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ACTIVITY OF THE EUROPEAN MOLE *TALPA EUROPAEA* (TALPIDAE, INSECTIVORA) IN ITS BURROWS IN THE REPUBLIC OF MORDOVIA

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Abstract

A new method of studying the activity of European mole *Talpa europaea* (Linnaeus, 1758) with use of digital portable voice recorders is developed. European mole demonstrates polyphasic activity pattern – three peaks of activity alternate three peaks of relative rest. Moles are found to have activity peaks from 23:00 to 3:00 h, from 6:00 to 9:00 h and from 15:00 to 18:00 h, and three periods of rest: from 3:00 to 6:00 h, from 9:00 to 15:00 h and from 18:00 to 23:00 h. Mole's rest is relative since animals show low activity during periods of rest. Average daily interval between mole passes is 2.5 h. Duration of audibility of continuous single European mole pass by the microphone varies from 11 to 120 seconds. On average, it is 37.5 seconds.

Key words: animals, daily activity, day-night activity, voice recorder.

Introduction

In many countries, the European mole *Talpa europaea* (Linnaeus, 1758) is an object of constant modern research (Komarnicki 2000, Prochel 2006, Kang et al. 2009). It inhabits mixed and deciduous forests, forest-steppes of Europe and Western Siberia to the east to Irtysh (Pavlinov et al. 2002, Zaytcev et al. 2014). For a long time, systematic researches on the ecology and biology of this species have not been conducted in Russia.

The biological activity of animals is corresponding and consistent with the level of daily and seasonal cycles in changing the complex of environment conditions where light factor is essential (Shilov 2001). Activity of many mammals is investigated under various conditions of the light regime. For underground animals, especially for the different mole species, such information is fragmentary.

Individual moles occupied a well defined home range, which varied in size from an average of 4300 m^2 for males to an average of 1658 m^2 for females. Range overlap was observed between animals of different sex, while home ranges patrolled by animals of same sex were largely exclusive. Overlap was highly reduced when core areas of activity were considered. Daily activity rhythms showed a regular alternation between periods of rest and

activity, each lasting about four hours. Activity patterns of females were better synchronized then those of males, a feature probably related to mating activity (Loy et al. 1992, 1994).

Mole shows more activity at night than during the day (Kuzyakin 1935), although Stein (1950) reported there was no difference. A lot of studies showed that the activity of moles alternates every three to four hours (Gorman and Stone 1990, Loy et al. 1992). Individual area and rhythms of activity were investigated using radio telemetry and radioactive isotope (Godfrey 1955, Gorman and Stone 1990, Loy et al. 1992, Macdonald et al. 1996). Analysis of daily and seasonal activity of North Caucasian mole (*Talpa caucasica* Sat., 1908) demonstrates that this species is active year-round, day and night (Dzuyev et al. 2015).

Studies by Macdonald et al. (1996) show that moles had a triphasic pattern of activity, but this became tetraphasic under drought conditions. These differences could be related to seasonal differences in soil moisture. On average, each mole spent only 0.9 % of its time within 6 m of another mole, and only 3 out of 46 dyads showed evidence of being attracted to each other; there was no evidence from the simultaneous movement patterns of neighbouring moles that they avoided each other. Although moles tended to return to the same part of their range at the same time on successive days, there was also some indication of gradual changes in the spatial pattern of daily home range use.

In the Middle Volga, the activity of European mole has not been studied before, so there was a hypothesis about the applicability of the polyphase activity rhythm of the animal in our conditions. Aim of this study is to assess activity of the European mole in its burrows. This paper presents the results of research in this area and describes the method that can be used to study other underground animals.

