Foraging Character of Deer Cervidae and Brown Hare (*Lepus europaeus*) on the Littoral Area of Pure Pine Forests in Lithuania

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Abstract

The main herbivorous mammals as Cervidae go in with hares Leporidae into general trophic chain as primary consumers. The basic interaction between these animals and forest woody vegetation mostly evidences in the feeding relations. Therefore the feeding character in herbivorous animals is the important item of this study. Limited factors could come drivers of the animal impact to forest. On the other hand, the interaction between animals and forest woody plants requires not only elements of this interaction but also an environment where this interaction occurs. Therefore, the habitat preference should be considered. We aimed to reveal the foraging character of deer and hares, and assess the animal - forest woody plants' interaction by considering the above-mentioned notes.

We employed the integrated method of belt transects (sample unit is 100 x 4 metres) and sample plots (50 x 2 metres, or 100m^2). The method of pellet group count has been used to assess the number and distribution of the local populations of investigated animal species, the age structure and sex ratio of local populations of moose and red deer, and age structure of the roe deer local population. We identified animal age and sex by pellet groups. Woody plants and their shoots within the feeding space of animals (that is from h = 0,1 to 2,2 m) were counted dividing damaged and untouched shoots. Browsing intensity ***I,*** and the share of woody species in animal diet ***P,*** were calculated by the consumption of all species of forest woody vegetation. Habitat preference of stands of the different age classes, composition and forest site types were estimated. The total number of sample plots is 504, and the total length of the route is 79.9 km on the study area of 2,736 hectares.

The specific climatic and geomorphologic diversity of landscape and local conditions as well as the absence of agricultural landed property determine the low carrying capacity and specific structure of the local fauna and their adaptations, as the mixed forest-forest edge ecotype in hares and forest ecotype in roe deer. The coexistence of forest plants and animals is directly and indirectly influenced not only by the determined abiotic and biotic factors but also by human factors including forest management, hunting and its restrictions, supplemental feeding in winter, picking of mushrooms and berries, and other recreational activities. The mentioned activities are particularly obvious on the study territory while the forests are managed by the separate regime that is approved by the legal acts for protected areas. The animal density is less than the permissible density in pure pine forests while there is the aberrant sex ratio and age structure in local populations. That is the indicator of disfavour in living conditions. Habitat preference values and plant consumption intensity varied temporally depending on the stand composition, forest site type and forest age as well as variability of the main weather parameters. The main criteria of the animal-plant interaction are the consumption of shoots and the browsing intensity of the main woody species. The shoot consumption in conifers more than 40-50% and more than 20-30% in deciduous species is the criterion of the irreversible decline in the certain species (e.g. *Populus tremula*, *Frangula alnus*).

Key words: herbivores, pure pine forests, protected area, population parameters, habitat preference, browsing intensity, level of shoot consumption

Introduction

Mammalian herbivores such as deer and hares undoubtedly have formative and significant influence to the forest. Long before the 20 century and later, the balance between herbivorous animals and territory carrying capacity has been pursued to maintain considering the supply of tree shoots, their consumption and share in the animal diet in winter (Petružis and Padaiga 1976, Padaiga 1996). Researchers and foresters from many countries underline the significant changes in stand composition, structure, competitive abilities and survival. The main reason for these changes is the multiple interactions between animals and forest vegetation. The herbivorous animals consume the largest part of forest woody vegetation and are rather important components in forest ecosystems. In the mean time, the permanent and changeable factors that associate with forest use (such as harvesting, forest fragmentation, management of animal populations, hunting, *etc*.),

caused changes in the natural interaction between animals and forest vegetation. On the other hand, the non-existence of the real herbivorous animals and non-consumption of some part of the forest phytomass induces the instability in forest ecosystem when the compensatory forest increment of biomass is at a standstill (Ammer 1996, Reimoser, F. and Reimoser, S. 1997, Schulze and Reimoser 1998, Hester *et al.* 2000, Pietrzykowski *et al*. 2003). Among all herbivorous animals, Cervids are the main object of mentioned problem. All the more, there are three deer species that mostly overlap on the same territories in Lithuania. At the same time, we should not leave out of consideration other herbivorous mammals as hares Leporidae that go in with Cervids into general trophic chain as primary consumers. Cervids are rather economically most important not only as game, or in an aesthetic context but also because of their specific feeding as the browsing of leading and lateral shoots and bark stripping and, what is more, they are apprehensible more than abstract "biodiversity". In the context of biodiversity conservation, the role of indicator species comes to Cervids (Belova 1995, Hanley 1996). It is considered that deer studies often allow us to assess alternatives of the consumption of environmental resources (Hanley 1996). Eventually, the main interaction between animals and forest woody vegetation mostly evidences through the feeding relations. Animal feeding is an active action. Their typical herbivory displays though the foraging and its efficiency depending on the food accessibility and supply. There is the feedback even as herbivorous animals regulate plant abundance and act all components of ecosystem, respectively. At the same time, food supply limit animal number. Therefore, the feeding character in herbivores is the important item of this study.

The importance of the interspecific competition in deer has been underlined in Lithuania (Padaiga 1996). The roe deer is dominant species, if several deer species occupy the same territory, and shoot browsing of trees and shrubs is lower than 50%, The red deer is dominant species as the browsing exceeds 50% while the roe deer and moose are sparse. In Latvia, red deer replace moose in habitats where the summer browsing is not critical (Prieditis A. and Prieditis Ā. 1999). The competition and trophic niche width mostly increase in non-vegetative period and decrease under optimal feeding conditions accordingly to the food supply. This is attributed to rather changeable winter and early spring in Lithuania (Belova 1997). The most significant impact caused by mammalian herbivores to forest is notably evident in the later autumn – early spring when woody vegetation becomes the main food supply for deer. Therefore, the species juxtaposition in the same territory and non-vegetative period would be under consideration.

The impact caused by animals to forest depends on the historically formed environmental conditions and notably on the animal - plant coevolution and long-term soil development as well as an influence of the climate and weather (Hobbs 1996). Which way of feeding animals will choose, depends on their physiological needs relating to the seasonal changes in animal organism, digestive peculiarities, necessity to use woody food as well as distribution of these food in forests. Both permanent (such as soil conditions, forest site type, climate, communications *etc*.) and changeable (that are related to stand age, food biomass, accessibility *etc*.) factors are important. Animals have to adapt constantly to the changeable circumstances by theirs biological and behavioural strategies that display in the population parameters and impact caused by animals to forest. Consequently, it is important to know the limiting factors that could be drivers of animal impact to forest.

