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Research Article

Habitat Quality Assessment of Herb-rich Spruce Forests in Estonia

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Abstract

The Natura 2000 network contains many different habitats in Estonia, including old-growth forests and semi-natural woodlands. Ten years after the establishment of the Natura 2000 network in Estonia, changes have occurred in habitat type and habitat quality.

Vegetation composition as well as the structural and functional qualities of a forest habitat type – Fennoscandian herb-rich forests with Picea abies (EU Habitats Directive habitat type 9050) – are analysed in this study. The study is based on sample plots measured in 2014 and are located in protected and non-protected areas. Aegopodium, Filipendula and Oxalis vegetation types are included for assessment of vegetation, tree structure and deadwood composition. Habitat composition and dynamics on conservation sites are compared with commercial forests and possible ecosystem restoration measures are discussed in the study. The 46% of the studied habitats had considerably lowered their initial conservation value and 49% were developed towards habitat type 9010 during 2004–2014.

Keywords: Forest habitat, Forest naturalness, Vegetation assessment, NATURA 2000, Conservation objectives

1. Introduction

Herb species richness of forest ecosystems depends on the light conditions on the ground and the site fertility. Old-growth forests usually develop quite a dense canopy of trees and bushes and this limits herb species richness. The formation of a herb-rich forest ecosystem is the result of factors restricting tree and bush canopy, e.g. partially unfavourable soil conditions or water regime for trees and bushes as well as minor frequent natural or anthropogenic disturbances. Boreal herb-rich forests usually grow in specific areas with calciferous bedrock and fertile, neutral brown soil (pH 6.0–7.0) [1], [2]. Nilsson [3] showed that the grazing of animals is the main cause for the herb-rich forests being dominated by conifers. Traditional small-scale farming systems support species richness and therefore, such agricultural areas contain many different vegetation types and habitats. On former agricultural land grassland species disappear and the forest species recover quite slowly. Vera [4] showed that the presence of old trees of oak (*Quercus robur*) or hazel (*Corylus avellana*) is an indicator of former agricultural land use of a forest stand in the hemiboreal zone. The slash and burn cultivation is known to increase the soil pH and fertility in the first years [5], [6] and thus creates 'man-made' herb-rich forest sites [7]. Remmert [8] explained that the natural forest regeneration cycle includes also a stage of grassland. Forest disturbances at various scales also contribute to herb species richness in forest ecosystems. Herb-rich forest ecosystems are most likely both the remnants of old-growth forests and the legacies of agricultural land use in Estonia.

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Regular habitat quality assessment is an important tool for monitoring and evaluating conservation and management on nature conservation areas. The success of such conservation efforts is indicated by the dynamics of different habitats and species and it depends mainly on the location, size, shape, connectivity and management of these areas [9]. Natura 2000 is a network of protected areas in the European Union established under the Habitats Directive [10] and Birds Directive [11] of the European Council. The Natura 2000 network covers 18% of the total land area in the EU [12]. Forests are extremely important for the Natura 2000 network as 30% of the total forest area is designated to the Natura 2000 network in the EU [13].

Boreal herb-rich forests are included in the EU Habitats Directive, Annex I, as habitat type 9050 "Fennoscandian herb-rich forests with *Picea abies*". The habitat type 9050 is reported only in Finland, Sweden, Lithuania and Estonia among EU countries. Paal [14] describes this habitat type as occurring in *Arctostaphylos*-alvar, *Calamagrostis*-alvar, *Hepatica, Aegopodium*, *Lunaria*, *Dryopteris*, *Filipendula* and *Molinia* vegetation types in Estonia where tree canopy is mainly dominated by Norway spruce (*Picea abies*), ash *(Fraxinus excelsior),* lime (*Tilia cordata*), elm (*Ulmus glabra*), and maple (*Acer platanoides*). In fact, several protected 9050 habitats are also found in the *Oxalis* and *Oxalis-Vaccinium myrtillus* vegetation types [15]. In southern Finland, the network of protected herb-rich forests is mainly a mixture of areas that floristically complement each other rather efficiently, and areas that have some other important biological and ecological values, such as features beneficial for old-growth forest species [16].