Material and Methods

The work was carried out in two districts of Republic of Mordovia – located in the centre of the European part of Russia. The study area belongs to the forest-steppe natural zone. The climate of the region is moderately continental with pronounced seasons throughout the year. The influx of direct solar radiation varies from 5.0 in December to 58.6 kJ/cm^2 in June. Total radiation throughout the year is 363.8 kJ/cm^2, the radiation balance is 92.1 kJ/cm^2. The average annual air temperature varies from 3.5 to 4.0 °C. The average temperature of the warmest month, July, is in the range of +18.9 to +19.8 °C. Extreme temperatures in June reached 33 °C (in 2019). Extreme temperatures in July reached 35 °C (in 2020). Extreme temperatures in August reached 32 °C (in 2016, 2019). The average annual precipitation is 480 mm. Over the course of observation lasting for many years, periods of more and less humidification were noted, ranging between the minimum and maximum values of 120–180 mm. Distribution of precipitation across the territory is not very diverse. The average long-term value of evaporation is calculated to be in the range of 390–460 mm (Yamashkin 1998, Andreychev 2017).

The study was conducted at the biological station (village Simkino) of Mordovian University in Bolsheberezniковsky district (54º17′ N and 46º16′ E) and in Saransk city district (54º16′ N and 45º11′ E) in 2016–2020. In the first section, the biotope is a mixed forest, and in the sec-

ond section, the biotope is a broad-leaved forest. Moles are distributed unevenly in the region because it is quite close to the southern border of their habitat which goes across Penza oblast, to the south of Penza (Zaytcev et al. 2014). In Volga Region the European mole is a common widespread species (Sokolov 1984). In the forest, where its activity was investigated, were registered 6 to 9 burrows per 1 km. According to the assessments of European mole habitats in the North-West of Russia (Rusakov 1965, Nesterkova 2014), favourable ones are defined as areas containing 15 or more burrows per 1 km, areas containing 5–10 burrows considered to be satisfactory, and areas containing less than 5 burrows are mediocre. Thus, the study was conducted in satisfactory European mole areas.

Before studying the mole, the method with the use of voice recorders was tested and improved in the study of the activities of different animal species (Russian desman, greater mole-rat, Eagle owl) (Andreychev et al. 2017, Lapshin et al. 2018, Andreychev 2019a). I looked for near-surface burrows of 50–55 mm in diameter that crossed dirt roads. I opened mole's burrows along the roadside and installed Olympus voice recorders perpendicular to burrow's direction. Each recorder was placed in a 0.3–0.5 liter water plastic bottle used as a container. The catch of moles after studying their activity at the end of August was performed with cylinders. It was done to determine the number of animals living in burrows. The total absence of moles was then established by means of voice recorders, which records were assessed for the absence or presence of moles' noises (Fig. 1). Up to five moles were caught from each of the burrows at the end of the summer, a total of 24 individuals were caught during the work.

Activity for certain months (June, July, August) was detected as follows: initially, activity of the animals was fixed at each place where a voice recorder was installed by registering the number of ani-

