Scandinavian Journal of Forest Research
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713711862

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Online publication date: 28 July 2010

To cite this Article Timonen, Jonna , Siitonen, Juha , Gustafsson, Lena , Kotiaho, Janne S. , Stokland, Jogeir N. , Sverdrup-Thygeson, Anne and Mönkkönen, Mikko(2010) 'Woodland key habitats in northern Europe: concepts, inventory and protection', Scandinavian Journal of Forest Research, 25: 4, 309 — 324
To link to this Article: DOI: 10.1080/02827581.2010.497160
URL: http://dx.doi.org/10.1080/02827581.2010.497160

Scandinavian Journal of Forest Research, 2010; 25: 309–324

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REVIEW ARTICLE

Woodland key habitats in northern Europe: concepts, inventory and protection

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Abstract
The woodland key habitat (WKH) concept has become an essential instrument in biodiversity-orientated forest management in northern Europe. The philosophy behind the concept is basically the same in all of the countries: to conserve the biodiversity of production landscapes by preserving small habitat patches that are supposed to be particularly valuable. This article reviews the definitions, inventories and implementation processes of WKHs in Sweden, Finland, Norway, Latvia, Estonia and Lithuania. Sweden and the Baltic countries have similar WKH models, while the models in Finland and Norway are clearly deviating. Depending on the country, the definitions emphasize different factors, such as soil and bedrock properties, stand structure and occurrence of indicator species. The mean size of the WKHs varies considerably, from 0.7 ha (Finland) to 4.6 ha (Sweden). The degree of formal protection also differs. Preservation of WKHs is primarily based on forest legislation in Finland, Estonia and Latvia, and on forest certification in the other countries. The implementation of the WKH concept is inconsistent between the countries, resulting in different sets of habitats being included in the WKH networks. This makes direct comparisons between the countries difficult, and may hamper the generalization of research results into other areas.

Keywords: *biodiversity, conservation, forest certification, forest legislation, forest management, production forest.*

Introduction

The traditional approach to nature conservation in northern Europe, as well as in other parts of the world, has been to set aside protected areas as national parks and nature reserves. This process began in the early twentieth century. The current proportion of protected forest area, according to statistics from the Food and Agriculture Organization of the United Nations (FAO), is for Finland 7.2%, Norway 1.5%, Sweden 12.2%, Estonia 6.2%, Latvia 13.6% and Lithuania 8.9% (FAO, 2006). Integration of biodiversity concerns into production forestry became a common practice in the Fennoscandian (Sweden, Finland, Norway) and Baltic (Latvia, Estonia, Lithuania) countries in the mid-1990s, although some of the conservation measures had already been recommended in the Swedish Forestry Act in 1979 (Götmark et al., 2009). The new forestry measures included, for example, green tree retention, prescribed burning, creation of corridors and buffer strips (Larsson & Danell, 2001; Vanha-Majamaa & Jalonen, 2001). Another new conservation component was introduced in the 1990s, namely preservation of small habitat patches called woodland key habitats (WKHs). Today they constitute an essential instrument in the conservation of biological diversity in production forests.

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(Received 11 March 2010; accepted 25 May 2010)

ISSN 0282-7581 print/ISSN 1651-1891 online
DOI: 10.1080/02827581.2010.497160

The main idea behind WKHs is relatively similar in all of the countries: to conserve biodiversity in production forests by delineating and preserving small habitat patches that are supposed to be particularly valuable (of key importance; hence the term key habitat) for maintaining landscape-level biodiversity. These small patches on productive forest land (forests capable of producing a merchantable stand within a defined period) would lose their value if managed similarly to surrounding forests. However, definitions, habitat types included, criteria for delimitation, legal status of WKHs, etc., vary among the countries (e.g. Nitare & Norén, 1992; Aasaaren & Sverdrup-Thygeson, 1994; Gundersen & Rolstad, 1998; Meriluoto & Soininen, 1998; Norén et al., 2002; Prieditis, 2002; Andersson et al., 2003; Gjerde et al., 2004).

Because in Fennoscandian and Baltic countries the majority of forests are privately owned and commercially managed, conservation of biodiversity critically depends on management actions that take place in the production forests, i.e. in areas outside the forest reserves. At present, all Fennoscandian and Baltic countries have national forest legislation, which sets certain minimum standards for conserving biodiversity in production forests, and several countries also have specific definitions and regulations concerning WKHs. More detailed standards for the identification, delimitation and management of WKHs have been included in forest management guidelines and forest certification criteria. Large-scale inventories have been carried out by the forestry and nature conservation authorities to map and delimit WKHs.

The potential differences in WKH definitions and terminologies may cause confusion and misinterpretation when, for example, statistics or research results about WKHs are compared between these countries. This provides the motivation for an overview of the WKH concept, and the aim here is to provide such an overview. The definitions of WKH and their implementation are compared among the countries. The article also reviews, based on national surveys, how the differences are reflected in the types, numbers and extent of WKHs, and in their legal conservation status. Finally, differences in the implementation of WKH systems across the countries, and the relevance and potential pitfalls in introducing the concept outside northern Europe are discussed.

Definitions, habitat types and identification criteria

Definitions

The term woodland key habitat was launched in Sweden in 1990 (Norén et al., 2002) and introduced to a wider audience in 1992 in a special issue of *Svensk Botanisk Tidskrift*, which was dedicated to the preservation of boreal forest in Sweden. According to the original Swedish definition (Table I), a key habitat is an environment (habitat patch) where red-listed species can be expected to occur (Nitare & Norén, 1992). The concept is based on two main assumptions. First, red-listed species do not occur evenly or randomly in the forest landscape but instead are concentrated in certain places. This could be a result of several different factors, including the habitat type, age, structure and continuity of the stand, location within the landscape and land-use history. Secondly, it is possible to identify WKHs based on their structural features and indicator species, and direct observations of red-listed species are therefore not needed (Nitare & Norén, 1992). The Swedish definition has been slightly changed to concentrate less on red-listed species and to give more emphasis to forest structure and history (Norén et al., 2002) (Table I).

The WKH concept was subsequently adopted in other Fennoscandian countries (Finland, Norway) in the mid-1990s, and in the Baltic countries (Latvia, Estonia, Lithuania) in the late 1990s to early 2000s. Essentially, the definitions are similar among the countries (Table I), i.e. WKHs are supposed to be sites where red-listed, rare or specialist species occur or are likely to occur. In Finland, the definition emphasizes permanent structural characteristics and requires that a WKH is in a natural or natural-like state (no or very little signs of human impact). Similarly, the Lithuanian definition underlines the intactness of WKHs (Table I).

The most notable exception is Norway, where two different systems to identify WKHs has been adopted. The first is mapping of nature types according to the method by Directorate for nature management (Direktoratet for naturforvaltning, 1999, 2007), which highlights, in addition to species, rare and vulnerable nature types especially important for biodiversity, and the ecological functions of the sites. This system is established to support municipal land-use planning (Baumann et al., 2002*a*) and is seldom used as a basis for forest management. The second method, the Complementary Hotspot Inventory (CHI) (or the Miljøregistrering i Skog (MiS)) was developed later, and is targeted for use in forestry planning (Baumann et al., 2002*a*; Gjerde et al., 2007). This system aims to identify areas that are particularly important for red-listed species by mapping fine-scale hotspots for 12 habitat types (*livsmiljø*). These habitat types are further classified according to positions along main environmental gradients (productivity and humidity) (Gjerde et al., 2007). The CHI system is used as a basis for nearly

Table I. Woodland key habitat (WKH) definitions in the Fennoscandian and Baltic countries.

