Delineation of the Territory of Lithuania for the Hares *Leporidae*: I. Estimation of the Habitat Suitability

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The delineation of territory for hares refers to the determination of their habitat suitability depending on the carrying capacity and favourability of living conditions. The main purpose of the study is to estimate hare habitats based on different categories of forests and adjacent lands. The main index of habitat suitability is the density of the hare population. The important factors for the delineation of the territory include climatic factors, forest cover, soil fertility, changes in topography, diversity on an area, size of a stand and other lands. In areas of low carrying capacity, and because of interdependence of other environmental factors, the density of elementary populations of hares is not more than the average population density throughout Lithuania. In areas of the pine with spruce forests the density of the European hare population is average and that of the mountain hare population is highest. In these areas there is a favourable ratio of foraging to shelter places. The measures of care would be applied under extreme conditions. On areas of mixed spruce-deciduous forests the living conditions for hares are more favourable. The impact of the main environmental factors determines the average and above average density of the European hare population, also the stable average and above average density of the mountain hare population, with a tendency towards more abundant population. On areas of the deciduous with spruce forests the density of mountain hare positively related to the snow depth because of better accessibility of food in the forest habitat. The most favourable areas have been delineated.

Key words: hares, forest category, environmental factors, habitat suitability, delineation of territory

Introduction

Both the mountain hare (*Lepus timidus* L.) and European hare (*Lepus europaeus* Pallas, 1778) have different status and are important components of the Lithuanian fauna. The European hare and the mountain hare settled in Lithuania long ago. However, Lithuania is in the outer zone of the mountain hare's distribution (Belova, 1999). Historically, the mountain hare was abundant and was the only species of *Leporidae* in Lithuania. Since 1989 it has been listed as an endangered species in the Lithuanian Red Data Book. Over time the mountain hare population has fluctuated between 3 and 6 thousand animals (Belova, 1989, 1999). In the 20th century the European hare has become widespread in conjunction with an expansion of the forest fragmentation. In the 1970s, the European hare population decreased 3 times. The population stabilized and has fluctuated between 60 and 85 thousand over the last 15 years. The main reason for the decline of the hare population was its natural fluctuation combined with the drastic impact of the human factors. Considerable changes in the habitat caused a change in the population, distribution, and range of the hare's tolerance to limiting factors (Belova, 1989). The prolonged decline of the European hare population exceeds the natural limits of the normal 20- to 25-year-old cycle of the population. Within this normal cycle, the population fluctuates every 2 to 8 years. Phases of the decrease and increase in the population occur every 10 and 12 years, respectively (Petrov, 1976; Ondersheka, 1984; Schneider, 1984; Reincholf, 1984/85; Belova, 1990, 1997). The population of the mountain hare increases through the stabilization to the maximum, then declines at regular intervals every 4 to 9 years (a longer 9- to 10-year cycle is characteristic of the northern hares – Dasman, 1966; Tomilova, 1974,1982). Within the current decline, the population dynamics have become unusual. The decline continues even when unfavourable influences have decreased. Then the influence of the natural factors increases (Belova, 1990, 1991, 1994, 1996). Climatic factors are considered to be the main regulator of the population. In areas where hares settled long ago, they usually have adapted to local climatic and other habitat conditions. Habitat conditions have to ensure the optimal animal density of the ecological population and other population parameters. The principal task of this work is not to examine the effect of separate environmental factors on the hare population. Questions of hare spatial distribution, impact of

predators, agricultural system and other reasons for diminishing hare population have been discussed by many authors. Hitherto, the state of hare population dependence on habitat conditions such as forest composition, habitat and other factors based on the category of forest was not recognized. The estimation of habitat suitability is of great importance and this problem is relatively little recognized too. This is important for the delineating of zones in Lithuania for the game animals, also for the maintenance of biological diversity in forest ecosystems. The main purpose of the study is the ecological estimation of hares' habitats on areas of various categories of forests and adjacent lands. Animals constantly adapt themselves to changing habitat conditions according to behavioural and biological strategies. These are expressed in population parameters. Density is the main and applicable index of the favourability of animal living conditions that determines the intensity of interactions between the hares and their habitats. The geomorphologic, soil and weather conditions of the territories, forest cover, size of stand, crop rotation and composition in the vicinity of forest, interaction between different animal species and their competition or the decline of a population have been taken into consideration. Depending on the habitat suitability including the carrying capacity of habitat we could apply different standards of the animal population densities that could help maintain the equilibrium between animals and plants. The separation and estimation of environmental factors should be allowed to reveal the hares' ecological reserves and possibilities to display these in the certain habitats on different areas of Lithuania. This study is a part of the general study on carrying capacity of animal habitats on areas of different categories of forests, including: pure pine; pine with spruce; mixed spruce-deciduous; and deciduous with spruce forests.

