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Population dynamics of the common shrew and pygmy shrew (Soricomorpha: Soricidae) in a clear-cut of a mixed forest in eastern Lithuania

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Abstract. Population dynamics (density, age structure, and sex ratio) of *Sorex araneus* and *S. minutus* was studied in late summers of 1987–1993 during small mammal community formation in a growing-up clear-cut area within a mixed forest in eastern Lithuania (Molėtai District; 55°09′ N, 25°20′ E). In the studied area the density of the common shrew was significantly greater and its multi-annual variation in density was more stable compared with the pygmy shrew (18.64 ± 2.49 and 5.57 ± 2.75 ind./ha, $p < 0.0017$; $s = 0.258$ and $s = 0.625$, respectively). Changes in the age structure (subadults/adults) and sex ratio of both shrew species correlated with density variations.

Key words: *Sorex araneus*, *Sorex minutus*, density, age structure, sex ratio, clear-cut, eastern Lithuania.

INTRODUCTION

In the East Baltic region, shrews (Soricomorpha: Soricidae) are represented by five species: common shrew (*Sorex araneus* Linnaeus, 1758), Laxmann's (masked) shrew (*Sorex caecutiens* Laxmann, 1788), pygmy shrew (*Sorex minutus* Linnaeus, 1766), least shrew (*Sorex minutissimus* Zimmermann, 1780), and water shrew (*Neomys fodiens* (Pennant, 1771)). However, the distribution of the species and their abundance are different in Estonia, Latvia, and Lithuania (Timm et al., 1998; Balčiauskas et al., 1999; Masing, 1999; Mitchell-Jones et al., 1999).

In Lithuania, the Soricidae family is represented only by three species – common shrew, pygmy shrew, and water shrew (Prūsaitė, 1988). Although special investigations of shrews have never been conducted in Lithuania, some data on their distribution, relative species density, and abundance were collected during small mammal community studies in protected and agricultural territories (Maldžiūnaitė et al., 1981; Mažeikytė, 1990, 1992, 1995, 2002a, b, 2003; Baleišis et al., 1993; Balčiauskas & Juškaitis, 1997; Juškaitis & Ulevičius, 2002; Mačiulis, 2002; Ulevičius et al., 2002; Pakeltytė & Andriuškevičius, 2004; Juškaitis & Uselis, 2005). The common shrew was found to be more widespread and numerous in

Lithuania compared to the pygmy shrew and water shrew (Balčiauskas et al., 1999; Mažeikytė, 2004). According to these authors, the common shrew inhabits almost all types of habitats, while the pygmy shrew most often inhabits moist habitats. However, data on the abundance or changes in the abundance of both shrew species in Lithuania are very scarce (Baleišis et al., 1993; Mažeikytė, 1995, 2002a, b, 2003; Juškaitis & Uselis, 2005) and, therefore, little is known about their population dynamics (multi-annual changes in abundance, sex ratio, age structure) in various habitats, including habitats transformed by human activities.

The main goal of this work is to examine the population dynamics (density, age structure, and sex ratio) of the common shrew and pygmy shrew. The study of shrews is based on the data gathered during a seven-year-long study of small mammal community formation in a clear-cut of a mixed forest during the post-clear-cutting plant succession.

STUDY AREA

The study area was in a mixed deciduous–coniferous forest of Vilkaraistis (495 ha, Molėtai District, eastern Lithuania, 55°09′ N, 25°20′ E). The forest was situated on hilly moraine uplands and extended among fields, meadows, and pastures. The forest was rich in various kinds of trees with the dominance of mature oak (*Quercus robur*) and spruce (*Picea abies*) stands. Other stands such as alder (*Alnus incana* and *A. glutinosa*), aspen (*Populus tremula*), ash (*Fraxinus excelsior*), and birch (*Betula* sp.) were frequent, while maple (*Acer platanoides*) and pine (*Pinus sylvestris*) stands were rare. The understory and shrub layer consisted mainly of lime (*Tilia cordata*), nut (*Corylus avellana*), and different young trees. The undergrowth and clear-cut areas constituted about 5.7% of the forest area. Sod-podzolic sandy loam and clay loam soils prevailed. The area of the forest was hilly, with wet and swampy ravines between hills.

