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Quantitative Estimation of Abundance of Shrews (Mammalia, Insectivora) after Wintering

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Abstract—Death rate of *Sorex araneus*, *Sorex caecutiens*, and *Sorex minutus* after wintering in Tver oblast has been estimated. Results of 12-year monitoring of permanent live trap lines are reported. Relative and absolute abundances were estimated in October and November and in April. Average death rate of *Sorex minutus*, a species of low abundance was kept constant from August through April, averaging 40.1%. Death rates of *Sorex araneus* and *Sorex caecutiens* in this period were 89.3% and 73.6%, respectively. During winter (from November through April) they equal 38.2% and 30.4%, respectively. Death rate in winter depends on the maximum abundance reached in summer and under the wintering conditions.

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Abundance of shrews tends to greatly fluctuate over seasons. It reaches its maximum after reproduction in late summer and is the least before reproduction in spring. The fall in abundance is usually explained by high death rate during winter [1]. The most reliable data on populational features of shrews including territorial behavior and density were obtained by direct observations over labeled shrews of certain species [1–8]. Works [9–12] provide data on long-term dynamics of population, but there are no data on seasonal fluctuations of abundance under various conditions and different density of shrew population. Shrews are a group of morphologically and ecologically similar species generally inhabiting the same area. The abundance of shrew taxa in the ecological complex may vary greatly; in some cases long-term dynamics of abundance varies asynchronously [8, 13]. Seasonal dynamics of populational features may be thus assumed to differ in different species.

The paper reports data of a long-term monitoring conducted from 1995 through 2006 with individual labeling of *Sorex araneus* Linnaeus, *Sorex caecutiens* Laxmann, and *Sorex minutus* L. The primary aim of the study was to quantitatively estimate the death rate of the three shrew taxa from October through April.

MATERIALS AND METHODS

The data were collected at the right bank of the Volga River in Staritskii raion of Tver oblast (56°N, 35°E). The climate is moderate, the average summer temperature is 17 °C above zero, and the average winter temperature, 9 °C below zero. The snow cover settles in late November and remains until middle April. Precipitation is all-the-year-round, averaging 650 mm. The area lies in the south taiga subzone; the forests are rather fragmentary, there are expansive fellings and agricultural lands gradually overgrowing with seres. In the period 1995–2005, we carried out a study using four stationary live trap lines in various biotopes such as an alder forest with birch trees and spruce underwood, a spruce-birch forest, a spruce forest with pine trees with green moss and bilberry, and a spruce forest accompanied by green moss and shamrock. The study area is a 1.5 km^2 compact woodland separated from neighboring forests by a river, fellings, and overgrowing meadows.

A technique of individual labeling of animals and recapture, which is described in detail in [14], was used. Live traps of a special design [15] consisting of 4 lines of 50 traps each were set at an interval of 7.5 m. There were 200 traps in total. The distance between the capture points in meters equaled the difference in the numbers of neighboring traps plus one, multiplied by 7.5. Each trap was set in the same place every year. The traps were put on the alert once a day and were checked twice every 1.5 h. Then the traps were not on the alert until the next day, thus allowing for visiting them by small animals. The trap lines were 1.5 km in total length. The caught animals were labeled by amputating a finger. With this technique the mortality among the labeled animals was less than 1%.

The paper addresses the overall data for the forest rather than biotopical distribution of the animals. I analyzed the shrew abundance estimated in fall and spring, i.e. in Octobers 1995, 1996, and 2003, Novembers 1996, 1997, and 1999, and Aprils 1996–2000, 2002–2006. The data on 533 *Sorex araneus* individuals from 1630 captures, 340 *Sorex caecutiens* individuals from 1477 captures, and 252 *Sorex minutus* from 557 captures have been analyzed.

All abundance estimations were based on the number of animals caught in one 7-day session. In case of multiple sessions during a month, the data over the period were averaged. The abundance rate is the total

Table 1. Relative abundance of shrews in different seasons

Species	October	November	April		
	Underyearlings		After wintering:		
			Total	Males	Females
S. araneus	22.2±7.5	16.8±2.6	10.3±2.2	6.8±1.9	3.5±0.6
S. caecutiens	15.3±0.9	14.2±2.3	11.2±1.6	7.2±0.7	4.0±1.0
S. minutus	3.8±1.6	8.0±1.8	8.2±1.7	4.8±0.9	3.3±0.9

number of animals caught in a line of 100 traps (750 m) during one session.

RESULTS AND DISCUSSION

Relative abundance. Abundance is characterized by the number of individuals recorded at a capture. Relative abundance was estimated as the total number of individuals recorded in one capture session per 100 traps. Average abundances of three species of shrew underyearlings in October and November and of males and females in April after wintering were calculated (Table 1).

The abundances of *Sorex araneus* and *Sorex caecutiens* naturally decline from October till April, though the overall number of animals recorded at the trap line did not decrease much. The abundance of recorded *Sorex araneus* individuals fell by 53.3% from October till April, the abundance of *Sorex caecutiens* declined by 26.8%. Only few individuals of *Sorex minutus*, generally exhibiting low abundance, were caught in October in some years. This accounts for their low averages in October. Thus, according to the data of relative estimation the total number of recorded individuals was a little greater in April than in October.

