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Breeding of the common shrew, *Sorex araneus*, under laboratory conditions

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A b s t r a c t . Captive breeding of the common shrew, *Sorex araneus* was conducted between 2003 and 2005. Young specimens were collected from natural populations in September of 2003 and 2004. They were kept under long day conditions (16 hours of daylight) until they reached sexual maturity and were then bred. Eleven out of 18 females gave birth to 17 litters, including 13 (76%) that survived to weaning. The total for all litters was 77 offspring, 54 of which (70%) left the nest. Males born in captivity and kept under variable photoperiod conditions attained sexual maturity (combined testis masses ranged from 167 to 236 mg). These results indicate that maintaining of continuous breeding colony under laboratory conditions of this species should be possible. The main problem remains relatively high animal mortality: 42% of caught shrews died before mating began and 57% of males born in captivity did not survive the acceleration of sexual development.

Key words: acceleration of the maturation, reproduction in captivity, sexual maturity

Introduction

The common shrew is characterized by very high cytogenetic variability: almost 70 chromosome races, which differ from each other by a set of uniarmed and biarmed chromosomes, have been described within its palearctic range (W ó j c i k et al. 2003). Research conducted on hybrid zones (that is an area where two chromosomal races come into the contact and interbreed; S e a r l e & W ó j c i k 1998) may provide important information regarding evolution mechanisms, such as the occurrence of isolation barriers or genetic divergence. However, there are many problems that cannot be solved by conducting research on animals obtained from natural populations. Captive breeding of this species will offer increased research possibilities. For example, keeping the shrews in captivity will enable the generation of specific types of cross-bred animals that occur rarely or not at all under natural conditions, examination of the chromosome meiotic drive (W y t t e n b a c h et al. 1998), or determination of whether postzygotic isolating barriers occur between individuals of different chromosome races (S e a r l e 1984a, C a s t a g n é et al. 1994).

The common shrew is considered a difficult species to maintain and particularly to breed in captivity. Their breeding was attempted by D e h n e l (1952), V o g e l (1972), V l a s á k (1973), F e d y k (1980), C a s t a g n é et al. (1994) and W y t t e n b a c h et al. (1998). A systematic and effective method of breeding common shrews and induction of sexual maturity of the offspring was presented by S e a r l e (1984b) and M e r c e r & S e a r l e (1994). Breeding of shrews born in captivity was carried out by W y t t e n b a c h et al. (1998), however, they did not provide any information about the effectiveness of the

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reproduction method they used. The purpose of this work is to present the results of breeding of young shrews that were collected at natural populations and reached sexual maturity in captivity.

Materials and Methods

Breeding conditions

Immature individuals of the common shrew of both sexes were used for breeding. They were caught in September of 2003 and 2004 in populations located within the range of the following chromosome races: Drnholec and Łęgucki Młyn. A total of 41 common shrews (18 females and 23 males) were used for breeding purposes.

The animals were bred in the building of the Institute of Biology, University of Białystok. The shrews were kept separately in plexiglas terrariums (0.40 × 0.30 × 0.30 m) (Fig. 1a) until they attained sexual maturity. Shrew mating and reproduction were carried out in two terrariums (0.60 × 0.45 × 0.30 m; total surface area – 0.54 m^2) connected by a plastic tube (Fig. 1b), which increased the space available for animals and facilitated the separation of a male and female by plugging the tube. A plexiglas plate divided the terrariums of both types into two sections: "a dining section" (ca. 1/5 of the terrarium length), where water and food were served and "a residential section" with a wooden nest box, an exercise wheel, moss, cotton-wool and as a substratum wood shaving, and other elements adding variety to the interior of the terrarium (e.g. pine cones, twigs etc.) (Fig. 1). The terrariums were cleaned when necessary, usually every 2–3 days. The cleaning was reduced to a minimum in terrariums with pregnant or lactating females. During the entire breeding period, room temperature was maintained at ca. 16ºC and air humidity between 70 and 90%. When the humidity fell below 70%, the terrariums were sprayed with water. The room had artificial lighting, which was electronically controlled. In the first breeding room, the daylight length equalled 16 hours (long day – 16 hours of light and 8 hours of dark), and in the second one, the day lasted 8 hours (short day – 8 hours of light and 16 hours of dark).

