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## Collaboration for Environmental Evidence

### Systematic Review No. 81

#### ***ARE WOODLAND KEY HABITATS BIODIVERSITY HOTSPOTS IN BOREAL FORESTS?***

#### **Draft Review Report**

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## Cover Sheet

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Systematic review	N <sup>o</sup> 81
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46 **Summary**

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49 **1. Background**

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51 The concept of Woodland Key Habitats (WKH, small-scaled presumed hotspots of  
52 biodiversity) has become an essential component of forest management in  
53 Fennoscandian and Baltic countries. There have been debates over the importance of  
54 WKHs in relation to production forests, and several research projects have focused on  
55 differences in biodiversity between these two forest categories. Results have been  
56 contradictory, and thus there is a need to summarize and clarify the already existing  
57 knowledge.

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59

60 **1. Objectives**

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62 Our objective was to summarize knowledge on comparisons of biodiversity qualities,  
63 such as dead wood and species richness, between WKHs and production forests in  
64 relevant countries i.e. the countries where WKH concept has been implemented. We  
65 also wanted to summarize the knowledge on the impact of edge effects by comparing  
66 WKHs surrounded by forests to WKHs surrounded by clear cuts.

67

68

69 **2. Methods**

70

71 We conducted searches in multiple databases and in Google Scholar after the keyword  
72 scoping. Main institutions in Sweden (Swedish Forest Agency) and Finland (Forestry  
73 Development Centre Tapio and Metsähallitus) with activities on WKHs were also  
74 consulted, through personal contacts or web-page searches. Researchers with much  
75 experience of WKH research were also contacted to obtain possible unpublished  
76 literature of interest.

77

78

79 **3. Main results**

80

81 Studies had been conducted in Finland, Norway and Sweden. Total number of studies  
82 found from databases was 1443. Forty studies remained after the abstract filter stages.  
83 Finally, 16 studies were included in the review, from which 14 studied the differences  
84 between WKHs and production forests, and only two studies compared WKHs  
85 surrounded by mature forests and WKHs surrounded by clear cuts. Our results suggest  
86 that WKHs indeed are hotspots of dead wood, diversity of dead wood, species  
87 richness and red-listed species. Also, we found differences between countries in these  
88 biodiversity qualities.

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## 94 4. Conclusions

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96 Although our results suggest that WKHs indeed are biodiversity hotspots, there is a  
97 lack of studies detecting how WKHs are able to maintain biodiversity qualities when  
98 surrounded by clear cuts. Hence, the importance of WKHs for the biodiversity of  
99 production forests is still rather ambiguous.

### 100 101 102 Main Text

#### 103 104 105 1. Background

106  
107 Globally, habitat depletion and fragmentation have contributed to the current rampant  
108 loss of biodiversity. In the boreal forest zone, the total forest area is not decreasing but  
109 habitat availability has rapidly diminished due to habitat degradation as a consequence  
110 of effective logging and intensified silvicultural practices. Before industrialization the  
111 forests were utilized in a less intensive manner by burnbeating, tar and potash  
112 production, and thinning (Esseen et al., 1997). From the beginning of 20<sup>th</sup> century,  
113 forest harvesting methods in Fennoscandia shifted from selection felling towards clear  
114 cutting. Intensive forest management altered the species composition and the structure  
115 of the forests from old-growth forest to young, even-sized, single-aged stands  
116 (Östlund et al., 1997; Löfman and Kouki, 2001). Forestry also reduces natural  
117 disturbances and decreases volume of dead wood (Esseen et al., 1997). Natural forests  
118 are primary habitats for a substantial number of threatened species and forestry is the  
119 main cause of species endangerment (Rassi et al., 2001), especially due to the  
120 reduction of dead wood (Siitonen, 2001). In Finland, 20-25% of all the forest-  
121 dwelling species are dependent on dead wood, and many of them are very specific in  
122 their substrate requirements making dead wood and dead wood diversity important  
123 biodiversity qualities (Siitonen, 2001).

