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Decade-long dynamics of the ground vegetation in an ecotone between coniferous forest and clear-cut site †

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Abstract: When the forest is clear-cut, there forms an ecotone complex (EC) made up of the forest, transition from forest to clear-cut under tree stand canopy and beyond the canopy, and the clear-cut per se. Our surveys were carried out in North Russian boreal forests (64.4° N, 41.8° E). We studied how the abundance of vascular plants in the forest – clear-cutting EC changed during the first ten years after logging.

The abundance of *Vaccinium myrtillus* and *V. vitis-idaea* declined immediately after tree stand removal both in the open clear-cut and in the EC transitional zones. The projective cover of bilberry declined gradually from the forest towards the clear-cut. The abundance of cowberry in the transitional zones was growing throughout the period of observations. As the tree layer was regenerating in the clear-cut, the abundance of the dwarf shrubs was also recovering.

The average projective cover of *Deschampsia flexuosa* remained stable in the forest part of the EC and it the transitional zones, not exceeding 2%. In the clear-cut, its abundance grew slightly already in the second year after tree stand removal and reached a maximum in 5-year-old clear-cuts. By the time of canopy closure 10 years after logging, its abundance declined notably.

Epilobium angustifolium in the forest part was very rare, its contribution to the ground cover not exceeding 1%. Its abundance in the forest edge impact area was also extremely low. Fireweed abundance in the clear-cut reached its maximum 3–5 years after logging and declined in 10-year-old clear-cuts.

Keywords: forest ecology, boreal forest, reforestation, dynamics, edge effect, bilberry, cowberry, hair-grass, fireweed

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1. Introduction

Boreal forests of European Russia today are a mosaic of plant communities in different stages of post-logging regeneration. Importantly, logging not only fundamentally transforms the actual site from which trees have been removed, but also alters the adjacent forest community. When the forest is clear-cut, there forms an ecotone complex (EC) made up of the forest, transition from forest to clear-cut site under and outside of canopy cover, and the clear-cut site per se. The changes taking place in the area transitional from forest to clear-cut site are interesting from both the theoretical and the practical perspectives. Transitional zones are where both large and small herbivorous animals concentrate [1,2]; the stock of useful ground vegetation species may be higher there [3,4]. The aim of our study was to investigate how the abundance of major ground vegetation dominants in the forest to clear-cutting EC evolved over 10 years after tree stand removal.

2. Materials and Methods

The surveys were carried out in the Arkhangelsk Region, Russia (64.4° N, 41.8° E) in 2014–2017. The territory belongs to the boreal biome. Mean annual air temperature (averaged over the past 10 years) in the study area was +2.8°C, mean annual precipitation was 660 mm. The coldest month is January (–11.7°C), the warmest month is July (+17.2°C). Snow-covered period lasts from early November through April, the duration of the growing season is around 150 days – from mid-May through September [5]. The most common forest type in the study area is bilberry spruce forest, and there also occur small areas of Sphagnum-type pine forest and haircap-moss spruce forest. Much of the spruce forest area has been cut over and secondary mixed forest areas dominated by aspen and birch are all around.

Fieldwork was done in adjacent bilberry forest and wavy hair-grass dominated clear-cut (2 to 10 years old) communities constituting an EC (Figure 1). Based on our previous studies [6,7] we assume the transitional zone to be 8 m wide on each side of the forest/clear-cut site interface. The ground vegetation was studied in 50 m long transects running from inside the forest into the clear-cut site (25 m into each community). The transects were broken down into sampling subplots (50x50 sq cm each), in which the percentage cover of species in the moss-lichen and the herb-dwarf-shrub layers as well as the average height of bilberry and cowberry shoots were estimated. Ground vegetation descriptions were produced in the same transects in the 2nd, 3rd, 4th, and 5th years after clear-cutting in one of the sampling sites, and 5 and 10 years after clear-cutting in the other sampling site.