Shrews were fed with ground meat (2 parts of beef, 1 part of pork or chicken liver and 1 part of chicken breasts). The meat was enriched with a vitamin and mineral supplement Salvikal (Beaphar, Netherlands), which constituted 3% of the total mass of the meat. After the meat had been ground and divided into portions, it was stored at ca. -15°C. Every several

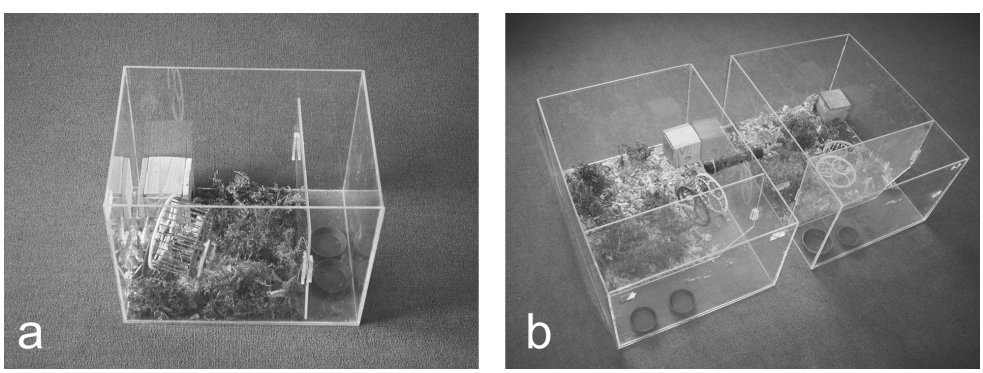

Fig. 1. Two kinds of terrariums used in present study – small terrarium for keeping young common shrew (a) and two large terrariums connected by tube for mating and reproduction (b).

days, shrews were served crickets, mealworms, and less frequently earthworms. Vegetable food was also part of the diet and included barley grain and sunflower seeds. Food and water were provided *ad libitum* once a day at around 12 o'clock.

Acceleration of the maturation process

Shrews attain sexual maturity in the second calendar year of their life (following overwintering). When breeding young animals, the maturation process can be accelerated by adjusting the photoperiod (Crowcroft 1964, Mercer & Searle 1994). In order to speed up the sexual maturity of shrews caught in the natural environment, they were exposed to long day conditions at all times. The short day stage was skipped because the animals were caught in September, that is, during a period with a shortening photoperiod. The animals that were born in captivity (only males) were exposed to variable photoperiod conditions: they were kept under long day conditions up to 15 days from the time they were separated from the mother, thereafter from about a two to four month period of the short day conditions and from about a two to four month period of the long day conditions again. One male was not exposed to the short day conditions at all, and for another male, this stage was shortened to 10 days.

The determination of sexual maturity in males (in females, this is practically impossible) was based on enlargement of the testes, which are visible as a bulge at the base of the tail, and/or by the presence of lateral gland secretion. Additionally, males have more developed neck muscles, which are easily palpable with the fingers; this also can be used as a diagnostic feature. These muscles develop only in males and are probably associated with the manner of copulation, in which a male holds a female by the skin on her head or neck with his teeth (Fig. 2). In the majority of males, signs of sexual maturity became visible about three months after starting procedure of adjusting the photoperiod.

