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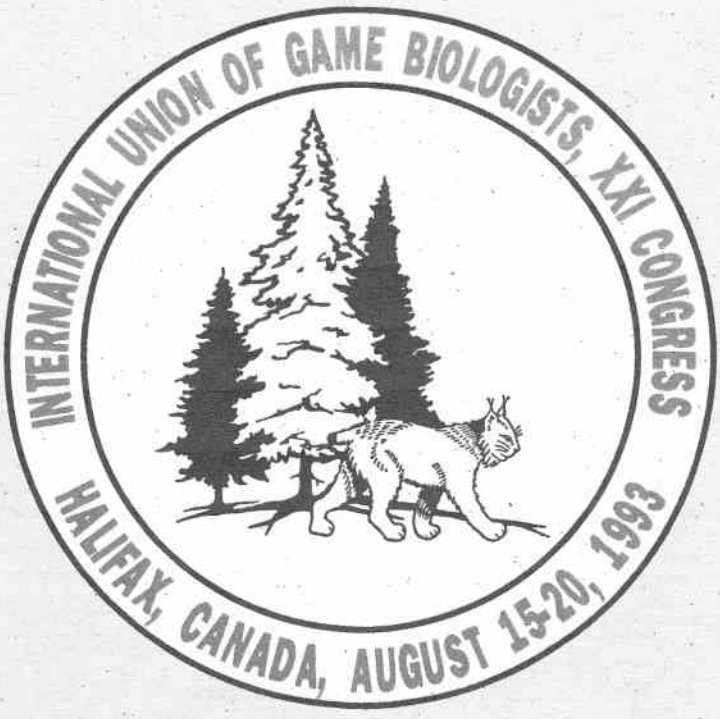

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Roe deer *Capreolus capreolus* population density and browsing pressure in a mixed-forest ecosystem

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Abstract

Browsing pressure of a roe deer (*Capreolus capreolus*) population on forest vegetation has been monitored in a 5000 ha mixed-forest ecosystem in south-west Germany over a period of 5 years. Within this period, attempts were made to reduce browsing pressure on economically important forest plant species via reduction of roe deer population density. Increased hunting pressure on roe deer resulted in a significant decrease of total browsing demand and browsing pressure. However, specific browsing pressure on some target plant species did not follow this pattern. This is interpreted to result from selective browsing by roe deer, fluctuations in species-specific food supply because of vegetation succession, differences in food plant palatability, and the different share of individual food plant species in the total browsing demand of roe deer. A method to monitor browsing demand, food supply, and browsing pressure is presented. Implications of the results for ungulate/forest management as well as the function of selective browsing in vegetation succession dynamics are discussed.

Introduction

Browsing pressure by deer species on forest regeneration can be a problem for forest management. Selective browsing can result in gradual loss of species, and very heavy unselective browsing can prevent forest regeneration completely. A simple management tool that can prevent these processes is the reduction of browser density. However, it is still controversial whether or not reduction of browser populations alone is an appropriate management measure to prevent or reduce browsing damage to economically or ecologically important forest plants. We had the opportunity to monitor the effects of a roe deer population reduction on the browsing situation in a mixed forest ecosystem over a period of 5 years.

Methods

The study area was the state-owned forest district "Warndt", located in the south-western corner of Germany near the French border, about 10 km west of the regional capital Saarbrücken. The hilly area has a size of roughly 5000 ha. The altitudes vary between 250 and 290 m asl. Annual precipitation is about 750 mm. The average annual temperature is 8.5°C, with relatively high frequencies of frost in winter and spring. Soils are poor and sandy on hills and loamy in flats and depressions. Major tree species for forestry are beech (*Fagus sylvatica*), fir (*Picea abies*), oaks (*Quercus robur, Q. petrea*), grove beech (*Carpinus betulus*), larch (*Larix decidua*) and pine (*Pinus sylvestris*). In particular on forest regeneration plots, they are mixed with economically unimportant woody plants like birch (*Betula pendula*), poplar (*Populus tremula*), rowan (*Sorbus aucuparia*) or willows (*Salix caprea, S. aurita*). The only ungulate species on the area are roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*).

