Estonian Journal of Ecology, 2011, **60**, 3, 209–224 doi: 10.3176/eco.2011.3.04

Re-evaluation of stand indicators for the assessment of the representativity status of the Natura 2000 habitat type forests

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Received 1 June 2010, revised 14 January 2011

Abstract. Habitat inventories and monitoring require the evaluation of the status of various characteristics of these habitats – indicator traits. In the case study of Estonian forests in Viru County (Natura 2000 Annex I forest habitat types *9010, *9080, and *91D0), the survey data of old-growth and natural forests were used to test for the efficiency of the indicator set that has been suggested for the evaluation of the habitat's representativity status. The data from expert-graded forests (121 stands) were alternatively clustered with *k*-means clustering, their characteristics were tested for indicator power with discriminant analysis, and the resulting efficient set of characteristics was clustered again for an updated classification.

In studying the differences between analyses of expert grading and cluster system, we found that different characteristics had different weights in forest classification. In addition to the standard structural characteristics, signs of anthropogenic activity and landscape pattern proved to be of importance. From the testing for various precision scales of classification, we concluded that different indicator traits of structure and composition are required, and the three-grade system appears to be practical for the purpose of avoiding over-interpretation. We found that additional studies are needed to define reasonable indicator traits for wet and swampy forests, and also for forests on unproductive soils.

Key words: forest structure, forest monitoring, indicators, representativity status, Natura 2000.

INTRODUCTION

Ecological assessment of habitat representativity

International and European environmental organizations are making serious efforts to stop the loss of biodiversity in various habitat types, including forests (European Commission, 1992; CBD, 2006; Oja, 2009). For that purpose, the Natura 2000 Network of important habitats in the EU has been established. The Natura 2000 Standard Data Form for habitat evaluation (European Commission, 1996a, 1996b, 2006) sets terminology and principles for the inventory and monitoring of habitats, including their representativity and conservation status. The major focus in interpretation manuals for fieldworkers is on the description of the habitat and its deductive comparison to a typical example (Airaksinen & Karttunen, 2001; Viceníková & Polák, 2003; Guth & Kučera, 2005; Auninš, 2010). In the case of Estonia, the comparative description of an old-growth forest is used to determine the habitat's representativity in three- or four-level grade system (Ministry of Environment, 2002; Paal, 2002, 2007; Palo, 2004). This representativity grading system consists of four grades, from grade A (an old-growth forest, historically continuous and without management signs) to D (hardly suits under the definition of a habitat type, but has a potential to develop into one in the future).

The commonly used representativity grading for forest habitats is based on an expert opinion given in the field according to mapping manuals. In theory, the adequate evaluation and monitoring of habitat type forests require the description of various aspects of these habitats, which would provide information about their status. The majority of monitoring and forest inventory methods are based on the evaluation of the number of forest structural elements and the registration of indicator species (Noss, 1990, 1999; Lindenmayer et al., 2000; Korjus, 2002; Andersson et al., 2003; Liira & Kohv, 2004; Brang et al., 2008; Winter et al., 2008; Adermann, 2009; Lamb et al., 2009; Oja, 2009). Informative characteristics are called indicators, but they must be tested for causal correlations, universality of use, power of extrapolation, and robustness for errors in practice, and they must be easy and inexpensive to apply (Liira & Kohv, 2010). There is no single universal indicator trait that would work uniformly in all habitats, and therefore a complex of indicative traits should be considered (Jonsson & Jonsell, 1999; Büchs, 2003; Zenner, 2004; Ranius & Jonsson, 2007; Liira & Kohv, 2010; Lõhmus & Kraut, 2010).

Only recently researchers in Estonia have become interested in more specific topics, such as the distinction of old near-natural forests rich in structural elements from managed ones and whether it varies along environmental gradients (Trass et al., 1999; Kohv & Liira, 2005; Liira et al., 2007; Liira & Sepp, 2009; Sepp & Liira, 2009; Liira & Kohv, 2010; Lõhmus & Kraut, 2010). Increasingly more attention has been paid to responses of forest species to changes in stands (Vellak & Paal, 1999; Meier et al., 2005; Vellak & Ingerpuu, 2005; Lõhmus & Lõhmus, 2008; Jüriado & Liira, 2009; Meier & Paal, 2009). It is also very important to consider direct and indirect anthropogenic effects (Pikk, 2003; Palo et al., 2004; Remm, 2005; Liira et al., 2007; Kaasik et al., 2008).