Country	Definition	Reference
Sweden	The term WKH is a new concept and refers to habitats (nature types) that are especially valuable from the nature conservation point of view, and where endangered, vulnerable, rare or care-demanding species can be expected to occur. (Translation from Swedish by the authors.)	Nitare & Norén (1992)
	WKH is a forest area which today has a very large significance for forest flora and fauna, on the basis of a collective assessment of the habitat structure, species composition, stand history and physical environment. Red-listed species occur or can be expected to occur there. (Translation from Swedish by the authors.)	Norén et al. (2002)
Norway: Directorate for Nature Management method for mapping of nature types	Selected nature types that are especially important for biodiversity. These are nature types that are especially species rich, rare or vulnerable, have an important ecological function, are habitats for red-listed species, or for other reasons are particularly important for biodiversity.	Direktoratet for naturforvaltning (1999, 2007)
Complementary Hotspot Inventory (CHI)	Fine-scale information on habitats of particular importance for red-listed forest species which are considered vulnerable to impact from forest operations.	Bauman et al. (2002*a*), Gjerde et al. (2007)
Finland	Sites in managed forests that are valuable for biodiversity, and where the occurrence of threatened and demanding species is the most likely. These habitats are natural or natural-like, and they have permanent structural characteristics supporting the species. (Translation from Finnish by the authors.)	Meriluoto & Soininen (1998)
Latvia	An area that contains habitat specialists that cannot sustainably survive in stands managed for timber production. A well-founded expectation that a habitat specialist exists is a sufficient criterion for designating as area as a WKH.	Ek et al. (2002)
Estonia	A forest area with a high probability of the non-accidental occurrence of an endangered, vulnerable, rare or care-demanding habitat specialist species.	Andersson et al. (2003)
Lithuania	An intact forest area with a high probability of a present non-accidental occurrence of an endangered, vulnerable, rare or care-demanding habitat specialist species.	Andersson et al. (2005)

all forest management in Norway. For this reason, further descriptions of the Norwegian system will focus on mostly this method.

Habitat types

The first step in operationalizing the WKH concept is to define those habitat types that can potentially constitute WKHs, provided that they have important structural features and/or indicator species in sufficient amounts. A wide spectrum of habitat types has been included as potential WKHs in the different countries. However, the various habitat types can be divided into seven main groups (see Appendix): (1) edaphic sites, (2) geomorphological sites, (3) hydrological sites, (4) sites based on dominating tree species and successional stage (mainly old stands with long continuity), (5) burned and other young successional stands developing after recent natural disturbances, (6) cultural biotopes, and (7) individual important trees. The first three groups of habitats (1–3) are based on permanent structural features, whereas the last four (4–7) are based on the dominating tree species in combination with changing successional features, i.e. on the age, continuity, disturbances or former land use of the site.

Sweden has the most extensive list of described habitat types: 51 different habitats were defined in the latest version of the inventory manual (Norén et al., 2002). The number of described forest or woodland-connected habitat types in the other countries ranges from 12 in Norway to about 30 in the remaining countries (see Appendix). Some of the habitat types cover narrow ecological gradients, and are easily distinguishable and generally small, such as spring-influenced forest or alder wetland forests. Some other habitat types cover wide ecological gradients, are common and can not be identified as WKHs based on the habitat type alone. For instance, "coniferous forest" is one habitat type in both Sweden and Latvia. However, sites included in this habitat type must be naturally regenerated (not planted), mature stands that have not been recently silviculturally treated.

Habitat types based on permanent structural features are included in WKH definitions in all the countries. Habitat types common to all of the countries include edaphically exceptional sites such as calcareous forests and calcareous eutrophic fens; geomorphologically or topographically outstanding sites such as gorges, ravines, steep bluffs and slopes; and hydrologically particular sites such as

surroundings of springs, streams, and different kinds of alluvial and other wetland forests (see Appendix).

Despite the similarities, there are also clear differences among the countries in the types of habitats that can be classified as WKH. The differences are most pronounced in WKHs based on successional and temporal elements. Finland lacks habitats based on disturbances (burned forests, etc.), whereas Latvia lacks habitats based on former cultural influence. Furthermore, the WKHs defined in the Finnish Forest Act only encompass habitats that are based on permanent edaphic, topographic or hydrological features. The Norwegian CHI system deviates somewhat from the other mapping systems. In this system, 12 main habitat types are described, but most of them are classified and ranked solely based on the density of habitat elements (see below).

Identification criteria

The second step in operationalizing the WKH concept is to define criteria on which the identification of WKHs is based, i.e. how WKHs can be distinguished from habitats lacking the key habitat quality. In all the countries the identification of WKHs is based on criteria that fall under three main categories: (1) stand-level structural features; (2) occurrence of individual habitat elements; and (3) occurrence of indicator species. Stand-level structural features describe the whole stand, e.g. as being uneven-aged, flooded, grazed, etc. These features are often obvious but difficult to quantify. In contrast, individual habitat elements, such as old living trees, snags and logs, can be measured, and their amounts can be expressed as numbers per hectare (Table II).

The numbers, names and hierarchical classification of the structural features and habitat elements that are used in identifying WKHs vary among the countries. Sweden has by far the most extensive lists of stand-level structural features (called key words at the biotope level) and habitat elements (key elements). Furthermore, to be able to describe key elements in more detail, it is possible to use key words at the level of individual key elements (e.g. tree cavity, fire scar, sun-exposed). In the Swedish system, as many as 79 key words at the biotope level, 61 key elements and 50 key words at the level of individual key elements are available (Norén et al., 2002). From each WKH it is possible to record a maximum of eight key words at the biotope level, eight key elements with their rough frequency (sparse, relatively common, abundant) and additionally four key words at the key element level for each element. In addition, minimum criteria for different types of key elements are given (e.g. a table of minimum diameters for different tree species in southern and northern parts of the country, a minimum of 10 cm diameter for logs).

The systems in Latvia, Estonia and Lithuania are almost identical to each other (Andersson & Kriukelis, 2002; Ek et al., 2002; Andersson et al., 2003). In each country, slightly over 10 stand-level structural features and slightly over 10 habitat elements (both categories called collectively "key elements") are available. The frequencies of individual key elements fulfilling the minimum diameters (25 cm for logs, 15 cm for snags) are estimated using a rough classification (1–5, 6–10, >10 per hectare).

The Finnish system differs from the previous ones in that no exhaustive list of habitat elements is presented in WKH guidebooks (Meriluoto & Soininen, 1998) or in inventory manuals (Soininen, 1996). Instead, examples of structural features and habitat elements (collectively called characteristic features) are listed in the descriptions of the different WKH types. Nevertheless, the characteristic features are practically identical to the stand-level structural features and habitat elements in the Swedish and Baltic WKH systems. The total volume of fresh and decayed snags and logs of different tree species is estimated at the accuracy of 1 $m^3\,ha^{-1}$ classes (Yrjönen, 2004).

Table II. Examples of stand-level structural features and individual habitat elements that are used in identifying woodland key habitats.

Types of structural features and habitat elements	Stand-level structural features	Habitat elements
1. Edaphic	Calcareous soil	
2. Geomorphological	Steep slope, boulder field, glaciofluvial formation	Rock wall, rock shelf, boulder
3. Hydrological	Spring influence, flooded, moist microclimate	Stool, spring, stream, dribble
4. Stand structure	Varying age, uneven structure, woody debris of many decomposition stages, signs of fire	Large old tree (tree species separately), cavity tree, hollow tree, snag, log (tree species separately), high stump
5. Cultural	Grazed, mowed	Old stone fence, pollarded tree
6. Other biological features	Rich in pendulous lichens, rich in wood-decaying fungi, signs of beaver activity	Large wood-ant nest, large nest of raptor or stork

Note: References: Soininen (1996), Meriluoto & Soininen (1998), Andersson & Kriukelis (2002), Andersson et al. (2003), Baumann et al. (2002*a*), Ek et al. (2002) and Norén et al. (2002).

The Norwegian CHI system recognizes 12 different habitat types. Conceptually, these include both stand-level structural/edaphic features (e.g. burned forest, rich ground vegetation) and individual habitat elements (snags, logs, old trees, hollow trees). Each of the 12 habitats can occur in different site types, further classified according to the main environmental gradients, *moisture* (based on vegetation type and topography) and *nutrients* (based on the occurrence of coniferous or deciduous trees). The habitats are identified and delineated according to stand-level structures or following the area with sufficient density of habitat elements. When several habitat types occur in the same location, partly or completely overlapping polygons can be drawn. Later, habitats belonging to the same habitat type are sorted and ranked based on a weighed (e.g. snags are given more weight according to their diameter class) density index (see further details on the ranking procedure in Baumann et al., 2002*b*).