Materials and methods

The habitat conditions were estimated and favourable composition of habitats and their optimal ratio singled out. Climatic conditions were evaluated using data from 1861 until 1965 (Dorfman et al, 1959; Bukantis, 1994), data from the last 30 years, and by the data of weather factors in the study areas during field work. The main climatic factors for hares were: the depth of snow (*cm*), structure of snow cover, the number of thaws, the number of winters with variable snow cover (%), regime of the air temperature during the cold and vegetative periods, congelation of the soil, and the relative moisture of the air during different seasons. To determine the degree of the inclemency of weather S_a within the cold period, Bodman's formula $S_a=(1-0.004t)(1+0.272V)$ was applied, where t is air temperature C^o, V is the wind speed, *m/s*. In order to determine the factor of rain L_f the formula $L_f=\sum mm/t$ (Puppe, 1966) was used where $\sum mm$ is the total quantity of the precipitation, and t is air temperature t^o.

Forests of Lithuania are in the broad-leaved coniferous forests' Baltic province of the medium continental climate zone of Central Europe. In accordance with continentality index K=77 to 81% (Bukantis, 1994), the overall climate of Lithuania tends to be mildly continental, as in whole Eastern Europe. However, in winter Lithuania is intermediate between maritime climate and continental climate. Several climatic sub-regions are singled out in different parts of Lithuania depending on the prevailing climate (Dorfman et al., 1959; Kaušyla, 1981; Bukantis, 1994; et al.). These sub-regions (viz. Ia,b, IIa,b,c, IIIa,b) differ by main climatic factors. The climatic sub-regions were chosen and grouped according to the category of forests and adjacent lands. The categories of forest are separated with respect to game animals. These categories are pure pine, pine with spruce, mixed spruce-deciduous and deciduous with spruce stands. The suitability for hares was evaluated by the climatic conditions of certain areas. Various territorial units were grouped according to the prevailing soils, topography, forest cover, characteristics of the categories of stands and adjacent areas. The study areas were estimated by the last data of forest and game management regulation, and land exploitation (namely species composition, fertility of the prevailing soils, habitat conditions, age, other characters of forest and their adjacent land) and also during field work. The soils of adjacent farmlands were estimated by the Lithuanian soil regionalization (Vaitiekūnas et al., 1965; Mališauskas et al., 1970). The fertility was assessed by the 100-estimation number system. The average density of hares for the last 30 years has been estimated by official annual census data. Although the annual density has not been related to habitat conditions and the official census data is not entirely accurate, the long-term data is sufficiently comparable and applicable for further analysis. Additionally, the forage and shelter characteristics of the habitats were estimated by the belt transect routes method (4x100 m). The frequency of occurrence of hares was calculated by the formula: $Ii= Ns/nL/G$, where Ns is the frequency of the finding of animal

tracks, *nL* is the number of route units *m*, and *G* is the coefficient of aggregation as a unit of ratio of a single and group tracks (Belova, 1990). The individual tracking method was used additionally in snow. The feeding conditions were established by the sample plot method. Two sample plots (5x10 m, 10x10 m) were used per route unit and one control plot was used per route. I take into consideration the mixed ecotype of European hares. I have investigated both forest units and adjacent areas that are 400 m or more from the forest edges, depending on the season and other environmental local conditions. The dependence of the hare density on the main habitat factors was estimated by mathematical statistics. The total number of sample plots of all categories of the territory was 772 in the forest habitats and 477 in the adjacent open areas. The number of hare tracking was 27. The total length of route was 1574 km; the total study area was 98.36 thousand hectares.

