

# Biology of *Crocidura sibirica* Dukelsky, 1930 in the southern West Siberia

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Our paper reflects the data of a comprehensive study of the main biological characteristics of the Siberian shrew *Crocidura sibirica* Dukelsky, 1930. 921 specimens were examined for the period 1978–2020. It has been found that the Siberian shrew is attracted to habitats that have been significantly disturbed by human activity (logging sites, hayfields, reclaimed coal dumps, burned areas), but avoids completely degraded areas and urban ecosystems. It reaches its maximum abundance in the low-mountain belt of the Kuznetsk Alatau in hay meadows. The population of the Siberian shrew is subject to cyclic fluctuations with a frequency of 3–4 years. Seasonal activity peaks in mid-August and September, with breeding in the second half of summer and early fall. Among the one-year-old animals, the predominance of males is observed. The diurnal activity of the Siberian shrew is polyphasic, mainly nocturnal. Peaks of highest activity were observed at 23–24 hours and 6–9 hours. In terms of running speed, digging ability, and swimming ability, the Siberian shrew is significantly inferior to its trophic competitors, the other shrews. In interspecific encounters, neutral, friendly interactions predominate; aggression is ritualized. In intraspecific encounters with large shrews, the Siberian shrew will occupy a shelter and attempt to drive an opponent from it. The food spectrum is based on the imaginal and larval stages of insects, arachnids, and centipedes. Among insects, ground beetle larvae, Brachycera, and Hymenoptera are the most preferred foods. The identified food spectrum corresponds to the biotopic distribution of invertebrates, indicating the absence of food selectivity. The trophic spectrum of the *C. sibirica* overlaps significantly with that of sympatric species of other shrews. Given the significant overlap of the spatial ecological niche, it can be assumed that the Siberian shrew avoids competitive interactions for food resources due to the mismatch of the peak of seasonal activity. Under the influence of competitive interactions with numerous species of the genus *Sorex*, the main features of the biology of the *C. sibirica* were formed.

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## Keywords

Dark coniferous forest, ecology, forest-steppe, long-term monitoring, meadow, taiga, white-tooth shrew

## Introduction

The Siberian shrew *Crocidura sibirica* Dukelsky, 1930 was described by N.M. Dukelskaya in 1930 from the vicinity of the Oznachennoye Village on the Yenisey River. It was originally considered a subspecies of *Crocidura leucodon* (Hermann, 1780) (Stroganov 1960); however, B.S. Yudin indicated it as a separate species (Yudin 1971, 1987). It was later determined that the Siberian shrew is actually closer to the *Crocidura suaveolens* (Pallas, 1811) than to the *C. leucodon*, based on the nature of its karyotype and the structural characteristics of the last premolar (developed hypocone) (Grafodatsky et al. 1988, 1991; Zaitsev 1991).

This is also supported by mitochondrial DNA analysis data - studies conducted on samples from the Kemerovo and Novosibirsk regions showed a high degree of relationship between the *C. sibirica* and *C. suaveolens* (Bannikova et al. 2009). Interesting, that the *C. sibirica* contains two mitochondrial lineages, one of which is mainly distributed in the western part of the range (Novosibirsk, Kemerovo), the other mainly in the southeastern part (Krasnoyarsk, Teletskoye Lake) (Gritsyshyn et al. 2022).

Recent studies propose two versions of the relationship between the *C. suaveolens* and the *C. sibirica*. The separation of the West Siberian line of the *C. sibirica* occurred about 20 thousand years ago. If we accept this date as the time of separation of the haplotypes of the *C. sibirica* proper and *C. suaveolens* s.str., it is difficult to accept the species status of the Siberian form due to the very recent time of its isolation. The lack of geographic structure of mitochondrial variability also indicates the recent origin of the modern range. In this case, the *C. sibirica* is only a morphotype of the *C. suaveolens*, isolated e.g. in the Altai in some steppe refugia bordering the forest during the last glacial maximum. Another hypothesis is that the *C. sibirica* is a true species whose "native" mtDNA is currently not found, having been completely replaced by the *C. suaveolens* mtDNA through hybridization during the period of active colonization of the modern range (Gritsyshyn et al. 2022).

At the same time, the *C. sibirica* differs from other shrew species in the structure of the skeleton of the limbs, but is more similar to the *C. leucodon* (Ilyashenko et al. 1999). The species status of the *C. sibirica* was acquired 40 years after the first description. There are no subspecies of the *C. sibirica* (Yudin 1989).

The genus of the white-toothed shrews *Crocidura* Wagler, 1832 contains 198 species, more than any other mammalian genus (Burgin et al. 2018). The Siberian shrew *Crocidura sibirica* Dukelsky, 1930 is endemic to the south of western and central Siberia, a sporadically widespread and small species throughout its range. This is the only member of the tropical genus to reach this far north, so its comprehensive study is of great theoretical importance (Yudin 1989).

A comprehensive study and generalization of information about the biology of animal species contributes to a better understanding of the role of these species in natural communities, taking ecological research to a fundamentally different level. The *C. sibirica* is a very promising and poorly studied species in this regard. It is mentioned in separate papers devoted to the phylogeny of the genus *Crocidura* (Motokawa et al. 2000; Han et al. 2002; Ohdachi et al. 2004; Bannikova et al. 2006; Gritsyshin et al. 2022). Recent studies have shown that the taxonomic independence of the Siberian shrew is problematic: the level of its genetic divergence from *C. suaveolens* s.str. does not correspond to a species level (Grytsishin et al. 2022). However, in our study we focus on the East Siberian part of the range of *Crocidura suaveolens* species complex, which, from the point of view of classical taxonomy, is inhabited by the Siberian shrew. The only paper on the biology of this species was published by B.S. Yudin in 1987 (Yudin 1987). Information on the structure of the lower jaw of the *C. sibirica* is described in the paper of S.S. Onishchenko and D.S. Kostin (2017). Other papers mention the *C. sibirica* as a sporadically distributed rare species, but information on its biology is based on data from single captures (Shapetko et al. 2009; Gorbunova 2016). Comprehensive studies of this species based on long-term observations and representative samples are lacking in the scientific literature.