The clear-cut in which observations were carried out had formed step by step and covered about 4 ha. It was within a mixed forest and at least 100 m from the forest border. Part of the mixed forest and part of a recently clear-cut plot (one-year post-clear-cutting) were selected as the study area (respectively, 38.1% and 61.9% of the total study area). A map and the description of the vegetation cover were made (see Mažeikytė, 1995 for details). The clear-cut plot was covered with leaf-bearing undergrowth, a natural meadow, and tracks left by tractors (respectively, 17.8%, 36.5%, and 7.4% of the total study area). The leaf-bearing undergrowth was composed of lime, aspen, and ash trees. The herbaceous cover of the meadow was mainly formed from *Aegopodium* sp., *Cirsium* spp., *Agrostis* spp., *Rubus* spp., *Urtica* sp., *Impatiens* spp., *Carex* spp., and the tracks of tractors were mainly overgrown with *Carex* spp., *Agrostis* spp., and *Trifolium* spp. A large amount of logging residues and numerous stumps were scattered all over the study area. In a year, these logging residues were huddled into two oblong heaps (1–2.5 m wide), and spruce seedlings were planted. During the local succession of vegetation, the area of undergrowth increased, while the area of the natural meadow decreased. The most luxuriant and the highest herbaceous vegetation in the clear-cut was in the 2nd–4th years of the study, and young trees reached a height of 3–4 m in the 5th year of the study.

MATERIAL AND METHODS

The study of shrews is based on the data gathered during 1987–1993 in a clear-cut within a mixed forest in the first stage of local plant succession. The method of non-enclosed plot was used, and all the mammals caught were removed from the study area. Every year, animals were studied in late summer, in the first half of August, using the grid system with mouse snap traps. Snap traps were set for four and a half days on a 1.53 ha area. Snap traps were laid on a 10 m × 18 m grid, with 10 m spacing between the traps. Each trapping point was provided with two traps. The traps were checked twice a day, in the morning and in the evening. Slices of brown bread crusts soaked with oil were used as bait. As a result, 300 common shrews and 89 pygmy shrews were caught. Of the common shrews 73.7% (limit 64.3–84.3%) and of the pygmy shrews 69.7% (limit 42.9–89.6%) were caught during the third–fifth days of the trapping period. It was related to the elimination of most individuals of the dominant species (the bank vole *Myodes glareolus* and yellow-necked mouse *Apodemus flavicollis*) in the first two days. Besides, a different number of captured common shrews and pygmy shrews may have been caused by the differences in their body size (a pygmy shrew is typically only about one-third the body weight of the common shrew) and territory/home-range requirements. The epigeal pygmy shrew requires a home-range twice that of the hypogeal common shrew (reviewed by Churchfield, 2002).

All the individuals caught were analysed in the laboratory using a standard morphological–physiological method. Two age groups of each shrew species were distinguished: adults (sexually mature over-wintered and young-of-the-year) and sub-adults (sexually immature young-of-the-year). Shrew population numbers were measured by the relative species density (RD, %) and density (D) (after Brower & Zar, 1984). The relative species density is the total number of individuals of a species expressed as a percentage of the total number of individuals of all species. Density was expressed as the number of individuals per area unit (ind./ha). To avoid the 'edge effect', a belt of the width equal to the inter-trap station distance was added to all sides of the study grid (reviewed by Smith et al., 1975) when we calculated the density of shrews. Also, the value of the cycle index (*s*, after Henttonen et al., 1985) was calculated to describe the fluctuation of population density.

The standard statistical approach (mean, standard error and limits, *t*-statistics for the comparison of the means, Pearson correlation and multiple regression and chi-square test) was used. Calculations were done with Statistica for Windows, version 5.0.