Results

Pure pine stands predominate in the area of the continental climate (viz. IIIb climatic sub-region) in the southeastern part of Lithuania, and in the littoral zone where the maritime climate (the IIa climatic sub-region) prevails. On the mostly wooded area of the IIIb sub-region (total forest cover of the pure pine forests is from 58.6% to 79% in the continental part and 71.6% in the littoral zone) snowy winters (snow cover from 65 to 75 cm while the limit depth of snow is 70 cm), blizzards (on average 18 days per annum) and a comparatively long duration of the snowy period (75 days or 12% of the winters of unstable snow cover) are characteristic. Early and late frosts are possible. This coincides with the increase of hare reproduction (Belova, 1989, 1990,1996). Snow is a less obstacle for the mountain hare (r=0.40) (Table 2) because of some morphological and behavioural features (e.g., more fur and wider feet), preference for the forest habitat and forest cover (r=0.25). Deep snow could make better feeding conditions in the forest through an increase in the accessibility of woody food. Therefore, the unstable snow cover is not favourable (r=-0.39). The dependence of European hare density (y) upon the forest cover of territory (x_1), number of winters with unstable snow cover (x_2) and the depth of snow cover (x_3) on areas of pure pine forests and adjacent lands is expressed by the equation $y= 109.21 - 0.18x_1 - 0.74x_2 - 3.03x_3$ (R=0.86). Because of preferences to forest habitats the mountain hare density negatively related to the number of winters with unstable snow cover that deteriorate foraging conditions. The dependence of the density of mountain hares (y) on the forest cover (x_1), depth of snow cover (x_2) and number of winters with unstable snow cover (x_3) is expressed by the formula $y= 0.12+0.19x_1+0.17x_2 - 0.26x_3$ (R=0.45, p<0.99). There is clumped distribution of hares. The index of the clumping is $\delta^2 / Ii > 1$ where δ^2=16.12 is dispersion and Ii=2.38±0.23 is the frequency of occurrence. The aggregation index is highest 6.77 in comparison with other forest categories. Hares prefer *Vaccinio-myrtillosa, Cladoniosa* forest site types (G=0.25). In littoral areas European hares distribute more evenly. There is different and rather unique climatic situation. It is known that the influence of the Baltic Sea is especially strong on the seashore of 30 to 100 km from the sea (Bukantis, 1992, 1994). The climate is attributed to Southern Baltic sub-region. It is mild and more similar to climate of West Europe, winters are with unstable snow cover comprise 50%. The average depth of snow cover is h=16 cm, the amplitude of the thermal fluctuations is comparatively less. The later weather is more stable. That is especially important for youngsters within the first living month (Puppe, 1966; Belova, 1989, 1997), for later offspring and for the earlier survived offspring. Besides, the survival of the first offspring is significant for the reproductive part of the population (Belova, 1997). This condition is found in the littoral part of pure pine forests and also in the continental southern forest. Meanwhile, there is more inclement weather. The inclemency index is greater in IIa than in IIIb (Table 1). Because of high air moisture micromigrations between the forest and open areas occur. However, the factor of rain L_f is not crucial. An increase in this factor determines leaving of forest by hares (r=-0.94). In the windy days in the Kuršių Nerija National Park hares come together in the forest habitats and use the merits of the diverse microclimatic conditions, and changes in topography as the index of the landscape mosaic. The mountain hare has not been observed on the Curonian spit (Figures 1, 2). Lithuania is separated into flat, wavy, hilly and greatly hilly types of topography. In areas of the pure pine forests and adjacent lands the topography is favourable (r=0.53 for the European hare and r=0.60 for the mountain hare) (Table 2). The soils are not rich. Soils in the forest areas are sandy, sandy loam, and soddy. Soils on adjacent lands are turfy soddy and sandy. The density of European hares depends more on soil fertility in the fields than in the forests (r= 0.31). The density of mountain hares does not depend on the soil fertility in the

Table 1. The average density of the ecological populations of European and mountain hares in the forests of different categories and territorial parts.

Forest category and territorial part	Area of woodland, thousand ha	Prevalent climatic sub-regions	Total forest cover, %		Average depth of snow, cm	Days with relative air moisture, Q>80%, n	Average air moisture, %	Inclemency of weather, S_a	Forest soil fertility, points	Density of hares n/1,000 ha	
			average	lim						European hare	mountain hare
Pure pine	254.1	x	58.6	31.2-79.7	22	129	80.1	2.20	1.8	**21**	**1.7**
littoral part (western)	9.4	IIa	71.6	71.6-	18	176	81.8	2.80	1.4	26	0.0
continental part (southern, south-eastern)	244.7	IIIb	51.7	31.2-79.7	23	120	79.7	2.10	1.8	11	1.7
Pine with spruce	867.7	x	31.0	17.5-45.9	23	141	80.1	2.40	2.6	**23**	**1.8**
eastern, north-eastern	437.4	IIc (+IIIb)	33.3	22.2-45.9	26	141	80.0	2.40	2.4	17	2.6
central-western, northern	68.2	IIb	34.2	32.6-35.8	19	141	82.0	2.35	2.8	36	1.9
central, south-western	161.5	IIIa (+IIIb)	30.1	20.0-39.3	18	139	81.0	2.42	2.8	28	1.1
southern	86.2	IIIb	30.1	20.4-39.7	23	124	79.5	2.40	2.6	25	0.8
western	114.3	IIa (+Ia+Ib)*	19.2	17.5-20.8	18	163	83.0	2.60	2.7	31	0.7
Mixed spruce-deciduous	563.8	x	27.0	19.8-37.7	20	148	82.1	2.42	3.1	**26**	**1.8**
north-western, western	376.3	Ib, IIb (+Ib)	28.1	19.8-37.7	20	154	82.6	2.45	3.0	26	1.7
eastern, north-eastern, central	116.8	IIc, IIb (+IIc), IIIa (+IIIb)	25.7	25.3-26.2	21	139	81.3	2.37	3.0	23	2.3
	70.7		24.6	22.6-26.5	20	139	81.0	2.40	3.4	26	1.3
Deciduous with spruce	364.9	x	20.3	9.0-28.6	20	142	81.4	2.36	3.9	**42**	**1.4**
northern, central-northern	256.9	IIb (+Ib)	21.0	14.0-28.6	20	142	81.4	2.36	3.8	40	1.7
central, south-western	66.1	IIIa (+IIb,IIIb)	15.2	9.0-21.4	18	142	81.5	2.35	4.1	52	0.4
eastern	41.9	IIc (+IIb)	25.7	25.7-	20	143	81.0	2.40	3.5	29	1.7

* mixed climatic sub-region

Table 2. The dependence of the *Lepus europaeus* and *Lepus timidus* density upon the main environmental factors in the areas of different forest categories.