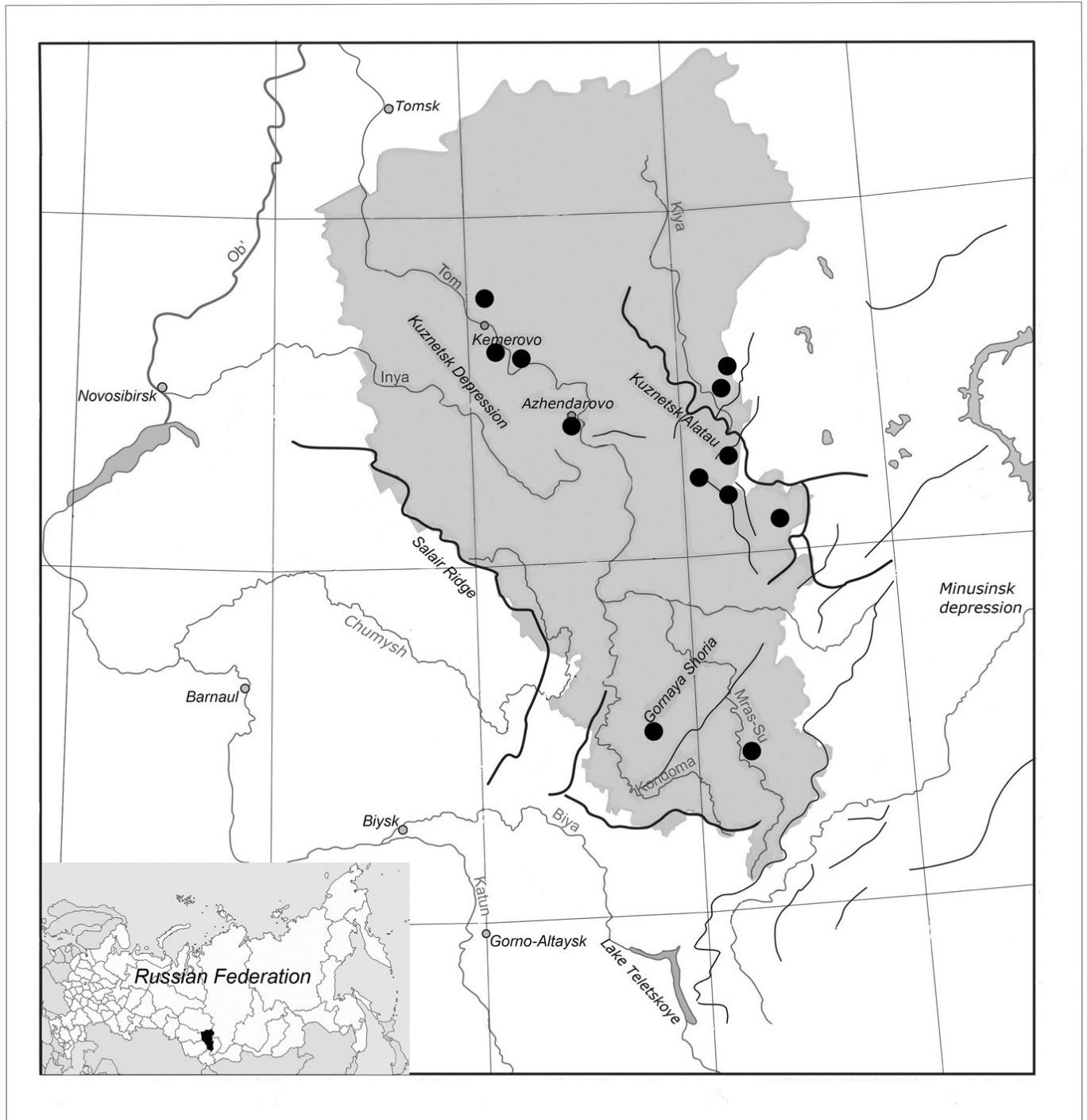
The Siberian shrew is included in the Red Book of Tomsk Region as endemic to the south of Western and Central Siberia (Moskvitina 2013). Sporadically distributed, rare. In 2008 it was included in the Red Book of the Novosibirsk Region (Yudkin and Shaulo 2008). In the third edition of the Red Book of the Novosibirsk region in 2018, it did not receive a conservation status (Glupov and Shaulo 2018). It has been listed as Near Threatened in China (Jiang et al. 2016). The status in the International Union for Conservation of Nature database is Least Concern (Stubbe et al. 2016).

The aim of our study was to explore the maximum possible spectrum of information on the biology of the *C. sibirica* and to form an understanding of its role in the communities of small mammals in Siberia.

## Materials and methods

For the study of the biology of the *C. sibirica*, captures and counting of the relative abundance of animals were carried out using standard 50-meter ditches with five pitfall traps located every 10 m (Ravkin and Livanov 2008). The study area is presented in Figure 1.

The main site of the long-term research was the "Azhendarovo" Biological Station on the territory of the Bungarapsko-Azhendarovskiy Regional Nature Reserve (Kemerovo Region, Krapivinskiy District), where monitoring studies of small mammals were carried out from 1978 to 2021. To estimate the absolute abundance of small mammals, a square plot of 2500 m<sup>2</sup> was fenced off. A fence about 25 cm high was dug about 5 cm into the ground. From the inside along the fence, pitfall traps were dug every 10 meters. The captures continued until no animals were caught in the traps in the square for three days (Nikiforov 1961).



**Figure 1.** Map of the study area. Grey represents the Kemerovo region (oblast); solid black lines show the mountain ranges; black dots indicate sampling sites.

The total number of captures and their location over the study area are shown in the Table 1. In addition to our data, we conducted a literature review to clarify the distribution and habitat preferences of the *C. sibirica*.

Mountain areas	Locations (coordinates)	Years	No. of captured specimens
Foothills of the Kuznetsky Alatau Mountain Range	“Azhendarovo” Biological Station (54°45.34368'N; 87°1.44217'E)	1979–2020	883

Kuznetsky Alatau, highlands	Rybnoye Lake (54°36.88098'N; 88°23.25923'E)	2005,2012	2
Kuznetsky Alatau, middle mountains	Bezmyanka River (54°55.65907'N; 88°21.7224'E), Shatay River (54°6.7164'N; 88°51.2028'E), Verhnyaya Ters' River (54°15.32418'N; 88°18.9621'E)	2008,2009	19
Kuznetsky Alatau, low mountains	Srednyaya Maganakovka River (54°20.33723'N; 87°55.15548'E), Belogorsk Village (55°1.15518'N; 88°29.40607'E)	2008,2011,2012,2014	21
Gornaya Shoria Mountains	Ust'-Kabyrza Village (55°1.15518'N; 88°29.40607'E), Kaz River (53°6.36618'N; 87°33.84997'E)	2008,2010	2
Kuznetsk Depression	Shcheglovskiy Village (55°33.6852'N; 85°56.23128'E), Starochervovo Village (55°5.71537'N; 86°22.84507'E), Shumiha River (55°9.5205'N; 86°20.20043'E)	2002,2003,2015	4

**Table 1.** The number of captures and their location

We assessed habitat confinement using the index of habitat fidelity ( $F_{ij}$ ) by Pesenko (1982) which has been used in studies of small mammals (Ivanter et al. 2017; Ivanter 2020; Ilyashenko et al. 2019, 2020). We calculated the index using the following formula:

$$F_{ij} = (n_{ij} \times N - n_j \times N_j) / (n_{ij} \times N + n_j \times N_j - 2n_{ij} \times N_j),$$

where  $n_{ij}$  is the number of specimens of the  $i$ -th species in the  $j$ -th sample (habitat) with a volume of  $N_j$ ;  $n_i$  is the number of specimens of this species in all catches with a total volume  $N$ .

The  $F_{ij}$  value varies from  $-1$  if the species is not present in the studied habitat to  $+1$  if the species is present only in the studied habitat. A zero indicates indifference to the habitat (i.e., the species does not prefer it, but does not avoid it). If the confinement indices are equal to zero or slightly different ( $\pm 0.25$ ) in one direction or the other in all habitats examined, the species is called eurytopic.

The nutrition of the *C. sibirica* was studied by the contents of the gastrointestinal tract according to the method of Dokuchayev (1990). 17 individuals were studied. The animals were captured in pitfall traps filled to 1/3 with water, making it impossible for the animal to eat other animals that entered the trap. The carcass of the animal and its gastrointestinal tract were weighed, and the species consumed was determined by chitin residues.

The study of the diurnal locomotor activity of the *C. sibirica* was carried out using the continuous timing method (Sergeev and Luchnikova 2002). During observations, the following eight basic types of behavior are recorded, which include several separate behavioral acts: grooming: cleaning, licking the fur and anogenital area, biting off parasites, scratching; nest improvement: construction and maintenance of a nest, the active state of the animal in the nest, preparation for sleep; responses to spatial restriction ("freedom reflex"): various attempts of the animal to leave the enclosure; defensive and search reactions (defense-search), which are active exploration of the

territory, searching for prey, hunting, hiding in case of danger, orientation reactions (sniffing, listening, looking around, standing on its hind legs); movement: all spatial movements of the animal; feeding activity complex: eating invertebrates and plants, necrophagia and coprophagia, drinking water, defecation and urination; sleep: long-term (in and out of the nest) and short-term, interrupted by other behavioral acts; rest: the motionless state of the animal during wakefulness (standing, sitting, lying). To determine behavioral stereotypes, square matrices of the probabilities of transitioning from one behavior to another were created with a confidence interval limit of 20% (Erdakov 1972).