The first updates toward standardized methods have been made in the evaluation and monitoring of the Natura 2000 habitat type forests that focus on biological diversity in Estonia (Viilma & Palo, 2008; Adermann, 2009; Liira, 2009). However, in order to ensure methodological adequacy and suggest future improvements in the list of structural indicators, the methods need to be tested in the field for practicality and universality of use in a wide range of habitats.

The goal of our research was to test the effectiveness of widely used forest structural indicators for the characterization of the representativity grade of forests belonging to some most common Natura 2000 habitat types, to compare the conformity of the trait-based approach with the grading given by an expert, and to determine which stand characteristics are non-specific to habitat type. The final task of our study was to develop an optimized forest habitat indicator complex, which should serve as an updated tool for an objective classification of Natura 2000 forests into representativity classes.

METHODS

Study site

Our pilot project was conducted in Ida-Viru County in north-eastern Estonia (Fig. 1). In 2007 the forest land coverage in the county was about 57.7%, compared to the Estonian total of 50.6% (data calculated without the area of Lake Peipsi) (Adermann, 2009). Ida-Viru County includes three landscape regions: the north Estonian coastal lowland, the Viru tableland, and Alutaguse, with a combined territory of 3369 km^2 (Arold, 2005). Alutaguse, situated in the central and southern parts of Ida-Viru County, is one of the most untouched and densely forested areas

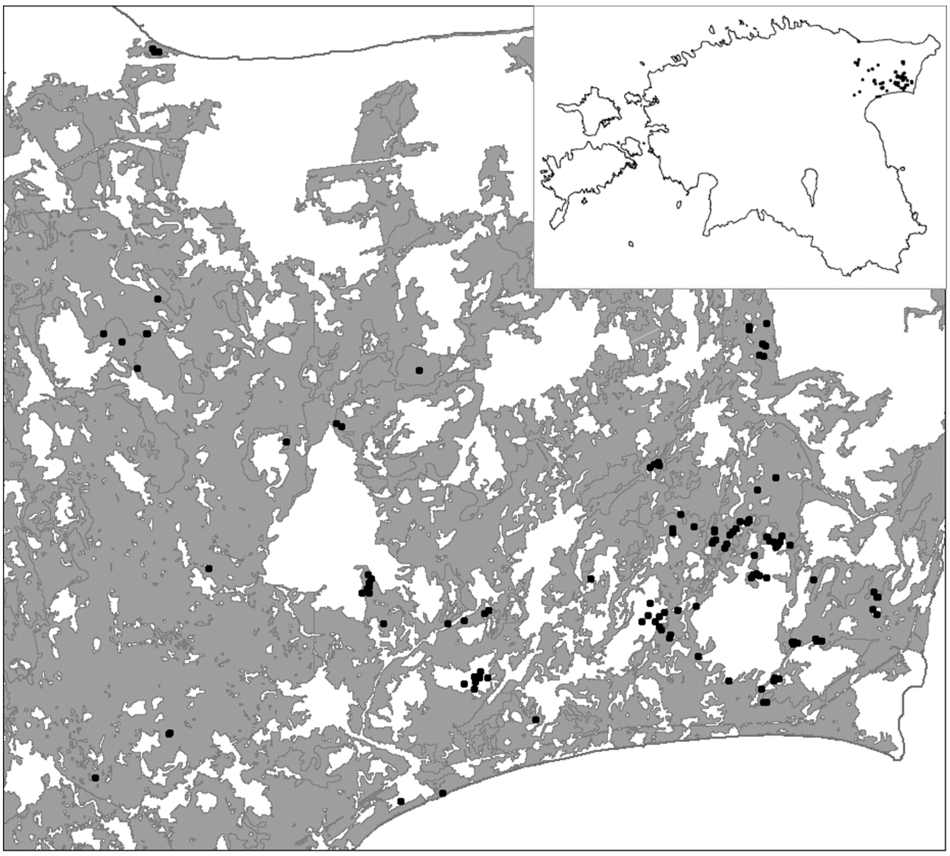

Fig. 1. Map of the forest study areas in northeastern Estonia. Grey areas are major forest areas according to the map layer of forests (based on Peterson, 2003).

