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CONSERVATION OF RODENTS *EX SITU*: EXPERIENCE OF KEEPING THE NORTHERN MOLE VOLE (*ELLOBIUS TALPINUS*) IN CAPTIVITY

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Key words

northern mole vole, *Ellobius talpinus*, conservation ex situ, captivity

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Abstract

The article presents data on the biology of *Ellobius talpinus* kept in captivity. The creation of semi-underground conditions in a terrarium and long-term observations of a group of mole voles during 2003–2014 are described. The course of the life cycle of these animals in the terrarium is presented: daily and seasonal activity, burrowing activity, diet and food preferences, and reproduction. It has been revealed that captive mole voles change their daily activity on the surface from crepuscular to diel or even diurnal, which is related to the absence of disturbance factors or sudden changes in temperature and light. Seasonal activity in captivity is not pronounced, and is represented by two cases of reproduction that occurred in the summer months. The burrowing activity is extremely high; mole voles burrow or clean their passages daily and often with every activity, without any particular need, demonstrating a stereotypical form of behaviour. Social behaviour, specifics of communication between individuals, and vocalisation are described. It has been noted that mole voles are characterised by high communication activity, both tactile between adults and when exploring the environment. Cases of special high-frequency vocalisation such as 'grinding' directed not towards another individual, but to the corners of the terrarium, where the mole voles were searching for the possibility of making passages, were repeatedly observed and recorded on video. The following aspects of behaviour were also analysed: reaction to the observer, new conditions, and disturbances, as well as features of group behaviour, including aggression, joint rest, and feeding. Mole voles consumed food both where it was placed and in their chambers, but most often they attempted to make stocks in the chambers. They preferred roots and bulbs of cultivated plants. The experience of forming breeding pairs was gained, which allowed us to study the course of pregnancy and the development and growth of the neonates and young. The appearance and condition of neonates are described along with the presence of teeth, the time when the eyes open, the process of feeding and weaning, growth and weight gain, the ability to move and burrow, and features of parental care. The experience gained demonstrates both the possibility of introduction of the species and the formation of reserve groups to restore lost natural populations.

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Збереження гризунів *ex situ*: досвід утримання сліпачка (*Ellobius talpinus*) у неволі

Марина Коробченко

Резюме. Представлено дані про утримання і особливості біології *Ellobius talpinus* в умовах неволі. Описано створення умов напівпідземного середовища у тераріумі та довготривалі спостереження протягом 2003–2014 років за групою сліпачків. Наведено перебіг життєвого циклу тварин в умовах тераріуму: добову і сезонну активність, рийну діяльність, харчування, харчові переваги, розмноження. Показано, що в умовах неволі сліпачки змінюють свою добову активність на поверхні з сутінкової на цілодобову і навіть денну, що пов'язано з відсутністю факторів непокою чи різких перепадів температури і освітлення. Сезонна активність в умовах неволі не виразна, представлена двома фактами розмноження, які відбулися у літні місяці. Рийна діяльність є надзвичайно високою, сліпачки рили або чистили ходи щодня і часто при кожній активності, без особливої потреби, демонструючи стереотипну форму поведінки. Описано соціальну поведінку, особливості комунікації між особинами, звукову вокалізацію. Відмічено, що для сліпачків характерна висока комунікаційна активність, як тактильна при контактах дорослих особин між собою так і при освоєнні навколишнього простору. Багаторазово відмічено і зафіксовано на відео випадки особливої високочастотної вокалізації типу «скреготання», спрямованої не в сторону іншої особини, а в кутки тераріуму, де сліпачки шукали можливість прокладки ходів. Проаналізовано також такі аспекти поведінки: реакція на спостерігача, нові умови, турбування і особливості групової поведінки, включаючи прояви агресії, спільний відпочинок, поїдання кормів. Сліпачки поїдали їжу як на місці викладки, так і в коморах, але найчастіше в коморах були спроби створення запасів. Вони надавали перевагу коренеплодам та цибулинам культурних рослин. Отримано досвід утворення репродуктивних пар, завдяки чому досліджено перебіг вагітності, особливості розвитку й росту новонароджених і молодих. Описано вигляд та стан новонароджених особин, наявність зубів, час до відкриття очей, процес вигодовування та відлучення від грудей, ріст та набір ваги, здатність до пересування та рийної діяльності, прояви турботи про нащадків. Отриманий досвід свідчить як про можливість введення виду в культуру, як і формування резервних груп для відновлення втрачених природних популяцій.

Ключові слова: підземні гризуни, *Ellobius talpinus*, збереження ex situ, життєвий цикл.

Introduction

In the protection, conservation, and restoration of natural populations of rare and endangered animal species, programmes and initiatives aiming to create reserve populations *ex situ* have a key importance [Golenko *et al.* 2008]. The first step in creating such populations is to form particular artificial groups, which requires certain experience in the keeping of animals for a long time under artificial conditions. The next stage is breeding and subsequent release of the animals into the wild. These tasks have been a key component in the work of zoos and vivaria, and are one of the seven main stipulations in the materials of the Red Data Book of Ukraine (RDBU) [Akimov, 2009], formulated as reproduction and breeding under artificial conditions.

In recent years, research has focused on scientifically sound management of controlled populations (those being conserved), which should guarantee their 'success' in the sense that they are stable in the conservation of genetic diversity and in the reduction of inbreeding. For the past forty years, the concentration of irreplaceably threatened animal populations in zoos has aimed at their conservation and minimisation of genetic decline during a long period, and considerable success has been achieved in management technologies of closed populations. Research, however, revealed that not all conservation programmes of closed and artificial animal populations kept in zoos can ensure achieving the 'stability' of these populations. It was found that, at present, most captive populations (in zoos and aquariums) do not conform to the stipulated 'viability criteria' that would ensure their long-term biological viability [Putnam *et al.* 2023].