Intra- and interspecific contacts were studied using 15 min pairwise encounters (dyadic tests). Experimental facilities were used to assess the animals' ability to climb, run, dig and swim. Running ability was assessed by the time it took the shrew to negotiate a 4.25 m horizontal transparent polyethylene tube. To assess swimming ability, the time the shrews spent moving in a 1 m circumference circular container filled with water with a 10 cm island in the center was recorded. Usually, the animals moved along the walls of the tank, making five circles, i.e. they covered a distance of 5 m. The animals were then removed from the water. To evaluate the digging ability, we used a transparent cylinder, 25 cm high. When the container was turned over, the shrew was under 8–10 cm of soil. Pre-dried and crushed chernozem was used as soil. We assessed the time it took for the animal to appear on the surface, as well as the animals' attitude towards digging (whether the animals attempted to dig or not when placed in a cylinder) and the response to fright (shrews tended to bury themselves in the ground in response to the external impact in most cases). In addition, the level of burrowing activity of the animals in the soil was recorded. A total of 15 animals were involved in the ethological studies.

## Results and discussion

**Distribution and typical habitats.** In the south of Western Siberia, the *C. sibirica* inhabits the areas from the Irtysh to the Yenisey Rivers (Yudin 1969, 1971, 1989). Previously, the Yenisei River was thought to limit the species' distribution to the east, but recent studies have found that the species' easternmost distribution point is on the right bank of the Yenisei River, 180 km from Krasnoyarsk, in the valley of the Kungus River (Vinogradov et al. 2014; Khritankov et al. 2017). In the Altai, it is known from different regions of the North-West, North-East, and Central Altai (Livanov et al. 2001). The northern border is on the outskirts of Tomsk (Zavarzino village) (Laptev 1958; Moskvitin and Moskvitina, 1998). It is rather difficult to characterize the southern limit of the distribution of the *C. sibirica* due to the uncertain taxonomic status of various populations of white-toothed shrews living in Siberia, Mongolia, and northern China, and the lack of information on the distribution of the species in China and Mongolia. Based on morphological characteristics in the territory of the former USSR, the *C. sibirica* extends south to the delta of the Black Irtysh River in eastern Kazakhstan and to Lake Teletskoye in the Altai. It has not been found in the Western and Eastern Sayan Mountains and Tuva (Yudin 1971). Considering that the *C. sibirica* and the *C. suaveolens* do not differ significantly according to the mitochondrial DNA data, the southeastern distribution of the species so far seems doubtful (Bannikova et al. 2006; Bannikova and Lebedev 2012; Zaitsev et al. 2014).

In the Kemerovo Region, the *C. sibirica* occurs in forest-steppe landscapes and taiga small-leaved forests, penetrating along river floodplains into mountain taiga (Ilyashenko et al. 1999, 2007, 2019).

The *C. sibirica* has not been recorded in captures from the northern plain taiga and the northern forest-steppe; occasionally it has been captured in the foreststeppe regions located on the right bank of the Tom River, in the birch and birchaspens forest-steppe. The northernmost known occurrence of the species in the Kemerovo Region is the village of Ust-Sosnovka (Yashkinskiy District) (Onishchenko et al. 2004). Here the *C. sibirica* were caught by the Sherman traps in the old aspen forest with fern and motley grass.

The *C. sibirica* is extremely rare in the Kuznetsk Depression. Here it has been observed only in the peripheral areas, where the landscapes have a combination of taiga and forest-steppe elements (Malkov 1987). Near the city of Novokuznetsk, in the partially cut dark coniferous taiga, the number of species in 1983 was three specimens per 100 trap-days, the next year it was not recorded. On the coal dumps, among the plantations of sea buckthorn and pine of different ages, located in the taiga zone, the number of the *C. sibirica* in different years ranged from 0.2 to one specimen per 100 trap-days. On the reclaimed coal dumps in the forest-steppe zone, the abundance of the *C. sibirica* was comparable to that in natural forest-steppe ecosystems – 0.3–0.4 specimens per 100 trap-days. In 1983–1984 the average percentage of the *C. sibirica* among shrews was 2.1% in the taiga zone, and 2.3% in the forest-steppe zone.

On the Salair Ridge in the Kemerovo Region, the abundance of the species is extremely low. It has been recorded only in secondary aspen-fir forests along the eastern foothills. Among small mammals, its percentage in these natural boundaries was 0.2%. On the western slopes of the Salair Ridge in the dark coniferous taiga, the proportion of the *C. sibirica* varied from 0.4–0.9% of shrews.

In the Gornaya Shoria Mountains the *C. sibirica* is rare everywhere and was recorded only in the Condoma River basin. Here its percentage among the shrews did not exceed 2%.

This species inhabits all altitudes of the western slopes of the Kuznetskiy Alatau Mountains. According to S.G. Babina (personal message), the maximum number of the species was recorded in the low mountains on hay meadows with motley grass and Poaceae – 4.9–5.4 specimens per 100 pitfalls-days. In the mid-mountains, it is captured in various types of dark coniferous forests, reaching a maximum abundance of up to three specimens per 100 pitfalls-days in sparse forests. Through taiga forests it penetrates to the border with subalpine meadows, where single records of the species are recorded. It is less common on the eastern slope of the Kuznetskiy Alatau. Their number in forests of different types ranges from 0.6 to 1.4 specimens per 100 pitfall-days (Yudin and Potapkina 1977).

On the middle course of the Tom River along with the Azhendarovskiy Ridge and in the adjacent territories (Ilyashenko et al. 1999), the *C. sibirica* is a common scarce species. Along the Azhendarovskiy Ridge and adjacent areas, the percentage of the species among small insectivores was 1.7%. The level of the relative abundance of the *C. sibirica* in the vicinity of the "Azhendarovo" Biological Station is about one specimen per 100 pitfall-days. The habitat confinements of the species are shown in Fig. 2.

