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DIFFERENT TYPES OF MARKING BEHAVIOR OBSERVED IN THE WILD DURING THE BREEDING PERIOD OF THE COMMON HAMSTER (*CRICETUS CRICETUS*, CRICETIDAE, RODENTIA)

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The marking behavior of the common hamster, *Cricetus cricetus* in the wild was recorded using camera traps and handheld video in the N.I. Bagrov Botanical Garden, Simferopol, Crimea. We described the following types of scent marking: with flank glands (in particular, compass-like movements in the grass and rubbing on a stone), midventral gland marking, etc. The variety of marking behavior types on different substrates may contribute to a more efficient use of olfactory signals in maintaining the social structure of the common hamster, which is notably important at high population densities in urban areas.

Keywords: mating, scent marking, flank glands, midventral gland, urban area

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Scent marking is one of the most common socially related behaviors of mammals, and scent glands on different body parts of the same animal may serve different functions (Doty, 2010). While there is variability in, and some debate about the mechanism involved, there is little doubt that scent marking is a fundamental component of territorial behavior and advertises dominance status within social hierarchies (Roberts, 2007). In particular, scent marking plays a role in the communicative process for the identification of sex and reproductive status (Johnston, 1983), for territorial defense, and life resources (Soso et al., 2014). It facilitates agonistic and sexual communication between conspecifics (Murphy, 1980), advertises social status (Huck et al., 1985) and allows detection and recognition of intra- and interspecific signals (Halpin, 1986; Staples et al., 2008). For example, beavers (*Castor canadensis*) build mud piles near their lodges and dams and then place preputial gland secretion (*castoreum*) on top, producing a scent mound (Müller-Schwarze, Heckman, 1980). Giant panda (*Ailuropoda melanoleuca*) marks with a specific anogenital gland that evolved for communication purposes (Nie et al., 2012). Pandas are prone to mark along ridge trails, using them as communal marking stations for communication (Schaller, 1985). North American river otter (*Lontra canadensis*) uses olfactory signaling and has a flexible social organization. They establish and frequently visit specific terrestrial locations known as latrines, where otters deposit spraints (feces), urine, and anal gland secretions (Bowyer et al., 1995; Ben-David et al., 1998; Blundell et al., 2002, 2002a). Furthermore, a wild boar (*Sus scrofa*) has been shown to run the side of its mouth down a tree trunk, repeating the wiping movement with both sides of the muzzle on opposite sides of the tree (Estes et al., 1982).

In many aspects, rodents have been good models for the scent-marking paradigm (Gosling, Roberts, 2001). Unlike large mammals, scent marking has been studied extensively in different species of rodents for example in gerbils (Kumar, Prakash, 1983; Gromov, 2015), mice (Arakawa et al., 2008), blind mole-rat (Zuri et al., 1997), etc. In particular, detailed studies of marking behavior were carried out on different species of Cricetidae family, for example: desert wood rat (Fleming, Tambosso, 1980), voles (Ferkin et al., 2004) and hamsters. Thus, Wynne-Edwards et al. (1992) conducted a detailed study of marking behavior in Campbell's hamster (*Phodopus campbelli*) and demonstrated that marking behavior occupies no more than 4% of the total time budget. Additionally, it was demonstrated that scent marks from the ventral glands in adult males serve a role in communication between males and, possibly, in territorial defense (Wynne-Edwards et al., 1992). Furthermore, it was shown that scent marking is a powerful factor in the integration of populations of this species, whose natural abundance is usually low and constant (Sokolov, Vasilieva, 1993). Another

study has demonstrated that dwarf hamsters (*Phodopus campbelli*) engage in social communication through the use of scent marks and distinguish between the scent of males and females (Reasner, Johnston, 1987). Golden hamster males (*Mesocricetus auratus*) were used to study the ability to distinguish individual differences in scent, including the scent of flank gland secretions (Johnston et al., 1993). Early experiments on the golden hamster reported two males coming into contact, sniffing each other's flank glands and then starting an aggressive interaction (Lipkow, 1954). Most of these studies were conducted almost exclusively in the laboratory but with direct theoretical application to what predictably occurs in free-ranging populations, however, there have been almost no attempts to experimentally document or test the functional or evolutionary significance of scent marking in wild (Wolff, 2003). In this way, experimental data is not always reproducible in the laboratory, and vice versa. It is necessary to concurrently conduct research in captivity and in the wild, corroborating or refuting the data obtained under laboratory conditions.