There is no upper size limit to WKHs in the Swedish, Norwegian or Baltic systems. A WKH can range in size from a single large tree to a forest area covering tens of hectares (Andersson & Kriukelis, 2002; Ek et al., 2002; Norén et al., 2002; Andersson et al., 2003). In the Norwegian CHI system, the minimum size for a delineated habitat (and thus, for a WKH) is 0.2 ha, except for hollow trees that are handled as points (Baumann et al., 2002*a*). In contrast to the other countries, an upper size limit of 1 ha has been generally used in the Finnish WKH definitions and inventory projects (Soininen, 1996; Yrjönen, 2004; Kotiaho & Selonen, 2006).

Indicator species have been used in the identification of WKHs in all the countries, but the emphasis on structural elements versus species has varied among the countries. In the WKH context, the term indicator species has been used for more or less specialized species that have rather high demands for their living conditions. They are supposed to occur mainly in WKHs, sometimes abundantly, but they can sometimes be found also in other habitats. Occurrence of an individual indicator species alone is not enough to determine a site as a WKH, but abundant occurrence of an indicator species together with other indicator species and habitat elements indicates that a site is a WKH, and it should also be possible to find threatened habitat specialist species there (Andersson & Kriukelis, 2002; Ek et al., 2002; Andersson et al., 2003).

The lists of indicator species include vascular plants, bryophytes, lichens, fungi (mainly polypores and other wood-decaying fungi), insects (mainly saproxylic beetles) and molluscs. The numbers of listed indicator species vary from 212 in Latvia to 461 in Sweden. For instance, the Swedish list of indicator species (called signal species) includes a total of 84 vascular plants, 55 species of bryophytes, 107 species of lichens, 185 species of fungi and 30 species of insects. The Norwegian CHI system does not use indicator species in this way. Instead, it uses structural features supplied with a few characteristic species consistently found within a specific habitat type to classify sites (Gjerde et al., 2007).

Mapping and delimitation

Mapping and delimitation

Soon after the WKH concept had been defined and the WKH types had been described, large-scale WKH mapping projects were carried out in each of the Fennoscandian and Baltic countries. The projects were performed by the respective forest authorities in both private and state-owned forests (Norway, Estonia, Lithuania), only in private forests (Sweden, Finland) or only in state-owned forests (Latvia) (Table III). In Finland and Sweden, WKH inventories in state-owned forests were conducted by the state forest management organizations (Metsähallitus and Sveaskog, respectively), and the large forest companies (Stora-Enso, UPM-Kymmene, etc.) inventoried their own forests. In contrast to the other countries, WKHs have not been mapped in private forests in Latvia. Put together, the WKH inventories in the Fennoscandian and Baltic countries have been among the most extensive conservation mappings conducted in forests anywhere. Most forestland in each country, more than 50 million ha in total, has been covered (Table III.). The total budget of the inventories in Sweden and Finland alone was about €30 million and involved about 100,000 working days.

The inventory procedures for locating, identifying and delimiting WKHs were similar in all countries, with the exception of Norway. The work usually started with the collection of information from aerial photographs, satellite pictures, forest management plans, historical maps, records of red-listed species and species surveys with the purpose of locating sites that possibly contain WKHs. Local knowledge was obtained by interviewing experts on different species groups, nature societies and other non-governmental organizations. Based on this prior information, potential WKH sites were marked on the map. The selected sites were then surveyed in the field, and if they fulfilled the WKH criteria they were delimited and described using the field forms and protocols described in the inventory manuals. The data were then stored in specific databases.

Table III. Implementation and extent of woodland key habitat mapping projects in the different countries.

	Sweden	Finland[d]	Norway[f]	Latvia[h]	Estonia[i]	Lithuania[j]
Commissioned by	Swedish government[a]	Ministry of Agriculture and Forestry	(a) DN method: Directorate for Nature Management; (b) CHI: Norwegian Ministry of Agriculture		Regional Forestry Board of Östra Götaland, Sweden and the Estonian Ministry of the Environment	Lithuanian Ministry of Environment and the Regional Forestry Board of Östra Götaland, Sweden
Inventories co-ordinated by	Swedish Forest Agency for small private forest owners, Sveaskog for state-owned forest. Forest companies and other large forest owners are responsible for conducting their own inventories[a]	Regional Forestry centres co-ordinated by Forestry Development Centre Tapio for private owners, Metsähallitus for state-owned forest	(a) Each municipality/ Directorate for Nature Management; (b) private companies carrying out resource mapping and making management plans for forest owners	State Forest Service of Latvia, the State Joint Stock Company (Latvijas valsts mezi) and the Regional Forestry Board of Östra Götaland, Sweden, for state-owned forests		State enterprise Lithuanian Forest Inventory and Management Institute
Main period of inventories	1993–1998,[a] 2001–2003[b]	1996–2004	(a) 1999–2007 (but supplements in progress); (b) 2001–2015 (the planning horizon)	1997–2003	1999–2002	2001–2005
Total area covered by the inventories (ha)	22,400,000 (all productive forestland)[c]	21,800,000 (all forestland)	(a) All land area; (b) not completed, but aim is ~6 million ha (all economically productive forest land)[g]	1,523,500	2,020,600 (all the forests except for strictly protected forest and areas covered by EFCAN project)	2,043,928 (all forestland except for strictly protected forests)
– State-owned land	4,100,000	4,800,000[e]		1,500,000		
– Private land	12,600,000	15,000,000[e]				
– Company land	5,700,000	2,000,000[e]		23,500		
Total budget of the mapping project	€13 million[a]	€16.5 million (private forests)	(a) €5590 by 2007;[g] (b) mean: €4–5 ha^{-1} by 2007, which will sum to ~€27 million if costs remain similar[g]			
Total working days used		38,500			14,800	

Note: References: Sweden: [a]Axelsson & Norén (2003), [b]Skogsstyrelsen (2004), [c]Official Statistics of Sweden (2008); Finland: [d]Yrjönen (2004), [e]Yrjönen (2006); Norway: [f]Baumann et al. (2002*a*), [g]Gaarder et al. (2007); Latvia: [h]Bermanis & Ek (2003); Estonia: [i]Andersson et al. (2003); Lithuania: [j]Andersson et al. (2005).

In Norway, the CHI inventory is integrated in the forest resource inventory that constitutes the basis of forestry planning. The CHI inventories cover most forest owners because a WKH inventory is requirement for forest certification, and CHI is the dominant method used. The CHI inventories are only carried out in the two oldest age classes of forest (out of five) and only in productive forest. This is a precautionary principle for finding and safeguarding the habitats that should be exempted from final felling (Baumann et al., 2002*c*). There are two main phases in the CHI procedure. First, the old, productive forest on almost all commercial forest land within a planning unit is inventoried for MiS habitats. Stands are then ranked based on the number and quality of CHI elements. Final selection of WKHs is made through negotiations among forest authorities, forest owners and a person with competence in biology. Thus, selection of WKHs in Norway is not based solely on ecological values, but rather on several aspects including economic considerations.

There are notable differences in the accessibility of the WKH mapping data among the countries. In both Sweden and Norway, the data are publicly available in interactive Geographical Information System (GIS) databases over the Internet (see http://www.skogsstyrelsen.se/, http://www.skogoglandskap.no/) and therefore easily accessible for different purposes (only in an aggregated form for Norway). In Latvia, the WKH database has been connected to the general database of forest resources to ensure the protection of WKHs (Bērmanis & Ek, 2003), available for forest and environmental authorities. In Estonia, the data were entered into the national database and distributed to different users (Andersson et al., 2003). In Lithuania, the State Forest Survey Service is responsible for the WKH database as part of the forestry database (Andersson et al., 2005). In Finland, in contrast to the other countries, the data are available only to the Forestry Centres and the forest owners (under the administration of the Ministry of Agriculture and Forestry), but not, for example, to environmental authorities (under the administration of the Ministry of Environment) or the public.

Woodland key habitat subcategories

Mapping resulted in different categories of WKHs based on either the ecological quality of the site alone, or on both the quality and formal conservation status of the site. In all the WKH mapping projects, the sites that were assessed as possible WKHs based on prior information were visited. If the habitat fulfilled the criteria, it was designated as a WKH. If the criteria were not quite met but the habitat still contained nature values it could be designated as a potential woodland key habitat (below: PWKH) (called an object with nature values in Sweden and other valuable habitat in Finland) in all the mapping projects except in Norway. The general idea in designating PWKHs was that given some time they would reach the WKH quality. The PWKHs were not specifically looked for in the inventories but they were marked on the map, described and stored in the databases when encountered.