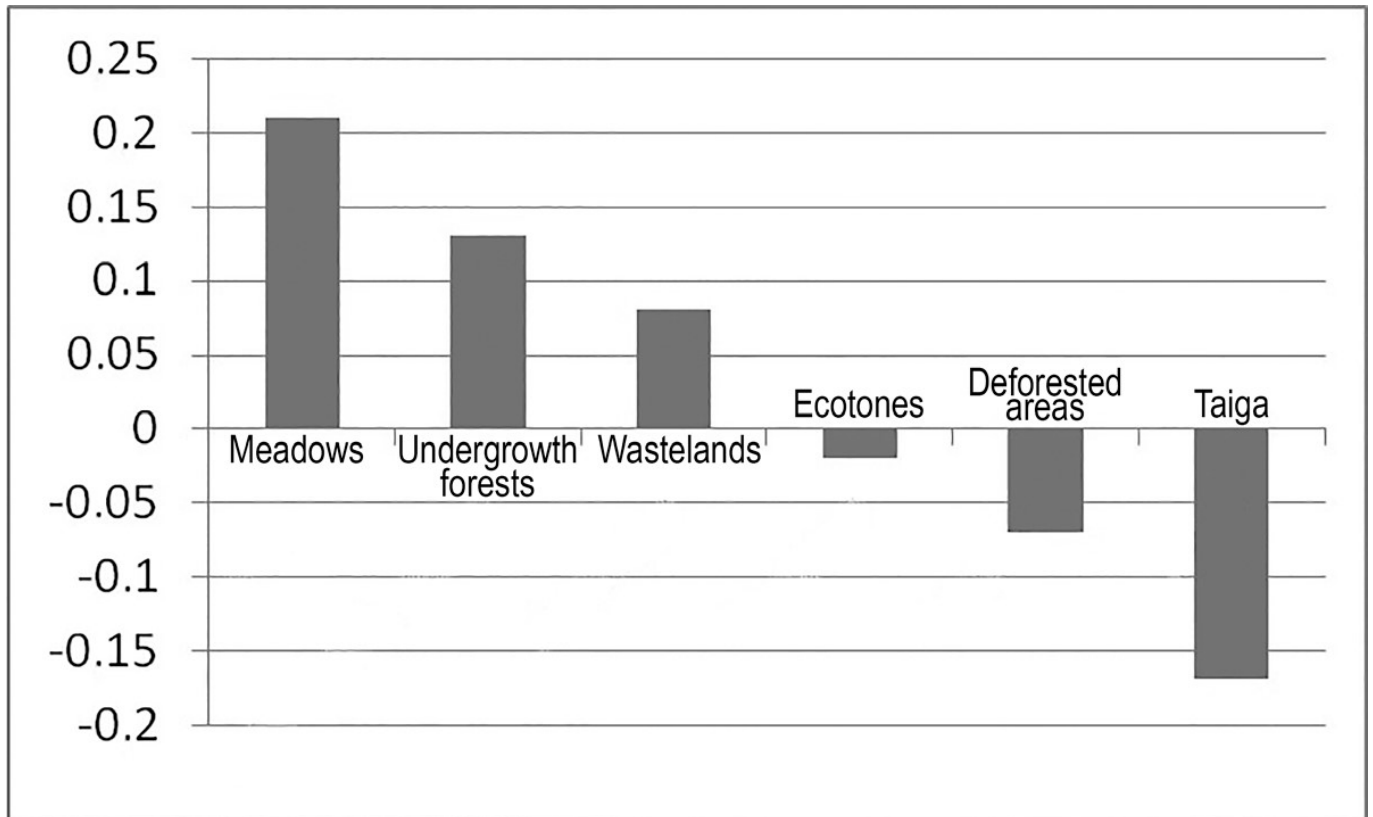
In the "Azhendarovo" Biological Station the most acceptable conditions for the species are created in the upland meadows, in the wastelands with nettle in the place of former settlement and in the undergrowth of fir, pine and aspen mixed forests recovering after clear-cutting. In the other areas of the Bungarapsko-Azhendarovskiy Regional Nature Reserve, where the forest-steppe elements of the landscape are more pronounced, the *C. sibirica* adhered to the edges of old deciduous forests and adjacent meadows.

An analysis of the distribution of habitats in different parts of the territory shows that the *C. sibirica* prefers habitats that have been significantly disturbed by human activities (regenerating deforested areas, hayfields, reclaimed coal dumps, burned areas), but avoids completely degraded areas and urban ecosystems.

**Absolute abundance.** Data on the distribution and abundance of the *C. sibirica* within the region are mainly based on relative counts. The absolute indices of the abundance of the *C. sibirica* in some habitats and interannual differences can be studied on the data obtained by counting the abundance in fenced sites using the method of L.P. Nikiforov (1961) (Table 2).

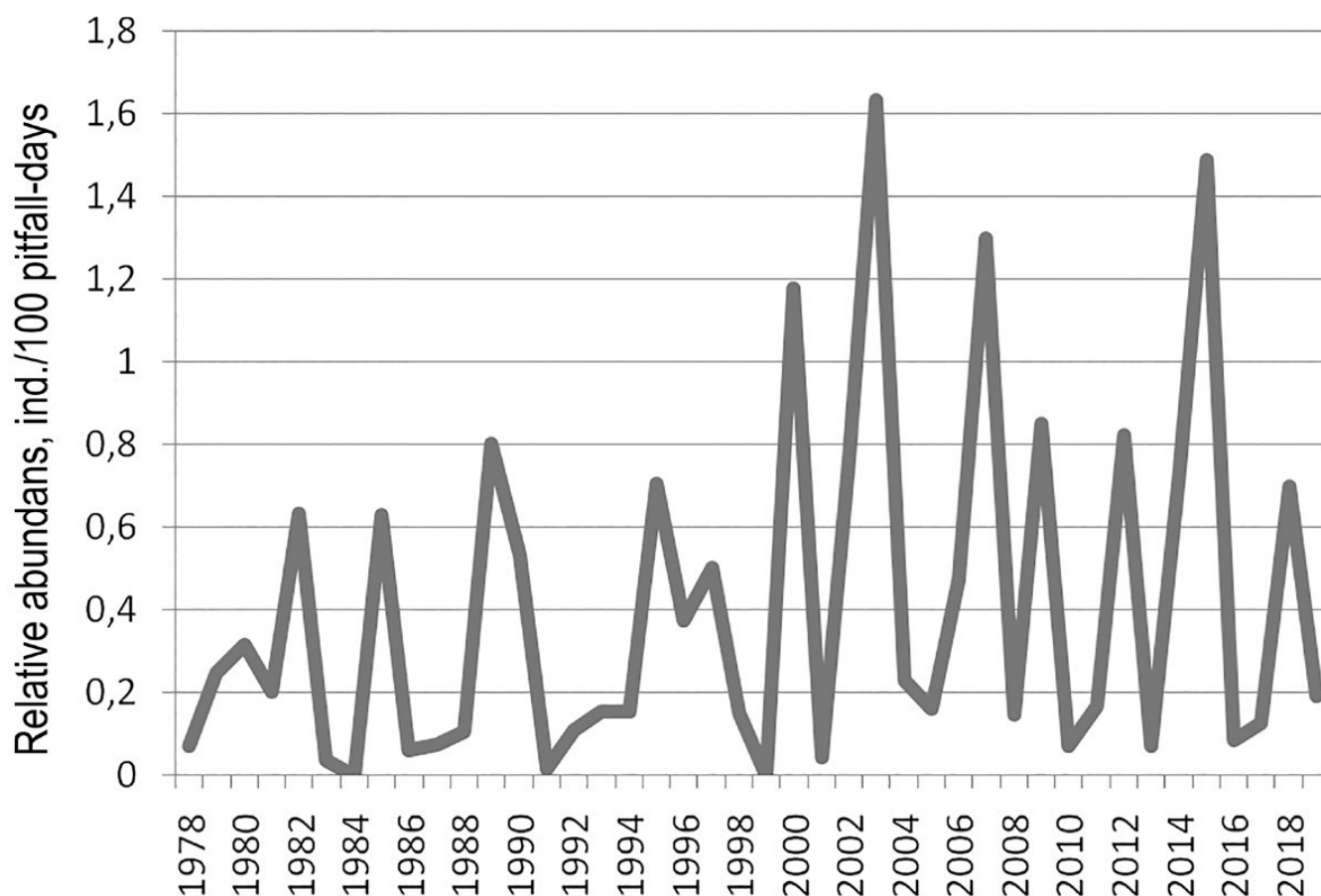
**Dynamics of seasonal and perennial abundance of the *C. sibirica* in smallmammal communities.** The perennial dynamics of the *C. sibirica* population was studied in the floodplain of

the Tom River in the previously deforested area of the dark coniferous forest (taiga). Before logging, the *C. sibirica* was extremely rare here of the restoration of the original taiga plant community, the abundance of the *C. sibirica* has remained at approximately the same level since 2000, although it is subject to cyclical fluctuations (Fig. 3).



**Figure 2.** Habitat confinements of *C. sibirica* in the valley of the river Tom, near the biological station "Azhendarovo". Meadows - floodplain terrace meadows with motley grasses and Poaceae; Undergrowth forests - mixed undergrowth forests of fir, pine and aspen recovering after clearcutting; Wastelands - nettle wasteland on the site of a former settlement; Ecotones - sites between recovering after clearcutting forests and meadows; Deforested areas - recovering after clearcutting dark coniferous forests; Taiga - fir, birch and aspen forests.