Considering that, there are a significant number of laboratory studies on marking behavior, equivalent research in natural settings is insufficient. For instance, studies on the behavior of common hamsters are notably rare and fragmentary, especially concerning scent-marking behavior (Ziomek et al., 2009). Nevertheless, such studies have been conducted. For example, one of them revealed that males establish breeding territories, which may encompass the burrows of females. These males mark their home range using various ways, including feces, urine, flank, midventral, anal and genital glands. Additionally, one specific type of marking behavior was described in the same study: males rotate around the vertical entrance to the burrow, rubbing their genital area against the ground while lowering their heads over the opening (Ziomek, 2011). Furthermore, a semi-natural study demonstrated that male common hamster's exhibit higher levels of aggression towards males with whom they are genetically less familiar, while displaying lower aggression towards neighboring males (Eichert et al., 2017). However, there is evidently a deficiency of information regarding the behavior of this species in its natural habitat, probably because it is nocturnal, secretive, and tends to avoid encounters with humans (Eibl-Eibesfeldt, 1953; Ziomek, 2011). This lack of information has served as strong motivation for our research, aimed at describing in detail little-known reproductive behaviors exhibited by free-ranging animal. The opinion about the common hamster, as an aggressive and difficult to rear species, has led to the situation that this species is rarely kept in captivity and therefore have only few behavioral observations reported (Ziomek et al., 2009). At the same time, studying the behavior of the common hamster under different conditions is an important task, as it population has dramatically declined across its range since the 1970s (Surov et al., 2016), and it was included in the IUCN Red List in 2020 with CR status (Critically Endangered Species) (Banaszek et al., 2020). Under laboratory conditions, the sexual behavior of the common hamster was observed by Reznik-Schüller et al. (1974) and Vohralik (1974). Ziomek and co-authors identified typical patterns of the common hamster behavior in the Poznan Zoo (Ziomek et al., 2009). The researchers had a goal to provide a reference for the study of hamster behavior in the wild. It was demonstrated that the occurrence of non-social behavior was notably greater than the social behavior. The authors rightly point out that collecting data on the behavior of the common hamster in the wild is quite challenging. Nevertheless, based on the table with describing observed behavior obtained in 2009 (which was further supplemented and adapted), the urban behavior of the common hamster was investigated and described in 2019 (Flamand et al., 2019), which also includes mentions of marking behavior.

Here it is worth mentioning that skin glands play an important role in the marking behavior of the common hamster. Various laboratory studies have been conducted on this topic. For example, under laboratory conditions, it has been shown that male common hamsters use flank glands for scent marking when entering a female's home range during her receptiveness (Eibl-Eibesfeldt, 1953). Flank glands were likely first described by Sultzer and later referenced by Vrtiš (Sultzer, 1774, cited in Vrtiš, 1930, 1930a). During the period of female receptivity, flank glands become much more noticeable in both males and females due to the release of the secretion, the smell of which can even be discerned by humans (Chernova et al., 2022). The signaling function was also suggested regarding the midventral gland (Schaffer, 1940; Sokolov, Chernova, 2001). Nevertheless, it is evident that information regarding the role of scent marks of free-ranging common hamsters is insufficient. In our study, we describe various patterns of common hamster behavior in the city park, with a focus on scent-marking behavior.

The research was carried out from 15–29 April 2021 in the N.I. Bagrov Botanical Garden at the Vernadsky University in Crimea, Simferopol (44°56′N, 34°07′E). These dates were chosen because in April, hamsters mostly awaken from hibernation and many females enter a receptive state (Surov et al., 2019).

The plot (4.5 ha.) was located in the northern part of mentioned above Botanical Garden. There we recorded a few natural predators – a marten and a few local domestic cats. The site is characterized by relatively dense growth of poison hemlocks (*Conium maculatum*) and less recreational use. Notably, that we found the largest number of burrows among the hemlock bushes; it seems quite possible that this plant, by its dense growth, became an excellent hiding place. Park employees piled cut weeds and branches here and the lack of people has created favorable conditions for the common hamster. During flowering, hemlocks exude a very unpleasant and irritating smell, so people do not go into

these bushes on the outskirts of the Botanical garden. In addition, this plant is known to have poisonous effect and toxic to both dogs and humans (Kennedy, Grivetti, 1980; Vetter, 2004). It should be noted that we conducted this study before the flowering of this plant.