The Finnish WKH mapping project differed from the other mapping projects in that only those habitat types defined in the Finnish Forest Act (Forest Act habitats (FAHs); see Appendix) were searched for and registered in the database. Furthermore, to qualify as an FAH, the site had to meet three criteria: to be in a natural or close-to-natural state, to be clearly distinguishable from its surroundings and to be small in size. Small size is not clearly defined in the Act or its statutes, but in general, FAHs had to be smaller than 1 ha (Soininen, 1996; Yrjönen, 2004; Kotiaho & Selonen, 2006). Sites that were larger than 1 ha, or that were not clearly distinguishable from the surroundings, could be classified as "other valuable habitats" (PWKHs) even if they fulfilled other criteria for a WKH. Other WKH types (see Appendix) defined in the Nature Conservation Act or described in the key habitat guides (e.g. Meriluoto & Soininen, 1998) have not been mapped, but they are identified and registered during ordinary forest management planning.

In the Norwegian CHI system, the habitats are ranked and a subset is prioritized as WKHs. The non-prioritized habitats, usually of poor quality, are not considered as WKHs but information on their location is still kept by the forest authorities.

Conservation status

The conservation status and means of protecting WKHs and different subcategories of WKHs vary greatly among the countries. In principle, protection can be based on forest legislation, forest certification or forest management guidelines (Table IV).

Legislation

WKHs have been included in the forest legislation in three countries: Finland, Estonia and Latvia. The Finnish Forest Act defines a list of habitat types that can be considered FAHs (see Woodland key habitat subcategories, above, and Appendix). According to the Forest Act, FAHs should be preserved even if they were not recorded and delimited in the mapping project. In principle, a forest owner may be fined if the characteristic features of FAHs are altered or

Table IV. Conservation status and area ha (number) of WKHs in the different countries.

Country	Protection of WKHs by legislation	Coverage of certified forest[a] (ha)	No. of sites	Mean size of WKHs (ha)	Total area of WKHs (ha)	WKHs[b] (% of total forest land)	Comments (references)
Sweden		PEFC (7,436,751); FSC (10,526,510)	81,900	4.63	379,200	1.3	Official Statistics of Sweden (2008)
Finland	Forest Act	PEFC (= FFCS) (20,806,165); FSC (9706)	111,357	0.67	128,371 74,371 43,000 11,000	0.6	Total (Yrjönen, 2006) Private land State-owned land Company land
Norway	Forest Act	PEFC (7,500,000); FSC (72,100)[e]	(a) 9374[c]; (b) 28,630[d]	(a) 21.3[c]; (b) 1.05[d]	(a) –; (b) 30 087[d]	(a) –; (b) 1.5[c]	(a) The numbers relate the WKHs in forest only. (b) The numbers reflect reported data on WKHs for less than the total forest area
Latvia	Forest Act	PEFC (= ESSFM & National Forest Standard) (0); FSC (1,620,915)	31,000	2.10	51,000	1.7	Ek & Bērmanis (2004)
Estonia	Forest Act	PEFC (0); FSC (1,083,157)	5455	2.90	15,852	0.7	Andersson et al. (2003)
Lithuania		PEFC (0); FSC (998,461)	5609	3.21	18,000	1.2	Andersson et al. (2005)

Note: [a]FSC (2010), PEFC (2010); [b]forest land area numbers for all of the countries (except for Norway) are from the Finnish Statistical Yearbook of Forestry (2007); [c]Gaarder et al. (2007); [d]Svein Olav Moum (Norwegian Forest and Landscape Institute, personal communication, May 2010); [e]B. M. Eidahl, personal communication, June 2010.

destroyed during forest management operations. However, minor management such as selection felling (selectively felling some of the trees, such as mature, economically valuable trees) and planting of trees can be permitted. If FAHs incur a substantial economic cost the forest owner can be compensated for this loss.

The Estonian Forest Act lists 10 different WKH types as examples, but the list of habitat types is not meant to be exhaustive (Anon., 2010*a*). Protection of WKHs in privately owned forests should be established through a contract between the forest owner and the Forestry Board. The contract shall specify the obligations of the owner in protecting a WKH, and obligations of the state to compensate any additional costs that are caused by the maintenance of biological diversity and by the restrictions on forest use arising from the contract. Management is possible, but the key elements of the WKH such as old trees and springs shall be maintained. WKHs in the state forests are protected by the law (Anon., 2010*a*).

The Latvian Forest Act states that specially protected forest areas, microreserves, shall be singled out in the forest. WKHs have a legal microreserve status provided that the habitat has been identified following the microreserve methodology (Bērmanis & Ek, 2003) which is fully compatible with the WKH mapping methodology (Ek et al., 2002). The important structural features (forest components of special importance) need to be preserved in management of the microreserves.

In Sweden, the Forest Agency has also the possibility to protect legally a WKH as a biotope protection area (based on the Swedish environmental legislation), but the funding is limited and thus only a small subset can be considered. If a WKH is legally protected, a permanent contract of protection is made and the forest owner is compensated for the loss in income from the forest, but the ownership of the land except for the trees remains unchanged. Conservation agreements for biodiversity-orientated management of WKHs can also be established between landowners and the Forest Agency, commonly running for 50 years, and with rather low levels of economic compensation for production losses. In Norway, the regulations of the Forestry Act state that the values in important habitats and WKHs must be safeguarded, and refer to the forest certification standards addressing this issue (Anon., 2010*b*).

Forest certification

The Forest Stewardship Council (FSC) has developed a concept, called high conservation value forest (HCVF) under which WKHs are protected (Anon., 2010*c*). The classification of HCVFs is dependent on the particular country. The Programme for the Endorsement of Forest Certification (PEFC) also

develops national certification standards that set the criteria for the protection of WKHs. Different forest certification standards are in use in Fennoscandian and Baltic countries and all the standards include criteria concerning WKHs, but the degree of protection of WKHs varies among the countries and certification standards (Table IV).

In Sweden, two certification systems are in use: FSC certification covering about 45% (10.5 million ha) and PEFC about 35% (7.9 million ha) of the productive forestland. Several forest owners are certified according to both systems, and thus figures on covered areas cannot be summed. According to the FSC certification standard WKHs are not to be logged. According to Swedish PEFC the forest owners must set aside 5% of their property and prioritize WKHs in doing so, but for WKH proportions above that, there is no obligation for voluntary protection. When a WKH has been found in the inventory the forest owners are informed and advised on how to maintain the nature values of the habitat, which usually, but not always, implies total exclusion from forest management (Axelsson & Norén, 2003). A large number of private forest owners in Sweden have established green forestry plans, in which a minimum of 5%, and often as much as 10–15%, of the productive forestland is set aside voluntarily for conservation purposes. Since priority is given to WKHs, such plans form an important instrument for their preservation.

In Finland, 95% of the forest land is certified by Finnish PEFC (FFCS), and FSC is used only marginally (Anon., 2010*d*). New FFCS criteria revised in 2005 set no requirements for the proportion of set-asides, but acknowledge WKHs and state that the main characteristics of WKHs should be maintained. The current FFCS standard does not acknowledge PWKHs ("other valuable habitats"), unlike the forest certification criteria prior to 2005. As a consequence, 150,000 ha of potentially valuable forests were excluded from FFCS. FFCS also sets the maximum size of 1 ha for WKHs even if the sites are larger than this. It is not required to maintain the exceeding WKHs if the total percentage of WKHs is more than 5% of the forest owner's total forest area. The latest PEFC standard criteria are currently under evaluation (Anon., 2010*e*).

More than 95% of the commercially productive forests in Norway are certified by the PEFC-endorsed Living Forests Standard (www.pefcnorge.org). This standard requires conservation of WKHs (Anon., 2010*f*), which should be left untouched or managed in a way that does not deteriorate the biodiversity qualities. Management is accepted if it improves the biodiversity qualities (Anon., 2010*d*). Private forest owners can apply for compensation if they have a high proportion of WKHs on their estate or offer aggregations of WKHs for possible voluntary protection as a nature reserve (Skjeggedal et al., 2010).

The Estonian Standard on Sustainable Forest Management (ESSFM), part of the FSC system, prescribes the protection of WKHs (Andersson et al., 2003). ESSFM requires also that the forest owner ensures preservation of WKHs. Key habitats should be managed according to forest management recommendations provided in the forest management plan (Anon., 2010*g*).

