair reduction). As to the type of moult — see Fig. 1.

actual action of temperature and humidity on the moult of shrews was much the same in both groups.

In group 1, shrew No. 3 began moulting 9 days after the setting up of the 18-hour day and shrew No. 13 towards the end of February. In this group 90% of the shrews in all moulted in the spring. The intensity of moulting was, however, the greatest in May (42.1%, Table 2). One shrew of this group changed the winter hair for the spring one as late as June and one in August. Instead it seems certain that only 2 out of the 22 shrews of this group responded to the prolonged day and moulted a month earlier than it takes place in the wild.

Group 2 had 3- and 4-hour day from February 1 to May 27 and 18-hour day from June 1. In spite of the short daytime 2 shrews changed hair in March and 2 others in April. The non-moulting specimens died out gradually and hence only 44.4% of the shrews in this group took part in the spring moult.

Experimental series II was set up in a similar manner only that the material was collected in July 1957 and consisted of 51 specimens, of which 47 were young, 1—2 months of age. At first both groups of this series (II) were kept at 18-hour day. The temperature and humidity of air were measured separately in either room of these groups. However, the 2—3° C difference in temperature between the two rooms in October, November and December 1957 does not seem to have had any influence on the earlier beginning of moulting. The humidity ranged between 60 and 95% in both the rooms.

In group 1 (30 shrews, Table 2) the day was being shortened from July 21 and settled at 4 hours from August 3. Two specimens began the autumn moult as early as August 21. In the next months the percentage of moulting specimens increased up to 20% (October) and after a slight drop in November reached 23.5% in December.

It was hard to obtain low temperatures in the laboratory and for this reason 10 shrews were exposed in their own cages to slight night frost out of door 5 times in October and November. Six specimens started moulting 3—5 days after this procedure.

Although the length of day was increased to 18 hours in the period from November 21, 1957 to January 3, 1958, some shrews ended the autumn moult as late as January. In all, above 95% of the shrews of group 1 changed hair.

The second group of shrews of series II ($n = 21$, Table 2) was kept at 18-hour day till November 21, 1957. Then the day length was gradually shortened and from January 3, 1958 settled at 6 hours. Out of the 10 shrews left alive in this group, 7 specimens moulted in January 1958 and

only one in February. In the period from 15 to 25 March the day length was increased to 18 hours. One shrew began the spring moult as early as 8 days before the lengthening of the daytime. About 85 % of the specimens of this group took part in the autumn and spring moults.

The materials presented seem to indicate that under laboratory conditions it is more difficult to control the time of spring moult than that of the autumn moult, and that shrews respond more readily to the conditions of the laboratory environment after spending there 2—4 months.

V. DISCUSSION

The observations offered in this paper on the moult of shrews in the laboratory are a supplement to my report of 1952 and the study on the moult of shrews in the wild.

Observations of the processes of moulting on living animals and the continuous watching of the same specimens made the determination of the duration and direction of moulting possible and corroborated the findings concerning the occurrence of hair reduction. Another essential result is the ascertainment that after the loss of the winter coat the same long 6-membered winter hair of characteristic black coloration may grow instead of the spring or summer hair both in *S. araneus* and in *S. minutus*. Its shortening by reduction (B o r o w s k i, 1952) resulting in spring hair was observed in a few specimens, but no example of the second reduction leading to the formation of summer hair was seen in the laboratory.

An examination of wild specimens showing hair reduction might suggest that this phenomenon is a wave moult or even a normal moult interrupted owing to some causes. The shifting of the boundary of the reducing hair in a living specimen with the light-coloured skin and not accompanied by the growth of new hair undoubtedly indicates the occurrence of the process of hair reduction (shortening without any normal changes of moulting). The mechanism of this phenomenon has not been explained as yet.

In all probability it could be explained by the application of the isotope of sulphur (S^{35}). L o t m a r (1956), for instance, found that in rabbits this isotope does not enter the old hair, but it penetrates abundantly into the growing hair. This would allow the faultless estimation whether a given hair is a relic of the previous moult or a newly grown hair.