The interaction between animals and forest plants requires not only elements of this interaction but also the environment where the interaction comes to pass. We have to consider the habitat suitability to animals in forests of the different categories and ecological regions (Padaiga and Belova 1994) by assessing the main local limiting factors and indicated importance of the population density that indicates favourability of animal living conditions. This parameter affects the animal impact to forest and subsequently in the forest vitality, productivity, further influence of phytopathogenes and pests, and economic rates. If the animal impact to forest is evident and significant, and some purposive tree species are at risk to extinct, the lower animal density should be maintained considering the reasons for changes in animal influence (Schori 1997, Stromayer and Warren 1997, Schulze and Reimoser 1998; *etc*.). Considerable attention should be devoted to the forest category and character of habitat distinguishing the indicator species (Niemi, Hanowski *et al.* 1997, Belova 1999b, 2004, *etc*.). Animals require habitats different in space and time-wise, and wherein they find food and shelter. The feeding and shelter conditions determine, which habitat animals will choose. The importance of the knowledge and assessment of animal habitats is generally underlined. All succession stages should be in the habitats of deer (Halls 1973) and hares (Belova 1995, 2001). The earlier succession stages are the mainspring of animal feeding (Padaiga 1996, Christian 1997, *et al*, Padaiga and Belova 2001). By the optimal feeding model (Focardi *et al.* 1996, Latham *et al*. 1999), animals forage in patches where the food biomass exceeds

the certain threshold. They go away as the food level decrease up to this threshold. The crossings of the different habitats are important for the animal-plant interaction. Animals, and especially females prefer these places (such as cutting area and stand, stand and meadow *etc*.) (Belova 1995, Padaiga 1996, Völk 1999, Bonenfant *et al*. 2003, *etc*.). The intensity of plant usage changes depending on the forest features (such as their species, age, height, development *etc*.) (Ander and Angelstam 1993, Heikkilä 1990, Ammer 1996, *etc*.). The key works in wildlife ecology and management, such as A. Leopold 1933, and further studies underline the necessity to consider the animal habitat conditions.

The indicated notes converged into the main purpose of this study that is to ascertain the foraging of deer and hare and assess the herbivorous animals - forest woody plants interaction on the territory of pure pine forests. This study is the inseparable part of the continuous investigations of interaction between the main components of forest biota on the base of monitoring network in the different nature regions of Lithuania.

Materials and methods

In order to meet the aim of study, we employed the integrated method of belt transects (sample unit is 100 x 4 m) and sample plots (50 x 2 metres, 100m^2). The pellet group count method (McCain 1948, Padaiga 1996, 1998, Belova 1989, 1997, Tottewitz and Stubbe 1998, Shank and Farr 1999, Campbell *et al.* 2004) has been used to assess the number and distribution of local populations of investigated animals, and age structure and sex ratio of the deer populations. We identified the age and sex of animals by pellet groups, namely, age by pellet groups of all three deer species, and age and sex by pellet groups of moose and red deer. The data obtained from the network of belt transects and sample plots underlay the base of the quantitative, qualitative and territorial assessment of deer populations. We conducted the counting of winter pellet-groups, which deer and hares had left on the study area, before the growing period in April 2001-2004. The total number of belt transects was 506 over 3 years.

We established rectangular sample plots strictly to the azimuth. This shape is accepted to be suitable to assess animal-plant interaction at the different layers of vegetation. It is more variable than transect and circular plot (Mosby 1960, Dasmann 1966, Petrak 1992). All woody plants and their shoots within the feeding space of deer and hares (*i.e*. from h = 0,1 to 2,2 m) were counted dividing damaged and untouched shoots. Browsing intensity *I,* and the share of woody species in animal diet *P,* were calculated according to the consumption of all species of forest woody vegetation by using the standard formulas (Aldous 1944, Padaiga 1996). According to the frequency of occurrence, we calculated the abundance of the each species of trees and shrubs on the feeding area using the formula $A = (G \times 100)/ T$, %, where *A* is the abundance of each species of trees and shrubs on the feeding area; *G* is the total number of the separate species of trees and shrubs in all sample plots; *T* is the total number of all species of trees and shrubs in all sample plots. The frequency of occurrence of woody species was calculated by the formula $O = (n \times 100) / N$, %, where *O* is the frequency of occurrence of each species of trees or shrubs; *n* is the number of sample plots where was found each species of trees and shrubs; *N* is the total number of all sample plots. The browsing intensity was calculated by the formula $I = (D \times 100)/ G$, %, where I is the browsing intensity of the each species of trees and shrubs; *D* is the number of damaged trees and shrubs in the separate species in all sample plots, and *G* is the above-indicated total number of the separate species of trees and shrubs both damaged and healthy.

What is the share of each species is in the animal diet during the non-vegetative period, we determined using the formula, $P = C \times 100/ \Sigma C$, %, where *P* is the share of the separate species of trees and shrubs in the animal diet in the non-vegetative period; *C* is the coefficient of consumption of each species of trees and shrubs that is calculated by browsing intensity *I* and abundance *A* of each species of trees and shrubs $C = I \times A$, %; and ΣC is the sum of the *C* of all species of trees and shrubs.

The preference index of habitats was calculated by the formula $P=(E_1/E_2-A_1/A_2)/(E_1/E_2+A_1/A_2)$ (Jacobs 1974, Belova 1995), where P is the preference index, E_1 is the number of pellet-groups in a certain plot, E_2 – the total number of pellet-groups, A_1 – the area of a certain plot, and A_2 – the total area. We estimated this index for habitats of the different stand age class, composition and forest sites. The preference value varies from +1 (positive preference), to 0 (random choice) to –1 (total avoidance), and show what habitat is most or less preferred by herbivorous animals in the different trial periods. The data were processed by the methods of statistics using *MS Excel* and *STATISTICA*. The significance level used was P<0 05. The total number of sample plots is 504, and the total length of the route is 79.9 km on the study area of 2,736 hectares.

Study Area

We conducted our study in the pure pine forests of the Kuršių Nerija National Park (KNNP) in western

Lithuania (55˚30' N 21˚07' E). The status of study area *per se* is motivated by the striving of ecologically, economically and socially based forest management including maintaining of sustainable forestry, landscape protection, key habitats and species, their diversity as well as protection and sustainable use of game resources. Management activities injurious to the environment and unrelated to functions of national park are restricted. The territory of national park is the integrated protected area under multifunctional management. The Kuršių Nerija National Park (KNNP) was established in 1991 aiming to preserve the most valuable complex of Lithuanian seaside with its unique landscape and the dune ridge, natural and ethno-cultural heritage, for sustainable use and care. In the classification of IUCN, KNNP has been recognised as Category II. Since 1997 KNNP has been a member of EUROPARC federation. In 2000, KNNP was included into UNESCO World Heritage List as a valuable cultural landscape. The total area is 26,474 hectares including 9,774 ha (36.9%) of the land and waters as the Baltic Sea (47.2%) and Curonian Lagoon (15.9%). That is the narrow sandy peninsula, which separates the Baltic Sea from Curonian Lagoon (Figure 1).

Northern area is the narrowest part with the width from 400 m to 3.8 kilometres at Bulvikis Horn. Moving dunes have covered moraine ground and the swamp, which remains appeared as the raised bog presently. Parabolic dunes were overgrown by the forests. Fragments of the old growth forests are preserved on the study territory. Because of the strong human impact, since the 16th century the natural environment has been destroyed and that caused severe sand shifting. Thus, the saplings of dwarf mountain pines were planted from 1825, and reforestation project has been implemented. Now forests (70.1% of the total area) are represented by the littoral pine stands with the main species *Pinus sylvestris* (53% of the total territory) and less share of the mentioned dwarf mountain pine *Pinus montana* (27%) There are some communities of the *Vaccinio-Betuletum* represented by *Betula pendula* (15%), *Alnetum (Alnus glutinosa* that covered only 206 ha or 3% of the territory), some stands of *Picea abies* (1%), and plant associations of verdurous dunes. Other tree species make up 1% including some hectares of *Quercus robur,* and *Fraxinus excelsior*. There are also several introduced species like locust *Robinia pseudoacacia*, aspen and poplar *Populus* sp.*,* field maple *Acer campestre,* sycamore *Acer pseudoplatanus*, tartar maple *Acer tataricum*, common beech *Fagus sylvatica*, red ash *Fraxinus pensilvanica* and Austrian pine *Pinus nigra*. Pure pine forests constitute nearly 80%, and sand area of dune meadows comprises 25.4% of the land. Only a small part is constituted by roads (24%), urban area (1.5%), swamps (0.3%) and meadows and pastures (0.2%). The share of arable area is quite small (0.05%), the same as gardens (0.02%) and inner waters (0.01%). There are 37 mammal species including 10 rare and 7 species entered into the Red Data Book, and above 200 bird species including more than 100 breeding species. The diversity of areas under different functional purposes is characteristic of the study area including the following five functional zones: conservation zone (no active intervention) including strict nature reserves (1,850 hectares or 18.9% of the total area) and nature reserves (5,653 ha, 57.8%); protective or buffer zone (73 ha, 0.8%); recreation zone that is rather larger than the conservation zone (1,937 ha, 19.8%) as well as commercial (2.3%) and urban (0.4%) zones.