Reproduction

Reproduction took place under long day conditions. After females and males that were caught in the natural environment attained sexual maturity, they were transferred to two large terrariums connected by a plastic tube, through which they could pass freely. A female was

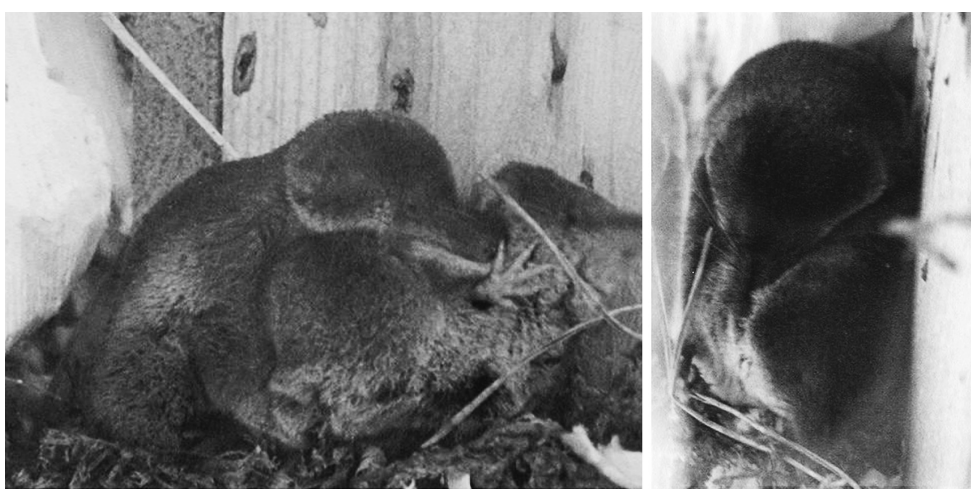

Fig. 2. Copulation of the common shrew (a photograph taken through the terrarium wall).

mated with several males one by one; she stayed with each of them for at least three days. The purpose of this procedure was to increase the probability of fertilization; if a certain male was incapable of fertilization, a female could have been impregnated by another male. A female was released into the terrarium first and after about two days a male was also introduced; during subsequent mating, the female stayed in the terrarium and the male was replaced. Thus, a reversed procedure was used in comparison to that used by S e a r l e (1984b); this approach was chosen due to the fact that in natural populations, in order to mate, a female must possess her own territory (R y c h l i k 1998). When the female was found to be pregnant, the male was removed from the terrarium. Increased body mass and food consumption, especially during the last week of pregnancy, were indications of pregnancy. Several days before giving birth females began to build nests using most of the material in the terrarium (moss, wood-wool). D e h n e l (1952) observed that the female completes her nest one or two days before the birth. The birth date was determined approximately by observing the female (significant decrease in body size, reddened and lengthened nipples, which was easiest to observe when the female was nursing the first litter) and checking the nest, which was rarely done in order to avoid disturbing the female.

Approximately 23 days after the birth (the length of lactation period; D e h n e l 1952, S e a r l e 1984b) the offspring were separated from the mother. In the case when determination of the offspring's birthday was impossible, the time of their separation from the mother was decided based on their first independent meal (V o g e l 1972) and/or their aggressive behavior towards the mother (D e h n e l 1952). Determination of the right time for this procedure is crucial because too early a separation of the offspring from the mother may result in their death (D e n h e l 1952). On the other hand, too late a separation may result in the mother's death; the young suckling that already have teeth, may bite her to death (one such case occurred in our study). After the lactation period, the offspring are transferred to a separate terrarium, and the female, after ca. 24 hours was again joined by a male. The offspring were kept together for several days. They were not aggressive towards each other, but after a few days the competition for food intensified. At that point, their sex was determined and they were transferred to separate terrariums. Young females were killed several days after the separation from the mother (by cervical dislocation) and karyotyped (according to F e d y k 1980), while males were subjected to the procedure for induction of sexual maturity and then were also killed and karyotyped.