in Estonia. The settlements of Alutaguse were in earlier times concentrated on the banks of the Narva River. Large forest and mire areas remained mostly untouched by human influence until the 18th century; cutting activity increased in the 19th and 20th centuries. Trees were extracted near historically settled regions (areas close to the northern cliff coastline and at Tudu and Avinurme) and in areas easy to reach (the western bank of the Narva River). Large mires with enclosed forest areas were preserved until the first half of the 20th century, when a number of narrow-gauge railways were built for forest extraction, and the drainage of mires intensified. The main changes in the forests of the Alutaguse region began after World War II, when forest stands that had been degraded and burned during the battles were cut again, and very intensive drainage of forest land began (Laasimer, 1965; Saaber, 1996). By today, small former villages have overgrown with forest, and the Alutaguse region is mainly forest land. Many of the Natura 2000 forest habitat patches are situated in this region.

Data sampling

The most common forest habitat types in Estonia are the western taiga (*9010), Fennoscandian deciduous swamp woods (*9080), and bog woodlands (*91D0) (Adermann, 2009). These three habitat types were selected as our study objects. During the years 2008–2009 we described the forests from each habitat type selecting 75 sites from western taiga, 24 sites from Fennoscandian deciduous swamp woods, and 22 sites from bog woodlands.

First we checked all potential habitat polygons from aerophotos (from the Estonian Land Board Geoportal) and excluded those clear-cut or with obviously intensive management. A circular sample area was positioned in the centre of each habitat polygon. In general, the forest sample plot had a radius of 10 m. The observed continuous characteristics in the sample plot area were transformed into estimates per hectare, and alternatively, all continuous and classification traits were treated as binary (presence/absence). The representativity grading was given by an expert in the field according to mapping manuals (Ministry of Environment, 2002; Viilma & Palo, 2008). Experts used a four-grade system: A – old-growth forests, old or continuously developed stand without forest management signs; B – stand with all typical structural characteristics, mostly old enough or continuously developed, but some management signs are detectable; C – because of earlier forest management, some structural features are missing or represented modestly, but the stand has been developed continuously and is undoubtedly a potential habitat for rare species; D – presently hardly a habitat fitting the definition of any Natura 2000 habitat type, but has a potential to develop into one in the future depending on management decisions.

The fieldwork data sheet was developed in accordance with the suggestions of the Estonian woodland key habitat inventory manual (Andersson et al., 2003) and other relevant sources (European Commission, 1996a, 1996b; Korjus, 2002; Ministry of Environment, 2002). We focused on forest structural features that are widely used as evidence of stand continuity and/or natural disturbances. During fieldwork we registered various stand characteristics, including the age of the oldest trees in the stand; tree and shrub species and their total coverage in each layer; the age layer-differentiation of the stand's canopy; gaps in the canopy; natural rejuvenation of stand; presence and number of large, suppressed old living and dead trees; presence and number of stumps; occurrence of lying dead wood in various sizes and stages of decay; presence of various biodiversity indicators, such as multi-stemmed trees, supporting roots, holes in trunks, bracket fungi, traces of woodpeckers, and forest fires in history. In addition, information about the degree of humidity and nutritional value ordinated scale data on the forest ecotype were used (Lõhmus, 2004). Around the sample area we registered several landscape structural features such as historical land use, ditches, habitat fragment size (small vs sufficient), open non-forested areas, roads, surface mining, and vast drainage systems.

Data analyses

First we analysed how the grading of forests performed by experts could overlap with the alternative analytical solutions for the classification of those forests, based on the expectation that all characteristics suggested by the literature and observed in the field were equally informative. Next we estimated the critical list of indicators to mimic the grading decision made by the expert or alternative analytical classifications. Finally, combining these results, we suggested a generalized list of indicators suitable for use in forest habitat evaluations.