To achieve such stability, it is necessary to develop methods of management optimisation of isolated populations with the inclusion of part of the metapopulation and a carefully thought out

exchange between populations along the entire spectrum from *ex situ* to *in situ*. The management of zoo populations as components of a complex species conservation strategy would require to study the specifics of genetic, physiological, behavioural, and morphological variations and their role in the viability of a given population, as well as to develop a number of methods and instruments to assess impact on population viability, both captive and those released into the wild [Lacy 2012; Putnam *et al.* 2023].

Despite the fact that yet more research is needed into scientifically sound management of captive populations in order to achieve their stability and long-term viability after they are released into the wild, conservation in captivity is important at the current stage and it contributes to the conservation of species of first priority for a longer period compared to what could be provided otherwise. Unfortunately, in most cases, as shown by the analysis of RDBU, species accounts include information on the absence of experience in keeping animals in captivity or that 'keeping the species in captivity is not difficult, but no experience in long-term keeping and, particularly, breeding.'

The northern mole vole, *Ellobius talpinus*, is no exception. This rodent species is highly adapted to the subterranean environment while actively using the terrestrial habitat as well. The northern mole vole is listed in the third edition of RDBU (2009) and remains one of the least studied mammal species of the Ukrainian fauna. Only a few special works have been published on the biological features of this species within the Ukrainian part of its geographic range [Zubko 1940; Sakhno 1971, 1978; Korobchenko 2008; Korobchenko *et al.* 2014 and others].

In regard to keeping northern mole voles in captivity, experience is limited by I. Sakhno's publications [Sakhno 1971, 1978][1], which mainly focus on the species composition of plants in the diet of the northern mole vole and on its food selectivity, as well as the publication by M. Moshkin and colleagues [Moshkin *et al.* 2007], who presented study results on physiological features of mole voles as adaptations to the subterranean ecotope (metabolism intensity, hormonal balance and immune state, and energetic costs of foraging, thermoregulation, and reproduction). The timeliness of such research is also related to the fact that in both Ukraine and other countries the interest and resources are usually focused on the conservation, protection, and breeding of captive populations of large- and medium-sized mammals, whereas small mammals (including rodents) are being generally neglected in this respect, although a large number of studies is devoted to this very group. The restoration of populations of steppe rodents has become especially relevant in the light of the devastating impact of military actions taking place on a large part of the range of *Ellobius talpinus.*

Programmes have already been developed on keeping and breeding small mammals, such as hamster, in captivity with their subsequent release into the wild in order to restore their extinct or declining populations [Stanytsina & Zagorodniuk 2021]. Principles of keeping small mammals in zoos have also been considered, which is effective for both species conservation and expansion of living zoological exhibitions [Gippoliti & Amori 2007].

Materials and Methods

Localities and numbers of the collected material. The author has gained experience in keeping *Ellobius talpinus* in captivity with a particular focus on creating artificial living conditions, methods of care, feeding, and observation of the animals. Observation data on the reproduction of mole voles in captivity have been collected. Information on the biology and life activities of vole moles kept in a terrarium for a long period is generalised. Such data have been collected in 2003–2013, during which mole voles were extracted from the Donets population (Luhansk Oblast, Ukraine).

The animals were trapped in two localities:

(1) nearby to the Novo-Illienko biological station, near the local railway station and in the Shariv Kut tract; (2) nearby to the Trokhizbenskyi Steppe Reserve, including two distant localities—Staryi Aidar and the outskirts of Kriakivka, Shchastia Raion.

[1] The author is also aware of the publication by D. Smirnov [Smirnov 1922] on this species with a description of the specifics of keeping mole voles from Murgap (Turkmenistan) in captivity in a glass terrarium, including feeding, behaviour, and communication.

Experimental groups and types of observation. Research into the biology of captive mole voles has been carried out since 2007 according to previous experience shared by and gained together with colleagues, particularly O. Kondratenko in 2003–2004 and I. Zagorodniuk in 2004–2014 [Korobchenko 2008; Korobchenko & Zagorodniuk 2008]. The obtained data were fully considered in further studies of the biology of captive mole voles. Systematic observations for a period of 16 months were carried out on a group of three mole voles (two males and one female), which were caught in June 2009 near Staryi Aidar, Stanytsia-Luhanska Raion, Luhansk Oblast, Ukraine.

This first group had an unsuccessful attempt of breeding in the spring of 2011 (the female could not give birth and died in the process of parturition). Thereafter, the experimental conditions were entangled: the second group of mole voles (three individuals), originating from Staryi Aidar and the Novo-Illienko station, was placed in a spacious terrarium in order to monitor their life activities. These very individuals reproduced a year after being kept, which allowed monitoring the growth and development of the young. In this terrarium, mole voles were kept under practically wild conditions. They were not tamed and therefore we could obtain data on their biology in a state close to natural. For a year, on the example of this family group, we studied the specifics of biology, life activities, and individual features of captive mole voles. Such aspects were considered as diel activity, burrowing activity in an artificial subterranean environment, locomotor activity, building of shelters and reaction to artificial shelters, vocal communication, reaction to the observer, behaviour under new conditions and when disturbed, group behaviour, feeding volume and food selectivity, reproduction and parental care, and specifics of growth and development.