Whether and when to interfere in the nest remains an unsolved question. Among rodents, a disturbed female may kill and eat her offspring. In the common shrew, such behaviour was not observed; it has been suggested that the female of this species tolerates interference in her nest (C r o w c r o f t 1957). However, in three cases, when researchers looked into the nest during early stages of the offspring's life (approx 5 days old), some young individuals were probably eaten (in one case, the entire litter was lost). It is difficult to determine the causes of this behaviour, but it seems probable that disturbing the nest in its early stages is among them. The fact that looking into a nest is highly stressful for females was also confirmed by F e d y k ' s observations made in a vivarium in Białowieża. Disturbed females moved their young to another nest, which was prepared earlier. In our study, all females built only one nest in spite of a relatively large area; lack of the possibility of transfer the offspring might have been a stress increasing factor.

The difference in mass of males caught in natural populations was tested by non-parametric analysis of variance (the Kruskal-Wallis test) at $P = 0.05$. Correlations between testes mass of males born in captivity and body mass or lifespan were tested by Spearman's

rank correlation test at $P = 0.05$. A Chi-square test was used to check deviation in sex ratio of young shrews born in captivity.

Results and Discussion

Sexual maturity

The average combined testes mass of males that were caught in the natural environment and attained sexual maturity in captivity (66.7%) equalled 206 mg (± 19 SD, n = 8) and was comparable with males who attained maturity in the natural environment (>200 mg, our observations). In contrast, the testes mass of males who did not reach sexual maturity was only 16 mg (± 2 SD, n = 4) and was slightly greater than the mass of testes of young males in natural populations (5 mg; Brambell 1935 acc. to Stockley & Searle 1994). The combined testes mass of these both groups of males were measured at similar time point, nine months after breeding began. The body mass of males that did not become sexually mature (7.44 g ± 0.45 SD, n = 4) did not differ statistically ($H = 0.12$, $P > 0.7$) from the body mass of sexually mature males (7.59 g ± 0.88 SD, n = 8).

The average combined testes mass (205 mg ± 20 SD, n = 8) of males that were born in captivity and underwent the process of sexual maturity acceleration was similar to the testes mass of overwintered animals despite the different length of time spent under short day conditions and the differing life span (Table 1). Both the male whose short day stage was abbreviated to 10 days (male no. 1; Table 1) and the male who did not pass this stage (male no. 2; Table 1) had relatively large testes masses. Meiotic divisions were observed in cytological preparations made from the testes of males born in captivity; these divisions were also present in preparations obtained from testes of males 1 and 2 (Table 1). This fact suggests that exposing animals exclusively to the long day conditions stimulates their sexual maturity, which was also indicated by the results obtained by Mercer & Searle (1994). However, it should be emphasized that these findings describe single cases and do not confirm the possibility of skipping the short day stage altogether during the procedure of sexual maturity acceleration, particularly for the animals that were born in captivity or were

Table 1. Characteristics of males born and matured in captivity.

Male no.	No. days spending in:		Age (in days from weaning)	Body weight (g)	Combined testes mass (mg)
	short day conditions	long day conditions			
1	10	55	65	8.20	179
2	0	73	73	8.09	167
3	55	52	114	8.60	195
4	55	53	120	8.10	221
5	52	67	130	8.91	187
6	104	54	170	6.90	206
7	62	109	178	8.98	198
8	63	113	184	10.16	236
9	61	116	187	7.22	217
10	62	124	193	7.77	176
Means ± SD	52.4 ± 29	81.5 ± 30	141.3 ± 48	8.29 ± 0.94	198 ± 22

caught during long daylight (June and July). The testes mass of males born in captivity was not correlated with body mass ($r_s = 0.18$, $P > 0.6$) or lifespan ($r_s = 0.36$, $P > 0.3$). During a section performed on females born in captivity, it was observed that uteruses of the majority of them were enlarged as early as ca. 15 days after they were separated from the mother. In natural populations, this phenomenon (enlargement of the reproductive tract) occurs among females from the first (June) litter, and their fertility is comparable to that of overwintered individuals. However, their contribution to population reproductiveness is relatively insignificant (up to 7.7% of all reproducing females; P u c e k 1960).