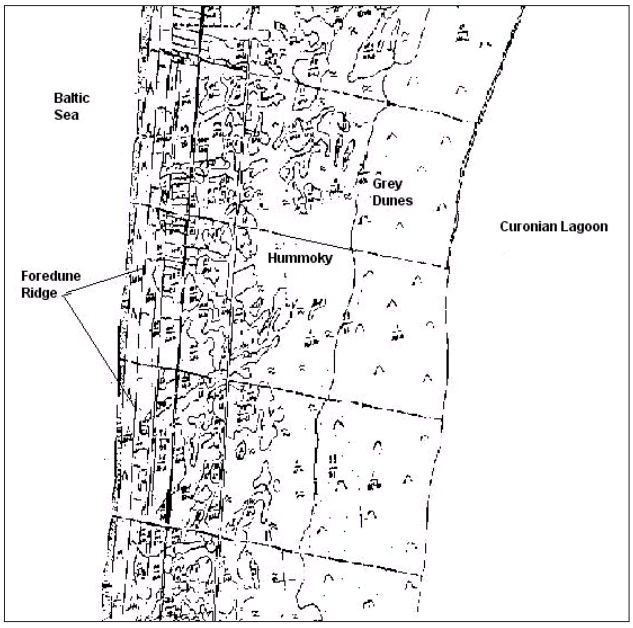


Figure 1. Scheme of the study area on the territory of the Kuršių Nerija National Park

Unique conditions are on the study territory. This is littoral lowland in the natural district of pine forests that belongs to the maritime climatic subregion IIa. Because of the specific topographical position of the peninsula, the climate is mild and greatly influenced by the Baltic Sea. There is the largest number of sunny days and high air humidity particularly in winter 82%, and in spring 76%. The annual long-term precipitation is 643 mm and reached 912 mm while 75% of the precipitation falls in a warm season. The warming effect of the sea is stronger (up to 3˚ C) than in the other parts of Lithuania. Under sea influence, autumn and winter are warmer than spring: the air temperature differs from eastern regions by 3 -3.5˚. The mean annual long-term air temperature is 6.2-6.4˚C, and reached –0.8-2.0˚C in winter. The snow appears at the end of November. The

snow cover forms at the end of December – beginning from January that is 10-15 days later than on the other territory of Lithuania. Meanwhile the snow cover is quite changeable as 50% of winters are with unstable snow cover and the average depth of snow of h=18 cm.

During the total trial period the weather was changeable while the weather inclemency was undistinguished in the initial non-vegetative period of 2000/2001. In the next period of 2001/2002, the weather was moderately severe but changeable in the early spring (air t˚ = -8˚C - +10˚C). It disturbed the feeding of roe deer in this region (Belova 1999b,c). In the study period of 2003/2004, the weather was quite severe. The wintry weather has steadied from November yet, and the air temperature was negative (-4˚C). The snow cover was most unstable in all study periods. Snow cover changed from 1 cm to 15 cm. In the first and last study periods, it melted later, and was out of the critical isoline. In the next December - January the heavy snow reached 60 cm. However, it was also unstable further. In 2002/2003, the instability of snow cover went with instability of air temperature that had reached – 23- -27˚C. Consequently, the weather in the non-vegetative period was disadvantageous for animal feeding and for thermal balance of moose. In early spring of the last study period 2003/2004, the weather and air temperature completely changed, that is in later March the air temperature changed from +3 to - 19˚C, and from -8˚C to +9˚C. Indicated climatic situation induces the changes in animal habitat selection. In the non-vegetative period, that lasted ca. 98 days on the study area, these weather conditions impelled animals to feed in the forests.

Results

The quantitative and qualitative characteristics of the populations and habitat use of herbivorous animals

The common species of herbivorous animals in the Kuršių Nerija National Park are the Roe deer (*Capreolus capreolus* L.), the Moose (*Alces alces* L.) and the Brown hare (*Lepus europaeus* Pallas). The number of pellet-groups left during non-vegetation period, the browsing pressure per 1,000 hectares, the animal sex ratio and percentage of fawns in the successive years are shown in Table 1 and Figure 2.

During successive years the density of Cervids and hares evidently fluctuated. The highest density of moose was fixed in 2002 (3 animals per 1,000 ha) and the lowest in 2003 (1 animal per 1,000 ha). The highest density of roe deer and hares was in 2001 (17 and 8 animals per 1,000 ha) while in 2003 the density of these herbivorous animals decreased (13 and 7 animals per 1,000 ha, respectively).

Table 1. The quantitative and qualitative changes in the local populations of deer and hares in 2001-2004 on the territory of the Kuršių Nerija National Park

Parameters	Species of herbivorous animals											
	Alces alces				*Capreolus capreolus*				*Lepus europaeus*			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Total counting area, ha	2,736											
Length of the belt transect, km	13.8	18.7	25.8	21.6	13.8	18.7	25.8	21.6	13.8	18.7	25.8	21.6
Area of the belt transect, ha	5.52	7.48	8.71	8.64	5.52	7.48	8.71	8.64	5.52	7.48	8.71	8.64
Animal-season	5	8	3	1	47	17	31	32	21	7	17	5
Animal density, n*/1,000 ha	**2**	**3**	**1**	**0,5**	**17**	**6**	**11**	**12**	**8**	**2**	**6**	**2**
Sex ratio □□ : □□	**1:0.2**	**1:0.2**	**1:2.2**	**1:0.5**	x	x	x	x	x	x	x	x
Share of Juv, %**	**35**	**88.3**	**29.6**	**40**	**9**	**26**	**6.1**	**10.9**	x	x	x	x

*n – animal number

** Juv% - share of juveniles in the local population by calculating the pellet groups

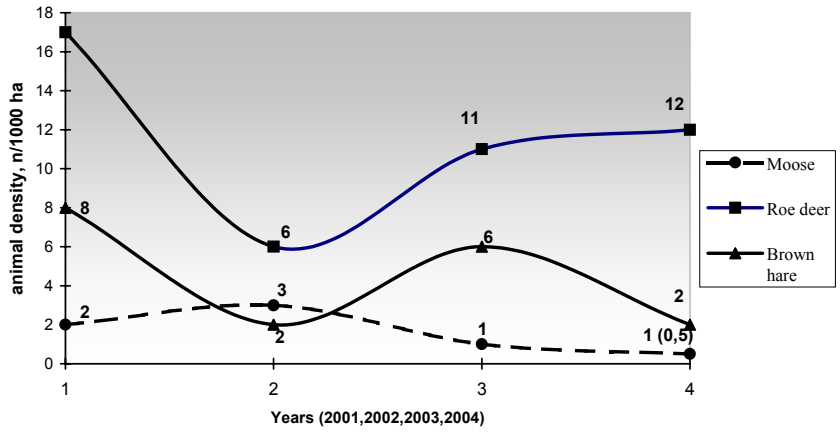


Figure 2. Changes in density of herbivorous animal, n/1,000 ha over the investigative periods from 2001 to 2004

The moose density was lower than the ecological density (2-3 animals per 1,000 ha) that is permissible on the protected areas, however it is more than economical permissible density (1-2 animals per 1,000 ha). In the same time, the density of the roe deer was observed to be lower than the economical permissible. There was no any red deer on the area of KNNP yet. Some individuals were constantly registered in the last three years. That were male, female and two fawns, however, they were not just yet involved into the census. These animals occur in the northern part of the study area close to the thickness of the *Pinus montana* and are not spread through the territory except the stag. He was tracked in the southeastern part of study territory moving away per 5-8 km from the locality of female and fawns. Meanwhile female and young deer stay there.

