Short Note

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Long-distance dispersal of two species of shrews (*Sorex caecutiens* Laxmann, 1788 and *Sorex minutus* Linnaeus, 1766)

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Abstract: Data on the dispersal of shrews are still rare, and for some species of Soricidae these are not available at all. Group marking with bait containing rhodamine B was used to study the dispersal of two species of shrews – Laxmann's shrew (*Sorex caecutiens*) and pygmy shrew (*Sorex minutus*) in the Middle Urals (Russia). Twelve Laxmann's shrews moved straight-line distances ranging from 80 to 4500 m. Five pygmy shrews dispersed from 475 to 2570 m. The are first field data obtained on dispersal distances of the pygmy shrew. The reported dispersal distances of the Laxmann`s shrew are the maximum known for this species.

Keywords: dispersal; long-distance movements; rhodamine B; shrews.

Dispersal is defined as "circumstances in which individuals leave their existing home ranges and do not return" (Stenseth and Lidicker 1992). This process can provide animals with several benefits, including colonization of vacant habitat and avoidance of inbreeding (Bowler and Benton 2005; Clobert et al. 2012). The main determinants of dispersal include the range of movements of the species and its ability to overcome various landscape discontinuities. For terrestrial forest dwelling species such obstacles are rivers, canals, roads, railways, pipeline and power line right-of-ways, clear cuttings, etc. Many species of small mammals, including murine rodents, are known to be able to travel distances of several kilometers (Clark et al. 1988; Dickman et al. 1995; Jung et al. 2005; Tolkachev 2016; Grigorkina and Olenev 2018). For example, the maximum distance recorded for mouse-sized mammals is 14,730 m (Maier 2002).

Shrews (family Soricidae) are among the least studied species in this respect. There are only a few studies that include data on their the long-distance movements (Bol'shakov and Bazhenov 1988; Faust et al. 1971; Michielsen, 1966; Shchipanov et al. 2001; Shchipanov 2007; Shchipanov and Pavlova 2016; Tegelström and Hansson 1987). Laxmann's shrew (*Sorex caecutiens* Laxmann, 1788) and the pygmy shrew (*Sorex minutus* Linnaeus, 1766) are among the smallest extant mammalian species. Nevertheless, they have ranges that occupy a significant part of Eurasia (Zaitsev et al. 2014). Given their high reproductive rates and regular local extinctions in the winter, it is incredible that these animals maintain their species unity across large areas. Long-range dispersal may be one of the key explanatory factors. However, there are very few data on the long-distance movement of Laxmann's shrews and none at all on pygmy shrews. This is primarily due to methodological difficulties in studying dispersal over long-distances in small mammals (Mohr et al. 2007; Nathan 2001; Stenseth and Lidicker 1992; Sutherland et al. 2000).

One of the solutions to this problem is the use of group self-marking through bait. This technique allows for the automatic marking of a large number of animals living in or passing through a local area (marking plot) and focuses all efforts on catching marked individuals outside the area (Grigorkina and Olenev 2018; Lavoie et al., 1971; Szacki and Liro 1991; Tolkachev 2016). Rhodamine B (RB) is a non-toxic dye that, when ingested with bait, binds to structures containing keratin, such as hair, vibrissae, and claws (Fisher 1999). Thus, this biomarker can be successfully used for group marking of animals (Cooney et al. 2015; Weerakoon et al. 2013). The mark is detected by yellow fluorescence under green light. The retention time of the mark in the bodies of mammals is at least several months (up to 1 year). The possibility of marking shrews with RB was shown previously (Mohr et al. 2007; Tolkachev 2019). Nevertheless, the long-distance movements of shrews have not been studied using this biomarker.

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We investigated dispersal distances of *S. caecutiens* and *S. minutus*, using group marking with the biomarker rhodamine B. The data presented in this work were obtained within the framework of a long-term (since 1990), ongoing study of small mammal communities inhabiting areas with different levels of industrial pollution (Mukhacheva 2021; Mukhacheva and Sozontov 2021). The investigated areas were located in fir-spruce forests in the vicinity (1–7 km) of the Middle-Ural Copper Smelter (MUCS). The plant located 50 km west of Yekaterinburg (56°51′ N, 59°53′ E), is Russia's largest works producing crude copper and sulfuric acid, which has been in operation since 1940.