With the help of live traps, we caught and visually marked 22 (12 males, 10 females) hamsters, some of them we visually tracked in real-time and recorded their movements with a handheld camera (Sony HDR – AS200V (60fps) throughout the night. In addition, we used 5 camera traps (BolyGuard SG2060-K) to capture animal behavior. Camera traps were set on from 19:00 to 06:00 near the active burrows and each night were moved to another location.

As a foundation, we utilized behavioral elements from the papers on the behavior of the common hamster from both the zoo and urban environments (Ziomek et al., 2009; Flamand et al., 2019). All recorded elements are shown in table 1.

Live trapping allowed for the safe capture and marking of hamsters using fur paint to distinguish individuals during the study. Using camera traps, we were able to identify only the marked individuals, but there were instances of trapping unmarked ones, so the sex could not be determined for these individuals using the camera traps. Tracking hamster behavior in real-time and capturing footage with camera traps offered valuable insights into their marking behavior. Throughout the entire study we recorded 4 episodes probably related to the marking (5 min 51 sec), 1 episode of saliva marking and alert pose (26 sec), 1 episode of sex interaction (43 sec) out of the total 14 captured behavioral episodes (total duration 23 min 14 sec). Out of the 6 existing video clips, we are certain that the hamsters we marked were present in 4 videos, and they were males. In one video, the animal was unmarked, making it difficult for us to determine the gender of this hamster. In the video depicting sexual behavior, we are certain that there was a male and a female, but the animals were also unmarked.

On the night of April 20, 2021, at 9:01 PM (GMT+3), a male identified as #10 first sniffed the ground and probably began saliva marking. Then, it moved from side to side along a circular axis, leaning on its front paws and making contact with the substrate of the hemlock bushes, probably using its glands for marking. It periodically paused to interrupt its saliva marking for more sniffing. Afterward, it resumed sniffing and then altered its movements. These movements involved a transition between saliva marking and gland marking of bushes. Probably, these movements are necessary for marking with both the flank glands and the midventral gland (video supplement № 1).

On April 21, 2021, at 8:45 PM, in another instance, an unmarked hamster first dug the ground beneath it with its forepaws, assumed an alert pose, and then continued saliva marking and pressing down, possibly marking, with midventral gland (video supplement № 2).

On April 23, 2021, at 8:19 PM, we recorded the male № 8 moving around while sniffing, standing in a wary posture, and then continuing to sniff the hemlock

Table 1. Ethogram with elements we recorded in common hamster behavior (adapted from Ziomek et al., 2009 and Flamand et al., 2019) supplemented with a new hamster marking behavior (*)

Element of behavior	Definition
Horizontal locomotion	Moving, walking, running
Sniffing	Sniffing the area/objects
Saliva marking*	Preserving the smell by raking the ground with his paws
Flank marking	Leaning on its front paws, making compass-like movements, for marking, or pressing its flank glands against solid surfaces
Midventral marking	Presses its midventral gland against surfaces, leaving secretions
Head rearing	Head raised, looking around, sniffing, sometimes also standing erected on hind legs, looking around with only the head over the burrow entrance
Vertical locomotion	Climbing on some object
Displacement grooming	Shortened, single muzzle cleaning
Self grooming	Full body wash or part of its (e.g. muzzle, abdomen, genital area)
Escaping	Runs away from the threator quickly returns to its burrow
Sexual behavior	When a male engages in sexual intercourse with a female
Threat posture	Stationary posture on all fours with front legs straight, ears and eyes pointing forward

bushes. After that, it started flank marking, leaning on its front paws, rolling over, and interacting with the hemlock bushes (probably marking them), then returned to the burrow. After spending no more than a second there, the hamster climbed back out, continued to interact with the hemlock bushes, sniffed them, swiped from side to side, and hid in the opposite bushes (video supplement № 3).

