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RECOVERED SUITABILITY OF DEER HABITAT IN HEMIBOREAL WOODLAND 23 YEARS AFTER VAST FOREST FIRE IN SLĪTERE NATIONAL PARK, LATVIA

Jānis Ozoliņš, Mārtiņš Lūkins, Samantha Jane Howlett, Aivars Ornicāns, Arvīds Priedītis, Āris Jansons

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A survey for the densities of moose (*Alces alces* L.), red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* L.) winter pellets along line transects was done in Slītere National Park, north-western Latvia. Aim of our study was to compare distribution and intra-specific proportions of the three deer species between intact woodland and an area that was severely burned 23 years ago. Despite a long time since fire impact, we found that both moose and red deer stayed mainly along edges between burned and intact zones however moose still preferred burned areas. Results are evaluated in comparison with changes in deer abundance at both the country and local management district level. Roe deer have almost vanished from the studied territory. An explanation for the local deviation from species proportion at larger scale may be a general increase in abundance of red deer that due to support by hunting policy recovered much faster and occupied both fire touched and intact territories while moose more specialized in foraging on fire affected vegetation and maintain a limited distribution across study area and country wide.

Key words: moose, red deer, roe deer, forest fire, deer abundance.

Jānis Ozoliņš, Mārtiņš Lūkins, Samantha Jane Howlett, Aivars Ornicāns, Arvīds Priedītis, Āris Jansons. Latvian State Forest Research Institute "Silava", Rigas str. 111, Salaspils, Latvia: e-mail: janis.ozolins@silava.lv

INTRODUCTION

Impact by various deer species on woodland vegetation and tree damage is a widely studied issue in forestry (Gill 1992, Reimoser & Gossow 1996). In natural forest ecosystems, herbivore – plant interactions are affected by both abiotic conditions, and inter and intra-specific interactions including competition and predation (Kuijper 2011). Forest fires are the most crucial abiotic drivers, causing sudden and lasting alterations to ecosystems. Describing the impact of fires on the fauna of boreal forests, moose and deer are mentioned as fire-dependent species, reliant on the plant communities that persist following frequent fires (Secretariat of CBD 2001). However, actual species interaction in a community, e.g. competition, is hardly detectable if it is manipulated by management to increase the density of a favoured species (Fryxell et al. 2014). Our case study from Latvia contributes to understanding of processes that occur in the decades following a large scale fire in a hemiboreal forest that has had little affect by commercial use but still feels the effects from the management of large game in the surrounding area. We hypothesized that total density of ungulate populations might follow the changes in species abundance at a larger scale while changes in deer species composition could be different due to specific environmental conditions in the fire affected area. We also anticipated that fire-altered habitats, especially considering their subsequent natural course of transformation, play an important role in forming site-attractiveness for animals to prefer long-term stay, foraging and rest. We analysed the correlation between presence and amount of encountered winter pellets, and general characteristics of forest habitats in nearest proximity to test this hypothesis.

MATERIAL AND METHODS

The study area is located in the north-western of Latvia within the territory of Slītere National Park. The protection of ecosystems dates back to 1923. By 1977, the total area of practically strictly protected ecosystems reached ca.15 000ha. Considering the study area also has a spatial overlap with the former border land of USSR, a major part of the forest and non-forest ecosystems has escaped commercial use for more than 50 years. The present woodlands cover a unique land surface of the ancient sea coast formed from numerous parallel sandy dunes dissected by wet depressions. The central part (ca. 1880ha) of study area is occupied by continuous open raised bog without forest cover. On 8th to 11th July in 1992, a sudden forest fire swept over the area severely damaging more than 3000 ha of woodland and raised bogs ecosystem complex.

Three deer species - moose *Alces alces*, red deer *Cervus elaphus* and roe deer *Capreolus capreolus* - inhabit the study area. Moose and roe deer are indigenous while red deer recolonized the territory only in the 1970s as a consequence of reintroductions in western Latvia (Skriba 2011). The dynamics of deer numbers and their mutual proportions among species are assessed at three levels – entire country, local forest management unit (Skriba 2011, Ziediņš 1985, Avotiņš 1980) and Slītere NP specifically if available. We also refer to unpublished results of winter pellet count surveys in 2001 from the fire affected area (Ā. Jansons, per. com.).