Time schedule

Since 1985, roe deer were captured and individualy marked with coloured ear tags or radio transmitters. From our marked animals we learned that forest regeneration plots are the major feeding sites and deer

spend most of their active periods there. Also in 1985, we started to develop a method to assess the food supply and browsing pressure on the identified feeding areas, as well as the diet of the local deer population (Guthörl 1987). In 1987, the first survey of the browsing situation, representative for the whole study area, was carried out. At that time the annual roe deer bag was still relatively low. In 1988, the state forest authority started to reduce roe deer population density in the study area, in order to reduce browsing pressure on young trees, in particular on the economically important oak species. The annual roe deer bag increased by more than 40%. In 1989, the roe deer bag was still clearly above average, and the visibility of roe deer was sharply reduced. We assumed a significantly lower roe deer population, and the second survey of the browsing situation was carried out.

From 1990 on, annual roe deer bags dropped to low levels. As a result of the high hunting pressure during the previous years, the roe deer population had become increasingly nocturnal. The fulfilment of the annual culling plan, that still required high roe deer bags, had become impossible for forestry personnel. In 1991, the third survey of the browsing situation was performed. We assumed that the roe deer population had at least partly recovered from the higher harvest quotas of 1988 and 1989. Our data on roe deer bags are based on the official bag records of the state forest authority.

Representativness of the browsing surveys

During the 1987 survey, we recorded browsing on 25 forest regeneration plots. The smallest plot was 0.3 ha, the largest was 16 ha. The plots were evenly distributed, with 3-6 plots in each of the six forest subdistricts. In 1989, we recorded browsing on 28 regeneration plots. Only 13 of these plots had been recorded during the 1987 survey and could be examined for the second time. The rest of the 1987 plots had been fenced or grown out of the reach of roe deer. The 1991 browsing survey concentrated on only 10 regeneration plots. These were the only remaining plots of the original 25 still within the range of roe deer. The 10 plots were evenly distributed over the area, and were the only ones used to compare browsing from three surveys.

Record and calculation of food supply, browsing demand and browsing pressure

A transect line with at least 5 record points/ha was laid over each forest plot. Artificially planted, homogeneous regeneration plots were represented by only 5 record points/ha, while natural areas were represented by >5 points/ha. At each point the degree of ground cover of each plant species was assessed following a Braun-Blanquet classification. The degree of use of each plant species by roe deer was assessed following criteria and classification as listed in Table 1. It must be noted that, different from Braun-Blanquet, only one vegetation stratum was recorded: 0-1.5 m. Secondly, the degree of ground cover was assessed as if the plant species had not been browsed in the year of the record. Particularly in the case of heavily used plant species this was necessary in order to calculate the original food supply. The relation between the degree of ground cover for a given plant species and use results in an index for the

Table 1. Definition of the degrees of browsing intensity for the quantitative analysis of the food spectrum.

0 - no browsing
1 - slight 1-5% of the plants or of the edible parts of the plants at the site consumed.
2 - moderate 6-20% of the plants or of the edible parts of the plants at the site consumed.
3 - intense 21-50% of the plants or of the edible parts of the plants at the site consumed.
4 - heavy 51-100% of the plants or of the edible parts of the plants at the site consumed.

species-specific browsing demand (Table 2). The degree of ground cover of the plant species and the highest possible use result in an index for the species-specific food supply at the record point. The relation between browsing demand and food supply of the plant species is the species-specific browsing pressure (%). The sum or respectively the average of these values for all food plants at the record point result in the total food supply, total browsing demand and total browsing pressure. The averages of these values for single record points can be projected to the level of a plot, a part of the investigation area or the study area (Guthörl 1990).

Results

Roe deer bags, total browsing demand, food supply and browsing pressure

Roe deer bags were relatively low until the hunting season 1987/88. The bags were clearly above average in the seasons 1988/89 and 1989/90, and since 1990/91, roe deer bags were smaller (Fig. 1). The food supply was similar in 1987 and 1989. It was clearly reduced in 1991 because of vegetation succession processes that had taken place on the reference plots since 1987. Browsing demand declined sharply to 50% of the former level from 1987 to 1989. The same applied for the total browsing pressure, which dropped from 14% to 7%. As no additional food sources were available for roe deer, the only explanation for reduced demand was a smaller roe deer population of about 50% of the original level. In 1991, browsing demand was almost to the old level again, indicating that the roe deer population had recovered. However, because of the reduced food supply, total browsing pressure had increased to 19%.