**Figure 3.** Perennial dynamics of *C. sibirica* abundance in the Tom River valley 1978–2019.

Habitats	Relative abundance, specimens per 100 pitfall-days	Conversion factor	Absolute abundance, specimens per hectare
High abundance phase			
Forests (taiga)	0.5	50.1	25.4
Meadows and steppe- forests	0.8	87.2	73.6
Low abundance phase			
Forests (taiga)	Not registered in captures		
Meadows and steppe- forests	0.1	89.6	5.7

**Table 2.** Data on the absolute and relative abundance of the *C. sibirica*

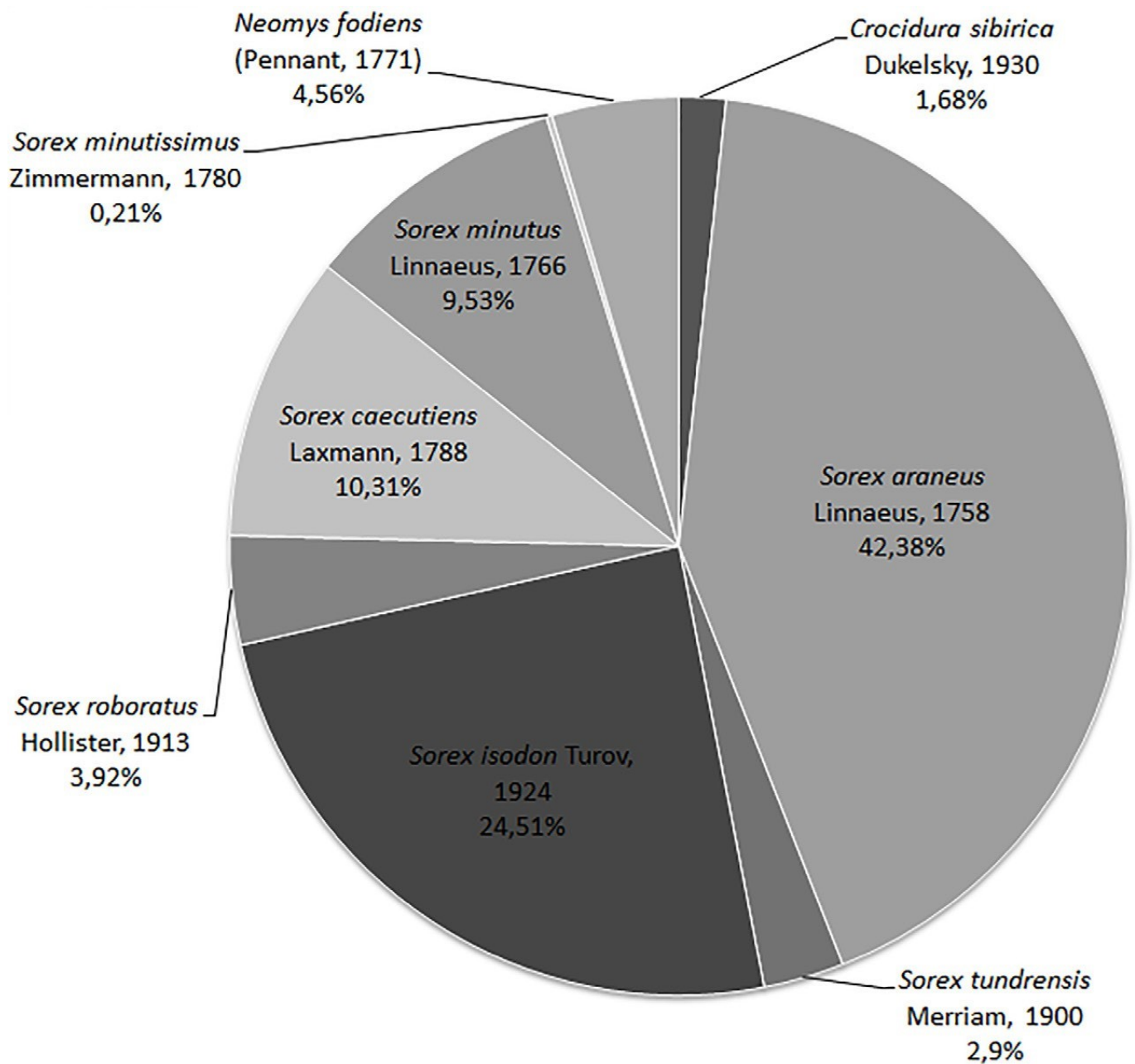
The abundance of the *C. sibirica* is very variable. During the years of depression of the family Soricidae, the abundance of the *C. sibirica* decreases more sharply than that of other species, and in some years it may be completely absent. In some years, there is a situation when the peaks of the abundance of the *C. sibirica* fall on the phase of decline or depression of the abundance of most species of insectivorous mammals, as was the case, for example, in 2003 and 2015 (Ilyashenko et al. 2015). According to our long-term data, the species makes up 1.68% of the shrew community in the middle reaches of the Tom River (Fig. 4).

In the main habitats, the abundance of the *C. sibirica* fluctuates synchronously. The most pronounced fluctuations are expressed in overgrown deforested sites and the relatively undisturbed dark coniferous taiga (Fig. 5).

The seasonal dynamics of the studied species is also specific: the first young animals appear very late, usually not earlier than mid-July, and in June, as a rule, overwintered animals are absent.

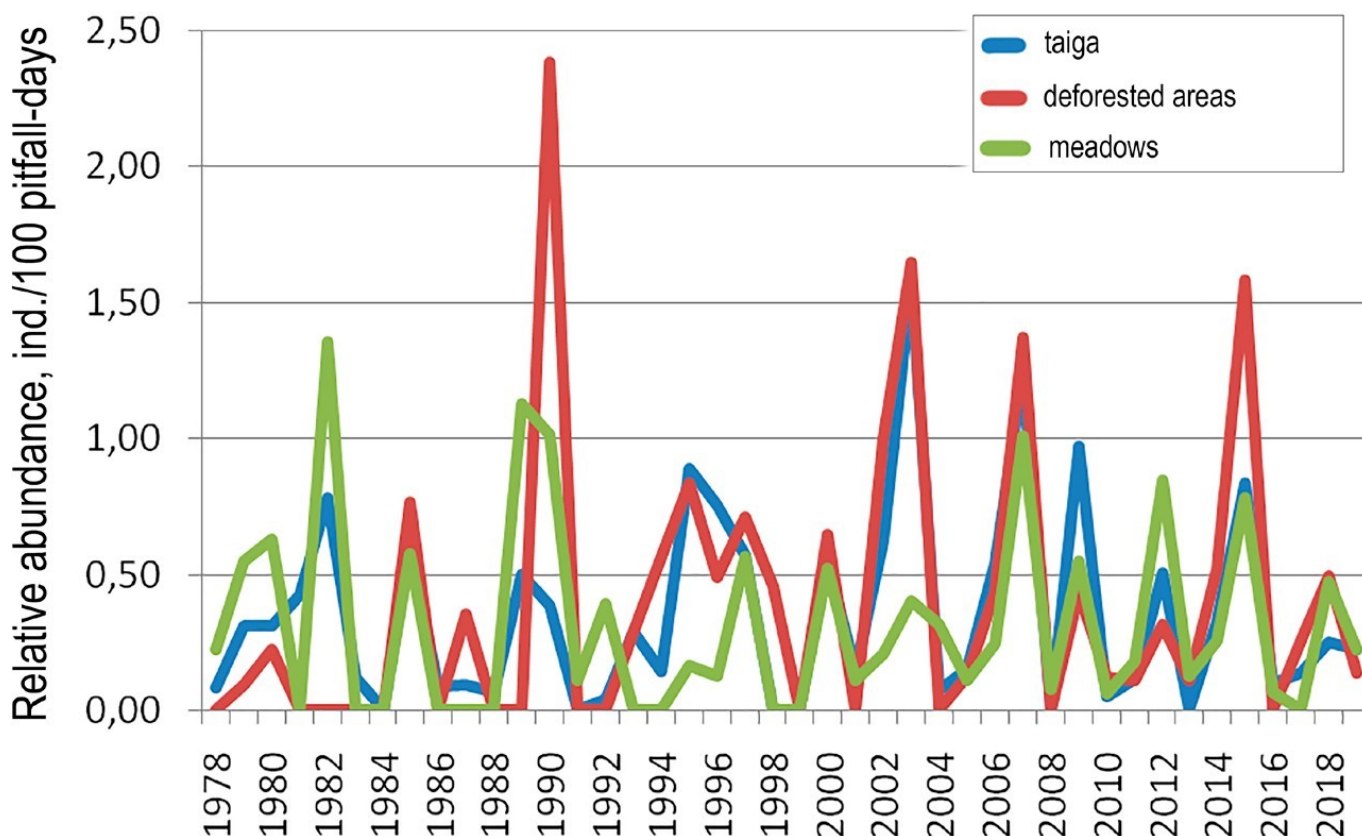
The peak of seasonal activity in years with a high abundance of *C. sibirica* occurs in mid-August and September when in some periods it is not inferior to the *Sorex tundrensis* Merriam, 1900 and the *Sorex roboratus* Hollister, 1913 in terms of the number of captured animals, and at the end of September, it sometimes surpasses the dominant *Sorex isodon* Turov, 1924 and *Sorex araneus* Linnaeus, 1758. Thus, in 2003, in the valley of the Tom River, an abnormal increase in the abundance of the *C. sibirica* was observed.