124  
125 Forest conservation has traditionally concentrated on establishing large forest  
126 reserves. Such reserves are vital due to their ability to maintain many taxa and  
127 ecological processes but they also have limitations. One of the main constraints is the  
128 limited area available for conservation (Lindenmayer and Franklin, 2002); large  
129 continuous areas of intact forests simply do not exist anymore in Fennoscandia,  
130 particularly in the southern boreal zone. Many areas of high priority for nature  
131 conservation are located on unprotected, productive private lands (Knight, 1999).  
132 However, protecting privately owned land for biodiversity involves many challenges.  
133 For example, traditional obligatory approaches, such as acquisition of land by  
134 government have resulted in an intense resistance by land owners (e.g. Hansson,  
135 2001; Wätzold and Schwerdtner, 2005). To respond to these challenges, there has  
136 been a shift in Europe from total protection of segregated areas to integration of forest  
137 management and conservation in a more holistic way (Parviainen and Frank, 2003)  
138 and the focus of conservation has shifted towards multiscale conservation measures  
139 (Lindenmayer and Franklin, 2002). In addition to large ecological reserves,  
140 intermediate conservation measures at lower scales, like setting aside small biological  
141 hotspots, and green tree retention, respectively, are taken place in the matrix.

143 One tool for intermediate-spatial scale conservation of the forest biodiversity is the  
144 conservation of small habitat patches called Woodland Key Habitats (WKHs). In  
145 Fennoscandia and Baltic countries the concept of WKH, i.e. presumed hotspots of  
146 biodiversity, has gained particular attention among forest managers and forest owners,  
147 and large-scale inventories of WKHs have been conducted (Timonen et al.  
148 unpublished manuscript.). Setting aside small parcels of forest with large ecological  
149 values is considered a cost-efficient way to conserve biodiversity in managed and  
150 fragmented forest landscapes (Lindenmayer and Franklin, 2002; Wikberg et al.,  
151 2009). The concept is based on two assumptions. First, red-listed species are  
152 presumed to be clustered into certain sites or habitats rather than to occur evenly or  
153 randomly in the forest landscape. Second, it should be possible to identify WKH's by  
154 their structural features as well as indicator species, and thus direct observation of red-  
155 listed species should not be necessary.

156  
157 WKH definitions differ between countries and emphasize either primary habitat  
158 factors, such as soil and bedrock properties, or secondary factors, such as stand  
159 structure and occurrence of indicator species. The number of WKHs varies from about  
160 5500 in Estonia and Lithuania to more than 100 000 in Finland. The mean size of the  
161 WKHs varies considerably, from 0.4 (Finland) to 2.1 ha (Latvia). WKHs are legally  
162 protected only in few of the countries and mostly WKHs are protected on a voluntary  
163 basis or by forest certification (Timonen et al. unpublished manuscript).

164  
165 There have been debates over the conservation value of WKHs, and several research  
166 projects have focused on differences in biodiversity between these two forest  
167 categories. Further, small sites such as WKHs might have difficulties to retain their  
168 original species composition and support species persistence over time since clear  
169 cutting, the prevailing logging method, in the surroundings may cause changes in the  
170 microclimatic conditions due to increased exposure to sunlight and wind.  
171 Consequently, studies on edge effects are relevant when the efficiency of WKHs is to  
172 be evaluated.

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## 175 **2. Objectives**

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### 177 **2.1 Primary objective**

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179 To systemically collate and synthesize published and unpublished evidence  
180 originating from the Nordic and Baltic countries as well as Russia, in order to address  
181 the following questions:

182

- 183 1. "Are Woodland Key Habitats (WKH) biodiversity hotspots (i.e. do they have  
184 higher biodiversity qualities) compared to the surrounding production  
185 forests?"
- 186 2. "Is there a difference in biodiversity qualities between WKHs surrounded by  
187 production forest and WKHs surrounded by clear cuts?"

188

189 Listed below are the biodiversity qualities that will be studied to assess the hotspot  
190 status in primary question 1., and to compare the differences between WKHs in  
191 primary question 2. The geographical scope is in Fennoscandian and Baltic countries,  
192 and in Russia. Both questions are stated above.

- 193  
 194 1. red-listed species richness  
 195 2. total species richness  
 196 3. volume of dead wood  
 197 4. dead wood diversity  
 198 5. volume of dead deciduous trees  
 199 6. volume of deciduous trees  
 200  
 201

### 202 3. Methods

#### 203 3.1 Question formulation

204 The question composed two elements:

- 205  
 206 1. *Subject* : WKHs surrounded by the production forest and WKHs surrounded  
 207 by clear cuts  
 208 2. *Outcome*: WKHs are or are not hotspots for biodiversity, WKHs surrounded  
 209 by production forest are richer or poorer in biodiversity qualities compared to  
 210 WKHs surrounded by clear cuts or there are no differences  
 211

#### 212 3.2 Search strategy

213 In order to collate information for the review the following steps were carried out:  
 214

##### 215 3.2.1 Review scoping

216 The keywords were tested to first of all find the most relevant ones, and secondly, to  
 217 find out whether there are enough studies conducted to execute a competent review.