Keeping conditions. A methodology was developed to create the conditions of subterranean environment in a terrarium. For this purpose, we used a glass terrarium with a basis size of 50x100 cm and a height of 30 cm. The terrarium was covered by stripes of organic glass to prevent the animals from escaping. In addition, small terrariums of the same height or litre jars with punctured caps or metal medical boxes with side openings were used for temporary storage of animals during the cleaning of the terrarium or other manipulations. However, given the size of the main terrarium, cleaning with a change of the substrate could be carried out even without displacing the animals.

When arranging the environment in the terrarium various substrates were used, such as sawdust, hay, and wood. Soil was not used in the terrariums, but a volume of about five litres of sand was put in a corner in the warm period of the year, in which the mole voles preferred to burrow. It is important to note that mole voles have a low rate of water metabolism and almost no odour is accumulated, meaning that the substrate requires changing no more than once a week. Each substrate change included the renewal of a volume of about 15 litres with the addition of hey and sawdust that are used by the mole voles to arrange their nests, most often near driftwood. Additionally, driftwood was used to provide means for wearing down teeth, which mole voles were doing regularly.

Food was placed on the surface, in the corner, and the mole voles either started to eat on the surface or dragged the food into the substrate. Drinking bowls were not used, instead wet juicy feed such as carrot and potato was given.

In a terrarium of the above size (with an area of 0.5 m^2), up to five adult mole voles caught at the same locality could be kept simultaneously, or a pair of adults with two or three of their own young already born in captivity. In our case, such a terrarium was inhabited by three adults and two juveniles. This space was clearly sufficient for them as evidenced by their active nest building and burrowing behaviour as well as their successful breeding.

Particular features of burrowing activity related to feeding should be noted. For instance, mole voles regularly moved the given food (cut vegetables and fruits) into chaotically chosen hiding places in different part of the terrarium, and such stocks were buried (in our case covered with substrate materials). These stocks were never large. Additionally, in one of the corners of the terrarium mole voles arranged a toiled under the substrate. These mole vole toilets are characterised with no scent, which, in our opinion, is related to the practically total absence of animal food in their diet and very small amount of urine. Owing to the latter, there was no need to change the substrate very often.

Diel, seasonal, and locomotor activity

Diel activity

Changes in the diel activity of captive mole voles were monitored during the entire period of their keeping. In the wild, we have repeatedly observed the burrowing activity of mole voles in the morning and during daytime (noon and afternoon), including digging holes and pushing out soil onto the surface, during which the animals almost entirely exited the burrows. In captivity, mole voles were kept in terrariums with a layer of sand on the bottom. Changes in their diel activity were recorded hourly for two weeks, and a number of features were revealed.

In particular, it was found that atmospheric conditions have an impact on the diel activity of mole voles. For example, when it is raining and several hours before (regardless of the time of the day) activity stops and the animals sleep in their 'nests'. Also there is almost no activity observed in periods between 7:00 and 10:00 and 14:00 and 17:00, but in the night (around 1:00) the activity of mole voles clearly increases and can last until the morning: the mole voles actively burrow, run, feed, and vocalise. This is in line with activity displayed in the wild. In particular, we have repeatedly observed the appearance of many fresh molehills in the dawn on the day following the start of the observation, which may indicate that active burrowing takes place in the night. It was also noted by I. Sakhno [Sakhno 1971], who reported that mole voles exit to the surface in the night to feed on aboveground parts of plants and he observed the animals on the surface late in the evening, after sunset.

When observing the captive animals, it was found that mole voles are active on the surface round-the-clock, which is different from what they demonstrate in the wild. It is related to the absence of factors of disturbance and abrupt changes in temperature and light. In the nature, according to many observations, aboveground activity is more common in the dusk–night period.

Seasonal activity

Changes in the seasonal activity of captive mole voles were not observed, and the animals displayed the same level of burrowing and aboveground activity, cleaning, nest arrangement, and food storage all-year-round. Seasonality was noted only in the reproduction of mole voles, which occurred twice (detailed further) in the summer period.

In captivity, mole voles preferred to arrange 'underground' nests, from which they continuously emerged onto the surface, and rarely changed the location of their 'nests' though occasionally it happened. There were no patterns in it whatsoever, neither seasonal nor those related to other factors. However, in the summer, mole voles often displayed not only aboveground activity, but they also arranged lairs directly on the surface of the substrate. It can be explained by two factors: the absence of predators and disturbance in general, and high temperatures. Although the subterranean environment provides considerably lower temperatures compared to the surface, in captivity and under conditions of artificial substrate (sawdust), which has a notable thermal insulation effect aggravated by the placement of the terrarium in an equally warm room (in Luhansk, indoor temperature in the summer months is about 30 degrees), the animals took advantage of the opportunity to cool on the surface of the substrate in the absence of disturbance effects.

It demonstrates that mole voles are able to easily change the placement of their nesting chamber or even switching to arrange aboveground nests. We can suggest that mole voles can also utilise this form of thermal regulation in the wild, arranging their nesting chambers both deep underground and on the surface.

Burrowing and locomotor activity

Mole voles demonstrate an exceptionally high locomotor and burrowing activity. When not sleeping or feeding, they were constantly busy with arranging their nesting chambers, burrowing tunnels in the substrate, moving the sawdust, sand or the hay they chopped, which were clear signs of constant burrowing activity and cleaning their tunnels. It was similar to a stereotypical form of behaviour rather than necessity. Examples of locomotor activity of mole voles are shown in Fig. 1.