RESULTS AND DISCUSSION

Relative species density of the common shrew and the pygmy shrew in a small mammal community

The results showed that the relative species density (RD) of the common shrew and pygmy shrew in the small mammal community during the seven-year-long study varied (from 3.9% to 33.8% and from 0.4% to 12.3%, respectively) (Fig. 1). The lowest percentage was observed in the first year of the study for both species, while the highest percentage was observed in the third (in 1989, for the pygmy shrew) and the fifth (in 1991, for the common shrew) year of the study. The highest rate (38.4%) of both shrew species in the small mammal community was recorded in 1991, when the RD of the dominating bank vole *M. glareolus* was the lowest (36.4%; Mažeikytė, 1995). As many as 78% (limit 69–84.2%) of the common shrews and 88.7% of the pygmy shrews (limit 85.4–100%) were caught in the clear-cut area, i.e. in natural meadows and leaf-bearing undergrowth, where numerous shelters and luxuriant and high herbaceous vegetation were present. Only 22% of the common shrews (limit 15.8–31.0%) and 11.2% of the pygmy shrews (limit 0–14.6%) were caught in the forest area.

A parallel study of small mammals in different tree stands of the Vilkaraistis forest revealed that the RD of the common shrew differed among stands and among years and ranged from zero to 21.4% and from 1.8% to 8.3%, respectively. The RD of the pygmy shrew in the small mammal community in the studied tree stands was lower and ranged from 0% to 11.1% and differed among years from 0% to 3.4% (the author's unpubl. data). Thus, the common shrew was more widespread and numerous in the main forest than the pygmy shrew. These results closely correspond to the present results obtained in the forest part of the studied

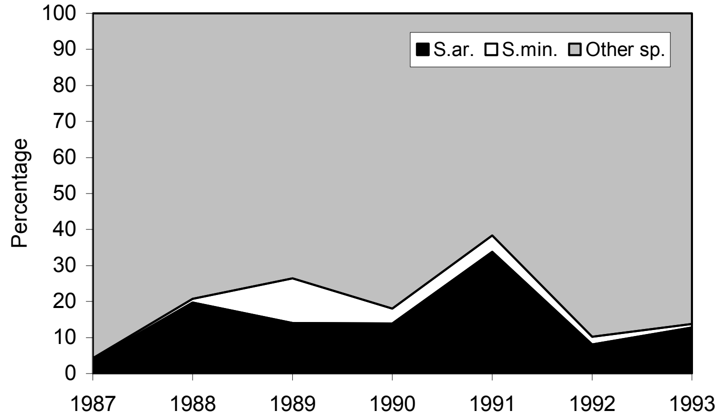

Fig. 1. Changes in the percentage of common shrews and pygmy shrews in the small mammal community in the summers of 1987–1993: S.ar. – *S. araneus*, S.min. – *S. minutus*, Other sp. – other species.

grid. Besides, three-year (1994–1996) investigations of small mammals in different habitats around the Vilkaraistis forest also revealed that the common shrew was more widespread and numerous than the pygmy shrew (RD: 14.3% and 1.9% of all small mammals captured, respectively) (Mažeikytė, 2002b). Other investigations throughout the territory of Lithuania showed that the RD of the common shrew and pygmy shrew in small mammal communities varies markedly in a number of different habitats in late summer (from 1.3% to 100% and from 1.1% to 60%, respectively) and depends on the nature of the habitat (Maldžiūnaitė et al., 1981; Mažeikytė, 1990, 1992, 2002a, 2002b, 2003; Baleišis et al., 1993; Juškaitis & Ulevičius, 2002; Mačiulis, 2002) and the year of investigations (Baleišis et al., 1993; Balčiauskas & Juškaitis, 1997; Ulevičius et al., 2002; Pakeltytė & Andriuškevičius, 2004; Juškaitis & Uselis, 2005). These results correspond to the results obtained by Churchfield (1990), who reported that the percentage of shrews in relation to other mammals may be highly variable, depending upon habitat, season, and even year.

Population density in shrews

The density dynamics in the populations of the common shrew and pygmy shrew was found (Fig. 2). The density of the common shrew in the studied area varied from 8.3 (in 1987) to 27.5 ind./ha (in 1990, peak year), and that of the pygmy shrew varied from 0.9 (in 1987 and 1988) to 21 ind./ha (in 1989, peak year). These results show that the amplitude of the common shrew density varied 3.3 times and was less variable compared to the amplitude of the pygmy shrew density, which varied 23.3 times. The calculated value of the cycle index for both shrew species also revealed different fluctuations in density ($s = 0.652$ for the pygmy shrew and $s = 0.258$ for the common shrew). Significant differences were observed in the mean density level of the common shrew and pygmy shrew