Assessment criteria and management considerations of the habitat type 9050 are still unclear in Estonia. Distinguishing between natural and human effects that influence herb species composition in forest ecosystems is complicated because of long-term human presence. As the habitat type 9050 is mostly semi-natural in Estonia, there should be a continuation of earlier land-use to maintain the habitat in good condition. Restriction of former management practices and strict protection of the habitat may lead to a thicker tree and bush canopy and disappearance of characteristic herb species. The aim of this study is to analyse the results of habitat quality assessment of herb-rich spruce forests, to develop the criteria for the habitat type 9050 and clarify the conservation policy for this habitat type.

2. Material and methods

The total forest area in Estonia is 2.2 million ha, covering 51.1% of the country's territory [17]. Forest areas belonging to different nature conservation regimes form 25% of the total forest area [17]. Estonian forests are in the hemiboreal zone [18]. Scots pine (*Pinus sylvestris*), Norway spruce and birch species (*Betula pendula* and *Betula pubescens*) are the most common and economically important tree species. There are ten different forest habitat types in the Natura 2000 network with a total area of 203,720 ha described in Estonia. The habitat type 9050 "Fennoscandian herb-rich forests with *Picea abies*" covers an area of 11,730 ha.

The first set of study areas (total area 138 ha, 35 sample plots, referred to as N9050 plots or sites) was randomly selected in the habitat type 9050 from the Estonian Nature Information System (EELIS) in southern Estonia. These areas (Fig. 1) are located in conservation areas (77%) and commercial forests (23%). These sites were assessed by five habitat quality classes according to Palo [19]: A – very good, B – good, C – average, D – potential and 0 – unfit. The assessment was done by EELIS in 2004 and by this study team in 2014. The assessment is based on habitat representative indicators (species) and on ecosystem structure, functions and restoration possibilities. The classification of vegetation types follows Paal [20].

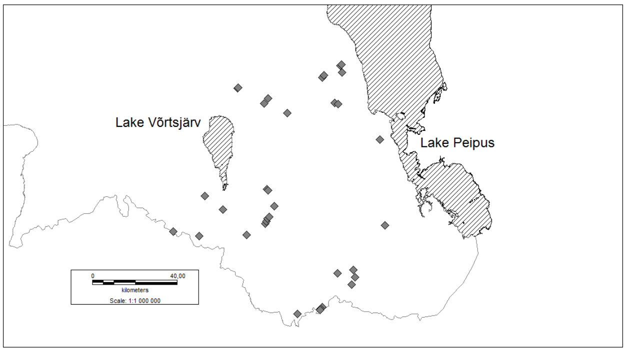

Fig. 1. Location of the study sites (n=35, N9050 sites) in the Natura 2000 habitat type "Fennoscandian herb-rich forests with *Picea abies*" in Estonia.

The second set of study areas (15 sample plots from commercial forests in *Aegopodium, Filipendula* and *Oxalis* vegetation types, referred to as ENFRP plots) were selected in accordance to suitable habitats, dominating layer tree species and forest age randomly from the Estonian Network of Forest Research Plots. The network was established in 1995–2004 [21] and the latest re-measurement data (2013–2015) was used in this study.

Vegetation and forest stand assessment was carried out on 14 N9050 plots and 15 ENFRP plots. The sample plots were circular with a radius of 20 m and selection was based on criterion that a sample plot had at least 100 trees in the upper tree-storey. On each plot the azimuth and distance from plot centre to each tree was measured along with the diameter at breast height (DBH). For every fifth tree, tree height and crown base were measured. Herbaceous species and mosses were surveyed using a step-line intercept method on N9050 plots [22]. On each plot the permanent quadrate (5x5 m) was located 3 m from the centre of the sample plot in the northern direction. Within the quadrate ground vegetation species were recorded on step-line, where after each step a 10x10 cm square was described, resulting in 100 squares in total. Ground vegetation on ENFRP plots were sampled in a subplot of 400 m^2 inside the main plot using the pin-point method developed by Kent and Coker [23]. The occurrence of herb-rich forest species on N9050 plots and ENFRP plots was compared to the list of characteristic species based on Finnish studies [24], [25].