R e p r o d u c t i o n

Eleven out of 18 females (61.1%) mated successfully (they gave birth to offspring). S e a r l e (1984b) and M e r c e r & S e a r l e (1994) obtained similar results, 74 and 50% mated successfully (after exclusion of nulliparous females, 61%) despite the fact that overwintered females were bred. Eight females were paired with males again after the offspring from the first litter left the nest; seven of them were fertilized, but the offspring of only three of them left the nest. Two females died during pregnancy and two others during the lactation period. Three females were mated again after the second litter left the nest; one of them was fertilized.

In total, the females gave birth to 17 litters; 13 of which were raised successfully (76.5%). In all litters, there were 77 offspring, 54 of which (70.1%) left the nest. The percentage of young individuals that left the nest is comparable with results obtained by S e a r l e (1984b), but is lower than the results of M e r c e r & S e a r l e (1994) by nearly 30%. The average number of offspring in a litter that left the nest equalled 4.2 (± 0.4 SE), while S e a r l e ' s (1984b) result was 4.8 (± 0.5 SE). W y t t e n b a c h et al. (1998) obtained a similar result (4.3 ± 0.2 SE), but it included both the offspring of shrews caught in the natural environment and those born in captivity (separate results were not provided). Two litters had males whose body mass was much lower than that of their siblings. On the day of separation from the mother, they weighed 3.8 and 3.6 g. The first male died a few hours after separation. The second male was left with the mother and survived, but after 4 days bit his mother to death (male no. 5; Table 1).

The sex ratio of the weaned offspring did not vary significantly from the expected ratio of 1 : 1 ($\chi^2 = 1.19$, df = 1, $P > 0.2$). Females constituted 57.4% of all young shrews, while in the M e r c e r & S e a r l e (1994) study males predominated (57%). The sex ratio in natural populations varies and such differences are significant only in June (in favour of males) and August (in favour of females) (P u c e k 1959).

Conclusions

Breeding was conducted according to the method described by S e a r l e (1984b) and M e r c e r & S e a r l e (1994) with the modification being that the breeding study described here was begun with young, sexually immature individuals that were obtained from natural populations in September. This approach creates a major hindrance during breeding because (a) mortality during sexual maturation is relatively high (42% of wild-caught animals died before mating), (b) not all individuals of both sexes are able to participate in mating: over 30% of males remained sexually immature, and mating of 40% of females did not have positive results, and (c) nulliparous females that are caught in the natural environment and

bred in captivity have lower reproductive output than parous females, as demonstrated by Mercer & Searle (1994) on overwintered animals bred in captivity. However, starting the breeding process from juvenile animals might be the only reasonable solution because catching an appropriate number of sexually mature individuals is often very difficult (the overwintering population is usually very small). It is likely that initiating breeding from young animals caught in earlier months, for example in June, would bring better results due to the fact that a large number of females from that period have enlarged reproductive tracts as do some males have testes (these changes were not observed in individuals from later litters; Pucek 1960). Therefore, obtaining sexual maturity of these individuals would probably be easier. Furthermore, "a hunger" phenomenon occurrent in *S. araneus* in autumn (Dehnel 1952) could be the reason for their poor shape and higher mortality.

Shrews born in captivity were in good shape and less stressed, unlike the individuals caught in the natural environment. Having the shrews born in captivity reach sexual maturity is not an issue and is much more effective (all males that underwent the photoperiod manipulation procedure attained sexual maturity) than that of young individuals caught in September in the natural environment. However, the relatively high mortality remains a problem; 43% of males survived until the point of chromosome preparation (preparations were made from individuals of different ages; Table 1).