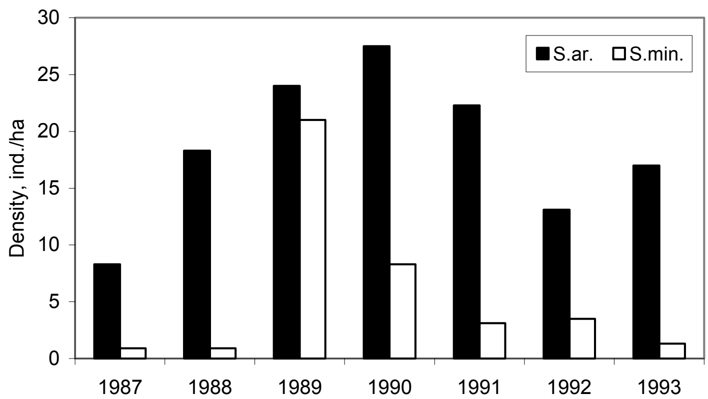

Fig. 2. Dynamics of the common shrew and pygmy shrew density in the summers of 1987–1993: S.ar. – *S. araneus*, S.min. – *S. minutus*.

(18.64 ± 2.49 and 5.57 ± 2.75 ind./ha, respectively; $t = 5.396$, $p < 0.0017$). The correlation between the density indices of the two *Sorex* species was positive, but statistically nonsignificant ($r = 0.577$, $p > 0.175$).

Because the study area was inhabited by three common rodent species, the bank vole, field vole, and yellow-necked mouse (Mažeikytė, 1995), we examined the relationship between the density indices of the shrew species and the rodent species. It was found that correlations between the density indices of the common shrew and the bank vole, field vole and yellow-necked mouse and between the density indices of the pygmy shrew and these three rodent species were negative (except between the pygmy shrew and yellow-necked mouse where the correlation was positive), yet very weak or zero (respectively, $r = -0.36$, $r = -0.45$, $r = -0.20$, and $r = -0.017$, $r = -0{,}196$, $r = 0.336$), and in general nonsignificant ($p > 0.1$). According to Hansson (1992), the absence of significant negative correlations (at both low and high densities) suggests that density indices are not affected by any interspecific competition for traps. We suppose that both shrew species have undergone a very weak interspecific competition in the study area because of abundance of shelters, luxuriant and high herbaceous vegetation, and availability of food resources, and the calculated density indices corresponded to the natural density of shrews.

It is known that shrew population density estimates exhibit high variation. So, summer density estimates ranged from 7 to 98 ind./ha for the common shrew and from 5 to 40 ind./ha for the pygmy shrew in England (reviewed by Churchfield, 1990), and from 4 to 26 ind./ha for the common shrew and from 2 to 7 ind./ha for the pygmy shrew in Germany (Kollars, 1995). In Poland, density estimates for the common shrew and pygmy shrew were about 19 and 10 ind./ha, respectively (Pucek, 1984). According to Churchfield (1990), several factors, such as the nature of the habitat, species, season, and year, contribute to the variation in shrew numbers. In many open habitats in eastern Lithuania, the relative abundance of the common shrew was found to range from 0 to 26 ind./100 trap-days in late summer; and that of the pygmy shrew, from 0 to 13.3 ind./100 trap-days, and depended on the nature of habitats and the years of the study (Mažeikytė, 2002b). Recently, Pupila & Bergmanis (2006) reported that in eastern Latvia the autumnal relative abundance of the common shrew and pygmy shrew in coniferous and mixed coniferous–deciduous forests varies on average from 0.1 to 1.9 and from 0.1 to 1.6 ind./100 trap-days, respectively. In Fennoscandia, the common shrew population was found to exhibit seasonal and erratic long-term fluctuations in density (Henttonen et al., 1989). In addition to high variation, Sheftel (1989) found a shrew community in central Siberia to be cyclic in density. According to our results, in late summer the density of the common shrew population in the study area in eastern Lithuania was greater and its variation more stable compared with the density of the pygmy shrew population. The density fluctuation of the pygmy shrew corresponds to 's' estimates ($s > 0.5$) for cyclic rodent populations proposed by Henttonen et al. (1985).