Species-specific browsing demand, food supply and browsing pressure

Table 3 gives an overview and contains only those 29 food plants that were present on the plots during all three surveys. Altogether, more than 50 plant species were identified as food plants of roe deer, but most of these species were used only sporadically. The species listed in Table 3 account for more than 95% of the total browsing demand. Only 12 of these food plant species followed the trend of total browsing demand and total browsing pressure (Table 3). Despite the small number of species in this group, it accounts for more than half of the total

Table 2. Browsing index for different degrees of browsing intensity and vegetation cover.

Degrees of browsing intensity	0	0-1	1	1-2	2	2-3	3	3-4	4
Vegetation cover	Browsing index								
r	0	0.1	0.3	0.6	1.0	1.8	2.5	3.8	5.0
r - +	0	0.3	0.6	1.6	2.5	4.4	6.3	9.4	12.5
+	0	0.5	1.0	2.5	4.0	7.0	10.0	15.0	20.0
+ - 1	0	1.5	3.0	7.5	12.0	21.0	30.0	45.0	60.0
1 (<5%)	0	2.5	5.0	12.5	20.0	35.0	50.0	75.0	100.0
1-2	0	7.5	15.0	37.5	60.0	105.0	150.0	225.0	300.0
2 (5-25%)	0	12.5	25.0	62.5	100.0	175.0	250.0	375.0	500.0
2-3	0	18.8	37.5	93.3	150.0	262.5	375.0	562.5	750.0
3 (25-50%)	0	25.0	50.0	125.0	200.0	350.0	500.0	750.0	1000.0
3-4	0	31.3	62.5	156.3	250.0	437.5	625.0	937.0	1250.0
4 (50-75%)	0	37.5	75.0	187.5	300.0	525.0	750.0	1125.0	1500.0
4-5	0	43.8	87.5	218.8	350.0	612.5	875.0	1312.5	1750.0
5 (50-100%)	0	50.0	100.0	250.0	400.0	700.0	1000.0	1500.0	2000.0

Scale of vegetation cover after Braun-Blanquet

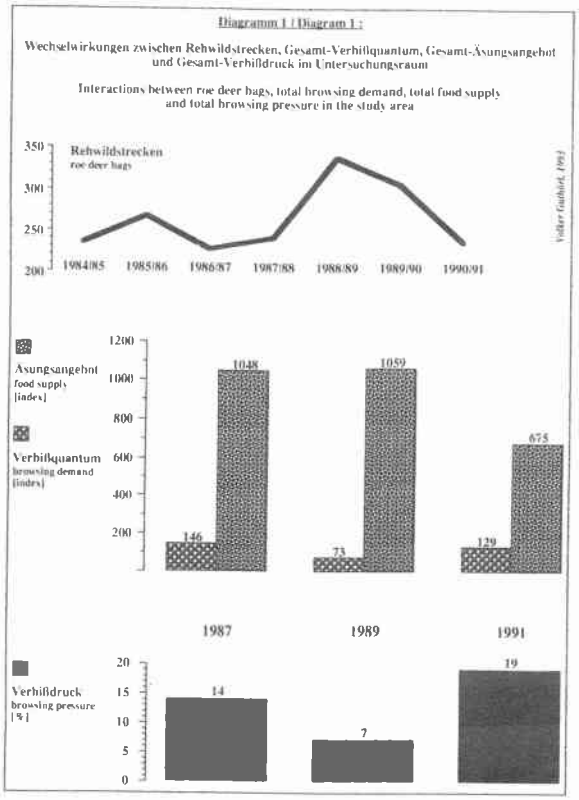

Figure 1. Interactions between roe deer bags, total browsing demand, total food supply and total browsing pressure in the study area.

browsing demand in each year. Blackberry (*Rubus fruticosus*) is a typical representative. When the total browsing pressure was 14%, the species-specific browsing pressure on blackberry was 17.5%. When the total browsing pressure dropped to 7%, the browsing pressure on blackberry dropped to 3.4%. At the time of the highest total browsing pressure of 19%, the browsing pressure on blackberry increased to 14.4% again. Seventeen food plant species do not follow the general trend (Table 3). Despite the larger number of species in this group, it accounts for less than half of the total browsing demand in each year. Rowan is a typical representative of this group. Regardless of the fluctuations of the total browsing pressure, species-specific browsing pressure on rowan remained on a high level during all three surveys.