The results of April estimation reveal a considerable number of male animals (63.5% of males and 36.5% of females of all species on the average) which may be accounted for by greater mobility of males in April.

Absolute abundance. Absolute abundance is the number of animals per unit area [16]. Density of animals was estimated as the number of settled individuals per 1 hectare. It should be noted that settled shrews are usually caught in live traps, while nomadic shrews are mostly caught with cone traps [17–19]. Thus, we can analyze populations of resident shrews and estimate them quantitatively using live traps.

When analyzing plots inhabited by small mammals, Slade and Russel showed that RMS deviation from the activity center matches other features of the plot and can be its metrical measure. The data of three separate captures are sufficient to estimate the RMS deviation, while other statistic estimations require data of more than 20 observations [20]. If the habitat can be approximated with normal distribution, we may find areas where individuals will predictably appear. Shchipanov et al.[21] have shown that the capture of an individual on the line is well approximated by normal distribution. On the basis of standard deviation (s), the following areas were recognized: high-activity area ($\pm s$ from the activity center, $2s$ in total), regular-activity area (between high activity area and boundaries $\pm 2s$ away from the activity center); the area of $6s$ ($\pm 3s$ away from the activity center) was regarded as a full plot. According to normal distribution, 68.3% of catches occur in the high-activity area and 95.4%, in the joint area of high and regular activity. If the trap line crosses an animal's habitat through the high-activity area, the animal may be caught several times in a catch session, but if the trap line crosses the regular-activity area, the animal will be caught only once [21]. If the activity center of an animal is beyond $2s$, this animal may be caught only during long-term studies. Thus the animals whose activity centers are within $2s$ from the trap line will be caught during a catch session, and the area inhabited by the caught animals can be calculated (Fig. 1). If the activity center is beyond $2s$, the probability of capture is below 5%.

Animal density per 1 hectare can be estimated from:

$$P = 10000N \,/\, (L4s + \pi(2s)^2),$$

where N is the number of animals at the trap line, L is the line length in meters (our line was 750 m long), s is RMS deviation of individual plots in meters, 10000 is the coefficient for estimating the density per 1 hectare.

Individual plots of three shrew species were estimated from RMS deviation. In October and November I estimated plots of all underyearlings caught three or

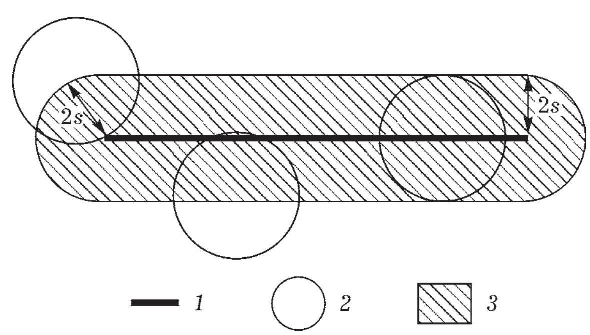

Fig. 1. Estimation area diagram. *1* — live trap line; *2* — individual plot; *3* — estimation area.

Table 2. Estimation area width and density of shrews in different seasons

Month	Age-sex group	Species	Estimation area width 4*s*	Number of animals in 100 traps per 1 capture session	Density, ind/ha
October	Underyearlings	*S. araneus*	30.4	22.2	9.4
		S. caecutiens	63.6	15.3	3.0
		S. minutus	*	3.8	*
November	Underyearlings	*S. araneus*	48.7	16.8	4.4
		S. caecutiens	70.6	14.2	2.5
		S. minutus	53.8	8.0	1.9
April	Males after wintering	*S. araneus*	143.7	6.8	0.6
		S. caecutiens	113.7	7.2	0.8
		S. minutus	116.9	4.8	0.5
	Females after wintering	*S. araneus*	86.3	3.5	0.5
		S. caecutiens	82.2	4.0	0.6
		S. minutus	59.2	3.3	0.7
	All individuals after wintering	*S. araneus*		10.3	1.0
		S. caecutiens		11.2	1.3
		S. minutus		8.2	1.2

*Not available

more times in one catch session. In April I estimated the plots of males and females separately (Table 2). These calculations yielded the density of animals per 1 hectare.

The areas where shrews occur vary in different months, especially large plots are inhabited by males after wintering (in April). This expansion of males leads to overestimation of male abundance disproportionate to abundance of females. When estimating the density of animals per unit area, the gender proportion in spring was 1:1, which is quite typical of these species.

Death rate. Abundance in a local population depends upon birth and death rates, as well as immigration and emigration. Labeling of shrew populations in various biotopes within and near the study area, showed no considerable migration of animals. In winter shrews tend to remain within their plots. Most of animals labeled a year ago remain in their natal areas after wintering. All the species studied are usually settled through the dispersal of underyearlings. The animals who had settled in fall shared a plot with an individual who had already wintered [22–24]. The migration of mature animals after wintering occurred in summer, reaching its peak in August [21, 25]. Therefore, migration during fall and winter is of little importance.