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LITERATURE

Brambell F.W.R. 1935: Reproduction in the common shrew (*Sorex araneus* Linnaeus). *Phil. Trans. R. Soc. Lond. B 225: 1–62.*

Castagné C., Mehmeti A.M. & Hausser J. 1994: Interbreedings between karyotypic Alpine races of the common shrew *Sorex araneus* (Insectivora, Mammalia). *Caryologia 47: 11–18.*

Crowcroft P. 1957: The life of the shrew. *Max Reinhardt, London.*

Crowcroft P. 1964: Note on the sexual maturation of shrews (*Sorex araneus* Linnaeus, 1758) in captivity. *Acta Theriol. 8: 89–93.*

Dehnel A. 1952: (The biology of breeding of the common shrew *S. araneus* L. in laboratory conditions). *Ann. Univ. M. Curie Sklod. Sect. C 6: 359–376* (*in Polish with English summary).*

Fedyk S. 1980: Chromosome polymorphism in a population of *Sorex araneus* L. at Białowieża. *Folia Biol. (Kraków) 28: 83–120.*

Mercer S.J. & Searle J.B. 1994: Captive breeding of the common shrew (*Sorex araneus*) for chromosomal analysis. In: Merritt J.F., Kirkland G.L. Jr. & Rose R.K. (eds), Advances in the biology of shrews. *Carnegie Museum of Natural History, Special publication no. 18, Pittsburgh: 271–276.*

Pucek Z. 1959: Some biological aspects of the sex-ratio in the common shrew (*Sorex araneus araneus* L.). *Acta Theriol. 3: 43–73.*

Pucek Z. 1960: Sexual maturation and variability of the reproductive system in young shrew (*Sorex* L.) in the first calendar year of life. *Acta Theriol. 3: 269–93.*

Rychlik L. 1998: Evolution of social systems in shrews. In: Wójcik J.M. & Wolsan M. (eds), Evolution of shrews. *Mammal Research Institute, Polish Academy of Sciences, Białowieża: 347–406.*

Searle J.B. 1984a: Hybridization between Robertsonian karyotypic races of the common shrew *Sorex araneus*. *Experientia 40: 876–878.*

Searle J.B. 1984b: Breeding the common shrew (*Sorex araneus*) in captivity. *Lab. Anim. 18: 359–363.*

Searle J.B. & Wójcik J.M. 1998: Chromosomal evolution: The case of *Sorex araneus*. In: Wójcik J.M. & Wolsan M. (eds), Evolution of shrews. *Mammal Research Institute, Polish Academy of Sciences, Białowieża: 219–268.*

Stockley P. & Searle J.B. 1994: Characteristics of the breeding season in the common shrew (*Sorex araneus*): male sexual maturation, morphology, and mobility. In: Merritt J.F., Kirkland G.L. Jr. & Rose R.K. (eds), Advances in the biology of shrews. *Carnegie Museum of Natural History, Special publication no. 18, Pittsburgh: 181–187.*

Vlasák P. 1973: Vergleich der postnatalen Entwicklung der Arten *Sorex araneus* L. und *Crocidura suaveolens* (Pall.) mit Bermerkungen zur Methodik der Laborzucht (Insectivora: *Soricidae*). *Věstn. Česk. Spol. Zool. 37: 222–233.*

Vogel P. 1972: Beitrag zur Fortpflanzungsbiologie der Gattungen *Sorex*, *Neomys* and *Crocidura* (Soricidae). *Verhandlungen der Naturforschenden Gesellschaft in Basel 82: 165–192.*

Wojcik J.M., Borodin P.M., Fedyk S., Fredga K., Hausser J., Mishta A., Orlov V.N., Searle J.B., Volobouev V. & Zima J. 2003: The list of the chromosome races of the common shrew *Sorex araneus* (updated 2002). *Mammalia 67: 169–178.*

Wyttenbach A., Borodin P. & Hausser J. 1998: Meiotic drive favors Robertsonian metacentric chromosomes in the common shrew (*Sorex araneus*, Insectivora, Mammalia). *Cytogenet. Cell Genet. 83: 199–206.*