218 This was done by using the following keywords in ISI Web of Knowledge search:  
 219

220  
 221

Keyword 1		Keyword 2	Hits
Woodland key habitat*			291
Woodland key habitat*	AND	species richness	54
	AND	red-listed species	30
	AND	dead wood	33
	AND	production forest*	28
	AND	managed forest*	30
	AND	clear cut*	7
	AND	hotspot*	4
	AND	biodiversity	93
	AND	Sweden OR Finland OR Norway OR Latvia OR Lithuania OR Estonia OR Russia ***	>100 000
	AND	deciduous tree*	∞
Key habitat*	AND	species richness	573
	AND	red-listed species	40
	AND	dead wood	111
	AND	production forest*	225
	AND	managed forest*	126
	AND	clear cut*	38

	AND	hotspot*	61
	AND	biodiversity	1,116
	AND	Sweden OR Finland OR Norway OR Latvia OR Lithuania OR Estonia OR Russia	>100 000
	AND	deciduous tree*	∞

222

223 After the scoping the list of keywords remained mostly the same. However, we  
 224 decided to not combine keywords “Woodland key habitat” and countries (marked by  
 225 \*\*\*). We also decided to add a new keyword (added and marked with ∞ in the “hit”  
 226 column at the table above). With the “Key habitat”-keyword we will combine one  
 227 other keyword at a time plus the countries, for example: Key habitat AND species  
 228 richness AND Sweden OR Finland OR Norway OR Latvia OR Lithuania OR Estonia  
 229 OR Russia

230

### 3.2.2 Database search

231

232 The following databases were used for the searches (Appendix 1):

233

- 234 • ISI Web of Knowledge
  - 235 1. Web of Science®
  - 236 2. BIOSIS Previews®
  - 237 3. CABI: CAB Abstracts®
  - 238 4. Food Science and Technology Abstracts™
  - 239 5. Journal Citation Reports®
- 240 • Scopus

241

242 The search terms used were:

243

Keyword 1		Keyword 2
Woodland key habitat*		
Woodland key habitat*	AND	species richness
	AND	red-listed species
	AND	red listed species
	AND	dead wood
	AND	production forest*
	AND	managed forest*
	AND	clear cut*
	AND	clearcut*
	AND	clear-cut
	AND	hotspot*
	AND	biodiversity
	AND	deciduous tree*
Key habitat*	AND	species richness
	AND	red-listed species
	AND	red listed species
	AND	dead wood
	AND	production forest*
	AND	managed forest*
	AND	clear cut*

	AND	clearcut
	AND	clear-cut
	AND	hotspot*
	AND	biodiversity
	AND	deciduous tree*
	AND	Sweden OR Finland OR Norway OR Latvia OR Lithuania OR Estonia OR Russia

244

245 **3.2.3 Internet search**

246 The first 100 results of each of the searches were considered and included in the  
 247 review if relevant. The search was conducted by Google Scholar. The same keywords  
 248 were be used as in the database search. To make sure all relevant studies would be  
 249 included to the review we also conducted similar searches in Finnish and Swedish  
 250 Google Scholar. To find the studies written in Finnish we used the Finnish key words  
 251 (equivalent to English ones) in Finnish Google Scholar. This was also done in  
 252 Swedish.

253

254 **3.2.4 Specialist searches**

255 The following institutions were consulted. Here we decided to restrain the  
 256 organizations to Sweden and Finland due to the fact that the material from other  
 257 countries would have been difficult to extract when written in native languages.

258

- 259 • Swedish Forest Agency (Sweden)
- 260 • Forestry Development Centre Tapio and Metsähallitus (Finland)

261

262 We also contacted personally the main authors involved in WKH research as a part of  
 263 the search of unpublished grey literature.

264

265 **3.3 Study inclusion criteria**

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267 The studies were assessed for inclusion in the review based on a hierarchical  
 268 assessment of relevance first by looking only the title (if the number of hits in >500).  
 269 If the title was relevant the abstracts were read, followed by reading the full text of  
 270 articles with relevant abstracts. Abstracts were considered relevant if they fulfilled the  
 271 relevancy requirements stated below. To assure that we did not miss any relevant  
 272 study, when there were uncertainties, we included a study to the next step.