3. Results

The assessment of N9050 sites on 35 study areas in southern Estonia (Table 1) showed that only 28 sites had conservation value as Natura 2000 habitats. In 2014, 7 sites were considered in the habitat quality class A, 13 sites in class B and 8 sites in class C. Three N9050 sites were described in 2014 as potential forest habitats and four sites as unfit sites. The reason for unfit classification was recent forest cutting on three sites (outside protected areas) and one site was wrongly mapped. Therefore only 80% of the studied sites actually had conservation value. Habitat quality class improved for 4 sites, remained the same for 15 sites and dropped for 16 sites during 2004–2014. Considering all aspects of the habitat type 9050, according to Paal [14], only 31% of the studied N9050 sites fit exactly into this habitat type, several studied N9050 sites may also be considered as the Natura 2000 habitat type 9010 "Western taiga".

Table 1. Number of studied sites of N9050 habitats by different habitat quality classes in commercial forests and protected areas according to assessments done in 2004 (official data in the EELIS) and in 2014 (our assessment). Habitat quality classes: A – very good, B – good, C – average, D – potential and 0 – unfit.

Habitat quality in 2004	Habitat quality in 2014	Commercial forest	Protected area	Total
A	A	1	6	**7**
	B	0	5	**5**
	D	0	2	**2**
B	B	0	4	**4**
	C	0	4	**4**
	D	1	0	**1**
	0	1	0	**1**
C	B	1	3	**4**
	C	2	2	**4**
	0	2	1	**3**
Total		**8**	**27**	**35**

A total of 100 vascular plant and moss species were identified on the N9050 plots (60 herb, 15 shrub and 25 moss species), and 151 vascular plant and moss species on the ENFRP plots (112 herb, 17 shrub and 22 moss species). The Shannon index (H) and number of species was the highest in *Filipendula* vegetation type. The comparison between N9050 and ENFRP plots by vegetation types showed, in fact, that ENFRP plots usually had more species and a higher Shannon index than N9050 plots (Table 2). The list of characteristic species in herb-rich forests based on Finnish studies [24], [25] was evaluated on N9050 plots and ENFRP plots (Table 3) and this showed also that ENFRP plots had more species and their diversity was higher than on N9050 plots. Several species characteristic of Finnish herb-rich forests (*Brachythecium salebrosum, Carex pallescens, Dactylorhiza maculate, Galium triflorum, Geranium sylvaticum, Juniperus communis, Moneses uniflora, Phegopteris connectilis, Plagiothecium laetum, Ribes spicatum, Rosa acicularis, Salix phylicifolia, Stachys sylvatica, Viola selkirkii*) were not found on N9050 plots or ENFRP plots. Tree composition was more complex and undergrowth denser on N9050 plots (Table 4).

Table 2. Average number of vascular plants and moss species and their diversity index on the sample plot in different vegetation types on N9050 plots and ENFRP plots.

Sample plot series	Vegetation type	Number of species		Shannon index	
		Vascular plants	Mosses	Vascular plants	Mosses
N9050 plots	*Oxalis*	13	6	1.92	1.04
	Aegopodium	24	4	2.70	0.87
	Filipendula	24	8	2.64	1.79
ENFRP plots	*Oxalis*	24	6	2.36	1.25
	Aegopodium	37	10	2.65	1.67
	Filipendula	41	11	2.99	1.95

Table 3. Occurrence of characteristic species of Finnish herb-rich forests [24], [25] (number of plots where the species were found) on ENFRP plots and N9050 plots.