Main environmental factors	Forest category							
	Pure pine		Pine with spruce		Mixed spruce-deciduous		Deciduous with spruce	
	correlation							
	r		r		r		r	
	Lepus europaeus	*Lepus timidus*	*Lepus europaeus*	*Lepus timidus*	*Lepus europaeus*	*Lepus timidus*	*Lepus europaeus*	*Lepus timidus*
Forest cover, %	-0.63*	0.25**	-0.85*	0.48*	0.32*	-0.01	-0.85*	0.59*
Fertility of forest soil	0.13**	0.13	0.65*	-0.56*	0.47*	0.12**	0.20**	0.18**
Fertility of adjacent lands	0.31*	0.01	0.47*	-0.43*	0.04	0.03	0.33*	-0.03
Size of fields (10-15 ha)	-0.68*	0.10**	0.20**	-0.23*	0.39*	0.15*	0.12*	0.08
Land topography	0.53*	0.60*	0.33*	-0.22*	-0.12	-0.09	-0.44*	-0.02
Depth of snow cover, cm	-0.81*	0.40*	-0.80*	0.64*	-0.44*	0.03	-0.46*	0.62*
Winters with unstable snow cover, %	0.51*	-0.39**	0.46*	-0.57*	-0.72*	-0.38*	0.16	-0.72*
Factor of rain, L_f	-0.39**	-0.04	-0.10	-0.06	-0.12	-0.20*	-0.28	-0.09
Average density of hares, N/1,000 ha	20.9±4.32	1.0±0.56	22.4±1.78	1.7±0.30	23.9±1.79	1.7±0.22	41.2±3.18	1.3±0.31

* correlation significant at $p < 0.05$
** correlation significant at $p < 0.10$

fields (r=0.00) and slightly depends on that in the forests (Table 2). Because of comparatively poor soils, highest forest cover, topography and climatic factors, the size of fields become more important as a regulating factor for European hares. Hares prefer narrower fields less than 10 to 15 hectares (Table 2). The density of European hare strongly depends on the size of adjacent fields. An increase in the size of fields negatively affected the hares. The factor of field size is less significant for the mountain hare (r=0.10). There are more small stands (less than 100 and 101-500 ha) and also habitat diversity and ecotone effect (r=0.85). The influence of soil fertility (x_1), topography (x_2) and size of adjacent fields (x_3) on the density of European hares (y) is noticeable on areas of pure pine forests and adjacent lands and is expressed by the equation $y= 45.85 - 0.47x_1 - 0.44x_2 + 252lnx_3$ (r=0.90). The effect of forest soil fertility (x_1), topography (waviness of the relief) (x_2) and forest cover of the territory (x_3) on the density of mountain hares (y) is expressed by the equation $y= -1.59 - 0.09x_1 + 0.73x_2 + 0.43x_3$ (R=0,81). The diversity of foraging and shelter conditions reduces the influence of the precipitation in the littoral zone and that of poorer soils and cold winters in the continental part. The density of European and mountain hares does not reach the optimum in the continental part because of local characteristics. Although the local populations are not abundant, comparatively higher density of European hares depends on more favourable climatic situation and habitat conditions, the status of the territory (such as reserve).

Pine with spruce stands prevail on the area which has continental climate (viz. IIc, IIb climatic sub-regions) and on the seashore (the IIa, Ia climatic sub-regions). The sea influence weakens toward the east. The weather is variable due to the alternating of maritime

Figure 1. The density of European hares on the areas of different climatic sub-regions.

Figure 2. The density of mountain hares on the areas of different climatic sub-regions.