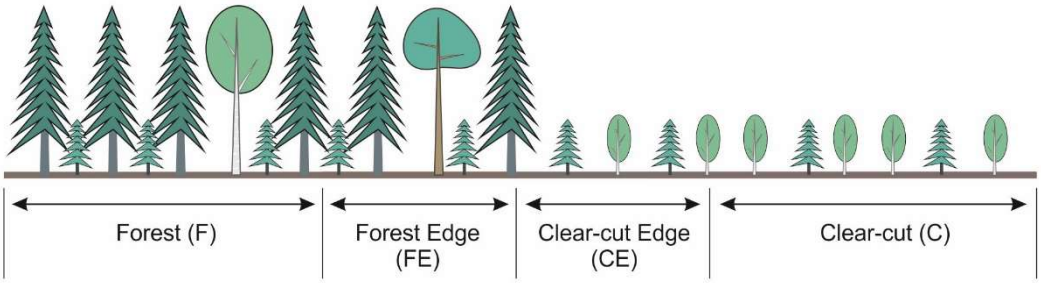

Figure 1. Arrangement of ecotone zones and their notations. See text for explanations

The effect of the clear-cutting age on the percentage cover of major ground vegetation dominants (*Vaccinium myrtillus* L., *V. vitis-idaea* L.; *Deschampsia flexuosa* (L.) Trin., *Epilobium angustifolium* L.) in different EC zones was studied by one-way ANOVA (Kruskal-Wallis test).

3. Results and discussion

Vaccinium myrtillus and *V. vitis-idaea* are the main subshrub species in north-boreal spruce forests. Bilberry and cowberry are the ground vegetation dominants in the surveyed bilberry-type spruce stands, with their average percentage covers at 20–25% and 10–20%, respectively. In the first years after tree stand removal, bilberry abundance in the clear-cut site declined and the average height of the subshrubs became lower than in the original forest community (Table 1). As the logging operations were performed in winter, mechanical damage could not be the decisive factor, but plots in the clear-cut site littered with logging debris either lacked or showed a sharp decline in the contribution of subshrubs. Another cause of subshrub abundance reduction is competition with typical clear-cut site dominants – boreal grasses [8,9]. A reduction in bilberry percentage cover, current-year increment, and number of shoots in cutover boreal forest sites has been reported by other researchers too [9-11]. As the overstory canopy formed in the clear-cut site, the percentage cover and height of bilberry shoots increased, but even 10 years after clear-cutting

these parameters remained significantly lower than in the forest community adjoining the clear-cut site (Table 1).

Table 1. Mean percentage covers and shoot heights of forest subshrubs in the ecotone complex 2, 5, and 10 years after clear-cutting.

Ecotone complex zone	Years since clear-cutting					
	2	5	10	2	5	10
Bilberry percentage cover:				Cowberry percentage cover:		
Forest	17.9±1.1^{a} (100%)	23.2±1.4^{a} (100%)	21.9±1.5^{a} (100%)	14.7±0.8^{a} (100%)	27.0±1.4^{a} (100%)	21.4±1.2^{a} (100%)
Forest edge	12.5±1.2^{b} (70%)	17.1±1.6^{b} (74%)	16.6±1.7^{b} (76%)	16.8±1.1^{a} (114%)	31.7±2.0^{ab} (117%)	24.7±1.9^{a} (116%)
Clear-cut edge	5.7±0.7^{c} (32%)	8.3±1.0^{c} (36%)	14.1±1.4^{b} (65%)	14.5±1.2^{a} (99%)	34.2±2.6^{b} (127%)	14.3±1.3^{b} (67%)
Clear-cut	2.5±0.3^{d} (14%)	5.2±0.6^{c} (22%)	6.5±0.8^{c} (30%)	8.5±0.8^{b} (58%)	26.6±1.6^{a} (99%)	12.7±1.1^{b} (59%)
Bilberry shoot height:				Cowberry shoot height:		
Forest	–*	14.8±0.3^{a} (100%)	16.3±0.4^{a} (100%)	–*	12.4±0.3^{a} (100%)	15.7±0.3^{a} (100%)
Forest edge	–	12.1±0.4^{b} (82%)	13.4±0.4^{b} (82%)	–	10.5±0.4^{b} (85%)	12.1±0.4^{b} (77%)
Clear-cut edge	–	10.0±0.4^{c} (68%)	11.6±0.5^{c} (71%)	–	8.5±0.4^{c} (68%)	9.3±0.3^{c} (59%)
Clear-cut	–	8.7±0.3^{d} (59%)	11.3±0.4^{c} (69%)	–	8.4±0.3^{c} (68%)	10.4±0.3^{c} (66%)