A survey for deer abundance and preference of habitat use was performed in April 2015. The area was crossed by 10 west-east directed parallel line transects at an average distance of 890m from each other. We used the deer winter pellet counts along transects for the index of abundance as suggested and approbated by numerous researchers (e.g. Briedermann 1982, Tottewitz et al. 1995, Sutherland 2000, Marques 2001).

We used the basic Arcpad application installed on Ashtech 10 GPS receiver. Pellet groups were counted within a 1 m wide distance on both sides of the route thus forming a 2 m wide survey belt. Positioning of transects were registered by the track-log function. The data of encountered pellet groups was collected by 5m horizontal accuracy regarding the direction of route.

We assumed that a 10ha area around the deer pellet group location may be an appropriate reference territory to describe animal preferences regarding foraging or resting. In other words, the more winter pellets in a certain spot, the more attractive and supportive the surrounding locality of 10ha. This assumption also facilitates further calculations because the figure 10 is an easily interpretable value in terms of smaller constituents, e.g. percentages. We chose a regular hexagon mesh to reduce sampling bias from edge effects that could potentially result from a rectangular grid shape, which is related to high perimeter-area ratio. Hexagons are the closest shape to a circle that have a low perimeter-area ratio and can still form a continuous grid. The regular hexagons were created by using the tessellation tool in ArcGis 10.1 software. The 10 ha size of hexagon was set from the hexagons side length of 195 meters as an input to tessellation tool.

Table 1. Abundance index of deer species is expressed from 1 to 4 depending on pellet density ha^{-1} summarised at hexagon level

Species	Density of pellet groups ha^{-1}	Assigned index
Moose *Alces alces*	10 <= 20	1
	20 <= 30	2
	>30	3
Red deer *Cervus elaphus*	5 <= 15	1
	15 <= 30	2
	30 <= 100	3
	>100	4

Our data were summarized within the hexagon area adding a unique hexagon number to the resulting table. Habitat characteristics were taken from the State Forest Register (SFR) database. In total we used the following variables: length of line route within the hexagon, number of counted pellet groups of the three considered deer species, area of wood land, area of non-forest areas i.e. predominately bogs, formerly burned area, forest site type/types within hexagon (17 present forest types according to SFR were considered), area of forest stands according to dominant tree species, and age class of the dominant trees (1 – 21 with range of 10 y per class).

Data were grouped according to selected categories of variables. Significance of difference between groups was examined by Mann-Whitney U test. Interaction between variables of different categories was tested by Spearman rank order correlation.

We also used Chi squared test to check the reliability of habitat characteristics summarised at the hexagon level in respect to the transect line location within the hexagon. The two hexagon groups were compared for representativeness – those divided by the transect line into more or less equal parts (difference in area ≤50%) and those divided into two apparently different (>50%) parts. The test did not show any significant difference between numbers of both groups thus we decided to not consider the variety of transect line locations within hexagons in our further analyses.

RESULTS

The total length of line transects was 90,9km divided into 45,3km crossing the burned area and 45,6km crossing unburned territory. Deer pellet groups were counted in 9,054 and 9,133 ha large areas accordingly.

While red deer pellets were equally spread within burnt and unburnt territory (158 and 186 respectively, U-test, P=0,089), moose pellet groups strongly dominated in the burnt area (64 vs. 9, U-test, P=0,027). Roe deer dung was found exclusively in the burnt area, however there was no statistically significant difference in roe deer distribution between both locations (U-test, P=0,696) due to its very scarce pellet occurrence (n=5). Although in total moose pellet groups were found 4,7 times less than red deer pellet groups (U test, P<0,001), there was a significant correlation between numbers of moose and red deer pellet groups inside the burnt area (see Table 3). Evidence of moose in the unburnt area correlated positively with birch *Betula spp.* dominated stands but negatively with stands dominated by Scots pine *Pinus sylvestris*. Red deer does not correlate with any tree species. Both moose and red deer significantly avoid non-forest lands. Age of forest stands displayed a minor impact on the distribution of pellet groups. Only red deer pellets correlated significantly with the presence of 91-100 and 171-180 years old trees in the burnt area (Table 4). There is also not much impact from the forest site types and it more likely relates to the least productive sites (Table 3).