and continental climate, especially in the west which receives much rain (Table 1). On the seashore of the western territory the annual precipitation is 912 mm and more, and rain factor L_f amounts to 45-47. Spring blizzards are characteristic. There is much precipitation in the Lowland hills because of their geographical situation and predominant direction of the wind. The average annual precipitation is 1,012 mm, over 154 days air moisture Q >80%, L_f is 56.3, and the temperature is cooler with variable winter conditions. In the east, precipitation is approximately 550 mm. In some southern areas the factor of rain (L_f) is lower, and the dependence of the density of European hare on the rain factor is not very strong (r=-0.23 only). The dependence of the density of mountain hare on this factor is very weak with some negative trend. The snow cover is stable but there are more moist days in comparison with pure pine forests. The density of hares is higher in the IIIa and mixed IIIa+IIIb sub-regions. The majority of pine with spruce forests belongs to the IIc sub-region, which predominates in the east. It is particularly snowy with frequent blizzards, even in April. Spring is late but the wintering of plants is more successful. This sub-region is least favourable for European hares and mostly settled by mountain hares (Table 2, Figures 1,2) because of the preferences of the conditions of this stand category and prevailing continental climate (Figures 1, 2). The continental conditions (such as these prevail) would be similar to the optimum for the hares. However, the depth of snow cover is more crucial (up to 100 cm). This is especially dangerous from the end of January to the beginning of February when the hare's metabolism becomes more intensive and the need of more qualitative food increases (Belova, 1989, 1990). Despite this fact, the density of mountain hare positively related to the snow depth (Table 2) because of preferable forest habitats and better accessibility of woody food in the forest. Because of the natural selection the animals of greater vitality have been surviving. The hares gather in places with good forage in forests. They prefer *Vaccinio-myrtillosa* (occurrence up to 56%), *Myrtillosa, Myrtillo-vaccinosa, Myrtillo-oxalidosa* (up to 67%), *Oxalidosa* (37%) site types. The feeding space increases (after the snowfalls reach 1.5 m and more). Mountain hares prefer denser stands (stand density 0.7-0.8) in summer. They often occur in the stands with dense undergrowth and in the thickets which provide more than 90% of refuge places) in spring and autumn. In summer European hare prefers adjacent lands near the forests and forest edges and in all seasons prefers forests with average and rare clumped undergrowth and stand density, especially along the thicket edges and avoids the sites without undergrowth (r=0.534±0.08). The average distance from the forest edge 100-500 m depending on elements of the diversity on the lands (r=0.35 ± 0.09). In IIIb sub-region the snowy winter predominates, too. There is danger for the first offspring and realization of the productivity. Meanwhile, the feeding conditions are better because of higher diversity of lands and plants, choosing and grouping of hares in more favourable places. The clumped distribution of hares occurs and the index of the clumping is δ^2/Ii >1, where δ^2= 17.53 is dispersion and Ii= 5.14±0.30 is the frequency of occurrence. The aggregation index is 3.41. The localities of both species European and mountain hares are similar in the forest habitats but the density of mountain hares positively related to the forest cover (Table 2). The average forest cover of the total territory is found to be 30.8% and the pine (up to 78.5%), spruce (up to 42%) and birch (up to 36%) stands prevail. The dependence of the density of mountain hares (y) on forest cover of territory (x_1) and the depth of snow cover (x_2) is expressed by the equation $y = -1.98 - 0.02x_1 + 0.65x_2$ (R=0.64). The influence of the interaction between forest cover (x_1) and the number of winters with unstable snow cover (x_2) is noticeable ($y = 0.93 + 0.27x_1 - 0.46x_2$, R=0.62). The interaction between the number of winters with unstable snow cover (x_1) and the depth of snow cover (x_2) is important for European hare as well ($y = 4.74x_1^{0.34} + 0.61x_2$, R=0.89). The density of hares differently depends on the forest soil fertility (Table 2). The soddy (11.4-73.3%), soddy peatland (4.1-67.5%), turfy soddy (3.6-33.4%) and peatland (5.2-33.9%) soils prevail. The interaction between forest cover (x_1) and soil fertility (x_2) influenced the density of European hares and is expressed by equation $y = 0.10*0.10x_1 + 0.70x_2$ (R=0.93). The interaction between forest cover (x_1), soil fertility (x_2) influenced the density of mountain hares and is expressed by the equation $y = -0.85 + 0.07x_1 - 0.07ex_2$ (R=0.43). The density of hares differently depends on the topography (waviness) (Table 2). The mountain hares prefer more hilly topography. European hares prefer mixed topography. The density of hares weakly related to the size of adjacent fields. The density of both European and mountain hares is slightly negatively related to the field size less than 15 hectares (r=-0.20 and r=-0.23, respectively, p<0.05). The influence and interaction of different environmental factors determine fluctuations of the density in different places of this forest category. In the western Ia and northeast-

ern IIb climatic sub-regions the living conditions of animals are diametrically different. In the IIc sub-region a significant forest cover and poorer soils prevail, while in the Ia sub-region the forest cover is average and rich soils predominate. We cannot say that only soil fertility and forest cover are key factors. On the other hand, in the east there are 50 - 72 small stands, less than 100 hectares in size, 17 stands between 101-500 hectares in size, and also 17 stands over 2,000 hectares in size. There is average density of European hares and comparatively high density of the mountain hares (Figures 1, 2). In the west and south the forests are divided according to their size almost similarly: there are 22 stands less than 100 hectares, 19 stands between 101 and 500 hectares, and 16 stands over 2,000 hectares. However, the density of European hares 27-35.4 is rather high and the density of mountain hares is comparatively low in the south (0.1) and somewhat higher in the west (0.4-1.0). This shows that the predominance of the small stands does not determine the abundant local populations. The number, size and diversity of stands are significant for hares in the presence of the interaction between other local factors such as weather, soil fertility, composition of plant communities, the character of adjacent lands, disturbance.