Fig. 1. Adult mole voles (*Ellobius talpinus*) in the terrarium where they lived and bred successfully for more than seven years. The bedding layer of sawdust, shavings and hay varied from 5–10 to 15–20 cm at different times of the year; in summer it was minimal, and mole voles often slept on the surface, in depressions they had made. Important elements are various kinds of driftwood and stones; nests were often built near them, and, at the same time, they were constantly used by the mole voles to wear down their teeth. In summer, sand was often used as a substrate, but shavings are also important for nest construction. Photo by the author, I. Zagorodniuk, and V. Foroshchuk.

Рис. 1. Дорослі сліпачки (*Ellobius talpinus*) в умовах тераріуму, в якому вони жили і успішно розмножувалися упродовж понад 7 років. Шар підстилки з тирси, стружки і сіна в різну пору року змінювали від 5–10 до 15–20 см, влітку він був мінімальним, і сліпачки часто спали на поверхні, у облаштованих ними лунках. Важливими елементами є різного роду коряги і каміння — біля них часто були влаштовані гнізда і одночасно все це вони неперервно пробують гризти. Влітку в якості субстрату часто використовували пісок, проте стружка також важлива для облаштування гнізд. Фото автора, І. Загороднюка і В. Форощука.

Mole voles run quickly, both forward and backward. They use their incisors for burrowing, push the substrate through the tunnels by their chest and then push it out first by their front legs, then turn around and use their hind legs, making wide semi-circular moves to push the sand out from the tunnel (this is why their mounds have a typical semi-lunar shape [Korobchenko & Zagorodniuk 2008]). In the fresh sand poured into the terrarium they start to make a tunnel, running forward and backward up to the walls of the container, tilting their head and pushing the sand with the head and front legs, then they start burrowing actively with their front legs.

Mole voles always run on their outstretched limbs, without bending down. It may be related to the fact that in the underground tunnels mole voles use their whiskers and the sensibility of their fur due to the vertical position of guard hairs as one of their adaptations to spatial orientation.

Captive mole voles tended to burrow tunnels and make mounds along the walls of the terrarium and before burrowing holes under various objects (driftwood, stone). All this indicate the desire of subterranean animals to feel a closed space. When they are in a terrarium filled with little substrate material, they feel uncomfortable and in a state of rest they hide their heads in the substrate or under themselves, exposing only their backs. This is a notable difference between mole voles and other rodents the author used to keep (*Phodopus*, *Meriones*, *Micromys*, *Dryomys*, and *Microtus*).

In captivity, mole voles always tend to build their nests in one of the corners of the terrarium or near driftwood, in one of its curves (in summer, on the surface of the substrate). To arrange the nest mole voles accumulate various materials: pieces of fabric, paper, hay, and sawdust, in which they burry themselves. They feel uncomfortable when the nests are not covered. When damage the tunnels created in the substrate, mole voles immediately start to repair them.

Noteworthy is the unique capability of mole voles to turn around in the narrow tunnels. In addition to the abovementioned capability to move quickly forward and backward within a single narrow tunnel, they are able to turn around on the spot, demonstrating extraordinary gymnastic skills based on the flexibility of their body unknown of any other group of mammals. In particular, when falling into spiral traps (types of Popov-Falkenstein trap: [Novikov 1949; Korobchenko 2018]) mole voles are able to turn around on the spot basically folding in half. In a tunnel with a diameter of 35 mm, a mole vole that seems to barely fit with its body dimensions in the trap, very quickly, in 2–3 seconds, turned its head along the body and then smoothly, with barely noticeable jerks, scrolled with the front part of his body in the direction of its tail, similarly to as reptiles do, almost without helping itself with its paws. Young mole voles, for which this tunnel was more spacious, moved the same way very quickly, almost unnoticeably for the observer, turning instantly in the opposite direction.

This feature allows the mole voles to escape from the trap very easily and not having to move backward, which indicates the high physical plasticity of these animals, which should be considered in the process of their trapping. The same we observed when relocating the mole voles using a narrow cylinder (small PET bottle with a cut bottom). The ability to turn around on the spot is a clear adaptation of mole voles to living in a system of underground tunnels. In particular, it is important in the burrowing of new tunnels without having to make chambers for turning around. At the same time, mole voles often push the soil out of the tunnels moving backward.

Communication and group behaviour

Vocal communication

While observing the captive mole voles, we have noted various demonstrations of social behaviour and communication between the individuals via both tactile interaction and vocalisation. Vocal communication is a particular feature of mole voles [Korobchenko *et al*. 2010: Table 4]. The group of captive mole voles was characterised by a high communication activity both between family members and with the surrounding environment in the process of space exploration. A special type of ‘grinding’ vocalisation was observed and recorded on video multiple times, which was directed not toward other mole voles but the corner of the terrarium where they were probably looking for the possibility of burrowing tunnels. We can suggest that such sound is used by the mole voles for the

exploration of remote space of substrate layers similarly to the principles of ground-penetrating radar, which usually operates at high frequencies. There is literature data about the possible use of ultrasound by mole voles [Volodin *et al.* 2022]. We consider that this type of vocalisation could be used by the animals in searching for cavities or kin.

Mole voles make specific sound when burrowing, such as 'cooing' and 'creaking', which is often related to changes in the living space of the terrarium, when pouring a new layer of sand. 'Creaking' is continuous (ca. 10 sec), when the mole vole rises its head, bares its teeth and slightly opens its mouth turning to the observer or other mole voles. They make other types of sound when burrowing. The mole vole starts burrowing actively with its front legs, for about 20 seconds, then stops, tilts its head and starts 'cooing', always in the direction of the burrowing. 'Cooing' is observed only when burrowing and thus this feature might be a tool of echolocation for analysing the quality of the underground cavity and an important adaptation to living in the subterranean environment. 'Cooing' takes place more often than 'creaking' during the day, and can be directed toward the observer or another mole vole. These sounds were produced by all three individuals when one of the males reacted aggressively to the attempt of picking him up by making a 'hissing' sound. Almost during the entire day, when resting in the 'nest', locomotor and burrowing activity, mole voles squeak and 'coo' quietly to one another. Vocal communication changed with time and new sounds appeared, particularly a loader 'cooing' as a reaction to the observer, especially before feeding.