According to the qualitative assessment of the local populations, in the first study period of 2000/2001 the males dominated in the moose population. There was a slim share of the juveniles in the roe deer population. The considerable decrease in the number of roe deer together with decrease in share of juveniles in the local population shows that the indicated period was unfavourable for animals. Roe deer density noticeably decreased from 17 to 6 animals per 1,000 ha. Further it started increasing but did not reach the economical permissible and ecological density yet (*i.e.* 10-20/1,000 ha). It should be noticed that the trend of the increase in roe deer population is indicated over the whole territory in Lithuania. In the moose local population the share of fawns comes to increase later on but further it decreases again, nearly 7 times. After the period of mild winter the share of juveniles increases near to optimal (that is 26% in moose and 30% in roe deer) in the roe deer and moose populations. Further, the decline in moose and roe deer number occurs again, and it slightly increases in the last study period only. As moose females increased in number, the sex ratio skewed noticeably from the optimum when the optimal population increment is ensured (*i.e.* ♂♂ : ♀♀ = 1 : 1.1 – 1.2).

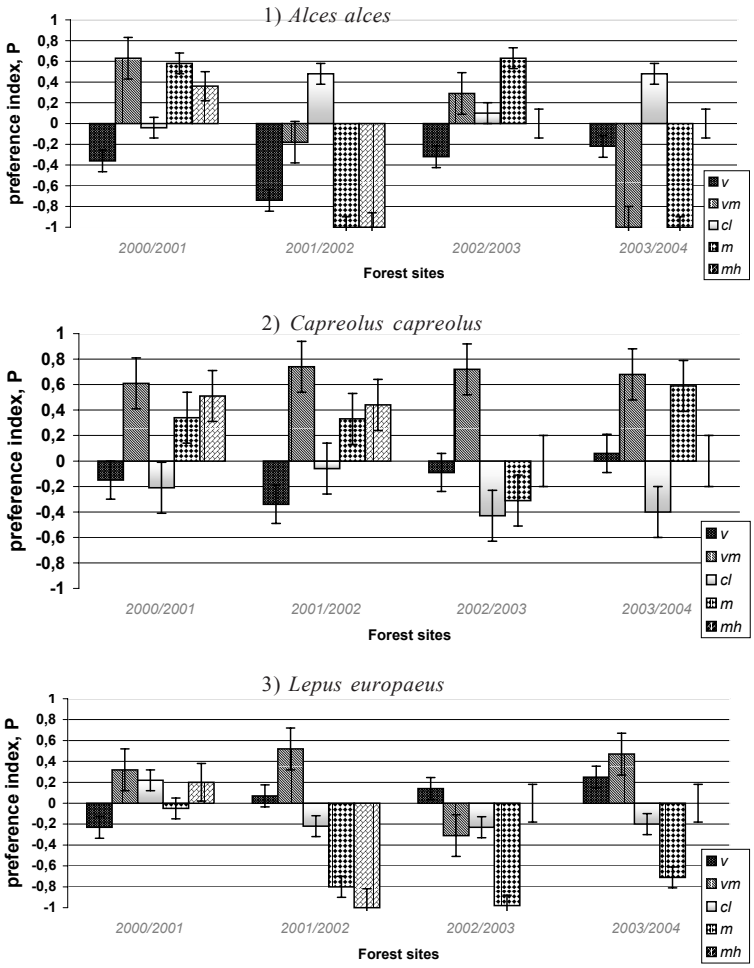
The decreases in number are explained as retreat of animals into areas of the more favourable feeding, and animal grouping there. Habitat preference values varied temporally and reveal that habitats are the most preferable depending on the stand composition, forest site type and forest age (Figure 3a-c).

In all trial periods moose mostly grouped in the mature and overmature mixed pine stands *Myrtillosa* and *Vaccinio-myrtillosa* with an average cover of deciduous undergrowth in the western part of peninsula (66.7% of all occurred animals). In the severe winter moose also occurs in the young pine plantations of I age class (89.8% of all occurrence) and in the pine associations of verdurous dunes preferring *Cladoniosa* sites. The preference of the clumped plant associations of verdurous dunes in animals of all species depends on the food availability and weather severity. Roe deer also preferred mature forests of the 4th age class and older (58.7% of all occurred animals) of the *Vaccinio-myrtillosa* and *Myrtillosa*, and notably less grouped in the stands of the 2nd age class. The *Cladoniosa* sites were disliked over all time spans of the investigation. There is underpopulation of hares. Animals grouped in the certain parts of the forests and adjacent open territories as forest gaps, dunes and verdurous dunes. The clumped distribution is characteristic of the local hare population. That is the general tendency of the hare distributions in the pure pine forests (Belova, 1996). In the initial study period hares less grouped in the mature and middle-aged pine forests mixed by birch, and in the verdurous dunes (17.8%, 9.7% and 8.5%, respectively). The main grouping habitats were differently aged young natural and previously planted forests and plant communities of the verdurous dunes, gaps and middle-aged forests and sea dunes on the seashore. Lately, in the periods of the changeable and severe winters, hares go out from the prior wintering habitats of verdurous dunes and gaps to the middle-aged stands. In the last period 2003/2004, they come back to plantations and gaps as well as mature and middle-aged forests.

The herbivory as the main relationship among animals and woody plants in forests

There are 15 species of forest woody plants and dwarf shrubs in the feeding space of herbivores and their diet on the study area. The most widespread woody plants in winter habitats were Scots pine *Pinus sylvestris* (its average occurrence is 72.24%), birch *Betula pendula* (35.12%), juniper *Juniperus communis* (23.84%) and dwarf mountain pine *Pinus montana* (12.99%). The average abundance of these woody vegetation species is 61.54; 9.18; 4.55 and 4.87 %, respectively. Herbivorous mammals use shoots most in non-vegetative period and less in the growing period preferring the well-developed annual shoots of oak *Quercus robur*, aspen *Populus tremula*, brier *Rosa canina* and broom *Sarothamnus scoparius*. However, these species are comparatively scarce of the abundance up to 1 % (Table 2). *Populus tremula* became quite sporadic species and was not registered in the last study period. That is a downtrend of the species on the study territory. This species was particularly consumed in the previous periods with the browsing intensity up to 81.8%. The main