In Latvia, the FSC is the dominant system (Bērmanis & Ek, 2003). All the state-owned forests are certified according to the FSC. The Latvian National FSC Standard includes WKH inventory and protection.

In Lithuania, the majority of WKHs are protected voluntarily as a result of the requirement of the FSC standard (Andersson et al., 2005) (Table IV). FSC requires that 5% of the biologically valuable forest area should be protected. Since 2005 the conservation of WKHs has been under discussion without a solution. Some of the WKHs are protected by including them on the list of Natura 2000 habitats (D. Stoncius, personal communication, 31 March, 2009). There is a fairly large variation in how different state forest enterprises protect WKHs. Some of them protect voluntarily only the WKHs that have no great economic value or that are very clearly special sites. Others, however, have agreed to protect also newly identified WKHs. Private forest owners are, in principle, able to obtain financial compensation for not logging WKHs in Natura 2000 sites. Nevertheless, there is large variation in how WKHs are implemented on private land, and even in the protected areas the WKHs may still be logged (D. Stoncius, personal communication 31 March, 2009).

Numbers and area of woodland key habitats in the different countries

The number of WKHs varies from about 5500 in Estonia and Lithuania to more than 100,000 in Finland (when only the WKHs protected by the Forest Act, FAHs, are considered) (Table IV). The mean size of WKH sites varies considerably, from about 0.7 ha in Finland to 4.6 ha in Sweden. The total area of WKHs also varies considerably, from less than 16,000 ha in Estonia to close to 400,000 ha in Sweden. In Norway, the CHI inventory is still in process, and total numbers are not available yet. In 2007, 4 million ha was completed or ongoing, while another 2 million ha remained (Gaarder et al., 2007). Preliminary results indicate that average size is 1.05 ha (S. O. Moum, Norwegian Forest and

Landscape Institute, personal communication, May 2010; see also Table IV).

The proportion of WKHs of total forest land varies from 0.6% in Finland (only legally protected FAHs included) to 1.7% in Latvia (Table IV). The coverage of PWKHs varies from 0.1% in Estonia to close to 0.4% in Finland, Latvia and Lithuania.

Assuming an even distribution in space, Latvian WKHs comprise a dense network (20 WKHs 1000 ha^{-1}) of rather large WKHs (mean >2 ha), while the Finnish system results in a network of small sites of intermediate density (~ 5 WKHs per 1000 ha of forest land). In other countries, the density is less than 4 WKHs 1000 ha^{-1}.

Control inventories and mapping efficiency

A control inventory of WKHs in Sweden was conducted in 2000 by the Swedish Forest Agency. An audit conducted in 489 study areas of 100 ha revealed that only 22% of the WKHs found during the control inventory were registered as WKHs during the original inventory (Hultgren, 2001). This implies that both the area and number of WKHs could be five times larger in Sweden than previously found in the original inventory (Hultgren, 2001). This caused the Forest Agency to intensify the inventories in areas believed to be especially in need of improvement.

In Finland, a control survey was conducted as a part of a habitat-mapping project (Yrjönen, 2004). One or two 500 ha areas were selected each year from the mapping area, and these areas were surveyed completely (i.e. all stands were visited). The survey suggested that about 80% of the FHAs had been found during the original inventory in Finland (Yrjönen, 2004). Conclusions based on these control surveys can be criticized, however, since the field staff were allowed to familiarize themselves with the background material and results of the original inventory, and thus the control survey was not an independent audit of the original inventory (Kotiaho & Selonen, 2006). Recording of WKHs was also included in the 9th Finnish National Forest Inventory, which was performed in 1996–2003. The results suggest that WKHs as defined in the Forest Act cover about 1.7% of the total forest area in southern Finland (Finnish Statistical Yearbook of Forestry, 2003), which is over six times more than was recorded in the WKH inventory.

So far, no general evaluation of the results of the CHI inventory in Norway has been conducted, as the inventory is still in progress. Still, some case studies have been conducted in areas where environmental values in forests have been mapped with both the Directorate for nature management method (DN 2007; also see above) and the CHI method. The results suggests that CHI coverage of all assumed WKHs lies between 25 and 70% and varies a lot between regions in Norway. Another summary, focusing on all nature types (not only in forest) and mapped with the Directorate for nature management method (Gaarder et al., 2007), concluded that only 20% of the total assumed WKHs have been mapped so far. An overall summary of CHI results and a comparison with national representative data will be conducted in 2010 (S. Søgnen, Norwegian Forest Owners' Federation, personal communication, March 2010).

In Latvia, several audits have been carried out to determine the accuracy of the inventories performed by different surveyors. The results from an audit conducted for the full-scale inventory in 1999 showed that 60% of the WKHs and 44% of the PWKHs were found (Bērmanis & Ek, 2003). In 2001 an audit was carried out in sample areas of 150 ha in 10 forest districts. The areas were first inventoried by the surveyors, and the auditors were not informed about the inventory results. The results of this audit suggest that 65% of WKHs and 45% of PWKHs had been found by the surveyors (Lārmanis, 2001). If the results from the different audits are combined it shows that on average 60% of the WKHs and 55% of the PWKHs have been found by the inventory (Bērmanis & Ek, 2003).

In Estonia, an audit conducted during the pilot phase of the inventory revealed that 42% of the WKHs were identified (Andersson et al., 2003). However, a full-scale audit to predict the accuracy of the whole inventory has not been performed.

In Lithuania, an audit has been carried out by the Lithuanian Fund for Nature and the Lithuanian Forest Research Institute. The auditors visited mostly randomly selected compartments which were on average 100 ha each. Each compartment consisted of subcompartments that were walked through to detect the WKHs. The auditors did not have prior information about the WKHs that were designated previously by the surveyors during the initial inventory. The result of the audit showed that surveyors had found 60% of the (P)WKHs (Andersson et al., 2005). Based on the audit it can roughly be estimated that 50% of the (P)WKHs have been mapped in Lithuania (Andersson et al., 2005).

Discussion

The ultimate motivation for WKHs is to maintain biodiversity in commercially managed forest landscapes. WKHs are assumed to represent natural hotspots in the landscape with either high species richness (richness hotspots) or concentrations of rare

specialist species (rarity hotspots). Setting aside such hotspots may provide a cost-efficient way to reconcile the needs to produce timber for industry and to preserve viable species populations, but scientific evidence of their efficacy is still largely missing (but see Laita et al., 2010).

Even though the original rationale has been rather similar in the Fennoscandian and Baltic countries, WKH systems differ slightly in their definitions. The implementation of the WKH concept is nationally and regionally variable, and susceptible to personal and communal subjectivity. In all countries, the processes of WKH identification and delineation have failed to map a comprehensive proportion of WKHs fulfilling the national criteria. According to control surveys this underestimation is most severe in Finland and Sweden, where a majority of WKHs may have gone unnoticed. In the Baltic states more than half of WKHs seem to have been mapped during the inventories. In Norway, no evaluation of the CHI results has yet been conducted, but preliminary case studies suggest that there are WKHs that have not been intercepted by the inventory. These results suggest that the field inventories need improvements, and more emphasis should be placed on training the field personnel so that surveys are conducted in a sound and consistent way. Inadequate implementation may seriously undermine the ecological efficiency of the WKH policy.

The efficiency of the WKH policy also depends on the conservation status of the habitats. If the protection is based on the goodwill of the forest owners and recommendations by forest authorities, their persistence and ability to retain biodiversity are uncertain. Forest certification provides a vehicle to reduce this uncertainty as it usually prescribes that WKHs shall be preserved. Alternatively, uncertainty could be reduced by the legal status of WKH, in which case sanctions can be applied against forest owners if WKHs are damaged by logging or other land use. Further, the efficiency of a WKH policy depends on how well ecological values are maintained or enhanced in WKHs once they have been recognized. This critically hinges on the forestry measures both in the WKHs and in their immediate surroundings. Usually the best management in WKHs is no management. However, some WKH types need management to maintain their characteristic features; for example, it may be necessary to remove spruce from deciduous stands. There is much variation among the countries in the degree of protection of the WKHs and in permissible forestry measures.

In Finland, Estonia and partly in Latvia, WKHs are protected by national legislation, and forest owners failing to set aside WKHs can be fined. The legal status covers both privately owned and state-owned forests. In the other countries, WKHs are mostly protected by means of forest certification and to some extent by voluntary decisions.