Indicating mean and error of the mean; percentages in parenthesis are the levels relative to the forest zone. Letter indexes refer to significant differences ($p < 0.05$) in the parameter among EC zones (one-way Anova). * No data available.

Similar data were obtained for cowberry. However, as cowberry is ecologically a heliophyte [12] and physiologically better adapted than bilberry to relatively high insolation, its recovery was faster than in bilberry. The sharply negative reaction of bilberry and the moderately positive reaction of cowberry to felling in coniferous forests is confirmed by the work of other researchers [8; 9].

Where the abundance and height of bilberry and cowberry in the clear-cut zone were always notably lower than in the forest, the situation in transitional zones was not so unequivocal. Thus, cowberry shoots in the FE zone were lower than in the F zone, which can be interpreted as adaptive response to higher insolation considering that the subshrub at the same time featured a high percentage cover (Table 1). The reduction in shoot height from forest towards clear-cut site in bilberry was accompanied by a decline in the percentage cover while the height reduction in cowberry happened simultaneously with an increase in the percentage cover.

The average percentage cover of wavy hair-grass, *Deschampsia flexuosa*, in all sampling sites remained stable in the F zone of the EC, not exceeding 2%, while its frequency of occurrence was quite high (30–70%). The abundance of *D. flexuosa* and other grasses in the transitional zone was low. In the clear-cut site, hair-grass abundance grew slightly

already in the second year after tree stand removal. The percentage cover of the species reached a maximum in 5-year-old clear-cut sites (Figure 2).

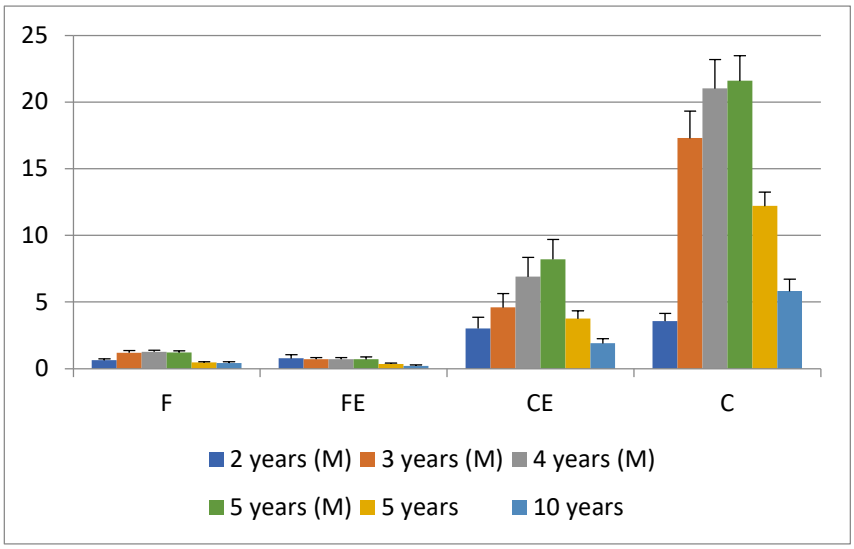

Figure 2. Changes in the average percentage cover of *Deschampsia flexuosa* in ecotone complex zones (F – forest, FE – forest edge, CE – clear-cut edge, C – clear-cut) during the study period (M – revisited monitoring sites (2nd to 5th post-clear-cutting years)). Means values and standard errors are shown.