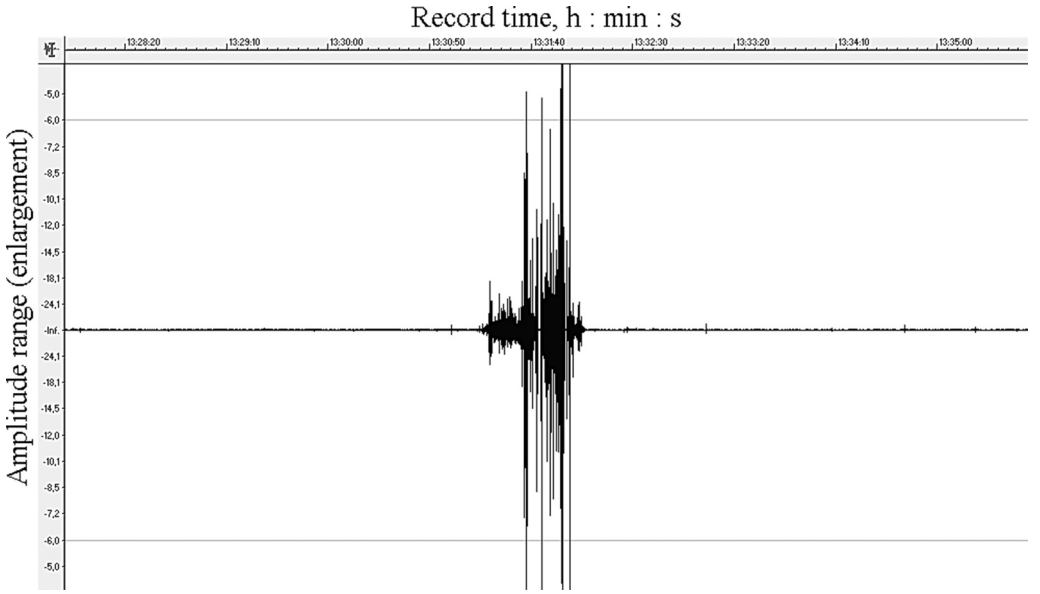

Fig. 1. Oscillogram obtained by recording noises by voice recorder in a burrow.

mal passes trough main (transit) passages near the recorder per day (24-hour period); this number was taken as 100 %. In total, 14 voice recorders were used. The studies were conducted on both sites in 7 burrows each. The area of each plot was 1 km^2. Then activity rate (%) was evaluated for certain hours, e.g. 15.00 to 16.00 h. To make description more convenient, days were conditionally divided by hours into periods of activity and relative rest. As a rule, the following record schedule was used: 3–4 days in each decade of each month. The duration of voice recorder usage in burrows depended on expediency. In continuous network of burrows with a small amount of fresh ground emissions, we kept microphones until alkaline batteries run out (completely discharged) so that to make objective assessment of activity. And, on the contrary, in continuous network of burrows with a lot of fresh molehills under changing weather conditions (long-lasting rains), in order to save voice recorders from moisture, working time was reduced to 48 h (2 days). Sound recordings were carried out in the same mole burrows. During the study, 123 sound records were received and processed with the total duration of 10,670 h (Table 1). More than 19,000 moles passes by microphones were recorded.

Table 1. The volume of material on the activity of the European mole.

Parameters	Months			Total
	June	July	August	
Bolsheberezhnikovsky district				
Number of sound records	27	28	18	73
Number of days recording	95	102	76	273
Average number of sound records per day	8	9	8	8
Saransk city				
Number of sound records	18	20	12	50
Number of days recording	60	68	43	171
Average number of sound records per day	8	10	8	8

Office processing of the audio recordings obtained was carried out using AIMP (2007) and Audacity (2015). This software allows identification and subsequent listening to the noises of moving mammals along the burrows by frequency characteristics in visual mode. Alternative software, in particular, SONY ELECTRONICS INC. (2019), was used to convert audio files from WMA to WAV and divide them into short sections for easy analysis in Audacity. Comparison of the average number of mole passes at a microphone per day for each month was made using One-way ANOVA. Statistical calculations were carried out by means of computer program AtteStat (2010), Past (Hammer et al. 2001).

Results and Discussion

Our data suggest that there are three periods of pronounced activity and three periods of relative rest in mole's daily activity (Fig. 2). They are found to have the first activity peak from 23:00 to 3:00 h, the second one from 6:00 to 9:00 h, and the third from 15:00 to 18:00 h. The last period is less pronounced than the previous two. Duration of rest periods is three to six hours. The first period of rest occurred