The observations made in the laboratory and the data obtained in the field (B o r o w s k i, in preparation) make it possible to ascertain that in spring we have to do with the normal spring moult, which may bring about the replacement of the old hair with the summer one or the re-growth of the winter hair, which next undergoes reduction. Both manners in which the winter hair changes to the summer one were observed

under laboratory conditions. The data obtained are compatible with the thesis of Schwarz (1955), who found the reduction of hair beside the moult in the shrews of the Ural Mts.

Stein (1954) in Germany, Crowcroft (1956, 1957) in England, and Popov (1960) in Kazan' (U.S.S.R.) did not observe any examples of hair reduction in shrews. None the less, in the light of my data the statement of Stein (1954) that „Die von Borowski (1952) gegebene Deutung als «Frühjahrshaarkleidreduktion» durch Abbrechen distaler Haarpartien ist falsch, es findet ein Wechsel des Haares, eine Haarkleiderneuerung statt" is unacceptable and concerns some definite climatic conditions only. Probably it does not apply to the species *S. araneus* or the genus *Sorex* throughout its geographical range.

It is possible that so far as the time of occurrence of the normal autumn and spring moults is governed by the length of day, the hair quality is controlled by the temperature and food (Roguski, 1963, and others). Short old-age hair might be expected after the third moult in the life of old shrews (Nos. 110 and 130), but they grew the normal winter hair. It is presumably connected with the quantity and quality of food offered them in the laboratory.

Observations made in the laboratory point to a great physiological plasticity of shrews, which enables them to execute the spring change of hair according to the weather conditions at least in two ways: by moulting and changing the winter hair to the summer one directly, or by the twofold reduction of the second winter hair, which grew after the spring moult, also resulting in the formation of the summer coat.

A more detailed discussion of this problem is here left out and will be included in the next paper, which will deal with the moult of shrews under natural conditions.

VI. SUMMARY

Shrews (*Sorex* L.) were reared in the laboratory from December 28, 1956 to December 28, 1958. Out of the total of 168 animals, 102 lived in captivity for a short time and did not undergo moulting. The course of moulting was observed in 66 specimens, living in the laboratory for 30—400 days.

1. During the spring moult a few animals grew the winter hair again, which next was shortened by reduction, as described earlier (Borowski, 1952), without characteristic changes in the skin. Other shrews underwent the spring moult consisting in the growth of short hair.

2. The hair on the ears, feet, tail, and lateral glands of males does not change during moults but is rubbed off with age or falls out.

3. The artificially controlled length of day can influence the occurrence of the moulting season in the *Soricidae* kept in the laboratory.

Acknowledgement: I wish to express my heartfelt gratitude to the late lamented Professor Dr. August Dehnel for his critical remarks and valuable help in the course of this study.