According to these steps of the algorithm, we first applied three-, four-, and five-class *k*-means clustering on the survey data of forests possessing standardized values. Standardization was performed on the basis of forest habitat type, forest age, and habitat environmental gradients. We then cross-tabulated all three cluster systems with expert grading and tested pattern complementarity with Log-Linear Analysis.

As the second step, we built four discrimination models with the help of General Discriminant Analysis (GDA), one for each classification system, repeatedly using the back and forward procedure for the selection of traits. The result of each model provided us with a potential list of characteristics that would help to recognize predetermined groups in observations. For greater universality and simplicity, we transformed the observed values of the characteristics into a two-state system (absent – 0 or present – 1 in the site) for habitat classification in GDA. For comparison, we also tested GDA with continuous characteristics, and these provided very similar results to the occurrence data (these analyses are not presented).

Thirdly we combined all four lists of predictive indicators and re-clustered the observed forests, using only those indicators that proved to be statistically informative. Analyses were performed in the program Statistica ver. 8. Classification results were also re-evaluated using photos taken in each forest sampling plot.

RESULTS

In the field, the expert graded 23 stands as having the highest representativity (grade A), 26 stands as of B grade, 36 as of C grade, and 36 as of D grade. The proportion of gradings in each forest habitat type was relatively similar (15–38%), except for *91D0, where the B-grade forests comprised 9% of the sample and C-grade forests 41%.

k-Means clustering analysis with a predetermined number of clusters of three, four, or five groups divided stands into relatively equally-sized groups. All three classifications demonstrated pattern correlation with expert grading (Table 1, left panel), as the chi-square test showed a significant classification conformity among expert grading and 3-cluster systems ($P = 0.0003$), 4-cluster systems ($P = 0.0016$), and 5-cluster systems ($P = 0.0069$). One can observe that when the number of clusters was increased, more than 80% of the stands remained in the same cluster as before or became equally divided between two clusters. In comparison with the expert-given ABCD grading, all classification systems showed the trend that forests of the highest grade (A) and lowest grade (D) were quite uniformly clustered into the same groups in *k*-means clustering analysis (Table 1, left panel), while intermediately graded stands tended to be dispersed into various clusters. This is particularly visible in the comparison with 3- and 5-cluster systems: the strongest

Table 1. Cross-table of forest study areas according to expert grading and results of *k*-means clustering of forests. Proportional frequency within the habitat is presented; the largest proportions are shown in bold

Preliminary clustering					Re-clustering using GDA results				
Cluster system	Expert grading				Cluster system	Expert grading			
3 clusters	A	B	C	D	3 clusters	A	B	C	D
1	**52**	31	**44**	11	1	**96**	**62**	**44**	11
2	39	**46**	25	25	2	4	**38**	**28**	19
3	9	23	31	**64**	3	0	0	**28**	**69**
4 clusters	A	B	C	D	4 clusters	A	B	C	D
1	**48**	**35**	22	25	1	**74**	**31**	22	0
2	43	15	22	6	2	22	**31**	19	17
3	9	23	**31**	22	3	4	**38**	**28**	17
4	0	27	25	**47**	4	0	0	**31**	**67**
5 clusters	A	B	C	D	5 clusters	A	B	C	D
1	**39**	15	17	3	1	**74**	**31**	22	0
2	13	23	25	19	2	22	**35**	22	17
3	**30**	**35**	**31**	14	3	0	23	22	14
4	0	12	19	**33**	4	4	12	17	25
5	17	15	8	**31**	5	0	0	17	**44**
Sum	100	100	100	100	Sum	100	100	100	100

qualitative agreement with the expert grading can be observed in the 3-cluster system and the weakest in the 5-cluster system. This suggests that the expert weights the importance of characteristics, i.e. the expert does not see traits as equally important within the complex.

Four GDA models built to quantify the trait weighting in the process of expert grading and three alternative classifications consisted of a total of 24 stand characteristics (Table 2). The GDA predictions to forests recognized the expert grading correctly in 65% of observations, 92% of 3-cluster systems, 89% of 4-cluster systems, and 85% of 5-cluster systems. Most of the significant characteristics were indicators that were common over all three forest habitat types, and only some characteristics had a significant dependence on the habitat type (Table 2). The most common predictive indicators in these four GDA models were the coverage estimates of the first and the second tree layer, the presence of age differentiation among trees, the presence of old living trees and large dead trees, lying dead wood, the diversity of decay classes, and the occurrence of holes in stems. In one or two models the presence of natural rejuvenation, old living trees and suppressed dead trees, bracket fungi, woodpeckers, signs of fire, and habitat fragment size were also important predictors.