Noteworthy is that mole voles also made other kinds of sound, particularly when interacting with the young, which to various tactile contacts responded with 'squeaking' sound.

Many publications have appeared recently with results of research into the vocal communication of subterranean rodents (such as *Spalax ehrenbergi*, tuco-tucos, and mole-rats), but the vocal communication of mole voles has not been studied. In a review [Schleich *et al.* 2007] devoted to the latest research results of communication of subterranean rodents, it was showed that vocal communication is an important adaptation to the subterranean environment and plays a key role in the general organisation of social animals. They use vocal signals according to certain behavioural mechanisms accompanying intraspecific and interpersonal contacts to demonstrate their status (reproductive, dominancy, or territorial) and as protection from predators. On interspecific level, vocal signals play an important role in reproductive isolation and speciation processes, and explain general principles in the evolution of subterranean mammals. As it was revealed in a number of research [Morton 1977; Heffner & Heffner 1992; Rado *et al.* 1998; Schleich *et al.* 2006], the specifics of vocalisation of subterranean rodents depend on the level of social organisation; the integration of individuals into groups, the support of the group's integrity, and the regulation of group activity lead to the development of the necessary signalling systems. Solitary species of subterranean rodents (*Ctenomys pearsoni, C. talarum, Spalax ehrenbergi*, and *Heliophobius argenteocinereus*) have a less diverse vocal repertoire and they have demonstrated fewer types of situation-related sounds compared to social species (*Heterocephalus glaber, Fukomys anselli,* and *F. mechowii*), the vocal repertoire of which is 3–4 times larger [Schleich *et al.* 2007]. According to our observation, the vocal repertoire of mole voles includes about 10 different sounds. Some authors [Heth *et al.* 1988; Schleich *et al.* 2007] noted that solitary species of subterranean rodents demonstrated mainly 'protective', 'attractive', or 'suffering' vocalisation, depending on the level of their social activity and in order to defend their home range, attract a mating partner, and exclude close intraspecific contacts. However, the significance of the diversity of vocal repertoire, and the impact of morpho-physiological and behavioural factors on the vocalisation of subterranean rodents remain poorly studied.

Reaction to the observer

When being trapped, mole voles demonstrate an aggressive behaviour, but in captivity they can be tamed if regularly take them in hand. Tamed mole voles are not aggressive nor reluctant. When kept with minimum disturbance, mole voles remain 'wild' in captivity and such mole voles cannot be manipulated with hand and they take a 'defensive' stance when it is attempted even with the greatest care—they open their mouth and bare their incisors, retreating into a corner and facing the observer.

During the entire period the mole voles were being kept, aggression could arose between individuals, as a result of which one of the males attempted to jump out of the terrarium. At the same time, when standing and jumping on the hind legs, the animal maintained a stable stance indicating that mole voles in the wild are able to escape from shallow rivulets and obstacles provided they can find something to grip with their front legs. When kept in groups, mole voles remain aggressive toward humans but when kept in solitude they are easily tamed and can be handled.

Our observations indicate that mole voles are able to see the observer at a distance of about 0.5 metres. We have regularly noted that mole voles do not react to the presence of humans in the same room, and they had demonstrated disturbance or interest (escaped, froze, or turned) only when the observers approached the terrarium. Similarly, the mole voles practically did not react to cameras, although they always reacted to sudden movements. This supports the idea that many subterranean rodents retain an active visual system, susceptible on at least close distances [Němec *et al.* 2007], which is an important adaptation to being on the surface, even for a short time, in the process of foraging, burrowing, and dispersal. We have regularly observed not only in captivity, but also in the wild that after pushing the next portion of soil out of the burrow, mole voles look out from it, extending at least half the body to inspect the surroundings. It could explain the more intense pigmentation of the head pelage. In most cases, it is a highly common feature [e.g. Artemieva 2022], although absent in mole voles from the Derkul population, which live on light, sandy substrates.

Behaviour under new conditions and during disturbance

When put in another terrarium with a layer of sand, mole voles demonstrate a high activity for a quite long period, constantly burrowing in the sand accompanied with a characteristic vocalisation. When disturbed, they retreat to a corner and bare their incisors.

Taming can be considered as a special form of disturbance. If do not pick up the mole voles regularly, they remain ‘wild’ and can bite hard when trying to take them in hand. However, together with the abovementioned colleagues, we have gained a fairly good experience of taming mole voles, particularly juveniles (Fig. 2). Mole voles get quickly used to constant contacts and demonstrate no aggression whatsoever when touched or picked up; they just move in the palms crawling between the fingers. Even if there are attempts to bite, those are rather related to the exploration of the surrounding space.

Group behaviour

From the beginning of being kept in captivity, aggressive behaviour was quite unusual during the first month; aggression between individuals was noticed only a couple of times, which manifested regardless of sex and during the distribution of food. An explicit dominance of any individual was not noted either; aggression was demonstrated by each mole vole, during which they were cooing loudly and gripped each other with their teeth by the sides and head, while the one attacked was making ‘pitiful’ whining-like sounds and ran into a corner. At this, the aggression stopped without further persecution. Moshkin *et al.* [1991] also did not note aggressive behaviour in males recently put together under laboratory conditions, although after six months they started to show aggression.