To assess the long-distance dispersal of these animals, we used a group marking technique with rhodamine B (RB) in June-September 2018–2019. We prepared the bait based on oat flakes according to published guidelines (Tolkachev and Bespamyatnyh 2019). The RB concentration was 800 mg/kg flakes. Before use, pieces of the bait were sprayed with unrefined sunflower oil. The experimental design included a marking plot where the RB bait was dispensed. The area of the marking plot was 1.5 ha in 2018 (Figure 1). In 2019, we relocated the marking plot to check for animal movements in the opposite direction. We also increased the area of the plot to 4 ha to intensify the group marking. Bait was distributed in

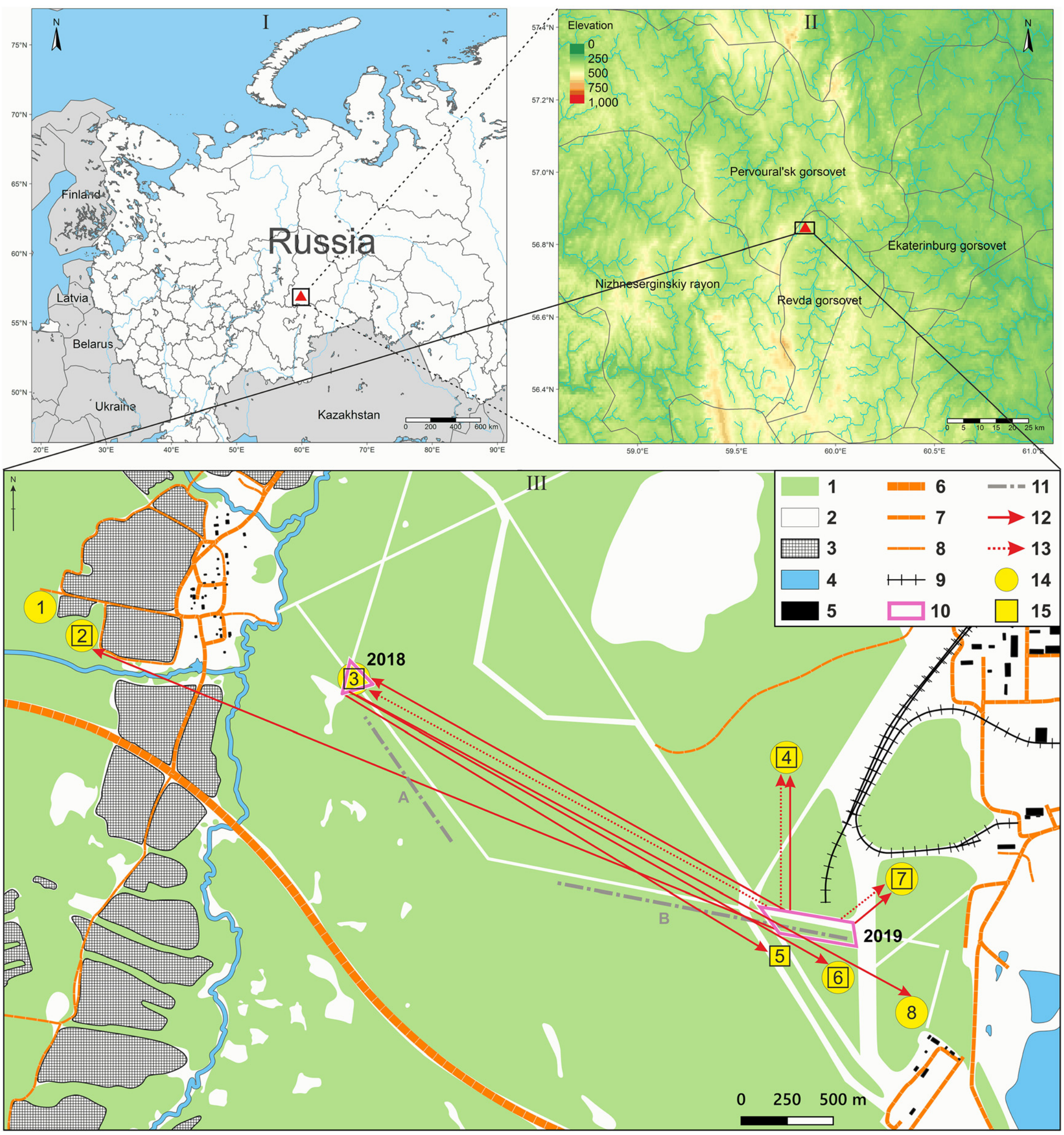

Figure 1: Spatial design of the experiment and the revealed movement directions of *Sorex caecutiens* and *S. minutus*: 1, forest; 2, unforested areas; 3, cultivated fields; 4, water bodies; 5, buildings; 6, paved roads; 7, gravel roads; 8, dirt roads; 9, railways; 10, marking plots in 2018–2019; 11A-B, snap trap transects; 12, observed movements of *S. caecutiens*; 13, observed movements of *S. minutus*; 14, snap and live trap test plots; 15, pitfall trap plots.

the nodes of the 5 × 5 m grid at a rate of 4 kg per $1{\cdot}10^4$ m^2. As shown earlier, this protocol is quite effective (Tolkachev 2019a). We repeated the marking in dry weather every 10–15 days during the summer (June 1 – August 30).