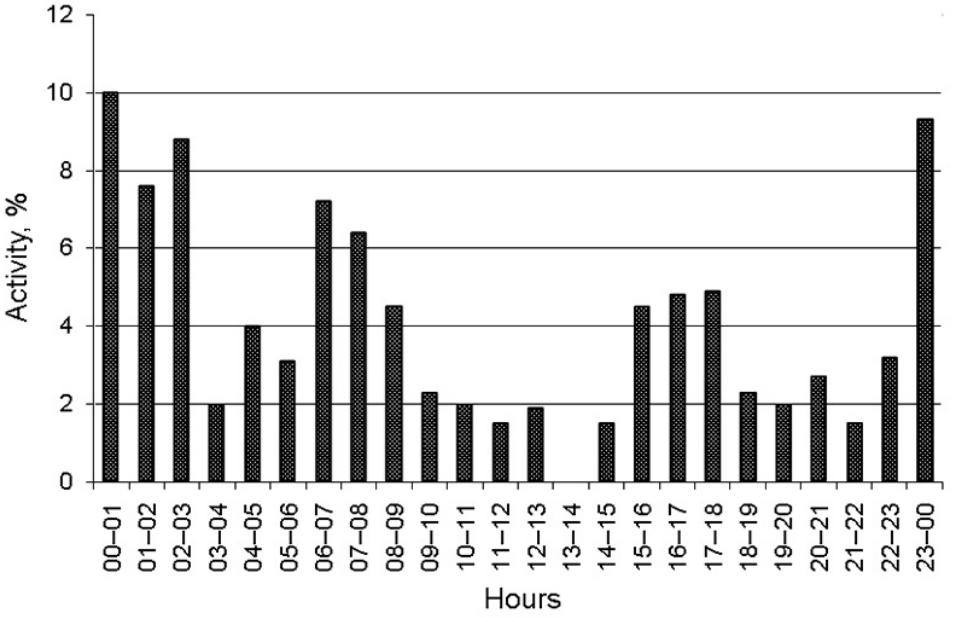

Fig. 2. Daily activity of the European mole in summer months.

from 3:00 to 6:00 h, the second – from 9:00 to 15:00 h, and the third – from 18:00 to 23:00 h. The mole's rest is relative since animals show low activity during periods of rest. For one hour, from 13:00 to 14:00 h, no passing of the animal through main passages was observed.

During periods of pronounced activity, moles travel along main passages 3–4 times per hour. The maximum registered number is five passes per hour from 00:00 to 1:00 h on July 11, 2016 and June 21, 2017. During periods of relative rest, moles travel through the main passages up to two times per hour. Most often we registered one pass per hour or no movement at all. The interval between single mole passes varies from 10 min to 15 h. The average daily interval between mole passes is 2.5 h. Duration of audibility of a continuous single mole pass by the microphone varies from 11 to 120 s. On average, audibility of mole passage by the voice recorder is 37.5 s.

The maximum activity in June is observed during certain periods: 23:00 to 00:00 h, 2:00 to 3:00 h, and 6:00 to 7:00 h. Moles are active for 23 h a day. High burrowing activity is probably caused by active search for food and patrolling individual area. The high activity of moles is also indicated by land activity, and by rates of molehills appearance in particular.

In July periods of activity shift to night hours. In the general rhythm of animals' activity, the number of daily passes is significantly reduced. For one hour, from 13:00 to 14:00 h, no passing of the animal through main passages is observed. From 9:00 to 13:00 h sporadic passes are registered. The highest activity is observed from 00:00 to 1:00 h. Evening activity (15.00 to 18:00 h) is slightly less than the night one. Morning activity (6:00

to 9:00 h) is even less pronounced during this month. The tendency to shift activity to nighttime is still observed in August. The number of moles' passes through the main passages is reduced. The maximum number of registered passes is fifteen per day.

Analysis of the number of mole passes per day in summer months (June, July, August) reveals that their average number varies from 8.15 to 9.62 (Fig. 3). In June the average number is 8 (min 3 – max 28) per day. In July it is 9 (min 2 – max 33), in August 8 (min 3 – max 15). It is important to note that the registered activity rate does not refer to a single animal living in a burrow. It is an indicator characterizing activity of all animals in the burrow. The burrow is inhabited by several animals. This fact is demonstrated by full catching of moles at a number of selected burrows after studying their activity. We caught two to five animals in one burrow.

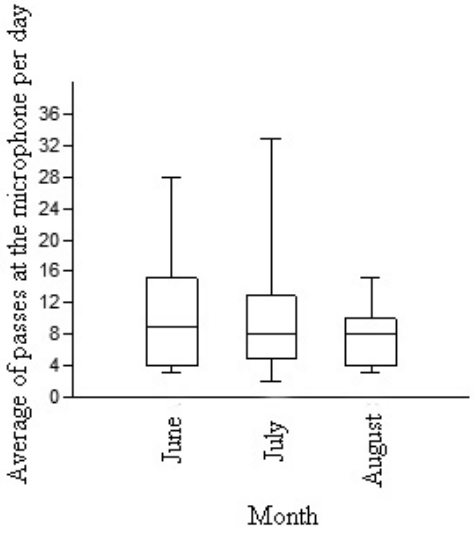

Fig. 3. Ranges of passes of European mole in a burrow per day.