In our case, competition and aggression were not recorded among the captive mole voles, neither between males nor females. Adults also did not show aggression toward the young; on the contrary, all adult members of the family displayed parental care. When juveniles were left by their mother, they started to make pitiful sounds to which another adult individual responded with coming to them, keeping them warm and guarding them. The mother returning did not show aggression toward the ‘babysitter’ and did not drive this family member away.

During the observations it was noted that in the state of rest mole voles sleep tilting the head to their front legs, and pressing themselves to and climbing on top of each other. Such behaviour is characteristic for social subterranean rodents and it ensures thermoregulation under conditions of the subterranean ecotope [Burda *et al.* 2007]. Mole voles always arrange a toilet in one half of the terrarium, visiting it regularly. They never leave excrements at their places of rest.

Fig. 2. Adult mole voles in captivity can be tamed: they are easy to handle and quickly get used to hands, do not show any aggression, do not try to run away and pose well for the camera, being busy not so much with human attention as with their own business (to go somewhere, gnaw something, etc.). Animals kept without being picked up are more wary and try to snap, but they can be picked up as well when putting the hand under their body or when picking them up by the skin. Photos from different years: top row—by R. Kish (2005), middle row—by M. Kolesnikov (2009), bottom row—by the author (2012).

Рис. 2. Дорослі сліпачки в умовах неволі як об'єкти приручення: вони легко йдуть до рук і швидко звикають до рук, не проявляючи жодної агресії, не намагаються тікати і добре позують перед фотокамерою, зайняті не так увагою до них з боку людини, як власними справами (намірами кудись прямувати, щось гризти абощо). Тварини, яких утримують без взяття на руки, є більш сторожкими і намагаються огризатися, проте і їх можна брати на руки, якщо підводити руку під їхнє тіло або якщо брати їх «за шкірки». Фото різних років: верхній ряд — Р. Кіша (2005), середній ряд — М. Колеснікова (2009), нижній ряд — автора (2012).

Feeding

Feeding specifics were determined by the fact that mole voles consumed the food both where it was placed and in their chambers, although the food in the chambers most often has remained untouched. The basis of their diet included root vegetables and bulbs of cultivated plants. They did not consume food of animal origin, and showed no interest to it when it was given (e.g. mealworms). A specific feeding spot was not arranged because mole voles were burrowing continuously in the entire space of the terrarium and would have buried any specific feeder anyways. Therefore, the food was placed in a corner of the terrarium, onto the substrate.

Feeding volumes and preferences

Captive mole voles were fed once or twice a day with pieces of carrot, potato, sunroot, radish, marrow, beet, and aboveground parts of plants, which were placed directly in the terrarium (Fig. 3). The feeding of mole voles was observed daily; the food given was weighted, as well as the leftovers on the following day.

The animals usually consumed the same volume of food—a group of 2–3 individuals devoured about 60–100 grams of food daily, that is, nearly 70% of their own weight.

Of the proposed food mole voles always preferred carrot and potato; the roots were usually given to them cut in half. The freshly cut food attracted them to the 'table' and allowed for gnawing on it more easily along the cut edges. The preferred types of food also included apples, although they were most often stocked by the mole voles in their fodder chambers.

In the wild, mole voles prefer plants with a well-developed root system and bulbs that contain a larger amount of nutriments and water. In addition to underground parts, mole voles also consume stems and leaves, although in lesser volumes [Sakhno 1975].

Stocking and consumption

Mole voles feed at the place where the food is laid out as often as in their chambers, which could be related to the safety of their lives in captivity. The consuming of food where it was placed is more common in unusual situations, for example, when the animals were temporary kept in smaller tanks, when they were placed in a new environment for photographing, or when they got hungry.

Usually, mole voles took the food to the nest part of the terrarium holding it with their teeth, and then started to eat holding it with their front legs. A characteristic feature was that before starting to eat and while holding the food with their front legs, mole voles were making purring-like sounds for about 10–15 seconds. We do not have an explanation for this strange ritual; it might be related to their sociability and informing other members of the family group about the availability of food. Young mole voles started to make food stocks in the age of 2.5–3.0 months.

Water, chalk, and gnawing

Mole voles did not drink water. Presumably, they had enough water contained in the juicy plant fodder. The observations made by I. Sakhno [Sakhno 1971, 1975] also confirm the absence of need for additional water. Obviously, it is an adaptation to living in the steppe.

Captive mole voles gnawed chalk almost every day. It was important to give them large pieces of chalk—slabs from dense natural deposits. Mole voles did not like the soft blackboard chalk used in the classroom—it was more essential for them to gnaw the chalk and not eat it, although both gnawing and eating chalk were obviously important. Hard chalk was available in the terrarium not periodically but continuously.

The constant need for gnawing is related to the quick growth of teeth (incisors). One time when the animals were removed from the terrarium, one individual broke the tip of one of its upper incisors (about 3 mm), which in ten days has fully regrown and aligned with the other incisor. That is, the growing velocity of incisors is about 9 mm per month. Obviously, in captivity, when burrowing is limited and chalk and driftwood is absent for wearing the teeth down, mole voles may suffer from the excessive growth of incisors.

Fig. 3. Adult mole voles with carrots. The animals manipulate their food well by holding it with their front legs and move their jaws freely, as other species of voles cannot do. A piece of chalk is also part of their diet, and this issue was constantly solved due to the fact that the university often supplied large natural pieces of chalk for the classrooms instead of blackboard chalk, which was very pleasing to both the mole voles and us researchers. Animals in an active state, if not busy burrowing, are constantly gnawing something (driftwood, chalk, stone, corners of the terrarium), which helps them to wear down their teeth. Photo by V. Foroshchuk.