In Sweden, the landowner is obliged to consult with the Swedish Forest Agency before performing logging, even if it is selective, in a WKH. If clear-cutting is planned and the consultation does not result in an agreement of voluntary protection, there is the possibility that the authority will formally protect the area, but the budget for this is very limited. Thus, at present some WKHs are being finally felled. However, forest owners certified according to the FSC have committed themselves not to log WKHs, and since 45% of all productive forestland is under FSC certification, this results in considerable amounts of WKHs being set aside. Further, the large forest companies, and also the forest owners' association Södra, with 52,000 associated private forest owners, do not accept logging contracts that imply logging in WKHs. The PEFC certification standard is less strict since it only protects WKHs up to a maximum cover of 5% of the productive forest land of a property. An environmental target set by parliament is that between the years 2000 and 2010 30,000 ha WKHs shall be protected as biotope protection areas. This process, which is the responsibility of the Swedish Forest Agency, is running behind schedule, and up to 2010 only about 17,000 ha had been established.

In Finland, it is permissible to take minor forestry measures if they do not alter the special characteristic features of the site. Forestry measures (selective felling) in the WKH itself, however, may cause severe reduction in ecological values even if primary features such as soil properties are not altered. Selective felling, for example, may considerably decrease the amount of or quality of dead wood immediately (physical damage to existing dead wood) or with time lags (reduced tree mortality). Nevertheless, according to recent forest management audits, 90–94% of all WKHs were totally or almost totally preserved in cutting operations during the 2000s (Kuusinen, 2006).

Norwegian WKH policy involves negotiations among forest owners, forestry authorities and biologists in the selection of the WKHs for protection. This may result in a suboptimal WKH network from an ecological perspective as some valuable sites may become excluded. However, negotiations engage different stakeholders in the process and may result in reduced resistance by landowners, which often bedevils traditional obligatory approaches such as government compulsory acquisition of land (e.g. Wätzold & Schwerdtner, 2005; Götmark, 2009). Judging from case studies, nearly all the mapped

high-quality WKHs have been set aside for protection (Sverdrup-Thygeson et al., 2009).

In Estonia and Latvia the principle is to leave WKHs outside forest activities (Andersson et al., 2003; Bērmanis & Ek, 2003). Furthermore, in Latvia, buffer zones and management actions that will conserve or increase biological values are recommended (Anon., 2005).

Regardless of the common conceptual background, the practical implementation of WKH policy has been variable among the countries. This has resulted in varying degrees of forest land being set aside as WKHs, rather different sets of habitat types being included in the WKH networks, and variable conservation status of the assigned WKH sites. Therefore, networks formed by the WKHs are likely to have varying ecological effects in the different countries. It is clear that WKHs alone are insufficient in retaining viable populations of all species in the landscape because the total area protected in WKHs is limited in all countries, not all habitat types are adequately covered by WKHs and there is some uncertainty involved concerning the persistence of WKH sites.

For example, the Finnish WKH policy provides rather stringent conservation status for WKHs, which seem to comprise a rather sparse (5 WKHs $1000\,ha^{-1}$) network of small sites (mean size 0.7 ha). The Finnish requirement that a WKH should be clearly distinguishable from its surroundings effectively excludes common habitat types such as heath forests. Therefore, WKHs do not provide much habitat for species associated with typical boreal coniferous forest. By contrast, the Swedish based system by definition aims at providing habitats for red-listed species irrespective of their habitat associations, and yields considerably larger habitat patches (mean 4.6 ha). The Norwegian CHI system aims at encompassing the whole spectrum of habitat types existing in the landscape in a complementary way. Therefore, comparisons and conclusions based on the WKH numbers should be made with caution since there are differences among countries in included habitat types and WKH subcategories.

Owing to the relatively small size of WKHs, edge effects are likely to affect their ecological quality (e.g. Moen & Jonsson, 2003; Aune et al., 2005). Thus, they may require buffer zones to retain their species, tree and stand structures. In addition, selective felling, if allowed, may severely decrease the ecological quality. More research is needed to reveal how much selective felling WKHs can sustain.

The original impetus for the WKH concept was to save the last woodland remnants with natural forest characteristics and their associated biodiversity. This is an evident priority in regions where the forests have been intensively managed for timber production for decades or even centuries, resulting in a high degree of fragmentation of the remaining high-quality patches. WKHs seem to improve the connectivity of naturally rare and scattered habitat types and they may be a more efficient tool to conserve scattered habitats than large reserves (Laita et al., 2010). However, applying the WKH approach to other forest landscapes where human land-use history differs from that in the Fennoscandian or Baltic countries should be done with caution. In particular, it may be more relevant to set aside large protected areas in regions where larger compartments of intact forests remain under natural-like dynamics. However, small areas such as WKHs could form important complementary areas in most types of forest landscape.

Acknowledgements

We thank L. Andersson, I. Angell-Petersen, T. Ek, I. Gjerde, S. Ikauniece, J.-E. Nilsen, J. Nitare, S. O. Moum, F. Rune, S. Saudyte, S. Søgnen, D. Stoncius and B. Thor for valuable information. This research was conducted as part of the Finnish Environmental Cluster Research Programme funded by the Ministry of the Environment. Comments from P. Kuokkanen, T. Lehesvirta, A. Otsamo A.-L. Ylisirniö and an anonymous referee are greatly acknowledged. We are also grateful to the Academy of Finland (project no. 7115560) for funding.

References

Aasaaren, Ø. & Sverdrup-Thygeson, A. (1994). *Nøkkelbiotoper i skogen* [Key habitats in forest]. Oslo: Norskog.

Anon. (2005). *Management of woodland key habitats in Latvia. Final report*. Riga: State Forest Service, Joint Stock Company & Regional Forestry Board of Östra Götaland.

Anon. (2010*a*). Estonian Forest Act. Retrieved February 25, 2010, from http://faolex.fao.org/docs/texts/est34231.doc

Anon. (2010*b*). FOR 2006-96-97 nr 593: Forskrift om berekraftig skogbruk. http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20060607-9593.html (In Norwegian) [accessed 21 May 2010]

Anon. (2010*c*). *FSC and biodiversity*. Retrieved February 25, 2010, from http://www.fsc.org/152.html

Anon. (2010*d*). *PEFC Finland's Annual Report 2008*. Retrieved February 25, 2010, from http://www.pefc.fi/pages/en/pefc-finland/annual-reports.php

Anon. (2010*e*). *PEFC Standard Revision in Finland 2008–2009*. Retrieved February 25, 2010, from http://www.pefc.fi/pages/en/news/standard-revision-2008-99.php

Anon. (2010*f*). *The Living Forest PEFC Forest Management Standard*. Retrieved February 25, 2010, from http://www.levendeskog.no/levendeskog/vedlegg/51Levende_Skog_standard_Engelsk.pdf

Anon. (2010*g*). *Estonian Forest Certification Standard*. Retrieved February 25, 2010, from http://www.eramets.ee/static/files/332.eng6_pfc2_1_forestcert%20standard.doc

Andersson, L. & Kriukelis, R. (2002). *Pilot woodland key habitat inventory in Lithuania. Final report*. Vilnius: Forest Department, Ministry of Environment, Lithuania; Linköping: Regional Forestry Board of Östra Götaland.

Andersson, L., Kriukelis, R. & Skuja, S. (2005). *Woodland key habitat inventory in Lithuania.* Vilnius: Lithuanian Forest Inventory and Management Institute, Kaunas; Linköping: Regional Forestry Board of Östra Götaland.

Andersson, L., Martverk, R., Külvik, M., Palo, A. & Varblane, A. (2003). *Woodland key habitat inventory in Estonia 1999–2002*. Tartu: Regio.

Aune, K., Jonsson, B. G. & Moen, J. (2005). Isolation and edge effects among woodland key habitats is Sweden: Is forest policy promoting fragmentation? *Biological Conservation*, *124*, 89–95.

Axelsson, A. & Norén, M. (2003). *Woodland key habitats*. Jönköping: National Board of Forestry.

Baumann, C., Gjerde, I., Blom, H. H., Stætersdal, M., Nilsen, J., Løken, B. & Ekanger, I. (2002*a*). *Environmental inventories in forests—Biodiversity. Part 1: Background and principles*. Skogforsk and the Norwegian Ministry of Agriculture.