Table 2. Dynamics in the ratios among the three deer species in the whole of Latvia, north-west locality of the country and Slītere NP

Species and its abundance (numbers/relative bulk[1] for red and roe deer)	1975	1982	1990	1997	2001	2007	2015
Moose							
country	19955	11033	12260	6974	11877	14413	21000
local management district	559	473	86	318	443	1511	-
Slītere NP	-	78	76	-	9,29[2]	-	4,01[3]
Red deer							
country	7894 0,4[1]	11262 1,02[1]	23180 1,9[1]	20462 2,9[1]	22595 1,9[1]	32393 2,2[1]	53000 2,5[1]
local management district	271 0,5[1]	1439 3,0[1]	190 2,2[1]	1154 3,6[1]	2179 4,9[1]	11755 7,8[1]	-
Slītere NP	12 -	47 0,6[1]	71 0,9[1]	-	3,3[2] 0,4[1]	-	18,9[3] 4,7[1]
Roe deer							
country	65516 3,3[1]	29526 2,7[1]	77015 6,3[1]	38419 5,5[1]	68183 5,7[1]	192566 13,4[1]	133000 6,3[1]
local management district	1630 2,9[1]	2987 6,3[1]	225 2,8[1]	856 2,7[1]	2623 5,9[1]	20445 13,5[1]	-
Slītere NP	-	68 0,9[1]	91 1,2[1]	-	0,95[2] 0,1[1]	-	0,3[3] 0,07[1]

[1] numbers are divided by the corresponding numbers of moose;
[2] index of the counted pellet groups per 1ha of burnt and naturally recovering wood land;
[3] index of the counted pellet groups per 1ha in all study area

Table 3.Woodland structure along the line transects applied for the deer winter pellet survey

Forest characteristics	Burnt area (ha)	Unburnt area (ha)	Significance of difference
Forests on nutrient poor soils or oligotrophic forests			
Sl - *Cladinoso-callunosa*	276,4	215,5	P<0,001
Mr- *Vacciniosa*	57,3	318,2	P<0,001
Gs- *Callunoso-sphagnosa*	2,1	0	n.s.
Mrs- *Vaccinioso-sphagnosa*	44,3	38,5	n.s.
Pv- *Sphagnosa*	56,1	30,3	P=0,006
Forests on medium rich soils or mesotrophic forests			
Ln- *Myrtillosa*	2,6	55,4	P=0,001
Dm- *Hylocomiosa*	0,9	18,3	n.s.
Dms- *Myrtilloso-sphagnosa*	18,9	80,1	P=0,004
Nd- *Caricoso-phragmitosa*	160,3	130,0	n.s.

Forest characteristics	Burnt area (ha)	Unburnt area (ha)	Significance of difference
Db- *Dryopterioso-caricosa*	15,2	17,1	n.s.
As- *Myrtillosa mel.*	0	0,007	n.s.
Forests on nutrient rich soils or eutrophic forests			
Vr- *Oxalidosa*	0	1,5	n.s.
Lk- *Filipendulosa*	0	2,8	n.s.
Ap- *Mercurialosa mel.*	0	12,1	n.s.
Ks- *Myrtillosa turf. mel*	13,0	23,5	n.s.
Kp- *Oxalidosa turf. mel.*	0	5,3	n.s.
Vrs- *Myrtillosoi-polytrichosa*	44,3	35,5	n.s.
Non-forested land	800,2	146,3	P<0,001
Stands according to dominant tree species			
Pine	304,6	793,8	P<0,001
Spruce	2,7	21,5	n.s.
Birch	23,0	148,6	P=0,005
Black alder	11,8	29,2	n.s.
Age class (years)			
11- 40	18,9	13,4	n.s.
41-100	169,5	504,8	P<0,01
101-140	75,9	169,2	n.s.
141-180	57,4	267,4	P<0,04
181-210	20,3	38,7	n.s.