Рис. 3. Дорослі сліпачки з морквою. Тварини добре маніпулюють поживою, тримаючи її передніми лапками, та вільно рухають щелепами, як ще не можуть робити інші види полівок. Шматок крейди також є частиною їх поживи, і це питання постійно вирішувалося завдяки тому, що в університет часто поставляли для аудиторій не штучну фасовану у формі брусочків крейду, а великі природні шматки, що дуже тішило і сліпачків, і нас як дослідників. Тварини в активному стані, якщо не зайняті риттям, то постійно щось гризуть (корягу, крейду, камінь, кутки тераріуму), що допомагає їм сточувати зуби. Фото В. Форощука.

Reproduction and growth

Data on pregnancy and fertility rate

Experience was gained in breeding mole voles in captivity. Obvious patterns of mating behaviour or mating competition between males were not observed. The mating behaviour manifested itself only by a change in vocal communication when in the evening and night mole voles were making new, purring-like sounds.

Pregnancy lasted a month and two offspring were born. At a low fertility rate, a high level of parental care was noted. Parturition took place in the 'nest' arranged by the female in the substrate using hay as lining. After giving birth, females were actively mating with the males for two days, the most actively on the first day. Mole voles, similarly to other voles, are characterised by post-partum oestrus, but lactation and nursing are usually not compatible with a second pregnancy [Smorkatcheva *et al.* 2016]. For comparison, there is data on the pregnancy and fertility rates of mole voles in natural populations from the Azov region [Zubko & Ostriakov 1961]. According to these results, mole voles under favourable conditions are able to reproduce all-year-round, including winter. They reach sexual maturity in the age of 90 days and older (i.e. three months and older). The average duration of pregnancy is 26 days[2], and even nursing females can become pregnant on the 9–10 day after parturition. According to the same source, litter size in the wild reaches an average of 3.3–3.8 neonates per pregnant female, with a typical range of 2–4 offspring per female (lim = 1…5). Captive females delivered a minimum number of offspring (two neonates twice) relative to the data on breeding in the wild.

On the growth and behaviour of the young

Neonates are blind and their pink body is covered with short and light-coloured vellus hair, with barely noticeable patches of darker shade. There are tenacious, thin claws on the fingers, barely noticeable teeth in the mouth, and beginnings of vibrissae on the snout. Their incisors are thin and more spread out laterally than in the adults, which might be convenient for grabbing the mother's nipples. The weight of neonates was 3–4 grams. Lactation lasted for 30–40 days. The rate of weight gain of neonates was about 0.5–0.7 grams per day, and at the age of one and a half months they had a weight of about 18–20 grams, that is, 40% of the weight of the mother. The weight of captive mole voles is higher than of those in the wild. Females weight slightly more than males.

Neonates could already crawl after the first week, and had a special form of locomotion—they fixed the front leg on the substrate and made circular movements around it (see Fig. 4). This could be seen as an adaptation to not walking in the burrow far from the nest in search of the mother (or the nest itself). When trying to stand on their limbs, the neonates could not hold their head and rolled over it or fell on their side. This is obviously related both to the relatively large size of the head and weak limbs, and perhaps it is part of the mentioned adaptation to stay close to the nest.

By the fourteenth day the pelage of young mole voles becomes denser, but the fur on the ventral side of the body remains sparse; the claws, teeth, and vibrissae at this age become notably larger. They could already stand on their limbs, but their movements were still chaotic. By the end of the third week post-partum, the newborn mole voles could already move linearly, but sometimes they still fell on their sides and rolled over to their backs.

The young mole voles opened their eyes on the 25–27 day, and from the 25th day they could feed independently and gnaw soft vegetables. The transition to independent feeding was accompanied with nursing by the female, and they were completely weaned from the mother's milk within a week. Young mole voles reached adult size within three months, and at this age their fur cover was distinguished by a more pronounced dark colouration. Similar key developmental stages with similar durations were reported earlier for populations from the Azov region [Sakhno & Ostriakov 1961] and Western Siberia [Novikov *et al.* 2015].

[2] This figure can be inferred from the cited work if consider that the period between two parturitions is 34–36 days, and a second pregnancy can occur on the 8–10 day after giving birth to the previous offspring.

Life expectancy

The subterranean environment provides protection from outer threats and contributes to the effect of natural selection in the favour of longevity in subterranean animals, including subterranean rodents. A maximum longevity of 30 years and older is common for social rodents of the family Bathyergidae (naked mole-rat, *Heterocephalus glaber*), whereas 20 years is common for species of the genera *Fukomys* and *Cryptomys* [Dammann & Burda 2007].

Longevity is also common for mole voles (*Ellobius talpinus*) and literature data provide a life expectancy of 5–6 years for female mole voles, but fertile females, including captive ones, live much longer compared to non-breeding females [Novikov *et al.* 2015]. In our study, the lifespan of mole voles was about eight years.

It was discovered that non-breeding females of subterranean rodents have a higher concentration of glucocorticoids, which indicates a higher level of stress that can lead to a lower life expectancy in individuals not taking part in reproduction. In the wild, it is usually only one female in the mole vole family that reproduces. However, it was noted that two captive females reproduced simultaneously [Novikov *et al.* 2015]. In our case, the first female started to reproduce after two years of being kept in captivity, while the second one after a year of being removed from the nature. That is, in both cases, the entire reproductive cycle took place in captivity (unlike the cases when the trapped females are already pregnant). Mole voles of two generations could co-exist peacefully in a single terrarium even after the offspring reached adulthood.