Three rounds of trapping of small mammals were carried out annually: in June (1st ten-day period), July (2nd ten-day period), and September (3rd ten-day period). For a complete accounting of the animals, different types of traps located at different distances (0–6 km) from the marking plots were used. Wooden snap traps with hooks (Tolkachev 2019b) were set in 6 test plots (3 lines in each plot per round). Each line consisted of 25 traps set at 5–7 m intervals and left open for four days with a daily check. The wooden live traps were set in 6 test plots (25 traps at 10 m intervals, set for three days, checked two times a day) during the second round. In addition, we examined shrews that were caught in Barber pitfall traps (15 traps in every test plot, in the nodes of each 10 × 10 m grid) during parallel studies of terrestrial invertebrates (second round of 2018, 2 test plots; third round of 2019, 6 test plots). In 2019, two long transects were additionally established, including 100 and 170 traps (in an alternating sequence of 4:1 snap traps to live traps), spaced 10 m apart. The traps were set for four days with a single daily check.

The shrews were identified to the species level (Zaitsev et al. 2014). Based on a complex of morphological and reproductive traits, the animals were classified as overwintered, immature or mature underyearlings. Unfortunately, animal dissection was not carried out due to the peculiarities of collecting and processing material from the Barber pitfall traps. Therefore, the sex of some animals was unknown. A total of 240 shrews of two species (*S. caecutiens, S. minutus*) were caught: 47 in snap traps, 21 in live traps, and 172 in Barber pitfall traps.

Rhodamine marks were detected according to published procedures (Tolkachev and Bespamyatnyh 2019; Tolkachev 2019). The range of distances at which the shrews with the RB marks could be detected was 0–4500 m. To estimate the distance of the movement of individuals, the minimum distance (with an accuracy of 10 m) from the point of capture to the nearest border of the marking plot was calculated. The calculation was carried out based on data from an eTrex 20 GPS receiver using detailed terrain maps. Data were visualized using tmap package v.3.3-2 (Tennekes 2018), R v.4.1.1 software (R Core Team, 2021) and QGIS v.3.16.

Over two years, 158 *S. caecutiens* were captured, including 14 with an RB mark, 12 of which were found outside the marking plot (Table 1). Straight-line movement distances ranged from 80 to 4500 m. The movement occurred mainly within one forest area. Nevertheless, all animals had to cross at least one open area – a clearing approximately 20 m wide. Three shrews that covered the longest distances (point 2, Figure 1) crossed a river approximately 5 m wide. After that, they could move through the field and along the river's floodplain, which could potentially be a landscape conduit. In the literature, only one study was found describing the spontaneous movement of individuals of this species over long-distances (Shchipanov et al. 2001). The maximum dispersal distance was 2500 m in that case. In our study, two animals were found at a distance of 4500 m from the edge of the marking plot. Group marking approach does not allow determining whether the animal had a home range before the start of the movement. Nevertheless, the considerable distance of the movement enabled us to confidently attribute it to dispersal. All the animals were immature, except for one female (mature underyearling) who moved 4150 m.

Table 1: Discovered cases of long-distance movements of two species of shrews.

Year	Test plot	*Sorex caecutiens*		*S. minutus*	
		Trapped[a] (Ind.)	Travelled distances[a] (m)	Trapped[a] (Ind.)	Travelled distances[a] (m)
2018	1	1	–	0	–
	2	0	–	0	–
	3	3 (1)	0 (1)	0	–
	4	0	–	0	–
	5	2 (1)	2900 (1)	8	–
	6	5	–	0	–
	7	0	–	0	–
	8	6 (1)	3300 (1)	0	–
2019	1	1	–	0	–
	2	29 (3)	4150 (1), 4500 (2)	30	–
	3	34 (2)	2500 (1), 2550 (1)	32 (1)	2570 (1)
	4	8 (2)	750 (2)	2 (2)	725 (1), 750 (1)
	5	0	–	0	–
	6	31 (1)	80 (1)	7	–
	7	26 (2)	450 (2)	2 (2)	475 (1), 500 (1)
	8	0	–	0	–
	A	1	–	1	–
	B	11 (1)	0(1)	0	–

[a]The number of marked individuals caught at a given point or at a given distance is shown in brackets.

A total of 67 *S. minutus* were caught. Most of them were immatures of both sexes. Only five individuals were marked. All of them were caught outside the marking plot (Table 1). An immature male showed the maximum movement, with a distance of 2570 m. As in the case of

S. caecutiens, all five individuals overcame landscape heterogeneity in the form of a clearing. We did not find data on the movements of individuals of this species outside of their home ranges in the literature. In test plots 4 and 7, only marked animals were captured. If these samples adequately reflect the composition of the population, then points 4 and 7 are located in transit habitats without residents. These were the most unfavourable conditions for this species in terms of the surrounding MUCS and high levels of pollution of the territory, particularly the soil, forest litter, and food objects of the shrews.

The method of group marking that we used made it possible to obtain new data on the dispersal of two species of shrews. These are first field data obtained on dispersal distances of the pygmy shrew. The reported dispersal distances of the Laxmann`s shrew are the maximum known for this species. Obviously, much more data is required to reliably estimate the distances, frequencies, and directions of long-distance movements of shrews.

Research ethics: All applicable international, national, and institutional guidelines for the care and use of animals were followed. The Bioethics Commission of the Institute of Plant and Animal Ecology, Ural Branch, RAS, approved the study (No: 6 May 18, 2021).

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