The trait pattern in the expert grading GDA models compared to the GDA models of clustering is distinguished by a more specific list of stand characteristics related to stand age (stand age itself, old large dead trees, etc.). This trend is visible along the representativity gradient as the wide range of average values of several traits (Table 2). The GDA models built for the cluster classifications emphasize more the structural diversity of stands, while age-related traits do not demonstrate a distinct graduation between clusters.

The re-clustering of stands into three-, four-, and five-cluster systems using only the GDA-suggested predictive set of characteristics provided an improved agreement among the re-clustering results and the expert grading (Table 1, right panel). The highest frequency stand can be seen on the diagonals of the cross-tabulations, particularly in three- and four-cluster systems. A chi-square test among expert grading and cluster systems showed stronger frequency pattern conformity, as the test P-value became $P < 0.0001$ for all cluster systems.

DISCUSSION

Developments in mapping and monitoring methods once again raised the question of the methodological aspects of representativity evaluation, addressing mostly the generation of an objective grade system applicable by multiple experts. The problem is how to build a grading system so that it would be independent of subjectivity and background knowledge. Most forest surveys establish an attribute set for habitat evaluation or monitoring by combining characteristics the authors consider to be indicative of structure or biodiversity (Lähde et al., 1999; Zenner, 2004). The chosen structural, functional, and compositional attributes of a stand may also be surrogates for other attributes, which are usually not directly observed

Table 2. The results of GDA models, which represent statistically significant stand characteristics efficiently discriminating the studied forests among classification groups. In the left half of the table, the significance level of each characterstic included in the model is presented (*$p < 0.05$; **$p < 0.01$; ***$p < 0.0001$, N.S. – non-significant). In the right half of the table, the max–min-range estimates for groups are presented. If a habitat is significant in the model, estimates are provided for all habitat types. Models prediction accuracy is given as the percentage of correctly classified forests

Indicator trait	Classification system				Habitat type	Max/min of group average			
	Expert (ABCD)	3 clusters	4 clusters	5 clusters		Expert (ABCD)	3 clusters	4 clusters	5 clusters
Max. age (log)	***	***	***	***		127/83	109/101	110/101	103/88
Habitat type (9010/9080/91D0)	N.S.	N.S.	**	**					
Varying aged stand (0/1)		N.S.	**	**			0.83/0.6	0.83/0.58	0.85/0.59
Habitat type*Varying aged stand		*			9010		0.83/0.5		
					9080		0.8/0.5		
					91D0		1/0.63		
Natural rejuvenation (0/1)			**	N.S.				1/0.67	
Habitat type*Natural rejuvenation				***	9010				1/0.93
					9080				1/0.8
					91D0				1/0.83
No. of tree species				***					4.32/2.84
No. of species (shrubs, undergrowth)		**	**				5.38/3.72	5.33/3.7	
Dominance of deciduous trees (0/1)		**	**				0.36/0.28	0.38/0.26	0.45/0.24
No. of storeys		**	***	**			2.95/2.46	2.92/2.49	
Habitat type*No. of storeys		**			9010		2.96/2.52		
					9080		3/2.75		
					91D0		2.83/2		
Tree storey I cover (%)		*		*			60.9/50		63.3/46.6
Tree storey II cover (%)		*		**			18.5/12.3		22.3/12.5
Gaps in canopy (0/1)		*	**	**			0.78/0.5	0.81/0.39	0.88/0.41
Old living large-sized trees (0/1)		***	***	***			0.88/0.4	0.96/0.52	0.95/0.5
Habitat type*Old living large-sized trees				*	9010				0.92/0.47
					9080				1/0.8
					91D0				1/0.25