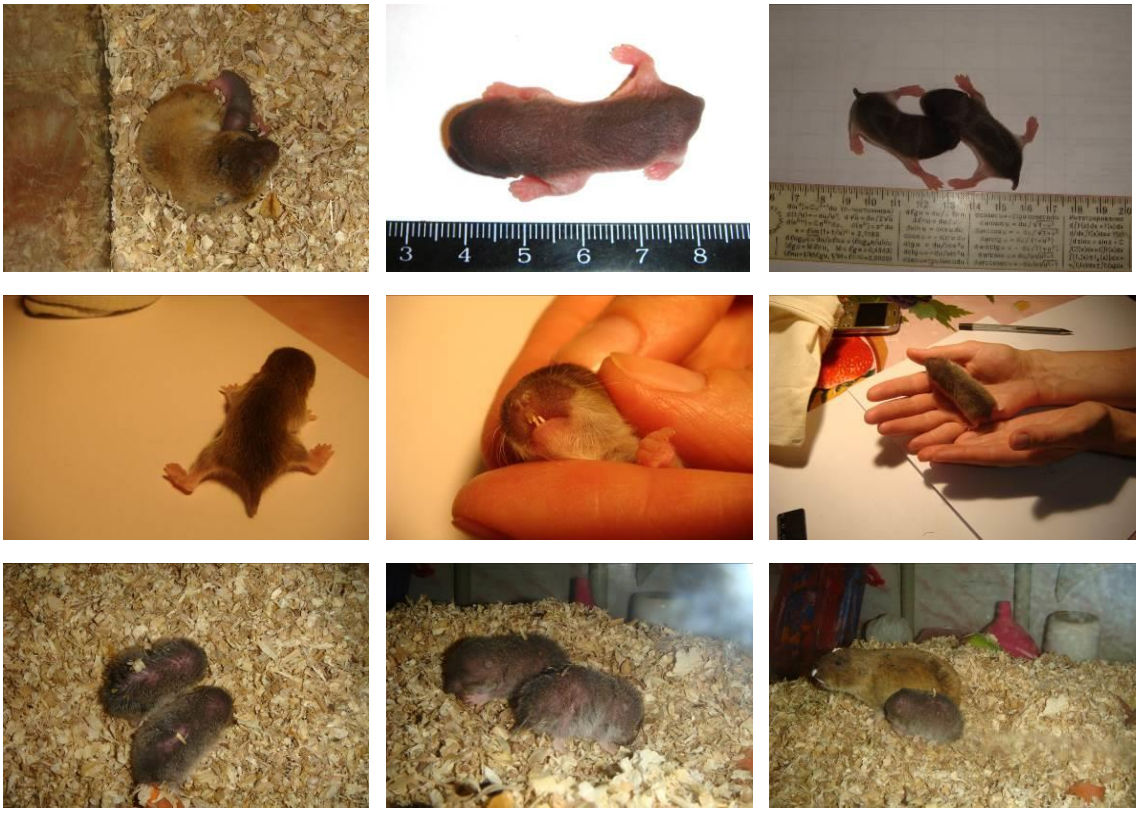

Fig. 4. Young mole voles of different age born in captivity: neonates, up to one-week-old (top row), two- to three-week-old, with teething (middle row), about a month-old, when they make their first attempts of independent feeding (bottom row). Photo by I. Zagorodniuk.

Рис. 4. Молоді особини сліпачка в різному віці, народжені в неволі: новонароджені, у віці до 1 тижня (верхній ряд), у віці 2–3 тижнів, з прорізанням зубів (середній ряд), близько місяця, коли є перші спроби самостійного харчування (нижній ряд). Фото І. Загороднюка.

Moulting

A change in the coat colouration of captive mole voles was noted—closer to autumn, the pelage became brighter. In summer, namely in June, all three individuals moulted, and the pelage had large bald spots, but after 15–20 days the animals were covered again by dense fur.

Autumn moulting was not recorded, which allows considering that mole voles have only one seasonal moulting, in spring–summer.

Conclusions

Experience has shown that keeping mole voles in captivity is relatively easy. The species has no special needs in feeding. It feels quite comfortable in small terrariums, remains active, and almost entirely avoids conflicts when kept in groups. When kept individually, it gets tamed very quickly and by the second to third week it calmly approaches the researcher's hands and takes food. In order to form normal social groups during their long-time keeping or captive breeding, it is necessary to form social groups in which the animals retain the forms of behaviour necessary for survival (as experience has shown, the smallest group consists of three individuals). Among the features described, the preservation of the system of vocal communication, warning of danger, and the necessary level of aggression toward other species (and also the researcher) when disturbed are of great importance.

The experience gained by the author can be used in the formation of reproductive groups (reserve populations) under artificial conditions, as well as in the development of measures for the formation of new local populations via releasing animals to new locations or where the species disappeared due to human economic activity or other reasons. Nevertheless, it is important to consider the difficulty of ensuring the keeping conditions, because the conditions in the terrarium correspond more to those on the surface and not of the subterranean ecotope. But the adaptability of mole voles to both the subterranean and aboveground environment makes it possible to keep them in captivity for a long time, unlike mole rats.

Experience has also shown the possibility of introducing mole voles into culture, which would significantly contribute to the currently existing range of domestic rodents (guinea pigs, hamsters, and gerbils). At the same time, this species, unlike many others (and all those named), is characterised by an extremely plastic behaviour, easy taming, lack of aggression, exclusive herbivory, and lack of odours. Due to these features, the species can be recommended both as a pet for keeping in zoo exhibitions and as a laboratory animal.

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