By the time of canopy closure 10 years after logging, its abundance declined notably. This pattern of change in the populations of grasses, namely *D. flexuosa*, in the community developing after spruce forest logging conforms to data found in the literature [13–15]. And in general, an increase in the number and proportion of grasses after logging is a characteristic feature of the regenerative succession of spruce forests [8; 16].

Fireweed, *Epilobium angustifolium*, in the F zone was rather rare, with the percentage cover not exceeding 1%. Its abundance and occurrence in the transitional zone (FE and CE) were also very low (Figure 3).

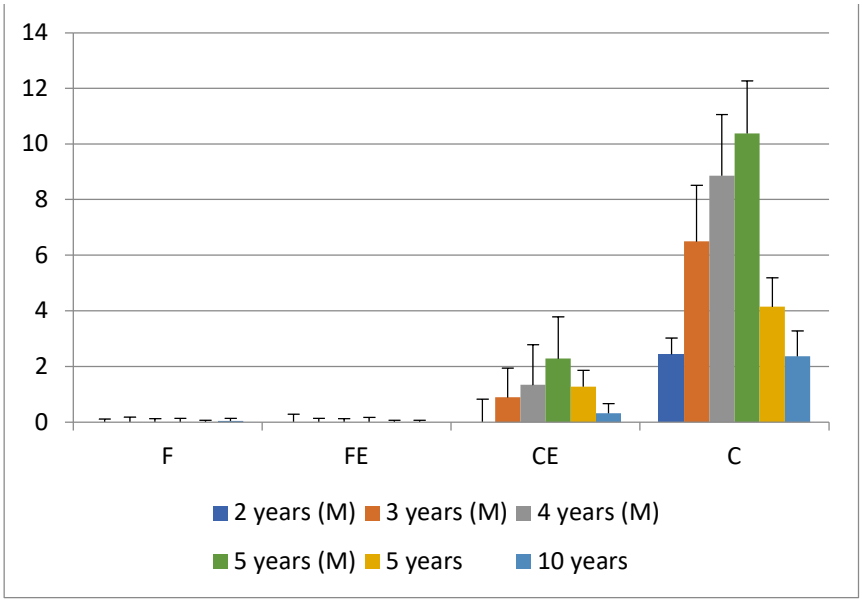

Figure 3. Changes in the average percentage cover of *Epilobium angustifolium* in ecotone complex zones (F – forest, FE – forest edge, CE – clear-cut edge, C – clear-cut) during the study period (M – revisited monitoring sites (2nd to 5th post-clear-cutting years)). Means values and standard errors are shown.

The occurrence and percentage cover of fireweed were notably higher in the clear-cut site than in other EC zones. This feature of this forest species to populate disturbed areas has been noted in other studies of boreal forests [17; 18]. The abundance of this species peaked 3-5 years after clear-cutting, while its percentage cover in 10-year-old clear-cut sites declined. This finding is in full agreement with published data on clear-cut sites in the study area [13].

4. Conclusions

Our studies have revealed patterns related to time since clear-cutting in the abundance dynamics of major ground vegetation dominants in bilberry-type spruce forest sites across the ecotone between forest and clear-cut site. In the first post-logging years, the FE, CE, and C zones showed a consecutive decline in bilberry abundance and a reduction in the subshrub's average height compared to the forest. As the overstory was forming in the cutover site, bilberry abundance started recovering but remained below the level inside the forest even ten years after clear-cutting. Cowberry, on the other hand, featured a higher abundance in the FE zone versus the F zone throughout the study period. The highest percentage covers compared to the F zone were found in CE and C in the 5th year after clear-cutting.

The percentage covers of wavy hair-grass and fireweed under canopy cover (F and FE) have remained very low (1–2%) throughout the period of observations. The percentage covers of these species in the transitional zone on the clear-cut side (CE) have increased but were still several times lower than in the clear-cut site (C).

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Conflicts of Interest: The authors declare no conflict of interest.

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