On the night of 24 April 2021 at 02:10 AM we made a video with a manual camera of male № 6 – the hamster sniffed, assumed an alert pose, then climbed into a rock, standing on its hind paws. After sniffing again, it started displacement grooming. Then, it attempted to get under a stone – the hamster's burrow was located beneath it. The hamster began to move, sniffing as it went. It then turned around, pressed its flank gland against the stone, followed by shaking and scratching the area of flank gland with its hind paw. The hamster sniffed once more, shook again, and pressed its flank gland against the stone once more. Next, the hamster heard a noise and climbed into the stone with its front paws, standing in an alert pose. A cat approaches it, and the hamster noticed, quickly running into its burrow (video supplement № 4). Later that night, at 02:50, using a manual camera, we recorded the same hamster № 6 shaking and scratching its hind paw with its flank gland and pressing its midventral gland against the substrate and fallen branches. Then, it started displacement grooming and disappeared from the scope of view (video supplement № 5).

One the night of 24 April 2021 at 21:12 PM we were able to record the sexual behavior of the common hamster with a manual camera. A male (without №) emerged from the bushes towards the female (№ 5) then started mating. After mating, the female escaped, while the male began groomed itself (video supplement № 6).

The obtained data align well with previous research. We recorded various forms of behavior exhibited by the common hamster in the wild, including sniffing, mating, different types of marking, grooming, and escaping from threats (table 2).

Furthermore, we were able to document different types of marking: by saliva, midventral gland secretion and two different ways of flank marking: typical flank marking in grass and flank marking by pressing gland onto rock. Typical flank marking is considered a common form of marking for number of rodents, with plenty of video footage capturing (additional YouTube links). A scent of secretion allows recognition of reproductive status, sex and enables individual identification (Johnston, 2003). In the modern urban landscape, the common hamster is often found in green islands, botanical gardens, and parks (Čanády, 2013; Surov et al., 2023). Under these conditions, flank marking is frequently observed in bushes or thickets. However, in the N.I. Bagrov Botanical garden we observed the hamster's marking for stationary substrate, as a stone slab (video supplement № 4), by pressing (almost rubbing) its flank glands on. This flank marking has often been documented in laboratory studies. It has been shown that male common hamsters press their flank glands for scent marking when entering a female's home range during her receptiveness (Eibl-Eibesfeldt, 1953). Since our research was conducted at the end of April, during the period of mating of the common hamster, we can assume that flank marking serves a communicative function, likely related to mating. Earlier observations of the golden hamster (*Mesocricetus auratus*) noted that males scent-marked the walls of the cage during interactions with females (Lipkow, 1954).

Table 2. Recorded numbers of behavior elements in all video

Video №	Hamsters sex and №	Behavior element	Number of actions
1	Male № 10	Sniffing	1
		Threat posture	4
		Horizontal locomotion	1
		Flank marking	2
		Saliva marking	2
2	Without №	Head rearing	1
		Sniffing	1
		Saliva marking	2
3	Male № 8	Sniffing	3
		Threat posture	1
		Horizontal locomotion	5
		Flank marking	2
		Escaping	1
4	Male № 6	Sniffing	5
		Threat posture	2
		Vertical locomotion	1
		Head rearing	2
		Displacement grooming	2
		Horizontal locomotion	1
		Flank marking	2
		Escaping	1
5	Male № 6	Midventral marking	1
		Horizontal locomotion	3
		Threat posture	1
		Sniffing	1
6	Male without № and Female № 5	Horizontal locomotion	3
		Sexual behavior	1
		Self grooming	1

It is evident that this marking behavior, when the hamster presses its flank glands, is not suitable for a softer substrate, such as hemlock bushes. If similar actions were performed on bushes, they would be piled up, making it impossible to leave a scent mark because they do not maintain a static state. In this case, another type of flank marking occurs more reasonable when an animal carries out a circular-like movements touching bushes and soft grass by its flanks, as we saw in the videos (video supplements № 1, № 3).

In the city, common hamsters are constantly exposed to elements of the urban environment. Concrete slabs or other integrated objects easily become part of a hamster's home range and serve as objects for scent marking, a common behavior aimed at maximizing detectability by other animals (Gosling, Roberts, 2001). Thus, objects of anthropogenic origin, such as the concrete slab in our video, become suitable substrates for scent marking. We observe a wide range of adaptations in the common hamster to urban existence, particularly evident in the diverse forms of marking behavior that facilitate the maintenance of spatial and social structure.