Comment: Forest types after: [http://biodiv.lvgma.gov.lv/cooperation/mezi/fol72051]

Table 4.Revealed significant relationships between deer pellet numbers and surrounded forest habitats

Compared variables	Burnt area[1]	Unburnt area[2]	Forest area in total[3]	r	P
Moose pellet numbers vs. red deer pellet numbers	+	n.s.	+	0,341[1] 0,198[3]	<0,001[1,3]
Moose pellet numbers vs. dominance of pine	n.s.	+	n.r.	-0,202[2]	0,016[2]
Moose pellets vs. red deer pellets in woodlands dominated by pine	n.s.	n.s.	+	0,207[3]	0,002[3]
Moose pellet numbers vs. dominance of birch	n.s.	+	n.r.	0,235[2]	0,005[2]
Red deer pellet numbers vs. 91-100y old tree dominance	+	n.s.	n.r.	0,167[1]	0,04[1]

Compared variables	Burnt area[1]	Unburnt area[2]	Forest area in total[3]	r	P
Red deer pellet numbers vs. 171-180y old tree dominance	+	n.s.	n.r.	0,219[1]	0,006[1]
Moose pellet numbers vs. deforested burned area	+	n.s.	n.r.	-0,229[1]	0.005[1]
Red deer pellet numbers vs. deforested burned area	+	n.s.	n.r.	-0,364[1]	0,0001[1]
Moose pellet numbers vs. *Sphagnosa*	+	n.s.	n.r.	0,211[1]	0,009[1]
Red deer pellet numbers vs. *Cladinoso-callunosa*	+	n.s.	n.r.	0.260[1]	0.001[1]
Red deer pellet numbers vs. *Sphagnosa*	+	n.s.	n.r.	0,161[1]	0,048[1]
Moose pellet numbers vs. *Vacciniosa*	n.s.	+	n.r.	-0.199[2]	0,017[2]

n.r. – analyse is not relevant because of the significant difference in tree dominance or forest site type between burned and unburned area (see Table 3).

The prevalence of red deer abundance over moose started in the 1980s and it is more pronounced in the north-west of Latvia at the level of entire forest and game management district rather than in Slītere NP (Table 2). Roe deer, however, have shown an explicit decrease in Slītere NP compared to both the country level and surrounded management district, particularly in our study area after the forest fire.

DISCUSSION

Our study was not designed to reveal any change to forest composition caused by fire, however from available forest site type and tree species and it respective age maps, we could follow how the fire has spread over area reaching its limits. Results demonstrate that the difference in forest characteristics between burnt and unburnt territory declines with the increase of site productivity meaning that the more productive the site, the less difference between areas with and without fire impact. It might indicate that more productive woodland was more susceptible to burning regardless of tree species or age while the fire ran more selectively across poor sites and non-forested bog area. On the other hand, forest stands of high productivity were much scarcer in our study area therefore the hexagons occurring within forest on rich soils may not provide enough representative material for comparison. Similarity in occurrence and the quantitative distribution of moose and red deer pellets inside the fire affected area indicates that both species may thrive due to the vegetation changes to the considered habitats created by the fire. It likely contradicts with our results that only moose prefer burnt areas in comparison to the fire intact zones while red deer is equally present in both types of habitat. However, underrepresented high productive forest stands would not be able to hold as many signs of moose occurrence as poor forest stands. Thus moose unlikely avoid rich forest types yet prefer fire touched patches regardless of productivity.

The area of pine and birch stands is significantly larger outside the burnt area. The age of forest stands seems relevant, too. Medium old and old forest stands were significantly less affected by the fire; however these stands also dominated in the age structure of the surveyed forest. Young forest (up to 40 years) within the burnt area is present at the same amount as outside, probably meaning that the fire moved through young tree stands more randomly. In total, the woodland was less represented inside the fire impacted area than non-forested lands. If so, we can assume that both the presence of oligotrophic site types and ecotones i.e. wet marshes located between woodland and raised bogs had reduced the fire to spread over even more larger areas. In the burnt area, we can establish more significant interactions between the characteristics of forest site type or age and pellet densities. After the fire, burnt areas were subject to continuous seral stages (Peter 2001), therefore moose prefer these habitats to fire intact areas. In the unburnt area, moose avoided tree stands dominated by pine and *Vacciniosa* forest type most likely due to a lack of forage in ground cover. In terms of tree cover, both moose and deer avoided open places inside unburnt area. At the same time, we should take into consideration that deer pellet numbers and their local densities do not necessarily reflect actual abundance of animals and their preference to habitats (Gibbs 2000). In our study area for instance, deer pellets in theory might be scarcer in open areas due to their faster decomposition by rain and wind etc. Decomposition by weather factors could impact our results, because deforested wetlands were more available just in burned area (Table 2) while the moose pellets prevailed in previously burned territory. Our division into burnt versus unburnt areas is quite speculative as moose pellets mainly occur on edges between burnt and intact areas (Fig. 1). It could be possible that moose just prefer to feed or reside on the most suitable habitats which coincide with the edges of fire impacted areas.