a) **Forest sites**



b) **Stand composition**

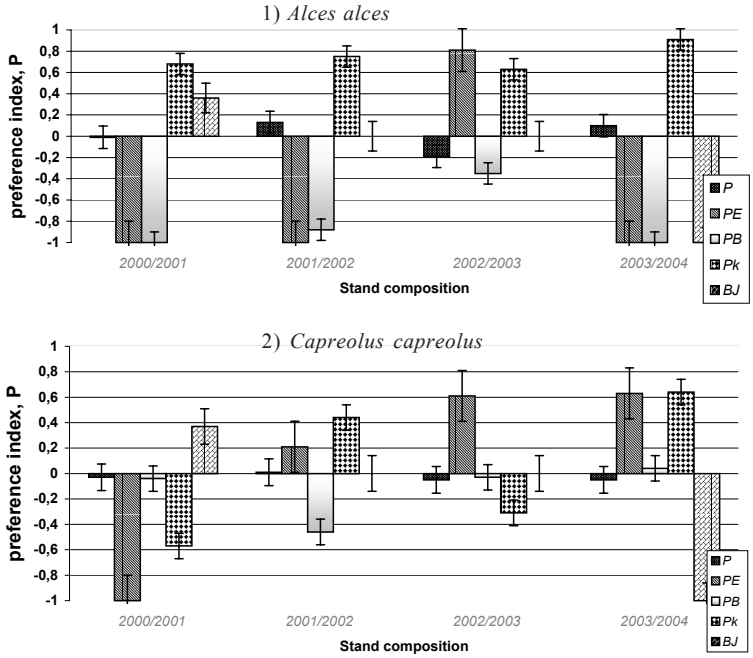
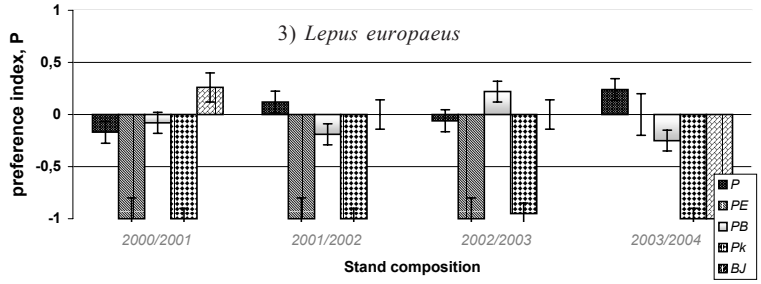


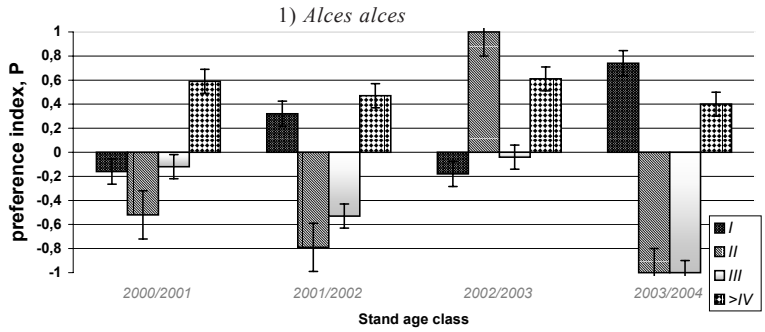
Figure 3. Changes in the habitat preference of Cervidae and *Lepus europaeus* in pure pine forests of different age classes forest sites and stand composition in the Kuršių Nerija National Park from 2000/2001 to 2003/2004 non-vegetative periods

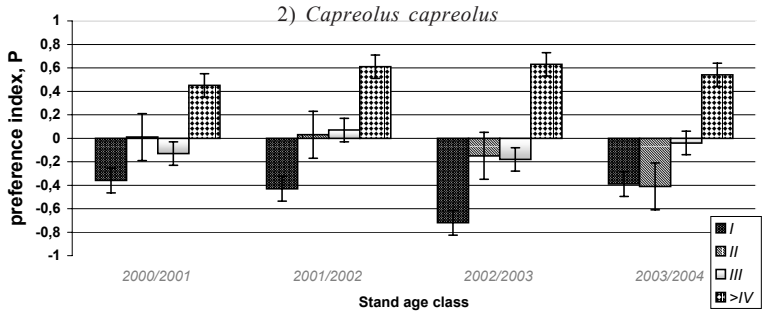
P - pure pine	*Pinus sylvestris*
PE - pine with spruce	*Pinus sylvestris - Picea abies*
PB - pine with birch	*Pinus sylvestris - Betula pendula*
Pk - mountain pine	*Pinus mugo*
BJ - birch with black alder	*Betula pendula - Alnus glutinosa*

v - Vacciniosa
vm - Vaccinio-myrtillosa
cl - Cladoniosa
m - Myrtillosa
mh - Mixtoherbosa



c) **Stand age class**





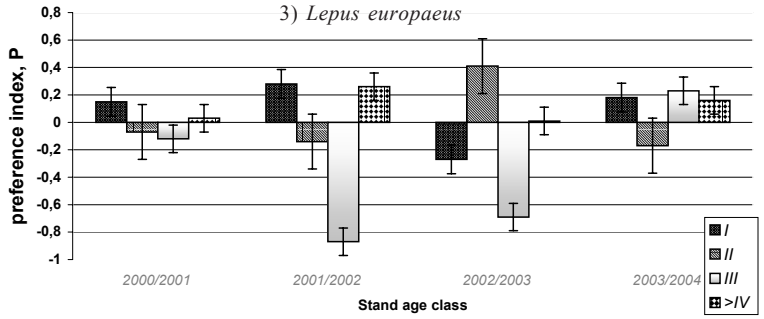


Figure 3. (Continuation)

species in diet were rowan *Sorbus aucuparia,* birch *Betula pubescens,* alder buckthorn *Frangula alnus,* broom *Sarothamnus scoparius* and Scots pine *Pinus sylvestris* as well as dwarf shrub *Vaccinium myrtillus.* The share of these species comprises from 1.1 to 53 % in diet while their browsing intensity on average reached 60% (Table 3). The most preferred deciduous species and variable accessible dwarf shrubs are typical of the underbrush of the mature and overmature stands where animals grouped in the non-vegetative period. The predisposition to choose the most preferred and at the same time rare plant species is obvious in the consumption of shoots too. Most consumed are shoots of *Frangula alnus* (75%), *Populus tremu-*

Table 2. Changes in the occurrence and abundance of forest woody species in pure pine forests of the Kuršių Nerija National Park

Species	Occurrence								Abundance			
	number				%				%			
	years				years				years			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Pinus sylvestris L.	98	103	113	89	72.59	73.05	71.07	55.97	67.78	61.78	55.06	52.57
Pinus montana Mill.	20	19	17	33	14.82	13.48	10.69	20.75	4.28	5.72	4.61	6.17
Picea abies L.	6	5	5	5	4.44	3.55	3.14	3.14	0.21	0.28	0.33	0.50
Quercus robur L.	3	5	8	8	2.22	3.55	5.03	5.03	0.1	0.18	0.36	0.65
Betula pendula Roth.	43	54	56	60	31.85	38.3	35.22	37.74	6.39	9.71	11.44	12.50
Populus tremula L.	2	2	0	1	1.48	1.42	0	0.63	0.05	0.07	0	1.19
Frangula alnus Mill.	6	3	8	1	4.44	2.13	5.03	0.63	0.75	0.53	0.9	0.08
Sorbus aucuparia L.	14	15	23	28	10.37	10.64	14.47	17.61	8.18	9.36	11.64	13.88
Juniperus communis L.	45	29	28	24	33.33	20.57	17.61	15.09	4.84	5.37	3.45	3.83
Salix spp.	11	18	14	21	8.15	12.77	8.81	13.21	1.38	3.05	1.99	4.22
Alnus glutinosa (L.) Gaertn.	4	2	1	1	2.96	1.42	0.63	0.63	0.47	0.32	0.23	0.27
Rosa canina L.	2	0	1	0	1.48	0	0.63	0	0.23	0	0.33	0
Daphne mezereum L.	1	0	0	0	0.74	0	0	0	0.14	0	0	0
*Sarothamnus scoparius (*L.) Wimm.	0	2	3	1	0	1.42	1.89	0.63	0	0.6	1.72	0.54
Vaccinium myrtillus L.	2	3	7	4	1.48	2.13	4.4	2.52	5.25	3.05	7.89	3.60