Note: 'A strip in a box' – a median, a rectangle – dispersion of values of rather main trend (25–75 % quantiles), pieces around (above and below) a rectangle – the minimum and maximum values.

Besides the moles, the activity of other animals (shrew, vole, etc.) was recorded in burrows. This information will be presented in a separate article. The noises of the studied moles are clearly distinguished from the noise of their commensals. Differences in the waveform of the sounds produced by these animals are discussed in previous articles (Andreychev 2018, 2019b). Each year, moles demonstrated polyphasic activity pattern when three peaks of activity alternate with three peaks of relative rest. Thus the mole also has polyphase activity in the region as does its closest relative the Russian desman *Desmana moschata* (Andreychev et al. 2020).

Comparison of the average number of mole passes near the microphone per day for each month was made using One-way ANOVA. It did not reveal statistically significant differences between the three months ($F = 0.58$, $df = 31, 63$, $p > 0.05$).

Experimental data can serve as a confirmation of our results on the polyphase rhythm of mole activity with three rest periods. Like wild moles, captive moles have a period of sleep lasting three to five hours followed by a period of activity of about the same duration. This activity pattern was usually repeated three times every 24 h (Mellanby 1967).

Other scientists have identified slightly different periods of mole activity. However, this can be explained by the fact that the differences are sexual in nature. Males are active at some time intervals, while females are active at other times. In females, the most pronounced periods of activity are observed in the morning (from 06:00 to 12:00 h) and in the afternoon (from 15:00 to 18:00 h), while the rest periods are

concentrated before sunrise (from 3:00 to 6:00 h) and around the noon (from 12:00 to 15:00 h) (Loy et al. 1992). As part of the discussion of differences and similarities in the activity of individuals of different sexes, a general trend can be found. A common feature of both males and females is the presence of three to four periods of activity during each 24 h, although the length of these periods is highly variable. However, despite the tendency to alternate periods of rest and activity, it is difficult to determine a certain pronounced period that differs from the others by the type activity (Loy et al. 1992, 1994).

Our results of research in nature are consistent with the results of previous experimental studies in our country. Using a MAG-8M tape recorder, it was shown that moles exhibit mainly nocturnal activity (Alexandrova and Frolova 1967). X-ray examination of the gastrointestinal tract showed the peculiarities of the animals' digestion, the cycle of which is completely over within 4–5 h (Spiridonova 1949). Such a short period of digestion creates the need for frequent food intake and makes prolonged fasting impossible. This information explains the reason for the three-phase activity of a mole, identified in our studies.

The presence of differences between activity rhythms of *T. europaea* males and females during the breeding season has already been noticed (Stone and Gorman 1985, Stone 1986). Studies of the mole in Mordovia revealed a partial coincidence of rest periods from 3:00 to 6:00 h and from 12:00 to 15:00 h as well as coincidence of activity periods from 6:00 to 12:00 h and from 15:00 to 18:00 h. In Scotland and in Mordovia, moles have slightly different periods of activity; these differences may be associated with geographical zoning of the area where the moles live.

Conclusions

Thus, the daily rhythm of the European mole has a polyphase character with frequent changes of activity and rest. It is active both during daylight hours and at night. But if during the day the activity is subject to fluctuations, then at night a stable high activity is recorded. In many regions of Russia, the mole is a malicious pest of gardens and kitchen gardens, so the periods of activity identified by us can be used to catch them. Periods of rest are characterized by a length of three to six hours. On average, the interval between mole passes per day is 2.5 h. This interval is important to know in order to catch all possible inhabitants of the burrows. The duration of audibility of a continuous single pass of a mole past the microphone ranges from 11 s to 120 s.

It is of undoubted interest whether there are differences in the studied aspect of the common mole in one of the populations on the southern border of the range compared to the populations that are located in good and mediocre land.

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