Characteristic species	ENFRP plots	N9050 plots according to habitat quality class in 2014			
	Total (n=15)	A (n=4)	B (n=5)	C (n=5)	Total (n=14)
Vascular plants					
Angelica sylvestris	7	0	0	0	0
Athyrium filix-femina	7	0	1	0	1
Calamagrostis canescens	5	0	0	0	0
Carex digitata	9	0	0	1	1
Circaea alpina	4	0	0	0	0
Convallaria majalis	12	2	1	0	3
Daphne mezereum	2	0	0	1	1
Dryopteris carthusiana	7	3	2	2	7
Equisetum pratense	7	1	2	1	4
Fragaria vesca	10	4	2	5	11
Gymnocarpium dryopteris	6	0	0	0	0
Lonicera xylosteum	4	1	2	0	3
Luzula pilosa	11	1	1	1	3
Maianthemum bifolium	14	4	4	5	13
Melica nutans	6	0	0	0	0
Milium effusum	6	0	1	0	1
Oxalis acetosella	13	4	5	5	14
Paris quadrifolia	9	1	0	1	2
Prunella vulgaris	1	0	0	0	0
Prunus padus	0	2	0	1	3
Pteridium aquilinum	1	0	3	0	3
Ranunculus repens	6	0	0	0	0
Rubus idaeus	9	1	1	0	2
Rubus saxatilis	13	3	4	3	10
Sorbus aucuparia	5	4	4	2	10
Trientalis europaea	12	2	4	4	10
Vaccinium vitis-idaea	0	1	1	2	4
Veronica officinalis	2	1	1	0	2
Viburnum opulus	2	0	0	1	1
Viola mirabilis	5	0	0	1	1
Viola riviniana	4	0	0	0	0
Mosses					
Brachythecium oedipodium	3	0	2	1	3
Brachythecium reflexum	3	0	1	0	1
Brachythecium rutabulum	3	0	0	0	0
Brachythecium velutinum	0	0	1	1	2
Cirriphyllum piliferum	8	0	1	1	2
Eurhynchium spp.	9	2	3	1	6
Plagiomnium cuspidatum	2	0	0	0	0
Plagiomnium affine	3	1	0	0	1
Plagiomnium ellipticum	4	1	0	0	1
Plagiomnium undulatum	3	1	1	0	2

Table 4. Occurrence of tree species and characteristics of ENFRP plots and N9050 plots.

	ENFRP plots			N9050 plots		
	***Aego-podium* (n=5)**	***Fili-pendula* (n=5)**	***Oxalis* (n=5)**	***Aego-podium* (n=4)**	***Fili-pendula* (n=2)**	***Oxalis* (n=8)**
Occurrence of tree species (number of plots where the species were found)						
Acer platanoides	0	0	0	4	1	3
Alnus glutinosa	1	1	1	0	0	3
Alnus incana	5	4	1	1	1	1
Betula pendula	4	5	4	4	2	8
Corylus avellana	0	0	1	3	2	6
Fraxinus excelsior	0	1	1	1	0	2
Picea abies	5	5	5	4	2	8
Pinus sylvestris	0	0	4	3	1	4
Populus tremula	2	4	1	2	1	7
Prunus padus	0	0	2	0	0	1
Quercus robur	0	0	3	3	0	1
Salix sp.	2	1	1	0	1	1
Sorbus aucuparia	0	0	1	4	2	2
Tilia cordata	2	2	0	0	0	1
Ulmus glabra	1	1	0	2	0	0
Characteristics of sample plots (± standard deviation)						
Number of tree species on a sample plot	4.6 ± 1.5			6.6 ± 2.4		
Forest age (years)	57 ± 12			117 ± 15		
Number of living trees (ha^{-1})	1009 ± 691			610 ± 164		
Volume of living trees (m^3 ha^{-1})	303 ± 94			426 ± 123		
Number of dead trees (ha^{-1})	97 ± 70			191 ± 102		
Volume of dead trees (m^3 ha^{-1})	11 ± 6			22 ± 13		
Number of undergrowth (ha^{-1})	96 ± 70			486 ± 233		

4. Discussion

The Natura 2000 network is the main implementation tool of the Convention on Biological Diversity in the EU, therefore it also has a global influence [26]. At the same time this EU-wide agreement has to be implemented nationally and also regionally in the member countries. Conservation activities should ideally be based on generally agreed criteria, i.e. stakeholders should understand and agree on protected habitat types and their characteristics from local to global level. Any classification and definition of a habitat type is a simplification and generalization of more complex systems based on agreed similarity criteria [27]. Different stakeholders see this complexity differently and thus struggle with achieving a common understanding.