Mixed spruce-deciduous stands are situated in north and west Lithuania, in central district and in the continental northeastern part (Table 1). The precipitation in these areas is uneven. In Lithuania there is surplus of moisture, especially in the western part. The precipitation makes up more than 850 mm and L_f is 41-54. The west and southwestern winds prevail. These carry along the air mass of the sea. Snow cover is unstable. In the northern part the spring is late. Because of mentioned conditions the plants are frequently destroyed by frost. The animal density is less (Figures 1, 2). In the central part the winter is more stable and snowy. There is contrasting weather, and the conditions of the wintering of foraging plants are better. High density of European hares (34 per 1,000 hectares) is in the IIb sub-region. This is lowest in the areas of the Ib subregion that is mostly moist. In the forests of the IIc subregion with high forest cover and poorer soils, the density of European hares is lower and that of mountain hares is higher. The interaction and influence of different factors determines fluctuations of the density of hares in different places of the mentioned forest category (Table 2). The dependence of European hare density (y) on forest cover of territory (x_1) and the depth of snow cover (x_2) is expressed by the equation $y = 55.36 + 0.43x_1 - 2.08x_2$ (R= 0.95). The density of mountain hare does not depend on forest cover and the relations with the depth of snow cover are very weak. There is a similar trend to positive relations. Snow cover is not crucial (i.e. the average depth of snow is 20 cm). There is some dependence of the mountain hare density (y) on the number of unstable winter conditions (x_1) and forest cover of territory (x_2) which is expressed by the equation $y = 1.93 - 0.39x_1 + 0.08x_2$ (R= 0.38). The densities of both species of hares are negatively related to the instability of winters from the above mentioned forest categories where the density of European hares positively related to this factor (Table 2). Because of unstable winter conditions 50-90% of adjacent lands become covered with ice. Thus, this factor gives trouble for the foraging on plants of lower layers while woody fodder is less acceptable because of less depth of snow cover. Due to unstable winter conditions and moist weather the first offspring often do not survive. The hares are constrained to recede and gather in places with good forage in forests. In the mixed spruce with deciduous stands the spruce (25-47%), pine (6-43%); birch (13-35.7%) and less grey alder (2-13%) stands predominate. The average forest cover of the total territory is 27%. Animals prefer to group in the *Hepatico-oxalidosa* (G=1,15), *Vaccinio-myrtillosa* (0.97), *Urticosa* (0.71), *Carico-mixtoherbosa* (0.67), *Oxalidosa* (0.63), *Myrtillo-sphagnosa* (0.59), *Oxalido-myrtillosa* (0.54), (occurrence is more than 50%), also *Myrtillo-vaccinio-sa, Vaccinio-cladoniosa, Vacciniosa, Ledo-sphagnosa, Carico-callunosa* (G=0.45-0.50, occurrence less than 50%). There is clumped distribution of the hares. The index of clumping is $\delta^2/Ii > 1$ where δ^2= 19.78 is dispersion and Ii= 5.27±0.37 is the frequency of occurrence. The aggregation index is 3.76. This is more than on the area of previous forest category. The small forest predominates in all sub-regions but hares are more abundant on the areas where forests are different by size. There is not strong relation of the density of hares with a certain type of topography. Animals prefer mixed topography. The density of European hares positively related to the nearness of the adjacent fields less than 15 hectares, and the density of mountain hares weakly positively related to the field size (Table 2). The prevailing soils are soddy peatland (25-69%), soddy (9.8-29%), (4.1-67.5%), turfy soddy (8.1-32%), turfy gley and gley (up to 40%) and peatland (8.2-33%). The soils are comparatively fertile. The density of hares very weakly relates to the fertility of adjacent fields (r=0.04 and r=0.03 of European and mountain hares, respectively).

The relation with the fertility of forest soils is stronger (r=0.47 of European hares, however, only r=0.12 of mountain hares). This is similar to the area of pine with spruce forests. This corroborates previous conclusions concerning the mixed ecotype of hares (Belova, 1990, 1996). There is certain relation of the density of European hares to forest cover (%, x_1) and soil fertility (x_2) which could be expressed by the formula $y = -17.61 + 0.20 \ln x_1 + 1.36 x_2$ (R= 0.93).