Recolonization of the burnt forest was undertaken in different ways by each of the three deer species. Moose abundance at the country level increased while at the local management district level a decline was recorded prior to the forest fire in 1990. In Slītere NP, a decrease of moose numbers was even more explicit. Red deer abundance grew at all spatial scales as seen from both population estimates and its relative bulk in the deer community. Roe deer passed a dramatic decline just in our study area while at the country level and within local management district its numbers were growing. In one of the

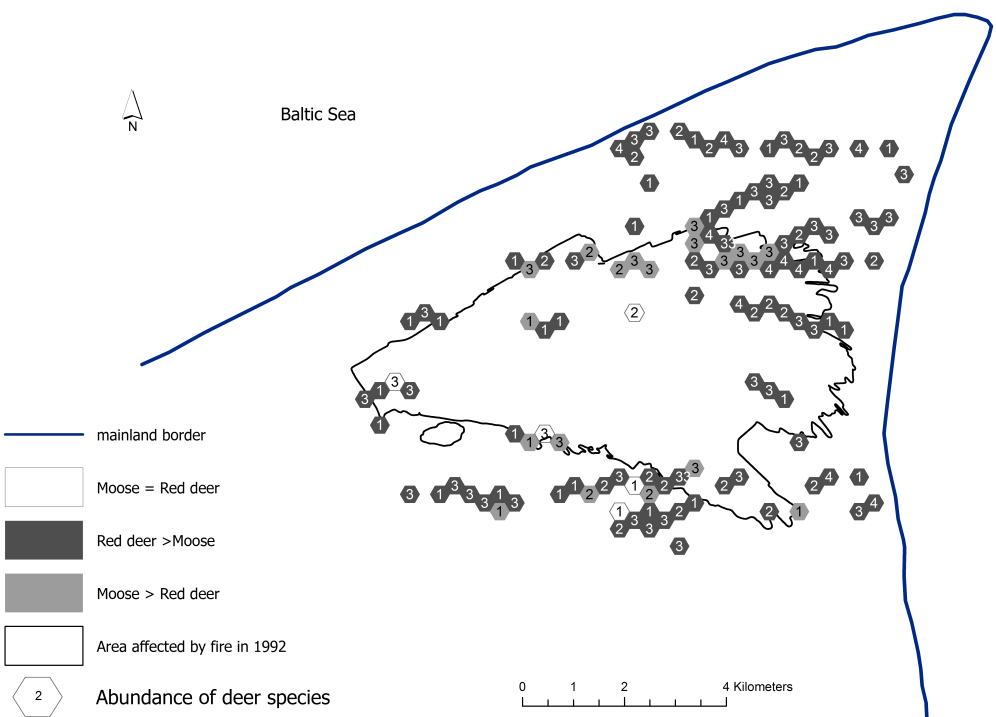

Fig.1. Location of pellet group counts and habitat characteristics summarized at a hexagon level (10ha) regarding the borders of fire-affected area.

largest burned areas for Europe (Poland), it was also established that red deer benefits from after-fire changes of habitat considerably more than roe deer (Borkowski 2004).

In summary, the hypothesis was approved that large scale changes, namely a targeted supplementing of red deer population by hunting policy and practise, may suppress the local impact of forest fire on habitat use by the deer community. We propose to use the concept of driving forces (Bürgi *et al.* 20014) as a helpful tool to explain the complex pattern of changes of abundance and mutual proportion of the two most spread deer species – moose and red deer over last 20 years at 3 spatial scales i.e. local area, region and whole country. We have identified 3 mutually interconnected driving forces. Firstly, the evolving hunting policy and hunting-lobby activities enhancing the efforts to sustain large numbers of red deer that have caused the changes to the relative proportions of two above mentioned deer species. Secondly, the legal protection status of the area since the early 1980s has diminished any extensive land-use practices, especially forestry logging and game hunting. Thus, the legal status has provided a unique circumstance of permanent low level human induced disturbances which likely does not occur anywhere else in Latvia outside of Slītere NP. Thirdly, the large scale fire in 1992 which tremendously changed the whole landscape, especially the composition and structure of vegetation, has altered the way that moose and red deer exploit food and other resources necessary for survival.

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