Table 3. Changes in the browsing intensity and share in the animal diet of forest woody species and dwarf shrubs in pure pine forests of the Kuršių Nerija National Park

Plant species	Browsing intensity, *I* %				Share in diet, %			
	years				years			
	2001	2002	2003	2004	2001	2002	2003	2004
Pinus sylvestris L.	1.94	2.16	2.47	0.44	8.65	12.70	7.84	1.80
Pinus montana Mill.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea abies L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juniperus communis L.	2.89	0.65	1.92	0.00	0.92	0.33	0.38	0.00
Quercus robur L.	100.00	80.00	72.73	35.29	0.66	1.34	1.53	1.80
Betula pubescens Roth.	50.73	13.72	11.01	10.12	21.36	12.71	7.27	9.88
Populus tremula L.	100.00	100.00	0.00	0.00	0.33	0.67	0.00	0.00
Alnus glutinosa (L.) Gaertn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sorbus aucuparia L.	98.29	43.45	45.30	55.25	52.98	38.80	30.40	59.87
Frangula alnus Mill.	96.88	93.33	88.89	100.00	4.78	4.68	4.59	0.60
Salix spp.	74.58	22.99	3.33	20.00	6.78	6.69	0.38	6.59
Rosa canina L.	100.00	0.00	100.00	0.00	1.52	0.00	1.94	0.00
Sarothamnus scoparius (L.) Wimm	0.00	100.00	100.00	100.00	0.00	5.69	9.94	4.19
Daphne mezereum L.	100.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00
Vaccinium myrtillus L.	3.11	56.32	78.57	54.26	1.10	16.39	35.73	15.27

Table 4. Changes in the shoot consumption of woody species and dwarf shrubs in pure pine forests of the Kuršių Nerija National Park

Plant species	Shoot consumption, %			
	years			
	2001	2002	2003	2004
Pinus sylvestris L.	1.74	1.65	0.34	0.14
Pinus montana Mill.	0	0	0	0
Juniperus communis L.	92.75	58.97	14.8	0
Quercus robur L.	18.75	3.87	3.84	9.63
Betula pubescens Roth.	81.82	64.29	0	0.99
Populus tremula L.	70.26	74.77	54.7	0.19
Alnus glutinosa (L.) Gaertn	60.75	24.52	20.5	0
Sorbus aucuparia L.	0.79	0.07	0.2	25.24
Frangula alnus Mill.	89.69	8.53	1.1	14.29
Salix spp.	0	0	0	28.15
Salix caprea	14.29	0	45.8	0
Rosa canina L.	86.96	0	0	0
*Sarothamnus scoparius (*L.) Wimm	0	91.49	100	87.82
Daphne mezereum L.	15.01	61.2	75.9	0
Vaccinium myrtillus L.	1.74	1.65	0.34	84.17

la (65%), *Quercus robur* (59%), and also Roe deer and hares preferred *Sarothamnus scoparius* (92%) and *Vaccinium myrtillus* (61.2%) when the snow cover is short-term and not more than 10cm. The distribution of faecal pellets and shoot browsing around a tree indicate the longer feeding in snowy periods in the same places. The shoot browsing reached more than 40-50% of the consumption level in the deciduous species but the browsing intensity of scarce species is quite higher than shoot consumption (Table 3), the occurrence and abundance of these species (Table 2).

The bark stripping was observed in only *Pinus sylvestris*. It occurred sporadically in the pine plantations of the 2nd age class. The number of damaged trees changed from 0.2% of the bark consumption, which comprised 564 cm^2 in 2001/2002 to 1.7% of the bark consumption, which constituted 2079.9 cm^2 in 2002/2003, and was not found in the last study period on the whole. By the wound freshness, the peak of the bark consumption was typical of the late winter (February) and early spring (March-April), and in mild midwinter when the air temperature does not change sharply. That was corroborated by our previous studies on regularities of the bark stripping (Padaiga and Belova 2001) determining the bark-stripping course and its dependence on the environmental factors.

The changeability of weather and snow cover shows up from the density independent factors. This causes the changes in animal feeding habit: browsing

of shoots or bark stripping. The changeability of the air temperature and snow cover negatively influences browsing intensity R= -0.36 ±0.022, *t*= 11.82, and R= -0.167±0.033, t=5.95. The shoot consumption of the main tree species directly and negatively related to the weather variability (from r= -0.95 for Scots pine to –0.34 for birch, $p<0.05$) except willows, brier, broom, and dwarf shrubs (Tables 5 and 6).

The decrease in the air temperature results in less bark stripping because of an impeded use of bark crystallizing liquids in a tree bark (Padaiga, Belova 2001). Meanwhile, the consumption of tree shoots of the main woody species closely and positively depends on the animal density n/1,000 ha. In this case strong positive dependence is notably expressed between consumption shoots of Scots pine, oak, aspen, alder buckhorn and birch and moose density (Table 6). Increase in the roe deer density leads to the higher consumption of shoots of *Juniperus communis, Sorbus aucuparia* and *Salix caprea* while consumption of the shoots of aspen, oak and birch negative related to roe deer density in contrast to the case of moose.

Discussion and conclusions

The range of the main herbivorous animals in the Kuršių Nerija NP as Roe deer (*Capreolus capreolus* L.), Moose (*Alces alces* L.) and Brown hare (*Lepus europaeus* Pallas), is supplemented with Red deer (*Cervus elaphus* L.). These animals directly related to woody vegetation mostly through the feeding. According to the hierarchical range, the feeding importance reaches the shelter one because of the food shortage

Table 5. Dependence of the main parameters of herbivorous animals - woody plant interaction on the animal density, n/1,000 ha, and weather conditions in non-vegetative period: Browsing intensity, %

Parameters	Animal density, n/1,000 ha						Changeability in the air temperature, V%		Changeability of the snow cover, V%	
	Moose		Roe deer		Hare					
Browsing intensity, % of:	*R*	± *m*	*R*	± *m*	*R*	± *m*	*R*	± *m*	*R*	± *m*
Pinus sylvestris	0.553	0.029	-0.182	0.040	0.492	0.031	-0.228	0.039	0.042	0.041
Juniperus communis	0.181	0.040	0.650	0.024	0.978	0.002	-0.462	0.033	-0.609	0.026
Quercus robur	0.693	0.022	0.249	0.039	0.702	0.021	-0.747	0.018	-0.073	0.041
Betula pubescens	0.301	0.038	0.765	0.017	0.762	0.017	-0.812	0.014	-0.420	0.034
Populus tremula	0.911	0.007	0.000	0.042	0.192	0.040	-0.957	0.004	0.414	0.034
Sorbus aucuparia	0.072	0.041	0.883	0.009	0.715	0.020	-0.694	0.022	-0.543	0.029
Frangula alnus	-0.214	0.040	0.388	0.035	-0.254	0.039	-0.270	0.038	-0.024	0.041
Salix spp	0.342	0.037	0.701	0.021	0.572	0.028	-0.873	0.010	-0.266	0.039
Rosa canina	-0.130	0.041	0.640	0.025	0.962	0.003	-0.103	0.041	-0.781	0.016
Sarothamnus scoparius	-0.225	0.039	-0.813	0.014	-0.778	0.016	0.769	0.017	0.481	0.032
Vaccinium myrtillus	-0.297	0.038	-0.706	0.021	-0.514	0.031	0.853	0.011	0.257	0.039
Daphne mezereum	0.225	0.039	0.813	0.014	0.778	0.016	-0.769	0.017	-0.481	0.032