**Reproduction.** Data on the breeding of the *C. sibirica* are given in the Table 3. Unfortunately, even massive 40-year captures give only the most generalized data about the reproduction of overwintered females. It is interesting to note that all cases of capture of such females occur in years when the number of the *C. sibirica* has decreased significantly. Probably, the peak of reproduction falls on the second half of summer and the beginning of fall, when the proportion of lactating females in captures reaches 100% of all overwintered females.



**Figure 4.** Structure of the small mammal community in the middle reaches of the Tom River according to data from long-

term studies 1978–2019.

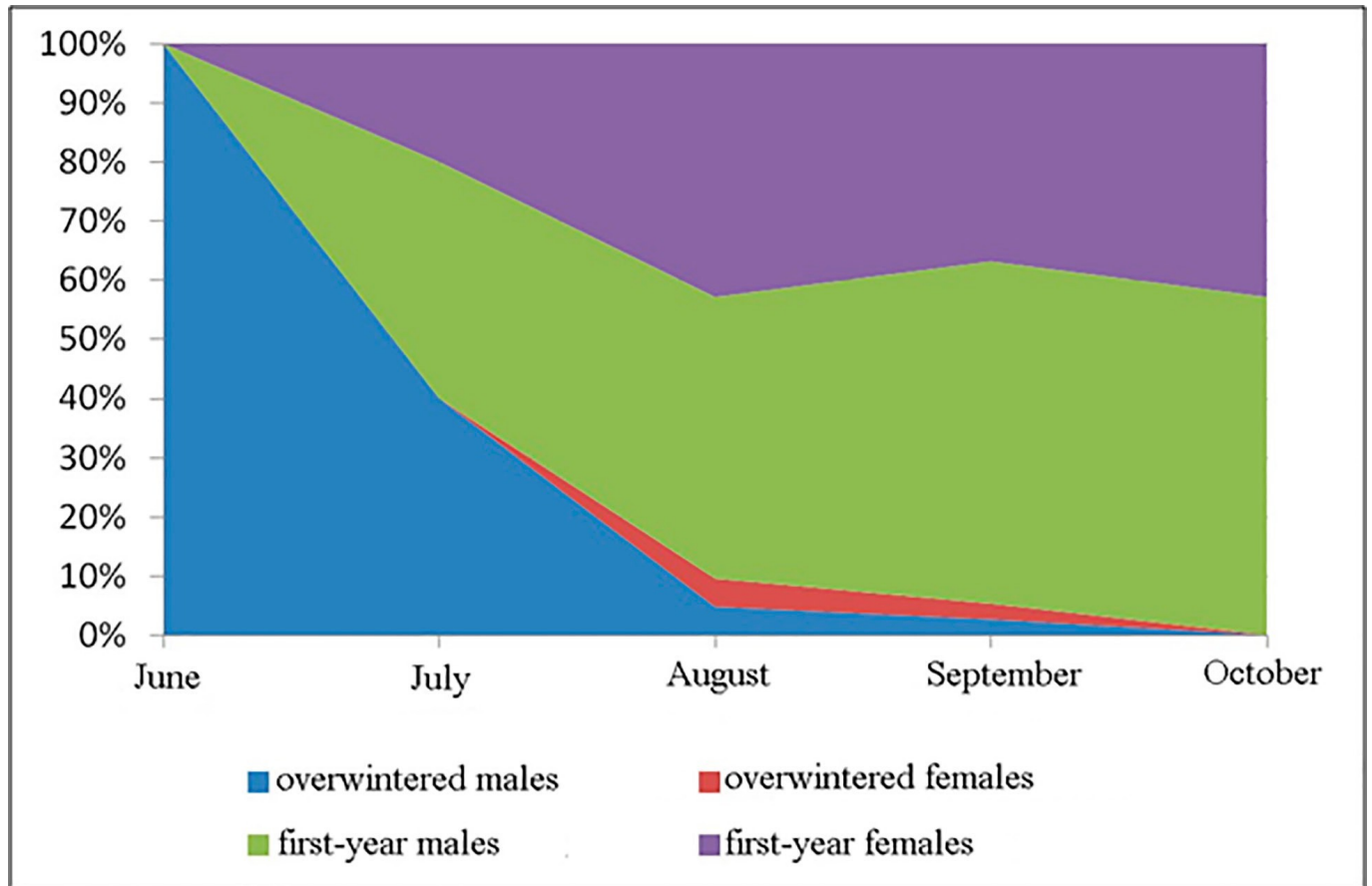


**Figure 5.** Long-term dynamics of *C. sibirica* abundance in the main habitats of the Tom River valley for 1978–2019.

	No. of pregnant specimens	No. of embryos	No. of lactating specimens	Percentage of pregnant, %	Percentage of lactating, %	No. of non-breeding specimens	Total no. of female specimens
July	2	7	0	66.667	0	1	3
August	1	0	7	9.090	63.636	4	11
September	0	0	5	0	100	0	5
Total	3	7	12	15.43	70.4	5	19

**Table 3.** Reproductive indices of overwintered *C. sibirica* females in the "Azhendarovo" Biological Station based on data for 1978–2020

Breeding first-year females of the *C. sibirica* were captured singly in August at the "Azhendarovo" Biological Station. The very small number of mature females is noteworthy, although some authors believe that this fact reflects only the peculiarities of the method of trapping with 50 m long trenches, in which only the mobile part of the population is caught (Shchipanov et al. 2003). However, even taking this condition into account and comparing the results of trapping with ditches, we can say that in the study area the proportion of mature females of the *C. sibirica* is lower than in other shrews. Another characteristic is the stable dominance of males over females among one-year-old animals (Fig. 6). After leaving the nest, juveniles remain together for several days, which is confirmed by the capture of entire broods in a single trap.