Deciduous with spruce stands are situated in northern, southern, central and northwestern Lithuania (viz. mostly to the IIb and mixed climatic sub-regions). There are similar average winter temperatures, quantity of the precipitation, stability of snow cover, air moisture. Only on the northern area the environmental conditions are more inclement. The quantity of precipitation is average. In the northwest and north over the Lowland hill to the eastern direction there is a less rainy region. The precipitation is slightly more than 700 mm and L_f is less than 40 (lim 36-40). The depth of snow is not crucial. A longer snowy period predetermines different importance of foraging of the hare species and their preferable habitats (Table 2). There are fewer winters with unstable snow cover or this number fluctuates from 0 to 25. The micromigrations of the hares between different habitats are characteristic. The mountain hare more prefers forest habitat and forest edges, and the density of hares positively related to forest cover (r=0.59). In southwestern and central Lithuania the winter is mild, snow cover is not stable and snow melts away 10-13 days earlier than elsewhere (39% of winter with unstable snow cover). There are frequent thaws. The depth of snow is not [a] limiting factor and climatic conditions are favourable for hares (Table 1). Hares prefer to group in the *Mixtoherbosa* (*G*=0.48), *Carico-mixtoherbosa* (0.24) sites. There is the only category of forests where clumped random distribution of the hares is observed. The index of clumping is $\delta^2/Ii > 1$, where $\delta^2 = 24.13$ is the highest dispersion and the frequency of occurrence $Ii = 4.18 \pm 0.55$ is lower than in the mixed spruce-deciduous and pine with spruce stands. The aggregation index 3.36 is less than on the above mentioned areas. The birch (26-48%), spruce (13-34%), aspen (5-12%), black alder (3-20%), ash (2-14%) and less grey alder (0.1-8%) and pine (2-19%) stands prevail. The soils are comparatively fertile. The prevailing soils are turfy gley and gley (20-75,4%), soddy peatland and peatland (14-62%), turfy soddy (3-28%), turfy carbonic (2-14%). The density of European hares depends less on the forest soil fertility (r=0.20) than on the soil fertility of adjacent lands (r=0.33) (differently from the mixed spruce-deciduous forests). The density of mountain hares is very weakly related to the size of the adjacent fields and the density of European hares is also weakly related to it (Table 2). There is an important relation of the density of European hares with the soil fertility (x_1) and size of adjacent fields (x_2) which is expressed by the equation $y = 12.06 + 0.62 x_1 - 0.45 x_2$ (R= 0.95). The density of animals depends on the complex influence of soil fertility (x_1), topography (x_2) and field size (x_3) and is expressed by the equation $y = 39.21 + 0.20 x_1 - 0.57 x_2 + 0.01 x_2^2 - 0.51 \ln x_3$ (R=0.90). It is shows that hares occur both in the forests and adjacent lands. The density of mountain hares slightly depends more on the forest soil fertility than in the previous forest category (Table 2). No dependence is observed on the soil fertility and size of an open land. The average forest cover of the total territory is only 20.5%. In the southwest the forest cover of the areas is least (only 7%). Small forest predominated in all sub-regions but hares are more abundant on the areas where forests are different by size. On the areas where forest cover is higher and soils are poorer, the density of European hares is lower and mountain hares are more abundant (Table 1, Figures 1 and 2). European hare density strongly negatively relates to forest cover of the territory (r=-0.85) as in pine with spruce forests where high forest cover predominates. Meanwhile, forest cover is favourable for the mountain hare. The density of mountain hares related to forest cover of territory (x_1), number of winters with unstable snow cover (x_2) and depth of snow cover (x_3) and is expressed by the formula $y = 1.68 + 0.37 x_1 - 0.63 x_2 - 0.08 x_3$ (R=0.79). The density of mountain hares is affected by a complex influence of forest cover of territory (x_1), soil fertility (x_2) and factor of rain (x_3) that is expressed by the formula $y = 1.20 + 0.58 x_1 - 0.01 x_2 - 0.06 x_3$ (R=0.59). High density of European hares (64 per 1,000 hectares) is in the IIIa-IIIb and in the northern IIb sub-regions (40-55 per 1,000 hectares). The interaction and influence of different factors determines fluctuations of the density of hares in different places of the mentioned forest category (Table 2).

The animal living conditions are optimized by their favourability for animals that meets animal needs. In accordance with Tables 1 and 2, and Figures 1 and 2 the differences of densities are not very distinct on the areas of certain forest categories excluding the density of European hares on the area of deciduous with spruce forests, and that of mountain hares in northeastern and southeastern mostly continental Lithuania (pine with spruce, pure pine, northern mixed spruce-deciduous

forest and northern stands of deciduous with spruce forests).

Discussion and conclusions

The habitat suitability and hare susceptibility to the seasonal changes are determined by the interaction between natural factors. The influence of these is reinforced by human factors. The hares are rather flexible to the anthropogenic changes but they are inflexible to the changes in natural factors (Belova, 1989). Significant factors are the location and conditions of certain climatic sub-region, the state of snow cover, stability of winter conditions, forest cover, other factors that predetermine shelter conditions and the carrying capacity of habitats. The density of hares fluctuates greatly in the territorial groups of similar soil fertility because of combined influence of several limiting factors and climatic factors. The important climatic factors are the depth and stability of the snow cover, regime of the temperature and its changeability, factor of rain, and precipitation during the vegetative season. The great importance of climatic factors was usually emphasized since they are especially related to the dynamics and increment of animal population (Puppe, 1966; Onderscheka, 1984, Belova, 1989,1997). Young hares of the first generation and females are more sensitive and about of 10% of the total loss of hares dead because of the direct influence of climatic factors (Puppe, 1966; Hecker, 1983; Onderscheka, 1984). The topography determines the fulfilling of reproductive potency and most favourable of which is mixed plain-wavy relief. The best indices of the European hare population are on areas with fields between 10-15 hectares. The importance of field size for the European hare has been emphasized earlier (Onderscheka, 1984; Belova, 1990; et al.). The structure of farmlands is of less importance for the European hare and of the least importance for the mountain hare. Winter stability and the depth of snow cover are most important for the mountain hare. The unstable winter induces the spreading of invasions, when hares gather in places with good forage and shelter. The unstable air temperature influences the ovulation of females, fluctuations of the offspring vitality, sex structure of the hare population, and food accessibility (Belova, 1997). In the pure pine forests and adjacent areas the high forest cover, poorest soils, deep snow cover and spring-autumn frosts negatively influence European hares. Stable winter conditions, deep snow are more favourable for mountain hare in the continental part of this area. The general situation is not crucial. More stable later weather is favourable for the later offspring and for the first group of offspring each year. The stability of weather is particularly important in the first 1.5 month of postnatal time (Belova, 1989). Such conditions are in some southern areas of the continental part of pure pine forests for the both species of hares, and on the littoral area for the European hare. The smaller fields (up to 10 ha, $r= 0.72\pm0.23$), diversity of the relief and forest edge effect are favourable. However, above mentioned poor soils predetermine lower diversity of plants, poor habitats (*cl, v*), and lower carrying capacity. The characteristic features of hares are their euritopic peculiarity, the ability to adapt themselves to deep-snow winters or more often thaws owing to the variability of their micromigrations, behaviour and the rhythm of activity, the character of feeding and other features, and also of an increasing synantrophizm. It is important to pay attention to the possibilities of the interspecific competition (viz. amensalism in relations with ungulates), and a possible increase in the intraspecific competition because of clumped distribution and gathering of hares in the more favourable places. The density of the European hare ecological population is less than the average density in Lithuania but it is and was stable over the time of common decline of the population. The density of mountain hares is average; however, the mentioned conditions give an opportunity to maintain a higher ecological population only on southern limited area. The measures of care would be applied under the extreme conditions.