$p<0.05$; n – animal number

Table 6. Dependence of the main parameters of herbivorous animals - woody plant interaction on the animal density, n/1,000 ha, and weather conditions in non-vegetative period: Consumption of shoots, %

Parameters	Animal density, n/1,000 ha						Changeability in the air temperature, V%		Changeability of the snow cover, V%	
	Moose		Roe deer		Hare					
Consumption of shoots, %	*R*	± *m*	*R*	± *m*	*R*	± *m*	*R*	± *m*	*R*	± *m*
Pinus sylvestris	0.908	0.007	0.035	0.041	0.279	0.038	-0.951	0.004	0.352	0.036
Juniperus communis	0.247	0.039	0.790	0.016	0.860	0.011	-0.734	0.019	-0.517	0.030
Quercus robur	0.996	0.000	-0.998	0.000	-0.414	0.034	-0.960	0.003	0.939	0.005
Betula pubescens	0.661	0.023	-0.636	0.025	0.492	0.031	-0.338	0.037	0.273	0.038
Populus tremula	0.981	0.002	-0.987	0.001	-0.502	0.031	-0.983	0.001	0.968	0.003
Sorbus aucuparia	0.245	0.039	0.793	0.015	0.703	0.021	-0.803	0.015	-0.420	0.034
Frangula alnus	0.862	0.011	-0.121	0.041	0.425	0.034	-0.674	0.023	0.257	0.039
Salix spp	-0.476	0.032	-0.189	0.040	-0.768	0.017	0.409	0.035	0.234	0.039
Salix caprea	0.225	0.039	0.813	0.014	0.778	0.016	-0.769	0.017	-0.481	0.032
Rosa canina	-0.324	0.037	0.190	0.040	0.611	0.026	0.435	0.034	-0.605	0.026
Sarothamnus scoparius	-0.228	0.039	-0.804	0.015	-0.708	0.021	0.793	0.015	0.434	0.034
Vaccinium myrtillus	-0.510	0.031	-0.598	0.027	-0.709	0.021	0.899	0.008	0.238	0.039
Daphne mezereum	0.225	0.039	0.813	0.014	0.778	0.016	-0.769	0.017	-0.481	0.032

$p<0.05$; n – animal number

in non-vegetative period (Belova 1999a, 2001). This is accompanied by exterior disturbances and stimulated the gathering of animals in the places of more favourable feeding. That is a consideration to motivate the choice of the study period investigating the animal-plant interaction. This study has provided information on the main criteria of animal - woody plant interaction as the consumption of shoots of woody vegetation and browsing intensity. The gathering of herbivores should affect their main food objects as the woody vegetation, in certain places in the non-vegetative period depending on the main density-independent factors as weather conditions. Whether herbivores prefer the same or different habitats, this will determine their impact to forest.

The foraging strategy of herbivores revealed that in accordance with ecophysiological adaptations and features of digestive system, the red deer mostly gets advantage in feeding as the feeder of intermediate type, and both roe deer and moose are attributed to concentrate selectors (Hofmann 1989, 1998, Petrak 1991, Homolka 1996). The specific habit of these species is use of the most nutrition parts of the plants then red deer. Although the morphological - physiological features of digestive system are species specific, it is important to consider the animal adaptability, habitat character, geographical and ecological peculiarities including seasonal changes in animal environment as well as the food capacity of habitat (Belova 1997, 2003). Despite the fact that roe deer are the concentrate selectors and more close to moose by their morphological - physiological features, the gramineous species comprise 81% of the diet in roe deer while woody species only 11% (Prusaite *et al*. 1983, Baleišis *et al*. 2003) especially on the open areas of the low forest cover. Meanwhile the woody food predominates in winter and later autumn. We should underline that three ecotypes of *Capreolus capreolus* are found in Lithuania such as forest, forest edges and field ecotypes depending on the local forest cover. Thus, animals of the field ecotype stay in fields all year round while other ecotypes prefer deciduous of medium and small size (Baleišis *et al* 2003). Previous studies of the niche overlapping in herbivorous animals (Belova 1997) have indicated that there are 96.2% of woody species in the diet of red deer and 92.4% in the diet of roe deer in non-vegetative season. There are 14 common species of the main 90 most preferable plant species, which are mostly used by herbivores but at different time (there roe deer debarked the bark of willows S*alex* spp. in December and January, and red deer debarked from January and later on) and are unlikely available to animals of different species. The overlapping of trophic niches is highest in roe deer and hares, roe and red deer, and red deer and moose. 6.2% of plant species are only in the diet of red deer, 32.1% are common with roe deer diet and 25.9% with moose diet. By common plant species the competitive ability of red deer to roe deer is 16.3% and to moose is 13.1%. That is the stronger competition is between roe and red deer (Belova 1997, 2001). Nevertheless, the competition between the two species of browsers, *Alces alces* and *Capreolus capreolus* is revealed itself in pure pine forests (Table 5 and 6) that are comparatively scanty in food.

Particular features of study area are comparatively even changes in weather conditions and contrasts are unrepresentative as distinct from the continental pure pine forests. Specific climate and geomorphologic diversity of landscape as well as the absence of agricultural landed property determine the low carrying capacity and distinctive structure of local fauna and their adaptations, as the mixed forest - forest edge ecotype of hares and forest ecotype of roe deer. The coexistence of forest plants and animals is directly and indirectly influenced not only by the determined abiotic and biotic factors but also human factors including forestry, hunting and its restrictions, supplemental feeding in winter, picking of mushrooms and berries, and other recreational activities. The last-mentioned activities are particularly obvious on the study territory while forests are managed by the separate regime that is approved by the legal acts for protected areas. The investigation of forest management shows that the open area tends to decrease in forests (*Kuršių Nerijos NP*….2001). The main reason for this process is the natural reforestation on areas uncovered by forest and non-forest area. The specific management includes reforestation on the fire-damaged and reconstructive areas of died *Pinus montana*. The thinning, sanitary and landscape cuttings are permissible, and local forestry aims to sustain and restore present forests and their components. Thus, there are no any clearcuts and the limit area for planting trees while the main task is to maintain the natural processes of reforestation on the recreational and protected areas. These patches became most attractive to hares. The underpopulation of hares and their clumped distribution are specific features. Hares mostly grouped in the certain parts of forests and adjacent open territories as forest gaps, dunes, sand-blow plains *"palve*" and hummocky area ahead of the Great moving dunes eastwards from the Baltic Sea. This area is sufficiently overgrown with grassy vegetation, small shrubs, birch and natural *Pinus* spp. groups in plant. Roe deer and moose prefer the mature and overmature stands (preference index ranged from 0.4 to 0.6) in all time spans. They distribute differently under the se-

vere winter conditions, when moose mostly (preference index reached 1 and more) gathered and foraged in the patches of young pine (browsing intensity reached 2.47%, and it was highest comparatively with other periods). Thus, the competition for the limited resources mostly reveals under the disadvantageous conditions, moreover, that study area is not rich in food. Usually relations between deer species are not distinctive, and they avoid contacts because of an indifference. While animals tried to meet their needs, but they failed to do it, then another time their memory suspends the need and incentive an animal to avoid unpleasant situation (Belova 1997, 2001).