Species-specific browsing pressure on oak species, which are economically important, was not significantly reduced in the period of low total browsing pressure. The respective indices for 1989 are higher than the indices for 1987. The reduction of total browsing pressure via reduction of the browser population was obviously not the appropriate management measure to reduce browsing pressure on oaks. On the other hand, species-specific browsing pressure on birch dropped in accordance with total browsing pressure. The question for systematic forest management is : What are the factors determining these species-specific digressions from the general trend? The

Table 3. Comparison of the surveys in 1987, 1989, and 1991: Browsing demand, food supply and browsing pressure in the whole study area.

	Browsing demand (index)			Food supply (index)			Browsing pressure (%)		
Species	1987	1989	1991	1987	1989	1991	1987	1989	1991
+*Athyrium filix femina*	0	0.003	0.63	21.9	4.9	6.1	0	0.06	10.4
**Betula pendula*	1.5	0.5	3.1	45.1	49.3	47.0	3.3	1.1	6.5
**Carpinus betulus*	4.4	8.3	23.6	15.6	39.0	35.6	28.2	21.3	66.4
+*Convallaria majalis*	0	0.3	0.15	17.2	6.8	3.0	0	0.9	5.0
+*Dryopteris filix mas*	1.7	0.5	0.13	11.8	42.4	7.7	14.4	1.3	1.6
+*Epilobium angustifolium*	19.5	6.7	24.6	82.1	26.2	38.4	23.5	25.5	64.2
+*Epilobium montanum*	0.001	1.0	0.04	10.8	7.5	1.5	0.04	12.7	2.6
**Fagus sylvatica*	9.7	12.5	6.1	112.2	190.6	83.5	8.6	6.6	7.3
**Frangula alnus*	4.4	2.6	4.4	12.5	17.2	12.3	35.2	15.3	35.6
**Galeopsis tetrahit*	0.3	0.02	4.0	16.3	1.6	10.1	2.0	1.5	40.0
+*Galium odoratum*	0	0.08	0	0.6	4.1	10.2	0	1.9	0
+*Hieracium sylvaticum*	8.8	0.08	0.04	17.6	0.5	0.63	50.0	16.0	6.3
+*Hypericum perforatum*	0.02	0	0	0.2	1.1	6.3	10.0	0	0
**Lonicera periclymenum*	0.4	0	0.15	18.8	5.5	3.5	2.0	0	4.1
**Melampyrum pratense*	12.8	1.4	2.6	26.6	15.5	10.6	48.2	9.1	24.7
**Mycelis muralis*	1.4	0.08	0.06	6.3	2.4	0.65	22.6	3.5	9.23
+*Picea abies*	0	0.3	1.4	72.9	57.1	66.9	0	0.6	2.1
**Populaus tremula*	0.8	0.3	2.0	5.7	11.9	12.1	14	2.5	16.6
+*Quercus petrea*	1.7	2.2	11.1	44.7	19.4	28.3	3.9	11.4	39.1
+*Quercus robur*	1.0	2.6	4.3	8.8	12.7	26.9	11.4	20.7	16.0
**Rubus fruticosus*	25.2	4.1	16.1	143.7	123.0	111.6	17.5	3.4	14.4
**Rubus idaeus*	39.8	11.6	14.5	242.4	338.0	105.9	16.4	3.4	13.7
+*Sambucus nigra*	0.01	0.8	0.1	0.2	5.8	1.2	4.0	13.0	8.33
+*Sambucus racemosa*	0.1	3.3	1.1	1.5	8.0	2.6	7.6	41.5	43.1
+*Salix aurita*	0.2	0.3	1.3	10.2	8.0	5.7	1.9	3.6	23.3
**Salix caprea*	9.5	1.3	4.6	44.5	19.2	17.2	21.4	6.6	27.0
+*Sarothamnus scoparius*	0.05	0.3	0.65	1.3	7.8	7.5	3.8	3.5	8.67
+*Sorbus aucuparius*	2.9	11.2	2.3	7.7	29.0	8.7	37.4	38.6	26.7
+*Viola spec.*	0	0.004	0	49.0	4.4	3.7	0	0.1	0
Total	146	73	129	1048	1059	675	14	7	19
*Total * (12 species)*	110	42	81	689	802	450	16	5	18
Total + (17 species)	36	31	48	359	257	225	10	12	21