In the pine with spruce forests and adjacent areas the factor of much snow is characteristic of the eastern and northeastern continental sub-region and impedes the realization of animal breeding potency. It affects more the European hare and less the mountain hare because of its later mating and certain morphological features. Comparatively poor soils are not favourable; the structure of adjacent lands is not significant. The lack of variability of adjacent lands, according to the sum of the perimeter of different areas (Leopold, 1933; Belova, 1989), stimulated the settling of hares mostly in the forests. The activities of forest management are favourable. The habitats of both hare species overlap. There is higher density of mountain hares and average and less than the average density of European hare. In south and central Lithuania the situation is more favourable for the European hare and less favourable for the mountain hare. The measures of care would be applied under extreme seasonal conditions. In the west-

ern part the soils are not rich and climatic situation is not favourable because of heavy rains, and the crucial rain factor. However, due to the adaptability and natural selection, animals are able to survive and their population increases. There is favourable alternation of the forest and field areas, diverse relief and size of stands, and the average carrying capacity of habitats for the European hare and higher carrying capacity for the mountain hare. The density of hares is average and less than the average but it is stable.

In the mixed spruce-deciduous forests and adjacent lands the situation of weather comparatively is not changeable, the quantity of precipitation is not crucial except in western areas that are especially wet. The density of European hares directly depends on the forest soil fertility and also positively relates to the forest cover of the territory (Table 2) while the density of mountain hares weakly depends on the forest cover. Also, in winter the foraging on the adjacent lands is difficult during unstable winters. The ecological populations of hares are more numerous on the areas of mixed topography. There are diverse topographic conditions and greater ecological stability. The adaptability of animals depends on the changeable seasonal abiotic and biotic factors. The soils are comparatively fertile. The mixed ecotype of the European hare distinctly revealed itself. The density of hares is higher than the average. The fluctuation of the density of hares shows the importance of the weather conditions to the reproductive potency and to the age and sex structure of the local populations. There is high carrying capacity of the habitats for the both species of hares.

In the deciduous with spruce forests and adjacent lands habitat conditions are mostly favourable for European hares. There are rich soils, mosaic landscape, and high carrying capacity of habitats. More inclement and changeable conditions of the northern regions could hinder population growth. However, the highest density of European hares is attributed to the interaction between other local conditions. The alternation of the average and small stands and farmlands is favourable for the euritopic animals (such as the European hare). On the areas of least forest cover the daily and seasonal moving of European hares are observed between open lands of different composition. There is random clumped distribution as on more woody areas. Random distribution prevails under improved environmental conditions and on the more diverse areas. The mountain hares mostly settled the larger complex of stands on the northern and east-northern areas of deciduous with spruce forests. There is average and higher than average density of hares.

The area most habitable for hares is in northern-central and north-eastern Lithuania. The western and west-central parts, where deciduous with spruce forests predominate (the IIb climatic sub-region), is more favourable for the European hare. The eastern and east-southern part, where mixed spruce-deciduous and pine with spruce forests prevail (the IIb and IIc climatic sub-region), is most favourable for the mountain hare. The second most favourable area for the European hare is the southern part and south –western part of mixed spruce-deciduous forests, and deciduous with spruce forests (the IIIa climatic sub-region) and mixed spruce-deciduous forests on the western territories (the Ia and IIa climatic mixed sub-region). The central part of the western mixed spruce-deciduous forests and local southern pure pine forests are more habitable for the mountain hare.

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РАЙОНИРОВАНИЕ ТЕРРИТОРИИ ЛИТВЫ ДЛЯ ЗАЙЦЕВ *LEPORIDAE:* I. ОЦЕНКА ПРИГОДНОСТИ МЕСТООБИТАНИЙ

О. Белова

Районирование территории для зайцев заключает оценку пригодности условий местообитаний и их емкости. Основная цель исследований заключалась в экологической оценке местообитаний зайцев на территории различных категорий лесов. Основным индексом благоприятности жизненных условий является плотность популяции зайцев. Для районирования территории зайцам важны такие факторы как климатическая принадлежность, погодные условия, лесистость, тип рельефа, разнообразие территории, величина лесного массива и других земель. В местах низкой емкости и в связи с взаимодействием средовых факторов плотность элементарных популяций зайцев не превышает их среднюю плотность в Литве.

Ключевые слова: зайцы, категория лесов, факторы окружающей среды, пригодность биотопов, районирование территории.