Reproduction of shrews in our climate comes to an end in August through September, though some wintered animals may be found until late November and first youngsters are not recorded at the lines before late May or early June. The abundance of shrews from October through April, therefore, depends only on their death rate. Table 3 reports our data on average death rates.

The highest death rate has been recorded in the common shrew during fall and winter. Over 5 months its abundance was gradually declining from 4.4 ind/ha to 1.0 ind/ha, i.e. it fell by 76.1%. The fall in the abundance of the other two species was not so dramatic, for it did not even reach 50%. *Sorex minutus* has the lowest decline in abundance, its average winter death rate being 36.2%. It is also worth mentioning that the common shrew shows considerably high death rate during fall.

Table 3. Death rate of shrews over fall and winter

Species	Death rate, %	
	from October through November	from November through April
S. araneus	53.5	76.1
S. caecutiens	17.4	45.8
S. minutus	*	36.2

*Not available.

Table 4. Death rate of shrews in different years

Years	Species	Density		Death rate, %
		November	April	
1996–1997	*S. araneus*	3.9	1.3	67.0
	S. caecutiens	3.2	1.3	59.3
	S. minutus	2.4	1.5	36.7
1997–1998	*S. araneus*	3.5	1.4	60.0
	S. caecutiens	1.8	1.5	16.2
	S. minutus	1.1	1.0	7.8
1999–2000	*S. araneus*	5.7	0.6	88.5
	S. caecutiens	2.3	1.2	48.7
	S. minutus	2.1	0.8	61.0

The average death rate of the common shrew in October and November account for 53.2%, while that of the Laxmann's shrew (*Sorex caecutiens*) account for 17.4%. When seasonal dynamics of shrew abundance had been estimated [26, 27], it was shown that a considerable reduction in shrew abundance, being greater in years of greater abundance, happens during fall. The abundance of *Sorex caecutiens* falls faster than that of *Sorex araneus.* It may be assumed that the reduction in abundance of the common shrew during fall continues until December and most of winter deaths of the species (from November through April) occur in November through December. Deaths become then fewer and winter death rate of the common shrew becomes almost equal to the death rate of the Laxmann's shrew.

Winter death rate depends on many factors such as conditions of wintering, summer abundance, abundance of predators, and many others. Therefore, winter death rates may greatly fluctuate over different years (Table 4).

The lowest death rate was documented in the winter of 1997–1998 which might be accounted for by favorable conditions of wintering, although winter death rate of the common shrew was greater than that of the other species.

The greatest abundance of shrews is reported to occur in late summer and the lowest in spring [28, 29]. Insufficient foodstuff is assumed to reduce the abundance of shrews during winter [30, 31]. According to our data, the first fall in the shrew abundance occurred immediately after its peak in August. At that time the average density of the common, Laxmann's, and pygmy shrew were 9.8, 5.1, and 2.0 ind/ha, respectively. From September through November the average abundance of the common shrew dropped by 55.2%, and of the Laxmann's shrew, by 51.2%. The drop in abundance of the pygmy shrew was as small as 6.1% (Fig. 2). This drop, however, does not indicate death rate because reproduction still continues in late summer till early fall, youngsters actively wander around, and most of underyearlings are not settled yet. All this leads to overestimation of the abundance, i.e, the death rate is underestimated.

Death rate of a population can be expressed as the difference between the maximum summer density of underyearlings in the end of reproduction and the spring density before reproduction. The death rate of species whose abundance fluctuates varies from year to year. The highest death rate occurs when the abundance is great and the lowest death rate occurs when the abundance is low. The death rate of the pygmy shrew, a species of generally low abundance, was 40.1% on the average over the period. The death rate of the common and the Laxmann's shrew accounts for 89.3% and 73.6%, respectively, in the period from August through April. The winter death rate (from November through April) among these species are 38.2% and 30.4%, respectively. The death rate of shrews over the rest of wintering may be even lower considering that abundance of shrews, especially of the common shrew, may continue to decline even in December.

Any considerable postwintering reduction of shrew population density occurs only after the peak abundance in the past year, while in other years winter

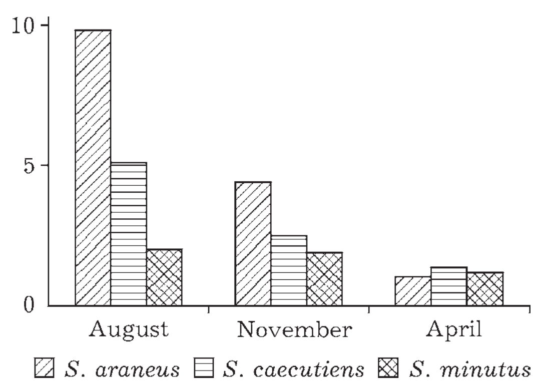

Fig. 2. Density (ind/ha) of 3 shrew species in different months.

deaths are not numerous, especially if abundance was low before wintering. Thus the abundance rates of the three species studied appear similar and quite stable in spring (after snow melts). The abundance reduction in fall may be caused by either insufficient foodstuffs or density-dependent populational mechanisms. It can be assumed that the abundance in spring and summer depends on the capacity of a habitat rather than on their abundance in fall.

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