Table 2. *Continued*

Indicator trait	Classification system				Habitat type	Max/min of group average			
	Expert (ABCD)	3 clusters	4 clusters	5 clusters		Expert (ABCD)	3 clusters	4 clusters	5 clusters
Old living supressed-sized trees (0/1)		N.S.							
Habitat type*Old living supressed-sized trees		*			9010		0.88/0.25		
					9080		0.88/0.17		
					91D0		0.67/0		
Old dead large-sized trees (0/1)	**		**	***		0.92/0.19		0.92/0.39	0.9/0.48
Habitat type*Old dead large-sized trees	*				9010	0.95/0.29			
					9080	1/0			
					91D0	1/0			
Old dead supressed-sized trees (0/1)		***					0.79/0.19		
Lying big dead wood (debris) (0/1)		**	***	***			0.98/0.6	0.96/0.62	0.96/0.41
Lying dead wood in many decay stages (0/1)	**	**	***	***		1/0.39	0.9/0.48	0.89/0.27	0.95/0.63
Multi-stemmed trees (0/1)	**					0.39/0.03			
Supporting/exposed roots (0/1)			*					0.25/0.15	
Holes in trunks (0/1)	*	***	**	**		0.83/0.22	0.8/0.29	0.88/0.18	0.85/0.41
Bracket fungi (0/1)			**	***				0.75/0.18	0.85/0.16
Habitat type*Bracket fungi				*	9010				0.85/0.21
					9080				1/0
					91D0				0.67/0
Woodpecker (0/1)			**					0.88/0.39	
Signs of forest fire (0/1)		N.S.							
Habitat type*Forest fire		**			9010		0.65/0		
					9080		0.2/0		
					91D0		0.33/0.13		
Stumps (0/1)	**		**			0.09/0.46		0.19/0.45	
Habitat is small-sized fragment (0/1)	*					0.03/0.19			
Correctly classified, %	65	92	89	85					

(Noss, 1999; McElhinny et al., 2005). In contrast to traditional approaches, we first tested for the agreement of the trait composition with expert grading and also estimated the informative/indicative power of traits used, as suggested by Kohv & Liira (2005). As Liira et al. (2007) and Liira & Kohv (2010) showed in an analysis along the vast gradient of productivity, in the first step the standardization of data at habitat type level was needed, also the potential noise and collinearity of factors had to be considered, and only after that ecologically reasoned indicators could be tested for their predictive power for forest classification. In our case, we used GDA to evaluate the predictive power of potential indicators only after the clustering of standardized characteristics of habitat type.

We found that the expert grading given in the field and various clusterings of trait composition revealed differences in the weighting of the traits regarding the information they carry. We found that in experts' grading of the studied forests the most significant surrogate trait affecting grading was the maximum age of the tree and traits related to stand age. It is obvious that ABCD grading is partly dependent on stand age and partly subjective. This leads to a subjective expert grading of stands. When the age was extracted from the model, the model's precision in the detection of ABCD grading decreased by 10–30%, except for the grade D forests, probably because old trees were mainly absent from these forests. Based on the statistical analysis of indicators explaining the ABCD grading system, we found that the system remained one-sided and unclear, and it is therefore very likely that other experts would grade some forests differently. This is illustrated by the results of the first cluster analysis.

The preliminary cluster analysis provided a grouping of forests where the age effect was underweighted and stand structural features were overweighted (Table 2). This is particularly visible in the 3-cluster system. Biodiversity indicators and fire disturbance also obtained higher weights in clustering analysis, which is probably acceptable. Consequently, suggestions from the independent classification of forests provided a very useful insight into the structural pattern of those forests and their structural differences. After corrections in the indicator list, the re-clustered system approximated fieldwork valuation (Table 1), and we observed the most correct prediction when the 3-cluster system was used (92%). The 3-class system is probably the most objective way to determine the representativity status of forest patches. Based on our data, the list of indicators in a 3-class system (ABC) will include the age of the oldest trees in the stand, diversity and abundance of shrub species, the number of tree storeys, tree storey I and II coverage, dominance or co-dominance of deciduous trees, presence of gaps in the canopy, occurrence of large and suppressed old living (and dead) trees, occurrence of lying dead wood in various size classes and decay stages, and the presence of holes in trunks. In some habitat types two other characteristics were important: traces of past forest fires and the age differentiation of the stand.