REFERENCES

1. Borowski, S., 1952: Sezonowa zmiana uwłosienia u *Soricidae*. Ann. Univ. M. Curie-Skłodowska, Sect. C, *7*, 2: 65—117. Lublin.
2. Borowski, S., 1958: Variation in density of coat during the life cycle of *Sorex araneus araneus* L. Acta theriol., *2*, 11: 286—289. Białowieża.
3. Borowski, S., 1963: Old-age moult in the Common shrew *Sorex araneus* Linnaeus, 1758. Acta theriol., *7*, 19: 374—375. Białowieża.
4. Borowski, S. & Dehnel, A. 1952: Materiały do biologii *Soricidae*. Ann. Univ. M. Curie-Skłodowska, Sect. C, *7*, 6: 305—448. Lublin.
5. Crowcroft, P., 1955: Remarks on the pelage of the Common shrew (*Sorex araneus* L.). Proc. zool. Soc. Lond., *125*: 309—315.
6. Crowcroft, P., 1956: On the life span of the Common shrew (*S. araneus* L.). Proc. zool. Soc., *127*: 285—292. London.
7. Crowcroft, P., 1957: The life of the shrew. Max Reinhard. 1—166. London.
8. Dehnel, A., 1949: Badania nad rodzajem *Sorex* L. Ann. Univ. M. Curie-Skłodowska, Sect. C, *4*, 2: 17—102. Lublin.
9. Dehnel, A., 1952: Biologia rozmnażania *Sorex araneus* L. w warunkach laboratoryjnych. Ann. Univ. M. Curie-Skłodowska, Sect. C, *6*, 11: 359—376. Lublin.
10. Dunajeva, T. N., 1955: K izučeniju biologii rozmnoženija obyknovennoj burozubki (*Sorex araneus* L.). Bjull. MOIP, Otd. biol., *60*, 6: 27—43. Moskva.
11. Lotmar, R., 1956: Nachweis von radioactiv markiertem Schwefel (S^{35}) im Kaninchenhaar mit seine Beziehung zu gewissen Problem des Haarwechsels. Zbl. Veterinärkunde *3*, 3.
12. Popov, V. A., 1960: Mlekopitajuščie Volžsko-Kamskogo kraja. AN SSSR, Kazan. filjal: 1—468. Kazan'.
13. Roguski, W., 1963: Wychów lisów w okresie formowania zimowej okrywy włosowej. Hod. drobn. Inwent., *9*: 4—5. Warszawa.
14. Stein, G. H. W., 1954: Materialen zur Haarwechsel deutscher Insectivoren. Mitt. zool. Mus., Berlin, *30*, 1: 12—34.
15. Schwarz, S. S., 1955: Biologija zemleroek lesostepnogo Zauralja. Zool. Z., *34*, 4: 915—927. Moskva.
16. Wolska, J., 1952: Rozwój aparatu płciowego *Sorex araneus* L. w cyklu życiowym. Ann. Univ. M. Curie-Skłodowska, Sect. C, *7*, 8: 487—939. Lublin.

Polish Academy of Sciences,
Mammals Research Institute,
Białowieża, woj. Białystok.

STRESZCZENIE

Obserwowano 140 osobników *Sorex araneus* L., 26 — *S. minutus* L. i 2 *S. caecutiens* Laxm., trzymanych w hodowli klatkowej w Zakładzie Badania Ssaków PAN w Białowieży w czasie od 28.XII.1956 r. do 23.XII:1958 r. Stwierdzono, że:

1. Przebieg linki jesiennej ryjówek nie odbiega od tego procesu obserwowanego w terenie.

2. Podczas linki wiosennej większość okazów zmieniała sierść zimową 6-członową na wiosenną 5-członową lub letnią 4-członową. Miały jednak miejsce przypadki (n = 4), gdy po sierści zimowej wyrosła ponownie sierść zimowa, a po rozjaśnieniu

się skóry nastąpiły redukcje włosa (bez czernienia skóry i bez śladów narastania włosa nowego). Kierunek przebiegu linki był taki sam jak w jesieni. W dwóch przypadkach linka wiosenna rozpoczęła się w okolicy ingwinalnej, a skończyła na wierzchu głowy, a więc tak jak się to dzieje w terenie. Kierunek pierwszej redukcji włosa zbliżony był do opisanego w 1952 r. (Borowski, 1952) tj. postępowała ona od okolicy ingwinalnej i gruczołów bocznych ku górze i przodowi ciała. Drugiej redukcji w hodowli nie obserwowano.

3. Linka starcza przebiegała nieregularnie (Borowski, 1963). W dwóch przypadkach nie różniła się niczym od normalnej linki jesiennej, po której zwierzęta uzyskały normalne futro zimowe. W terenie nie spotkano się z podobnym przypadkiem.

4. Włosy na małżowinach usznych, stopach i ogonie niepodlegają wymianie w czasie linek, a z wiekiem wycierają się lub wypadają.

5. Sztuczna długość dnia jest w stanie zmienić czas wystąpienia linki u ryjówek w hodowli.