Recalculating the present deer density into the conditional density on the grounds of the equivalent that is 1 moose = 3 red deer and 1 red deer = 4 roe deer (Padaiga 1996), general conditional number of deer reaches 8/1,000 ha. This parameter corresponds to the economical permissible deer density in pure pine forests. Herewith, the sex ratio and age structure of local populations are aberrant, and that is the indicator of disfavour of living conditions. Consequently, the changes in the sex ratio in behalf of females in the local moose population indicate that there was deterioration of animal living conditions on the territory of littoral pure pine forests. Increase in the juvenile number is the parameter of conditions favourable for survival, and it has the compensatory character. The increase in females provokes a tendency of increase in consumption of the main woody species because females usually select more productive feeding habitats and use more qualitative food then males. In this case no any animal death have been recorded, while the moose hunting was still forbidden in the whole country.

The intrusion of sparse local group of red deer into specific moose habitats persists in pure pine forests. However, they have not an advantage over the other herbivorous animals yet. Habitat preference values and plant consumption intensity varied temporally depending on stand composition, forest site type and stand age as well as variability of the main weather parameters. Increase in roe deer density leads to the higher consumption of shoots of different woody species in contrast to the case of moose that is juniper *Juniperus communis,* rowan *Sorbus aucuparia* and goat willow *Salix caprea.* Whereas the consumption of shoots of aspen *Populus tremula*, oak *Quercus robur*, and birch *Betula pubescens*, negative related to roe deer density. Investigations indicate the necessity to consider the main criteria of animal-plant interaction as the consumption of shoots of the main forest woody species and the browsing intensity.

Considering the delineation of territory for game animals and determination of the main forest categories, the main parameters for monitoring of the animal – plant interaction are the browsing intensity, the level of shoot consumption and abiotic factors in non-vegetative period that limited these parameters. One of the main implications of this study is consideration of the critical threshold in consumption of woody plants, which is important for the ecological balance between animals and plants. That is the shoot consumption of 40-50% for the deciduous species and 20-30% for conifers (Padaiga 1996, Belova 2004, 2005). This corresponds to "floral index" (Guibert 1995) proposed to maintain the animal-plant ecological balance. In this case, an index value of 27% indicates that deer number is under carrying capacity of habitats while optimal values are 27-37%, and 37-50% shows the destruction of balance, however it could be renewed.

It should be underlined that the shoot consumption more than 50% in conifers and more than 20-30% in deciduous species is the criterion of the irreversible process of decline in the certain species: in our case these are *Populus tremula*, *Frangula alnus*. The way of restoration of the ecological balance is the monitoring of animal number, population parameters, hunting and state of their foraging habitats.

The number of pellet groups is considered as the index of habitats (Morellet *et al*. 1996) while the plant consumption shows an animal impact to the environment. The pellet group count in early spring before the growing season is the basis of quantitative and qualitative assessment of the sex ratio and age structure in local populations. An increase in the number of females indicates the deterioration of animal living conditions on the territory of littoral pure pine forests. The increase in females provokes a tendency of an increase in consumption of the main woody species because females usually select more productive feeding areas and use more qualitative food than males. However the increase in the number of juveniles is the parameter of conditions that are favourable to survive and contains the compensatory character.

All investigated herbivorous animals are game, and their resources are used depending on the census results (hares) and the impact caused by deer (roe deer and moose) to the forest trees on the sample plots. On the bases of the request of KNNP representatives (users of hunting grounds tender their application for the use of game resources), the general hunting policy and following restriction or permission to use the certain species is implemented.

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КОРМОДОБЫВАНИЕ ОЛЕНЯМИ CERVIDAE И ЗАЙЦЕМ-РУСАКОМ *LEPUS EUROPAEUS* В ЛИТОРАЛЬНОЙ ЗОНЕ ЧИСТО СОСНОВЫХ ЛЕСОВ ЛИТВЫ

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Резюме

Основное взаимодействие между древесной растительностью леса и растительноядными Cervidae наряду с Leporidae, представляющими первичных потребителей в одной трофической цепи, наиболее проявляется трофическими связями. Следовательно, потребление пищи растительноядными определяет направление данного исследования. Важно знать лимитирующие факторы, выступающие в качестве стимулов влияния зверей на лес. С другой стороны, для взаимодействия между растительностью и растительноядными, необходимы не только обе части этого взаимодействия, но и среда, где оно проявляется. Это обосновывает необходимость определения предпочитаемости местообитания и цель исследования по оценке характера кормодобывания оленьих и зайцев и их взаимодействия с лесной растительностью, учитывая вышеизложенное.

Для исследования использовали комбинированый метод ленточных трансект (единица пробы 100 х 4 м) и пробных площадок (50 х 2 м, 100 м^2). Численность и распределение местных популяций зверей, их половая и возрастная структура определялись методом учета групп экскрементов на трансектах и площадках. В пределах кормового пространства зверей (от h = 0,1 до 2,2 м) учитывали все древесные растения и их побеги, разделяя поврежденные и нетронутые. Рассчитывалась интенсивность обгладывания ***I,*** и доля древестных растений в рационе зверей ***P*** на основании потребления древестных растений всех пород. Определялась предпочитаемость местообитания различных по возрасту, составу и типу лесонасаждения. Исследовано 504 пробных площадок на маршруте длиной 79.9 км на общей площади 2 736 га.

Специфичность климата и герморфологическое разнообразие ландшафта и условий местности при отсутствии сельскохозяйственных угодий обуславливает низкую кормовую емкость и особую структуру местной фауны и их адаптации как смешанный лесо-лесоопушечный экотип зайцев и лесной экотип косуль. Сосуществование лесных растений и зверей подвергается прямому и побочному воздействию не только определенных абиотических и биотических, но и антропогенных факторов, как лесное хозяйство, охота и ее ограничения, дополнительная подкормка зимой, сбор грибов и ягод и другие рекреационные активности. Последние особо явны на территории исследований, тогда как уход за лесом осуществляется по особому режиму, правовыми актами установленными охраняемым территориям.

На территории чисто сосновых лесов плотность населения зверей непревышает допустимой плотности, но половая и возрастная структура местных популяций отклоняется от оптимума, что является показателем неблагоприятности жизненных условий. Значения предпочитаемости местообитания и потребления растений флуктуируют в соответствии с составом, возрастом насаждения, типом леса и варибильностью погодных параметров. Основным параметром взаимодействия между древесной растительностью леса и растительноядными является уровень потребления побегов и интенсивность обгладывания основных древесных пород. При этом уровень потребления побегов хвойных более 50% и лиственных – более 20-30% является критерием невозобновляемого процесса упадка определенных пород, из них *Populus tremula*, *Frangula alnus*.

Ключевые слова: растительноядные, чисто сосновые леса, охраняемые территории, предпочитаемость местообитания, популяционные параметры, интенсивность обгладывания, уровень потребления побегов