Some problems in the evaluation of forests tend to be particularly common in semi-managed forests as stumps are an indicator of management. The effect of management in the reduction of biological diversity is actually very difficult to estimate, as it has both positive and negative effects and also depends on several other factors, such as age and structural and landscape factors (Liira et al., 2007; Lõhmus et al., 2007; Lõhmus & Lõhmus, 2008; Liira & Sepp, 2009). Fewer problems are faced with stand age, as the oldest tree found might be a better characteristic than the medium age of the storey in the stand. Single or some remnant trees usually also stay in a stand after natural disturbances, and they play a decisive role in forest continuity. Other natural forest structural indicators such as old standard-sized trees or lying dead wood in many stages of decay proved to be useful indicators for evaluation, as they generally help to distinguish grade A forests from grade D forests. Additionally, the probability of a stand belonging to grade A is also increased by the presence of holes in trunks and multi-stemmed trees. We also tested the indicative power of the landscape parameters of the forest patch, but only the fragment area (small vs sufficient) affected the grading of some sites.

As shown by earlier studies, efficient structural indicators and grading thresholds are frequently forest site type specific, working most efficiently in high-productivity habitats (Korjus, 2002; Liira et al., 2007; Liira & Kohv, 2010). This leads to the recognition that many definitions of forest grading have been established on the basis of certain forest types, e.g. *9010 and *9020 (old broad-leaved deciduous forests), while moist habitats have been ignored because of their small present-day frequency in Western Europe and their structural specificity (e.g. *91D0, *9080) (Prieditis, 1997, 1999; Andersson et al., 2003). In the studied swamp and bog forests, the used list of indicators effectively recognized extreme quality classes, while in intermediate-grade forests the drainage and fertilization of forest soils caused very confusing results by supporting a structure that is unnatural to those wet forests (Pikk, 2003; Kaasik et al., 2008). Features such as the proportion of deciduous trees and the diversity in the shrub layer, which in forests of the boreal western taiga indicate increased biodiversity and habitat quality (Kouki et al., 2004; Liira & Kohv, 2010), can be used as a negative indicator from the natural point of view in nutrient-poor swamp forests. For instance, in deciduous swamp forests the growth rate increases as a result of drainage (Pikk, 2003), increasing also the proportion of large lying dead wood, which serves as an additional substrate for species that have specialized in colonizing decaying wood. On the other hand, as a result several small microhabitats in deciduous swamp forests become overgrown. Drainage also increases the competitiveness of spruce, which over time will change stand composition as well as light conditions and microclimate. Further research is needed to find out which substrates and microhabitats are critical for habitat-specific species in intact deciduous swamp forests to balance those processes in valuation (Prieditis, 1997, 1999).

Research into the structural characteristics of forest habitats has shown that many traits are quite universal in various approaches while others are unique. As our analyses revealed, in using alternative clustering in contrast to expert opinion, many characteristics tended to be more generalistic than in the expert's view. Additionally, as shown by earlier studies (Viilma et al., 2001, Liira et al., 2007; Liira & Sepp, 2009; Sepp & Liira, 2009; Liira & Kohv, 2010), stand evaluation must take into account the status of all habitat layers (from the 1st tree layer to the ground layer) and the status of various functional or taxonomic groups. This means that the forester type of approach, which concentrates mostly on trees, is insufficient even if trees are the core species or edificator species in the stand. In the present study we only used selected functional or taxonomic indicators, and did not use the composition of herb layer or common indicator species as suggested in earlier studies, because the monitoring of habitats requires the use of indicators that have a constant status during a broader season than just the peak of the growing season.

CONCLUSIONS

Problematic cases occur frequently in real life situations if (i) the habitat type is incorrectly determined and habitat-specific indicators are in use, (ii) the habitat has unclear grading because of intermediate structure, or (iii) both. In such complicated situations, the solution is based on the expert's subjective opinion and depends on the expert's extra knowledge of the reference system or their having a very specific 'sixth sense', which embodies additional rare traits or their combinations.