Moreover, since we found that the majority of burrows are located within trees and hemlock bushes; this observation aligns well with previous findings related to the common hamster's habitat. In a prior study on urban populations, it was discovered that burrows were more frequently situated near trees and bushes rather than in open areas (Katzman et al., 2018). Such location choices can be explained by the protection that vegetation provides against predators and the availability of food near trees and bushes (Flamand et al., 2019). Diet of the *Cricetus cricetus* shifts from crop towards tree products in urban habitats, probably in response to a significant difference in availability (Tissier et al., 2019).

Additionally, we noted that several individuals could share the same burrow. It should be noted that in urban environments with high population density, common hamsters often use the same burrows, although not simultaneously (Feoktistova et al., 2013). In this case, marking frequently visited locations becomes particularly important for maintaining the stability of the social structure.

Our observational findings not only align perfectly with existing data but also add valuable supplementary information. The fact of occurrence of such an unusual form of marking behavior confirms the high plasticity of the common hamster (Surov et al., 2019). Depending on the nature of the vegetation, they can apparently adapt to their environment with the manifestation of specific behavioral patterns, particularly marking behavior, to enhance its efficiency. Thus, the data obtained providing perspective for further research on common hamster behavior in the wild.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All procedures performed on animals were carried out in accordance with EU guidelines for the protection of animals used for scientific purposes (Directive 2010/63/EU) and were approved by the Ethics committee of the A.N. Severtsov Institute of Ecology and Evolution Russian Academy of Sciences (protocol № 45 issued 08.04.2021).

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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Video supplements

№1. (20.04.21 at 21:01) Male flank marking

№2. (21.04.21 at 20:45) Saliva marking

№3. (23.04.21 at 20:19) A hamster flank marks near the burrow

№4. (24.04.21 at 02:10) Male #6 flank marking and escaping near the stone

№5. (24.04.21 at 02:50) Male #6 marking substrate using its midventral gland

№6. Sexual behavior of the common hamster

Supplement video files link

https://drive.google.com/drive/folders/1Sz8netwH-T0LldrHUIXWjnWuqq1URkO3?usp=drive_link

Additional YouTube links
(Video materials from other authors)

1) https://www.youtube.com/watch?v=5YVeHOodFbM (7:00–7:11) (A fragment of the film —Expeditionen ins Tierreich) Director: Gunther Josef Goldman

2) https://www.youtube.com/watch?v=3lvYi4H1lTA (0:47–1:02) (Author: David Cebulla)

3) HYPERLINK "https://eur01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3Dkze6e9NA-oQ&data=05%7C02%7Cjoanna.ziomek%40amu.edu.pl%7C91c8f4f4a69548cfd91608dc22336d47%7C73689ee1b42f4e25a5f666d1f29bc092%7C0%7C0%7C638422851471241337%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=GXypF05%2FBldUvqwAqnU-u2HTSa4CNTqjr%2BuLrg70E3dw%3D&reserved=0" https://www.youtube.com/watch?v=kze6e9NA-oQ (Full video) (Author: Urszula Eichert)

РАЗЛИЧНЫЕ ТИПЫ МАРКИРОВОЧНОГО ПОВЕДЕНИЯ, НАБЛЮДАЕМЫЕ В ПРИРОДЕ В СЕЗОН РАЗМНОЖЕНИЯ У ОБЫКНОВЕННОГО ХОМЯКА (*CRICETUS CRICETUS*, CRICETIDAE, RODENTIA)

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С помощью фотоловушек и ручных видеокамер регистрировали маркировочное поведение обыкновенного хомяка (*Cricetus cricetus*) в Ботаническом саду им. Н.И. Багрова (Симферополь, Крым). Описаны разнообразные формы маркировки: с помощью боковых желёз (в частности, циркулеподобные движения в траве и потирания боковыми железами о камень), маркировка средне-брюшной железой и др. Разнообразие форм маркировочного поведения обыкновенного хомяка на разном субстрате может способствовать более эффективному использованию пахучих меток в поддержании социальной структуры вида, что особенно важно при высокой плотности популяций в условиях городской среды.

Ключевые слова: половое поведение, маркировочное поведение, боковые железы, средне-брюшная железа, городская среда