* Plant species for which the trend of species-specific browsing demand and species-specific browsing pressure follows the trend of total browsing demand and total browsing pressure.
+ Plant species for which the trend of species-specific browsing demand and species-specific browsing pressure does not follow the trend of total browsing demand and total browsing pressure.
N.B. - This overview contains only those food-plant species that were present on the investigation plots during all the three surveys (29 species).

answer lies in the fluctuating availability of the food plant species, and different palatability of food plants.

Table 4 shows the 29 regular food species of roe deer, divided into four groups: Group A contains the favoured food plants. In this group, the averages of the species-specific browsing pressure lie above the average of the total browsing pressure. These plants are heavily used, even in times of low population densities. If the share of these favourite food plants in the total browsing demand is low, reduction of the selective browser population does not change the situation of these plants, as it was

Table 4. The four groups of food plants of roe deer in the study area, species-specific browsing pressure (as a measure of their palatability), and their share in the total browsing demand. (Average values for 1987, 1989, and 1991.)

		Species-specific browsing pressure in the whole study area	Share in the total browsing demand
Favourite food plants	+*Hieracium sylvaticum*	48%	2.6%
	+*Epilobium angustifolium*	35%	14.6%
	+*Sambucus racemosa*	37%	1.3%
	+*Sorbus aucuparia*	36%	4.7%
	+*Quercus petrea*	16%	4.3%
	+*Quercus robur*	16%	2.3%
	+*Sambucus nigra*	13%	0.3%
Palatable food plants with a high share in the total browsing demand	**Carpinus betulus*	40%	10.4%
	**Melampyrum sylvaticum*	32%	4.8%
	**Salix caprea*	19%	4.4%
	**Frangula alnus*	27%	3.3%
	**Galeopsis tetrahit*	15%	1.2%
	**Mycelis muralis*	16%	0.4%
Less palatable food plants with a high share in the total browsing demand	**Rubus iaeus*	10%	18.9%
	**Rubus fruticosus*	12%	13.0%
	**Fagus sylvatica*	7%	8.1%
	**Betula pendula*	2%	3.6%
	**Populus tremula*	10%	0.9%
	**Lonicera periclymenum*	2%	0.1%
Less palatable food plants with a low share in the total browsing demand	+*Dryopteris filix-mas*	4%	0.7%
	+*Picea abies*	<1%	0.5%
	+*Salix aurita*	8%	0.5%
	+*Epilobium montanum*	5%	0.3%
	+*Sarothamnus scoparius*	6%	0.3%
	+*Athyrium filix-femina*	2%	0.2%
	+*Convallaria majalis*	2%	0.1%
	+*Galium odoratum*	<1%	<0.1%
	+*Hypericum perforatum*	<1%	<0.1%
	+*Viola* spp.	<1%	<0.1%

(Comp. Table 3)

the case in our study area. Group B contains palatable food plants of roe deer (species-specific browsing pressure above average), which have a relatively high share in the total browsing demand. The supply of these plant species and their share in the total browsing demand are relatively high. In times of low population density, roe deer cannot use the high species-specific food supply to the same degree as in times of high population density. In the case of a reduction of the browser population, species-specific browsing pressure on Group B species drops. Group C contains less palatable food plants of roe deer (species-specific browsing pressure below average), that nevertheless have a relatively high share in the total browsing demand. As long as the total browsing demand is high, browsing pressure on these species is high as well. Group C species are the "bread and butter plants" of the roe deer. However, as soon as the total browsing demand is reduced, roe deer rely on the more palatable

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