In analysing differences between expert grading and trait compositions, we found that in addition to the age-dependent characteristics of the stand structure, also stand structure complexity, signs of anthropogenic activity, and landscape pattern should be recorded. Traits that could be considered in the field survey include characteristics of fragmentation, ditching, fertilization, and distance from sources of pollution. For the monitoring of the nature quality status of the forest, we need precisely defined characteristics for the estimation of habitat status. Some initial practical testing has been done by Statistical Forest Inventories (Adermann, 2009). In order to optimize grading systems, different additional indicator traits should be tested in upcoming studies. Particularly, the indicator trait lists for bog woodlands, swamp forests, and forests on unproductive soils are incomplete.

ACKNOWLEDGEMENTS

This work was supported by grants from the University of Tartu (BF07917), Estonian Science Foundation (ETF7878), Ministry of Education and Research (SF0180049s09, SF0180012s09), and Environmental Investment Centre (LLOOM08239) and by the European Union through the European Regional Development Fund (FIBIR Centre of Excellence).

We acknowledge the help in fieldwork arrangement by the Environmental Board in Viru Region, Oonurme Village Society, State Nature Conservation Centre in Ida-Viru Region, and especially Mrs Kaili Viilma. We are grateful to Karina Seeberg Kitnaes and anonymous reviewers for their comments on the manuscript and Alexander Harding for editing the text.

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Loodusdirektiivi metsaelupaikade esinduslikkusklasse eristavate tunnuste määratlemisest

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Meie töö eesmärgiks oli loodusdirektiivi metsaelupaikade seisundi seireks sobivate elupaigatüübist sõltumatute indikaatorite informatiivsuse testimine. Tunnused pidid sobima ka esinduslikkusklasside (A-C(D)) objektiivseks eristamiseks erinevate ekspertide poolt.

Selle ülesande lahendamiseks kirjeldasime aastatel 2008–2009 Ida-Virumaal kolmes metsaelupaigatüübis (*9010, *9080, *91D0) 121 proovialal (r = 10 m) metsa struktuurilist mitmekesisust. Metsa esinduslikkusklasside eristamisel lähtusime senistest kirjeldavatest juhenditest. Kameraalselt analüüsisime alternatiivseid klassifikatsioonivõimalusi, kasutades *k*-klasterdusmetoodikat 3-, 4- ja 5-klassilise süsteemiga. Seejärel koostasime igale uuritud klassifikatsioonile üldise diskriminantanalüüsimudeli (GDA), rakendades mitmesuunalist tunnuste valikut. Selgus, et ekspert tähtsustas eelkõige puistu vanimate puude vanust ja kändude esinemist, hinnates mitmeid teisi tunnuseid elupaigatüübispetsiifiliselt. Alternatiivsed klassifikatsioonid võtsid edukalt arvesse ka puistute üldist struktuurilist mitmekesisust. Viimaks kombineerisime kõigi nelja süsteemi olulised indikaatorid ja viisime nende alusel läbi metsade uue klasterdamise. Saadud klassifikatsioonid jaotasid metsi esimesest versioonist tunduvalt sarnasemalt eksperthinnangu alusel määratud esinduslikkusklassidesse, lisades omalt poolt sisukaid täpsustusi (tabel 1).

Analüüside põhjal leiame, et kõige optimaalsem on 3-klassiline esinduslikkusastmik ja sobivaimad tunnused on: puistus leitud vanima puu vanus, põõsaliikide ning puurinnete arv, I ja II rinde katvus, lehtpuude arvukas esinemine, häilude ning puuõõnsuste leidumine, vanade elavate ja surnud puude ning igasuguses jämedusastmes ja lagunemisstaadiumis lamapuidu olemasolu. Mõnedes elupaigatüüpides võivad olulised olla ka ajaloolisele tulekahjule viitavad märgid, puistu vanuseline heterogeensus ja puistu või selle ümbruse majandatus. Me veendusime, et seirel tuleb eraldi käsitleda nn maastikulisi tegureid, mis võivad puistu esinduslikkusklassi alandada tema struktuurilisest mitmekesisusest sõltumatult. Meie analüüsi põhjal osutus olulisimaks negatiivseks maastikuliseks teguriks puistu paiknemine fragmendina. Samuti selgus, et täiendavat uurimist ja arendamist vajavad soometsade ning toitainevaesel pinnasel kasvavate metsade struktuuri-indikaatorid.