Age structure and sex ratio

Multi-annual changes in the age structure of the common shrew and pygmy shrew populations were found (Fig. 3). Subadult shrews constituted the greatest part of both populations, except pygmy shrews in 1987, 1988, and 1993. The difference between the frequency of occurrence of subadult and adult common shrews during the seven-year-long study was statistically significant (Table 1). Between subadult and adult pygmy shrews this difference was statistically significant only in 4 out of 7 years, the values of frequency were equal at the beginning of investigations (in 1987, 1988), and the difference was statistically nonsignificant at the end of investigations (in 1993) (Table 1). The number of adult shrews was rather small and varied from 3.3% (in 1992) to 28.2% (in 1993) in the common shrew and from 50% (at the beginning of investigations) to zero (in 1991 and 1992) in the pygmy shrew.

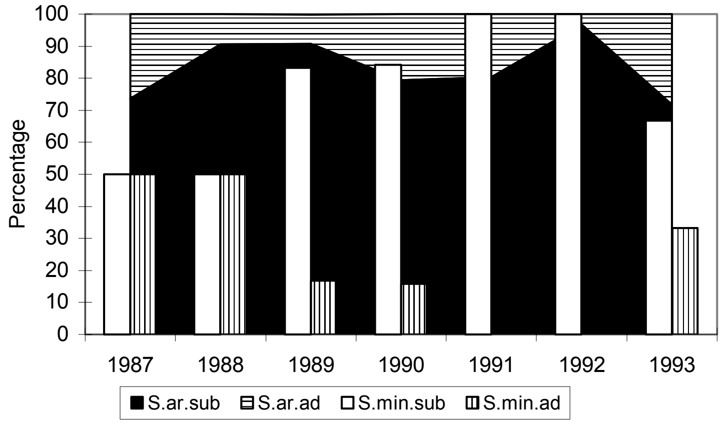

Fig. 3. Changes in the age structure (%) of the common shrew and pygmy shrew populations in the summers of 1987–1993: in the background – *S. araneus* (S.ar.), columns – *S. minutus* (S.min); sub – subadults, ad – adults.

Table 1. Changes in the frequency of subadults and adults in *S. araneus* and *S. minutus* populations during the seven-year-long study, and the computed chi-square (χ^2) values (significance level: df = 1; $\alpha = 0.10$, $\chi^2 = 2.706$; $\alpha = 0.05$, $\chi^2 = 3.841$; $\alpha = 0.025$, $\chi^2 = 5.024$; $\alpha = 0.01$, $\chi^2 = 6.635$; after Brower & Zar, 1984; * subadults predominate)

Species	1987	1988	1989	1990	1991	1992	1993
S. araneus							
Subad/ad	14/5	38/4	50/5	50/13	41/10	29/1	28/11
χ^2	3.368*	25.928*	35.2*	20.571*	17.647*	24.30*	6.564*
S. minutus							
Subad/ad	1/1	1/1	40/8	16/3	7/0	8/0	2/1
χ^2	0.5	0.5	20.001*	7.579*	5.143*	6.125*	0.0

We tested the null hypothesis that males and females of both shrew species occur with the same frequency in their two age groups. We used the chi-square (χ^2) test for this purpose. The computed χ^2 values showed that males and females often occurred with the same frequency in the subadult age group of common shrews (Table 2). The exceptions were the years 1991 and 1992 when the frequency of males was more expressed ($\chi^2 = 3.512$ and $\chi^2 = 3.448$), and 1993 when the females predominated ($\chi^2 = 2.893$, $\alpha < 0.10$). This was also true for adult common shrews, except in 1989 when only females were caught ($\chi^2 = 3.2$). As shown in Fig. 2, the population density of common shrews gradually decreased in 1991 and 1992 after a peak density in 1990, but their density increased in 1993.

The computed χ^2 values for the subadult pygmy shrews showed equal sex frequencies in the years of the investigation, with one exception in 1990 when the frequency of males was more expressed ($\chi^2 = 3.062$, Table 2). Only a few adults of the pygmy shrew (except in 1989) were caught and most of them were females. The computed χ^2 value showed that males and females occurred with the same frequency in 1989. It should be noted that the pygmy shrew population reached the maximum density in 1989, while in 1990 its density clearly decreased (Fig. 2).