Conservation initiatives succeed only by combining social and ecological sustainability and by ensuring the integration of policies affecting biodiversity [28]. Cross-sectoral coherence is important as Natura 2000 influences also other sectors, mainly forestry and agriculture. This means that implementation of the Natura 2000 network on specific sites goes beyond conservation policy and biological approach. For example, Sarvašová et al. [29] concludes that cross-sectoral approach was missing in the implementation of Natura 2000 in Slovakia, resulting in a top-down process. Also in Austria implementation of Natura 2000 varied from active participatory involvement to top-down approaches [30]. The participation of local landowners has been lacking in many cases concerning the Natura 2000 network. However, private forest owners are very diverse in their management intentions and their conservation motives might be as strong as income motives [31], [32]. Private forest owners value their “home forest” (including biodiversity) much more than as just a simple income generator. Direct implementation of top-down approaches and strict “no management allowed” rules are in most cases not appropriate for preserving specific habitats. Ideal conservation tools should be based on landowners’ attitudes and motivations [33], which, in most cases, produce better conservation results and attitudes. The European Commission [34] has revealed in their analysis that 63% of habitat types and species have an unfavourable or bad conservation status in the EU. This suggests that there is a need to analyse the management regimes of these areas for future directions in both policy and management perspectives [35].

This study shows that several Natura 2000 sites actually do not conform to the site classification as Natura 2000 habitats or the sites are losing their conservation value in Estonia. The 46% of the studied habitats have lost their initial value and 49% have developed towards habitat type 9010 in the course of their successional development. The Natura 2000 network was formed in Estonia quite rapidly in 2004, resulting in a drastic change of management in many of these areas. Due to the EU accession the designation and implementation of the Natura 200 network was done hastily in several Eastern European countries [29]. After ten years since establishment, changes have taken place in habitat types and habitat quality in the Natura 2000 network. As protected unmanaged areas develop differently from predicted trajectories, habitat management and restoration treatments should be applied to meet the set of conservation objectives.

Most of the study areas were ‘man-made’ herb-rich forests that actually need frequent management activities for maintaining their valuable features. These activities include controlled burning, removing of understory trees and bushes or drainage. Otherwise these forests over time lose their habitats or change to different habitats. Succession and structural complexity builds over time and in the absence of catastrophic disturbances such sites move towards old-growth forests [36], [37].

Spies [38] studied the differences between the diversity and occurrence of plant species in young, mature and old-growth Douglas-fir stands and the results indicated that after canopy closure, the trend in understory diversity was to increase slightly from young to old growth. This finding suggests that within the old-growth age-class, diversity may be higher in the early stages of old growth and lower in the later stages. This might be also the reason why the results in vegetation analysis in N9050 sites showed lower species richness than in similar commercial forests (ENFRP sites). Hansen et al. [36] showed that the value of younger natural stands is often underestimated in the biodiversity conservation. Our results suggest that several forests in the habitat type 9050 have been developing to old-growth forests in the habitat type 9010 during the last decade. Hokkanen [24] stated that despite the fact that old-growth forests may have species typical to herb-rich forests they should not be considered as herb-rich forests. Palo and Gimbutas [39] showed that there are currently too many forest stands with on-going natural succession in Estonia and semi-natural forest habitat types urgently need maintenance and the influence of traditional practices (fire, grazing, selective cutting) for the benefit of the structure and composition of the stands.

5. Conclusions

There have been negative changes in the habitat type 9050 and habitat quality in the Natura 2000 network since the network was established in Estonia. The 46% of the studied habitats have considerably lowered their initial value and 49% have developed towards the habitat type 9010 during 2004–2014.

The habitat type 9050 is mostly a human-influenced semi-natural forest that needs frequent management activities for maintaining the habitat in initially described good condition in Estonia. Such management activities should be acknowledged and supported in the Natura 2000 network. In the Estonian case the implementation of the Natura 2000 network as a set of natural habitats where management is not allowed leading to inefficient conservation policy and destruction of semi-natural forest habitats. Appropriate habitat restoration measures should be applied on the sites where protected habitats have already lost their value.

Both state and private forests have a significant role in preserving valuable habitats in Estonia. The state should give more decision power and support to private forest owners concerning nature conservation and, in return, this will help the owners to protect their forests and encourage the management that can enhance the conservation value and biodiversity of valuable habitats.

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