Baumann, C., Gjerde, I., Blom, H. H., Stætersdal, M., Nilsen, J., Løken, B. & Ekanger, I. (2002*b*). *Environmental inventories in forests—Biodiversity. Part 4: Guidelines for ranking and selection 2002*. Skogforsk and the Norwegian Ministry of Agriculture.

Baumann, C., Gjerde, I., Blom, H. H., Stætersdal, M., Nilsen, J., Løken, B. & Ekanger, I. (2002*c*). *Håndbok i registrering av livsmiljøer i Norge. Miljøregistrering i skog—biologisk mangfold. Instruks for registrering 2001* (Hefte 3) [Environmental inventories in forests—Biodiversity. Part 3: Instructions for inventories]. Skogforsk and the Norwegian Ministry of Agriculture. (In Norwegian.)

Bērmanis, R. & Ek, T. (2003). *Inventory of woodland key habitats in Latvian state forests. Final Report 1997–2002*. Riga: State Forest Service, Latvia; Joint Stock Company "Latvijas valsts meži", Latvia; Regional Forestry Board, Östra Götaland, Sweden.

Direktoratet for naturforvaltning (1999). *Kartlegging av naturtyper —Verdisetting av biologisk mangfold* [Mapping of nature types—Valuation of biodiversity] (Håndbok 13, 1st ed.). (In Norwegian.)

Direktoratet for naturforvaltning (2007). *Kartleggning av naturtyper—Verdisetting av biologisk mangfold* [Mapping of nature types—Valuation of biodiversity] (DN-Håndbok 13, 2nd ed., rev. 2007). (In Norwegian.)

Ek, T. & Bērmanis, R. (2004). *Woodland key habitat concentrations. Survey method*. Riga. State Forest Service, Latvia; Joint Stock Company "Latvijas valsts meži", Latvia; Regional Forestry Board, Östra Götaland, Sweden.

Ek, T., Suško, U. & Auziņš, R. (2002). *Inventory of woodland key habitats. Methodology.* Riga: State Forest Service.

FAO. (2006). *Global Forest Resources Assessment 2005. Progress towards sustainable forest management* (FAO Forestry Paper). Rome: Food and Agriculture Organization of the United Nations.

Finnish Statistical Yearbook of Forestry (2003). Vantaa: Finnish Forest Research Institute.

Finnish Statistical Yearbook of Forestry (2007). Vantaa: Finnish Forest Research Institute.

Forest Stewardship Council. (2010). *Global FSC certificates: Type and distribution.* Retrieved February 7, 2010, from http://www.fsc.org/fileadmin/web-data/public/document_center/powerpoints_graphs/facts_figures/09-99-15_Global_FSC_certificates_-_type_and_distribution_-_FINAL.pdf

Gaarder, G., Larsen, B. H. & Melby, M. W. (2007). Ressursbehov ved kvalitetssikring og nykartlegging av naturtyper [Resource need in evaluation and further mapping of nature types]. *Miljøfaglig Utredning Rapport* 2007: 15 (In Norwegian.)

Gjerde, I., Sætersdal, M. & Blom, H. (2007). Complementary hotspot inventory—A method for identification of important areas for biodiversity at the forest stand level. *Biological Conservation*, *137*, 549–557.

Gjerde, I., Sætersdal, M., Rolstad, J., Blom, H. H. & Storaunet, K. O. (2004). Fine-scale diversity and rarity hotspots in northern forests. *Conservation Biology*, *18*, 1032–1042.

Götmark, F. (2009). Conflicts in conservation: Woodland key habitats, authorities and private forest owners in Sweden. *Scandinavian Journal of Forest Research*, *24*, 504–514.

Götmark, F., Fridman, J. & Kempe, G. (2009). Education and advice contribute to increased density of broadleaved conservation trees, but not saplings, in young forest in Sweden. *Journal of Environmental Management*, *90*, 1081–1088.

Gundersen, V. & Rolstad, J. (1998). *Nøkkelbiotoper i skog. En vundering av nøkkelbiotoper som forvaltningstiltak for bevaring av biologisk mangfold i skog* (Rep. 5/98). Norsk Institute for skogsforskning.

Hultgren, B. (2001). *Kontrollinventering av nyckelbiotoper år 2000* [Control inventory of key habitats in year 2000] (Rep. 2001:3). Jönköping: National Board of Forestry.

Kotiaho, J. S. & Selonen, V. A. O. (2006). *Metsälain erityisen tärkeiden elinympäristöjen kartoituksen laadun ja luotettavuuden analyysi* [Especially important habitats as defined in the Forest Act—Analysis of the quality and reliability of the inventory] (Rep. 29). Suomen ympäristökeskus.

Kuusinen, M. (2006). *Yksityismetsien luonnonhoidon laadun seurannan tulokset 1996–2005* [Follow-up results from the quality of management in privately owned forests]. In P. Horne, T. Koskela, M. Kuusinen, A. Otsamo & K. Syrjänen (Eds.), *METSOn jäljillä. Etelä-Suomen metsien monimuotoisuusohjelman tutkimusraportti* (pp. 229–234).

Laita, A., Mönkkönen, M. & Kotiaho, J. S. (2010). Woodland key habitats evaluated as part of a functional reserve network. *Biological Conservation*, *143*, 1212–1227.

Lārmanis, V. (2001). *Audit of woodland key habitat inventory.* Riga. Swedish County Forestry Board, Östra Götaland, Sweden.

Larsson, S. & Danell, K. (2001). Science and the management of boreal forest biodiversity. *Scandinavian Journal of Forest Research*, *16*(Suppl. 3.), 5–9.

Luonnonsuojelulaki (1996). *Finnish Nature Conservation Act.* Suomen säädöskokoelma 1096/96.

Meriluoto, M. & Soininen, T. (1998). *Metsäluonnon arvokkaat elinympäristöt* [Valuable habitats in forests]. Metsälehti Kustannus & Tapio.

Metsälaki (1996). *Finnish Forest Act.* Suomen säädöskokoelma 1093/96.

Moen, J. & Jonsson, B. G. (2003). Edge effects on liverworts and lichens in forest patches in a mosaic of boreal forest and wetland. *Conservation Biology*, *17*, 380–388.

Nitare, J. & Norén, M. (1992). Nyckelbiotoper kartläggs i nytt projekt vid Skogsstyrelsen [Woodland key-habitats of rare and endangered species will be mapped in a new project of the Swedish National Board of Forestry]. *Svensk Botanisk Tidskrift*, *86*, 219–226. (In Swedish with English abstract.)

Norén, M., Nitare, J., Larsson, A., Hultgren, B. & Bergengren, I. (2002). *Handbok för inventering av nyckelbiotoper* [Handbook for key habitat inventory] (2nd ed. 2005). Jönköping: Skogsstyrelsen.

Official Statistics of Sweden (2008). *Statistical Yearbook of Forestry 2008*. Jönköping: Swedish Forest Agency. (In Swedish with English summary.)

Prieditis, N. (2002). Evaluation frameworks and conservation system of Latvian forests. *Biodiversity and Conservation*, *11*, 1361–1375.

Programme for the Endorsement of Forest Certification (2010). *Statistical figures on PEFC certification.* http://www.pefcnorge.org/vedl/Forest/ [accessed 21 June 2010].

Skjeggedal, T., Gundersen, V., Harvold, K. A. & Vistad, O. I. (2010). *Frivillig vern av skog—Evaluering av arbeidsformen. Samarbeidsrapport NIBR/NINA 2010*. Oslo: Norwegian Institute for Urban and Regional Research (NIBR).

Skogsstyrelsen (2004). *Inventering av nyckelbiotoper—Resultat till och med 2003* [Key habitat inventory—Results 2003]. Jönköping: Meddelande 4. (In Swedish.)

Soininen, T. (1996). *Talousmetsien avainbiotooppien tunnistaminen—Maastotyöohje, kokeiluversio* [Identification of key habitats in production forests—Inventory manual, pilot project] (Rep. 27). Suomen ympäristökeskus.

Sverdrup-Thygeson, A., Bergsaker, E., Brandrud, T. E., Dale, T., Elsrud, O. E., Rønning, E. & Skuland, S. (2009). *Miljøregistrering i Skog (MiS)—Utvelgelsesprosessen og skogeiers oppfatning* [Environmental inventories in forest—Selection procedure and the forest owners' perceptions] (NINA Rep. 480). Oslo: Norsk institutt for naturforskning. (In Norwegian with English summary.)