Changes in the age and sex structure of shrew populations in different phases of the cycle in central Siberia were reported by Sheftel (1989). He found that the sex ratio amongst juveniles of *Sorex caecutiens* became more female biased in the prepeak and especially peak years, while in the years of lower numbers the sex ratio was more male biased.

Our regression analysis revealed that changes in the age structure (subadults/ adults) and sex ratio (males/females) of common shrews in summer significantly correlated with density variations ($r = 0.963$, $p < 0.005$, $R^2 = 0.927$, $Y_D = 2.8228 + 1.117\, X_{subad}$; $r = 0.839$, $p < 0.01835$, $R^2 = 0.704$, $Y_D = 15.68 + 1.2288\, X_{male}$; $r = 0.755$, $p < 0.05$, $R^2 = 0.570$, $Y_D = 15.118 + 1.3322\, X_{female}$, respectively). That was also true for pygmy shrews ($r = 0.998$, $p < 0.00000$, $R^2 = 0.996$, $Y_D = -0.0305 + 1.1895\, X_{subad}$; $r = 0.956$, $p < 0.00078$,

Table 2. Changes in the frequency of males and females in two age groups of *S. araneus* and *S. minutus* populations in the summers of 1987–1993, and the computed chi-square (χ^2) values (significance level: df = 1; $\alpha = 0.10$, $\chi^2 = 2.706$; $\alpha = 0.05$, $\chi^2 = 3.841$; after Brower & Zar, 1984; * males and ** females predominate)

Years	*S. araneus*				*S. minutus*			
	Subadults		Adults		Subadults		Adults	
	Males/ females	χ^2	Males/ females	χ^2	Males/ females	χ^2	Males/ females	χ^2
1987	6/8	0.071	1/4	0.8	0/1	0.0	0/1	0.0
1988	23/15	1.289	1/3	0.25	1/0	0.0	0/1	0.0
1989	20/30	1.62	0/5	3.2**	23/17	0.625	5/3	0.125
1990	30/20	1.62	8/5	0.308	12/4	3.062*	1/2	0.0
1991	27/14	3.512*	4/6	0.1	5/2	0.571	0/0	
1992	20/9	3.448*	0/1	0.0	6/2	1.125	0/0	
1993	9/19	2.89**	5/6	0.0	2/0	0.5	0/1	0.0

$R^2 = 0.913$, $Y_D = 1.4643 + 5.625\ X_{ad}$; $r = 0.995$, $p < 0.00000$, $R^2 = 0.989$, $Y_D = -0.4428 + 1.6745\ X_{male}$; $r = 0.989$, $p < 0.00002$, $R^2 = 0.978$, $Y_D = 1.1073 + 2.3897\ X_{female}$, respectively).

CONCLUSIONS

The relative density of the common shrew and pygmy shrew in the small mammal community in a heterogeneous environment of a clear-cut area within a mixed deciduous–coniferous forest in eastern Lithuania varied from year to year and probably depended on the abundance of shelters and local plant succession in the study area as well as on the shrew abundance in the main forest.

In summer, the common shrew was more abundant and multi-annual variation in its density was more stable compared with the pygmy shrew, whose density was more variable and corresponded to cyclic rodent populations. Subadult shrews constituted the greatest part of the common shrew and pygmy shrew populations. Changes in the age structure and sex ratio of both shrew species correlated with density variations.

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Mets-karihiire ja väike-karihiire (Soricomorpha: Soricidae) populatsioonidünaamika segametsa raiesmikul Ida-Leedus

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Mets-karihiire (*Sorex araneus*) ja väike-karihiire (*S. minutus*) populatsioonidünaamikat (asustustihedust, vanuselist ning soolist struktuuri) uuriti hilissuvel kinni kasvaval segametsa raiesmikul Ida-Leedus (Molėtai rajoon, 55°09′ N, 25°20′ E) aastatel 1987–1993. Selgitati, et mets-karihiire asustustihedus oli oluliselt suurem ja aastate lõikes stabiilsem kui väike-karihiirel (vastavalt 18,64 ± 2,49 ning 5,57 ± 2,75 ind./ha, $p < 0,0017$; $s = 0,258$ ja $s = 0,625$). Asustustiheduse varieerumine sõltus mõlemal liigil populatsiooni struktuurist: noor-, isas- ja emasloomade vahekorrast.