**Figure 6.** Seasonal dynamics of sex and age structure of *C. sibirica* population according to 1989 data.

**Diurnal activity and behavior.** The average diurnal activity of the *C. sibirica* is very low – 27.2 minutes per hour. This species is characterized by a 24-hour rhythm of diurnal activity, approaching diphasic, that is, in the diurnal rhythm, two periods can be distinguished – day and night. The *C. sibirica* is most active at dusk. The peaks of the highest activity are noted from 23:00 to midnight and at 6:00–9:00, and the animal is quite active during the rest of the night hours (Fig. 7).

The intensity of feeding reaches a maximum by 4:00–6:00. With a high abundance of food, its storage is observed. The *C. sibirica* moves mainly on the surface, does not suit underground passages and shelters. As the sun rises, the activity of the shrew falls, reaching a minimum by 17:00–18:00. The behavioral repertoire is dominated by grooming, the improvement of a temporary shelter, and the eating of stored food. The increase in activity begins with the complete sunset (Luchnikova and Malashkina 2000).

When analyzing the behavioral repertoire and identifying the stereotype of shrews' behavior, eight basic behavioral forms are observed: grooming, shelter improvement, reactions to spatial restrictions – the "reflex of freedom", defensive-orientational-search reactions, movement, food activity, sleep and rest of activity.

The "active" block is characterized by intense motor activity and includes defensive- search reactions, movement, nutrition activity, and the "reflex of freedom" (Fig. 8).

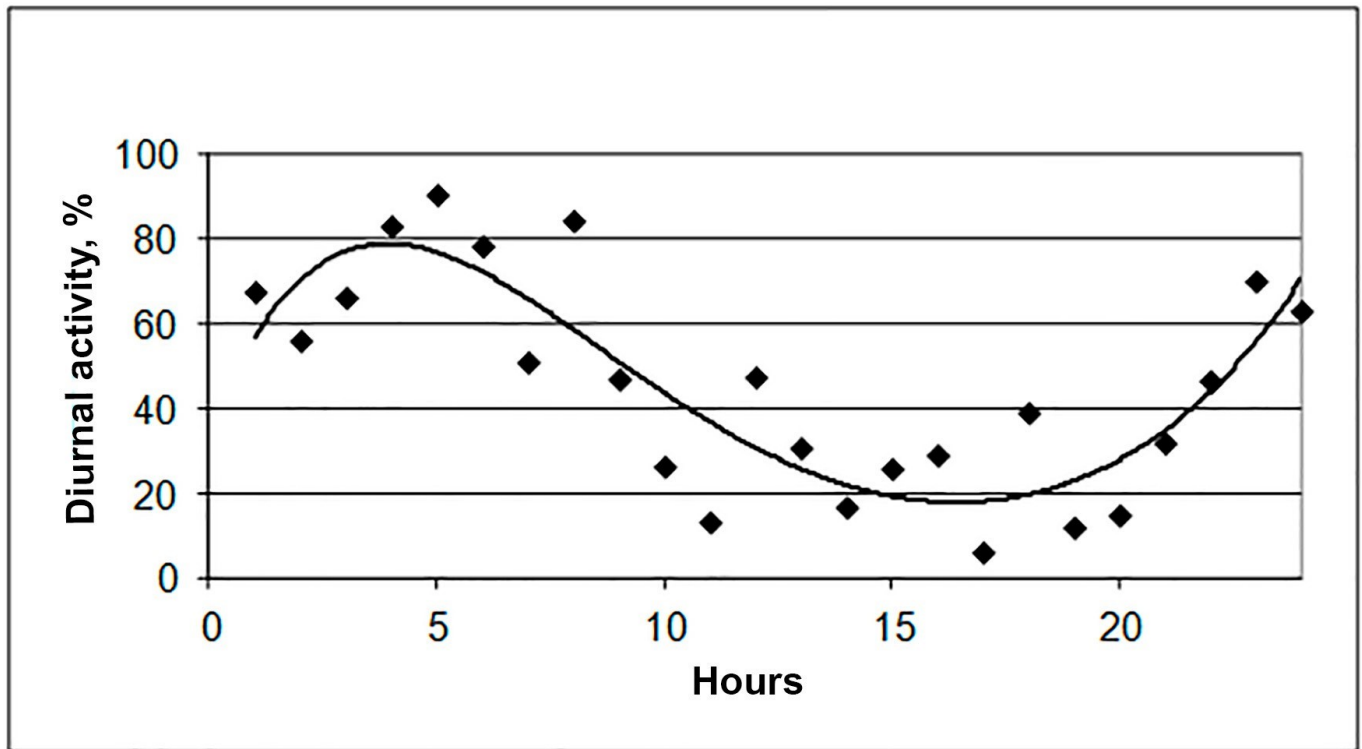
Mutual transitions from a "quiet" part to an "active" one and vice versa are most likely to occur through defensive-search reactions that follow the grooming, rest, or shelter improvement. The animal's sleep can also be interrupted by defense-search reactions. This complex combines transitional reactions; they precede the spatial movements of the animal or accompany them.

In general, the stereotype of behavior does not differ from the previously studied stereotypes of shrews of the genus *Sorex* (Sergeev and Luchnikova 2002), but the determination of the nature of movement activity led to rather unexpected results. In terms of speed of movement, it is twice or three times inferior to other shrews. The reason for this is that during the experiment, the *C. sibirica* mainly demonstrated orienting behavior, which was expressed in frequent stops with constant sniffing. For comparison, other species of shrews in most cases moved in a straight line without obvious stops.

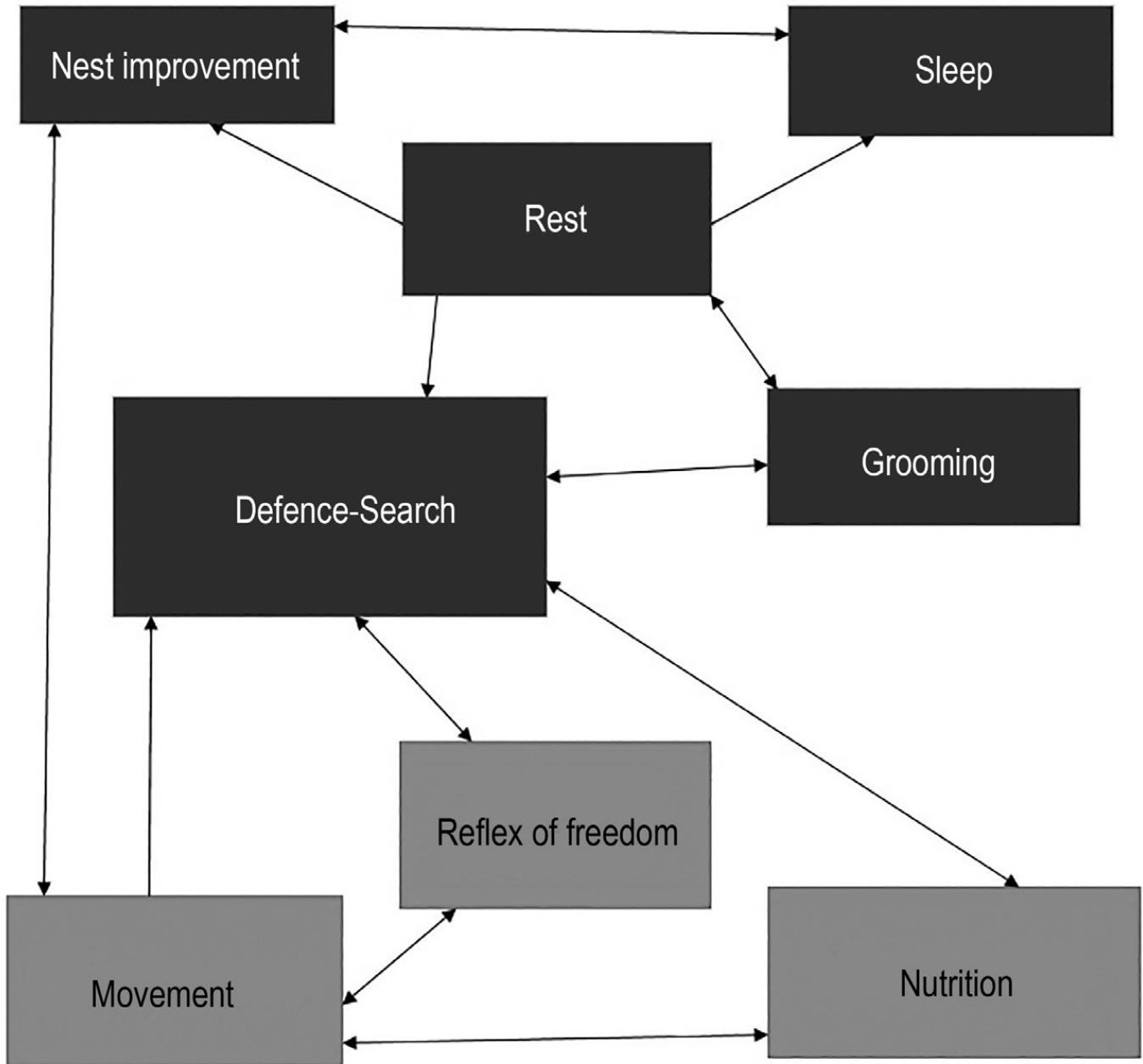
This may be explained by the fact that *C. sibirica* are more cautious in unfamiliar surroundings, which is manifested in the predominance of orientational behavior (Table 4).