Vanha-Majamaa, I. & Jalonen, J. (2001). Green tree retention in Fennoscandian forestry. *Scaninavian Journal of Forest Research*, *16*(Suppl. 3), 79–90.

Wätzold, F. & Schwerdtner, K. (2005). Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of European biodiversity conservation policy. *Biological Conservation*, *123*, 327–338.

Yrjönen, K. (2004). *Metsälain erityisen tärkeät elinympäristöt. Kartoitus yksityismetsissä 1998–2004. Loppuraportti* [Especially important habitats as defined in the Forest Act. Survey in private forests in 1998–2004. Final report] (Julkaisuja 9/2004). Maa- ja metsätalousministeriö, MMM. (In Finnish.)

Yrjönen, K. (2006). *Metsälain erityisen tärkeiden elinympäristöjen kartoitus (METE-kartoitus) in METSOn jäljillä. Etelä-Suomen metsien monimuotoisuusohjelman tutkimusraportti* [Survey of especially important habitats as defined in the Forest Act. Diversity programme report from the forests of southern Finland]. In P. Horne, T. Koskela, M. Kuusinen, A. Otsamo & K. Syrjänen (Eds.), *Maa- ja metsätalousministeriö, Metsäntutkimuslaitos ja Suomen ympäristökeskus, Vammalan kirjapaino* (387). (In Finnish.)

Appendix
Woodland key habitat types in the Fennoscandian and Baltic countries

Main habitat features	Sweden	Finland	Norway	Latvia	Estonia	Lithuania
1. Edaphic	Eutrophic or calcareous fen; calcareous coniferous forest; calcareous deciduous forest; temperate deciduous forest (abiotic factors); herb-rich alder forest	**Rich fens[a]; fertile patches of herb-rich forest [a]**	**Rich ground vegetation[d]**; rich fens; calcareous forest; ultra basic and heavy-metal rich lowland soils	Open calcareous fen or meadow	Surroundings of a calcareous fen or moist meadow; alvar forest	Surroundings of a calcareous fen or moist meadow
2. Geomorphological	Canyon; ravine; steep bluffs; scree; small fissure valley; river bank; stream valley; coniferous forest on sandy soil; forest on rocky outcrop; esker spruce forest	**Gorges[a]; ravines[a]; steep bluffs and the underlying forest[a]; low-productive sandy soils[a]; exposed bedrock[a]; stone and boulder fields[a]**; south-facing esker slopes (OH); Small kettle holes on eskers (OH)	**Stream gorges[d]; clay ravines[d]; rock walls[d]**; ravine and rock wall; south-facing bluff and scree; north-facing coastal bluff and boulder fields; edge scrubland	Ravine forest; slope forest	Rock bluffs (klint forest); other steep bluffs; steep slopes of rivers and lakes; glide slopes of rivers and lakes; slopes towards other water bodies; stream bank	Ravine; steep slope; slopes towards a river; slopes towards a lake or wetland; stream bank
3. Hydrological	Spring-influenced forest; natural forest stream; herb-rich stream sides; riparian forest; forest by waterfall; small temporary water body; spruce wetland forest; mixed wetland forest; pine wetland forest; deciduous wetland forest; alder wetland forest; wetland forest of temperate deciduous tree species; peatland–forest mosaic	**Surroundings of springs[a]; surroundings of streams[a]; surroundings of streamlets[a]; surroundings of small ponds[a]; herb/grass birch–spruce mires[a]; fern-rich spruce mires[a]; thin-peated herb-rich spruce forests[a]; black alder wetland forests[b]; peatlands with sparse tree stand[a]; flood meadows[a]; small mineral-soil islets in undrained mires[a]**; undrained small herb/grass mires[c]	Springs and spring streams under timberline; important stream water system; rich wetland forest	Spring-influenced forest; riparian forest; spruce and mixed spruce wetland forest; pine and pine–birch wetland forest; temperate deciduous wetland forests; black alder wetland forest; bog-forest mosaic	Spring-influenced area; floodplain of a stream; low bank and floodplain of a river; shore of a temporary water body; pine or birch wetland forest; temperate deciduous wetland forests; black alder wetland forest; small islands and peninsulas	Spring-influenced area; floodplain of a stream; low bank and floodplain of a river; shore of a lake; shore of a temporary water body; spruce and mixed spruce wetland forest; pine or birch wetland forest; temperate deciduous wetland forests; black alder and birch wetland forest; islands and peninsulas in water and wetlands
4. Based on dominating tree species and generally long continuity	Natural coniferous forest; coniferous forest; natural mixed forest; natural deciduous forest; aspen forest; natural forest of temperate deciduous tree species; heath forest of temperate deciduous tree species; stands with common yew	Old coniferous and mixed stands[c]; old deciduous stands[c]; stands with significant admixture of naturally regenerated temperate deciduous tree species[b]	**Aggregations of snags[d]; aggregations of logs[d]; aggregations of trees with nutrient-rich bark[d]; aggregations of trees with pendulant lichens[d]; aggregations of old trees[d]**; old coniferous forest; coastal spruce forest; coastal pine forest; rich mixed lowland forest; old deciduous forest; herb-rich	Coniferous forest; mixed coniferous–deciduous forest; aspen forest; other deciduous forest; temperate deciduous forest	Spruce and mixed spruce forest; pine and mixed pine forest; aspen forest; other deciduous forest; temperate deciduous forest	Spruce and mixed spruce forest; pine and mixed pine forest; other deciduous forest; temperate deciduous forest

Appendix (*Continued*)

Main habitat features	Sweden	Finland	Norway	Latvia	Estonia	Lithuania
			birch–cherry forest; rich temperate deciduous forest; old nutrient-poor temperate deciduous forest			
5. Natural succession after disturbance	Burned area; deciduous stand established after fire		**Burned forest[d]; late successions of deciduous trees[d]**; burned area	Fire-scarred forest; beaver activity area; wind-fallen forest	Fire-scarred forest; area influenced by beaver dam	Fire-scarred forest; area influenced by beaver dam
6. Cultural biotopes	Wooded meadow; Remnant wooded meadow (with pollarded trees); wooded pasture; grazed forest; hazel grove; deciduous grove; secondary natural deciduous forest; secondary natural forest of temperate tree species; moist meadow; deciduous edge zone of field or meadow	Wooded meadows[b]; wooded pastures[c]; hazel groves[b]; dry juniper meadows[b]; meadows adjoining forest[c]	Wooded meadow; wooded pasture; natural pasture; pollarded woodland; grazed forest; mowed meadows; mowed and grazed peatlands/mires; parks		Typical wooded meadow; overgrown wooded grassland (previous meadow/pasture); typical wooded pasture; wooded grasslands (not specified subtype); hazel grove; old park	Still managed wooded meadow; still managed wooded pasture; recently overgrown wooded grassland; overgrown wooded grassland (previous meadow/pasture) wooded grassland and previous meadow/pasture; forest islands in arable land; old park
7. Individual trees	Coniferous tree; other deciduous tree; temperate deciduous tree	Large individuals trees and tree groups dominating the landscape[b]	Hollow deciduous tree[d]; large old trees	Giant tree	Giant tree	Single giant tree; group of giant trees

Note: Grouping into main groups, and within the groups, done by the authors. In the column for Finland, the superscript letters refer to habitat types included: [a]in Finnish Forest Act (in bold), [b]in Finnish Nature Conservation Act, and [c]in other valuable habitat types (not based on legal protection). In the column for Norway, [d]habitat types included into the Environmental Inventories in Forests (CHI) system (in bold). Temperate deciduous in the habitat names refer to stands dominated by temperate deciduous tree species in the genera *Acer*, *Fagus*, *Fraxinus*, *Quercus*, *Tilia* and *Ulmus*. Sources: Sweden: Norén et al. (2002); Finland: Finnish Forest Act (1996), Finnish Nature Conservation Act (Luonnonsuojelulaki, 1996), Meriluoto & Soininen (1998); Norway: Direktoratet for naturforvaltning (2007); Norwegian CHI system: Baumann et al. (2002*a*); Latvia: Ek et al. (2002); Estonia: Andersson et al. (2003); Lithuania: Andersson et al. (2005).