



# Proceeding Paper Decade-Long Dynamics of the Ground Vegetation in an Ecotone between Coniferous Forest and Clear-Cut Site <sup>+</sup>

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Abstract: When the forest is clear-cut, there forms an ecotone complex (EC) made up of the forest, the transition from the forest to the clear-cut area under the tree stand canopy and beyond the canopy, and the clear-cut area per se. Our surveys were carried out in North Russian boreal forests ( $64.4^{\circ}$  N,  $41.8^{\circ}$ 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 area and in the EC transitional zones. The projective cover of bilberry declined gradually from the forest towards the clear-cut site. The abundance of cowberry in the transitional zones grew throughout the period of observations. As the tree layer regenerated in the clear-cut area, the abundance of the dwarf shrubs also recovered. The average projective cover of Deschampsia flexuosa remained stable in the forest part of the EC and in the transitional zones, not exceeding 2%. In the clear-cut site, its abundance grew slightly in the second year after tree stand removal and reached a maximum in 5-year-old clear-cut area. By the time of canopy closure 10 years after logging, its abundance had 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 area reached its maximum 3-5 years after logging and had declined in 10-year-old clear-cuts.

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

## 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 the forest to the 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 the 10 years after tree stand removal.

## 2. Materials and Methods

The surveys were carried out in the Arkhangelsk Region, Russia ( $64.4^{\circ}$  N,  $41.8^{\circ}$  E), in 2014–2017. The territory belongs to the boreal biome. Mean annual air temperature



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). (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 conducted 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 assumed 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 ( $50 \times 50$  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 northern boreal spruce forests. Bilberry and cowberry are the ground vegetation dominants in the surveyed bilberry-type spruce stands, with their average percentage coverage 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 the 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).

Ecotone Complex Zone	Years Since Clear-Cutting					
	2	5	10	2	5	10
Bilberry percentage cover:				Cowberry percentage cover:		
Forest	$17.9 \pm 1.1$ <sup>a</sup>	$23.2\pm1.4~^{\rm a}$	$21.9\pm1.5~^{\rm a}$	$14.7\pm0.8$ $^{\rm a}$	$27.0\pm1.4$ a	$21.4\pm1.2~^{\rm a}$
	(100%)	(100%)	(100%)	(100%)	(100%)	(100%)
Forest edge	$12.5\pm1.2$ <sup>b</sup>	$17.1\pm1.6$ <sup>b</sup>	$16.6\pm1.7$ <sup>b</sup>	$16.8\pm1.1$ a	$31.7\pm2.0$ $^{\mathrm{ab}}$	$24.7\pm1.9$ <sup>a</sup>
	(70%)	(74%)	(76%)	(114%)	(117%)	(116%)
Clear-cut edge	$5.7\pm0.7$ <sup>c</sup>	$8.3\pm1.0\ ^{ m c}$	$14.1\pm1.4$ <sup>b</sup>	$14.5\pm1.2$ a	$34.2\pm2.6~^{\rm b}$	$14.3\pm1.3$ <sup>b</sup>
	(32%)	(36%)	(65%)	(99%)	(127%)	(67%)
Clear-cut	$2.5\pm0.3$ <sup>d</sup>	$5.2\pm0.6$ <sup>c</sup>	$6.5\pm0.8$ <sup>c</sup>	$8.5\pm0.8$ <sup>b</sup>	$26.6\pm1.6~^{a}$	$12.7\pm1.1$ <sup>b</sup>
	(14%)	(22%)	(30%)	(58%)	(99%)	(59%)
	Bilberry shoot height:			Cowberry shoot height:		
Forest	_ *	$14.8\pm0.3$ a	$16.3\pm0.4$ a	_ *	$12.4\pm0.3$ a	$15.7\pm0.3$ <sup>a</sup>
		(100%)	(100%)		(100%)	(100%)
Forest edge	-	$12.1\pm0.4$ <sup>b</sup>	$13.4\pm0.4$ <sup>b</sup>	-	$10.5\pm0.4$ <sup>b</sup>	$12.1\pm0.4$ <sup>b</sup>
		(82%)	(82%)		(85%)	(77%)
Clear-cut edge	-	$10.0\pm0.4~^{ m c}$	$11.6\pm0.5~^{\rm c}$	-	$8.5\pm0.4$ <sup>c</sup>	$9.3\pm0.3$ <sup>c</sup>
		(68%)	(71%)		(68%)	(59%)
Clear-cut	-	$8.7\pm0.3$ <sup>d</sup>	$11.3\pm0.4~^{ m c}$	-	$8.4\pm0.3$ c	$10.4\pm0.3~^{ m c}$
		(59%)	(69%)		(68%)	(66%)

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

Indicating mean values and standard errors; percentages in parenthesis are the levels relative to the forest zone. Letter indexes ( $^{a}$ ,  $^{b}$  etc.) refer to significant differences (p < 0.05) in the parameter among EC zones (one-way Anova), identical letters mean no differences between two zones, different letters mean that there is a difference between the two zones. \* 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 the forest towards the 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 had already begun to grow slightly 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).

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 the 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].



**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)). Mean values and standard errors are shown.

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)). Mean 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 revealed patterns related to time after clear-cutting in the abundance dynamics of major ground vegetation dominants in bilberry-type spruce forest sites across the ecotone between the 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) 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) increased but were still several times lower than in the clear-cut site (C).

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