Grooming	Shelter improvement	“Reflex of freedom”	Defensive-search reactions	Movements	Nutrition activity	Sleep	Rest
1.3±0.7	4.3±0.2	2.5±0.5	6.7±0.4	4.4±0.8	3.7±1.0	32.8±5.2	4.4±1.2

**Table 4.** The proportion of different behavioral forms in the daily rhythm of the *C. sibirica*, MeanSE, minutes per hour



**Figure 7.** Diurnal exponential smoothed activity of *C. sibirica*. Rhombuses indicate empirical values.



**Figure 8.** Stereotypical scheme of *C. sibirica* behaviour. Dark grey represents the 'dormant' part, light grey the 'active' part.

It is also interesting that, even though the morphological specialization of the *C. sibirica* and the *S. roboratus* has a similar orientation (Sergeev and Ilyashenko 1991; Ilyashenko et al. 1999), the ability of the *C. sibirica* to dig is much lower than that of the *S. roboratus*. As it was supposedly based on morphological analysis, the animals of this species in the experiments not only showed the maximum time of digging out of the installation from the ground but more often than others they were never dug out of the ground after a two-minute time interval. Long-term observations of animals in enclosures with an environment close to natural showed that, unlike other species of shrews, the *C. sibirica* practically does not show any attempts to dig. Perhaps this is due to the different levels of specialization of these species for running, which is also distinguished by the running of shrews in short powerful jerks and frequent stops. In terms of its ability to swim in an experimental setup, the *C. sibirica* is also much inferior to most species of shrews (Luchnikova 2004).

The behavior of the *C. sibirica* during interspecific encounters was described for only four pairs of animals, which is explained by the extremely low abundance of this species (Ilyashenko et al. 1999). At the beginning of encounters, the period of acquaintance with a partner was distinguished by a large manifestation of aggressive interactions – sniffing turned into aggressive vocalization, and teeth demonstration. When showing its teeth, the *C. sibirica* opens its mouth wide and chirps loudly, which distinguishes it from other shrews, which, with aggressive vocalization, only slightly open their mouths. At the end of the acquaintance period, *C. sibiricas* are mainly characterized by the manifestation of friendly integration interactions: the animals sniff, sit side by side for some time, sleep, huddled together in one nest. With a sufficient amount of food, animals of this species can coexist for a long time in one cage (Luchnikova 2004).

Intraspecific encounters with aggressive large species, like the *S. araneus* and the *S. isodon*, is quite intense. During these encounters the *C. sibirica* occupies a shelter and tries to fence out an opponent from it. Aggressive demonstrations and attacks of the shrew provoke an attack by the enemy. Despite the fact that *C. sibirica* is significantly smaller than its rivals, about half of the time the fight ends with the opponent fleeing.

The smaller and more peaceful the *S. caecutiens* and the *S. minutus*, after aggressive vocalization of the *C. sibirica*, immediately run away, trying to leave the enclosure, and the *C. sibirica* does not pursue them. Therefore, direct aggressive fights are not observed.

**Nutrition.** According to the analysis of the contents of the gastrointestinal tracts of the *C. sibirica*, they can be classified as a species with a wide range of nutrition. The food is based on the adults and larvae of insects, arachnids, and millipedes. Among insects, the most preferred types of food include ground beetle larvae, species of Diptera, and Hymenoptera (ichneumons and ants). In the gastrointestinal tract, adults of Lepidoptera and earthworms were noted. The occurrence of the earthworms does not exceed 12%, which distinguishes the *C. sibirica* from other shrews of the Tom River valley (Table 5).

Food type	Occurrence, % (N=17)
Coleoptera	70.6
Larvae of the ground beetles	47.1
Imago of the ground beetles	35.3
Larvae of the Coleoptera	11.8
Imago of the Coleoptera	17.5
Short-horned flies of the order Diptera	35.3
Hemiptera	23.4
Hymenoptera	29.3
Ants	17.5
Parasitoid wasps	11.8
Myriapods	23.4
Arachnids	35.3
Spiders	17.5
Harvestmen	17.5
Earthworms	11.8
Plant residues	17.5
Imago of the Lepidoptera	5.9

**Table 5.** The composition of the feed of the *C. sibirica* on the data of 2003–2004

The revealed dietary spectrum corresponds to the habitat distribution of invertebrates (Teplova et al. 2003). The most numerous species are eaten first, which indicates a lack of food selectivity. The exception is the harvestmen from the order Opiliones, whose percentage in the counts is low, but according to the analysis of the contents of the gastrointestinal tracts, their occurrence reaches

17.5%.

In experiment, the *C. sibirica* eat almost all the offered invertebrates, and first of all, live but inactive insects, then the *C. sibirica* begins to hunt for rapidly moving prey. Unlike other shrews, the *C. sibirica* pursues its prey more persistently, moving intensively around the enclosure. The size and hardness of the integument of invertebrates are not of fundamental importance when choosing food, since the *C. sibirica* can gnaw even large ground beetles (up to 2.5 cm).

Analyzing the feeding spectra of other small insectivorous mammals (Yudin 1971; Dokuchaev 1990; Teplova 1999; Ivanter 2019), we did not reveal any fundamental differences in the diet of the *C. sibirica*.

## Conclusion

Long-term comprehensive studies suggest that the low abundance of the *C. sibirica* throughout the studied range is caused by competitive interactions with numerous shrews of the genus *Sorex*, which form complex multi-species communities including up to 7 species of shrews. This is evidenced by the general tendency to occupy disturbed and self-growing territories, the predominance of the defensive-orientation-search complex in the behavioral stereotype, and the shift of reproductive activity to late summer and early fall. Despite the above and the low reproductive activity of females in the population, the total number of the species remains stable, although and subject to greater fluctuations than other shrew species.

The database on captures of small mammals in the “Azhendarovo” area is available at [https://www.researchgate.net/publication/344747624\\_Small\\_mammal\\_population\\_monitoring\\_at\\_the\\_Azhendarovo\\_Biological\\_Station\\_from\\_1978\\_to\\_2019\\_Kemerovo\\_Region\\_Russia](https://www.researchgate.net/publication/344747624_Small_mammal_population_monitoring_at_the_Azhendarovo_Biological_Station_from_1978_to_2019_Kemerovo_Region_Russia)(accessed 04.09.2023).

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