273

274 **3.3.1 Relevant subject:**

275 All the studies that investigate WKHs surrounded by production forests, and WKHs  
 276 surrounded by clear cuts, and include collected data.

277

278 **3.3.2. Types of outcome:**

279 WKHs are or are not hotspots for biodiversity, WKHs surrounded by production  
 280 forest are richer or poorer in biodiversity qualities compared to WKHs surrounded by  
 281 clear cuts or there are no differences.

282

283 **3.3.4. Types of studies:**

284 The selected studies were those that presented comparisons of biodiversity qualities  
 285 between WKHs and surrounding production forests, and studies comparing

286 biodiversity qualities between WKHs surrounded by production forests and WKHs  
287 surrounded by clear cuts. We accepted articles in peer-reviewed journals, book  
288 chapters, theses, or reports from governmental or non-governmental organizations.  
289 Other type of grey literature could also be included. Both quantitative and qualitative  
290 presenting studies were to be included.

291

### 292 **3.4 Study quality assessment**

293

294 Material found during the search was categorized into three quality categories:

295

- 296 1. Peer-reviewed articles from internationally recognized journals
- 297 2. Books, book chapters, reports, non-peer reviewed journal articles, Masters and  
298 PhD theses
- 299 3. Unpublished grey literature

300

### 301 **3.5 Data extraction**

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303 To extract information from selected studies, we compiled quantitative and qualitative  
304 data from each of the studies. The following information was extracted:

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### 316 **3.6 Data synthesis**

In our previous study (Timonen et al. unpublished manuscript) we concluded that  
there are differences among the countries (Estonia, Finland, Latvia, Lithuania,  
Norway and Sweden) in the definitions and implementation of the WKH concept.  
Therefore, we expected that such differences may translate into ecological differences  
as well. Vegetation zone may also have an impact on biodiversity qualities, such as  
dead wood and dead-wood associated species. Hottola and Siitonen (2008), for  
example, found a landscape effect connected with the intensity and length of forest  
management history with highest species richness in areas with the shortest  
management history. Hence, in addition to the comparisons of biodiversity qualities  
between WKHs and production forests we also analyzed differences among countries  
and among boreal forest zones. In order to retain enough data points for vegetation  
zones we categorized vegetation zones into three groups: 1) sub-boreal (nemoral and  
hemiboreal combined), 2) southern boreal and 3) middle-northern boreal (middle and  
northern boreal combined).

The chief purpose of a meta-analysis is to provide an estimate of the true effect based  
on all studies that are available. To obtain this estimate, different test statistics, means  
and variances or simple significance levels are first transformed into a common

336 currency called effect size and then combined (Rosenthal, 1991; Gurevitch and  
337 Hedges 1993; Cooper and Hedges 1994). In this systematic review we have conducted  
338 meta-analyses using Meta-Win 2.0 (Rosenberg et al., 2000).

339

340 The structural biodiversity qualities that we extracted and analyzed from the data were  
341 the volume of dead wood, diversity of dead wood and volume of deciduous dead  
342 wood. When we analyzed the dead wood volume in WKHs and production forests  
343 between countries only Finland and Sweden were compared since there were not  
344 enough studies from Norway. The exact methodology to derive dead wood volumes  
345 and dead wood diversity metrics varied a somewhat among the original studies.  
346 However, within a study these parameters were calculated in the same way for WKHs  
347 and production forests.

348

349 In order to test whether WKHs are species richness hotspots we extracted the mean  
350 number of species (observed species richness) from the WKHs and production forests  
351 from each of the relevant studies. However, a few of the studies reported only the  
352 mean number of species records (number of observed individuals or fruiting bodies)  
353 and not the mean species number. To utilize the most of the available data we used  
354 both of these as hotspots indicators so that the mean species number was preferred and  
355 the mean species record was only used when the mean species number was not  
356 reported. The overall difference in diversity between WKHs and production forests  
357 might be dependent on the indicator that is being used i.e. mean number of records  
358 and mean number of species. Thus, we tested whether the effect size differed between  
359 these two indicators by only using data from two studies including both indicators.  
360 The effect size was stronger (mean effect size = 0.79, 95% Bootstrap Confidence  
361 Interval 0.44 to 0.93) when summary analysis was conducted using mean number of  
362 species compared to mean species record (mean effect size = 0.33, 95% Bootstrap CI  
363 0.25 to 0.39). We also analyzed the possible differences of effect sizes from all the  
364 data, using mean number of species and mean number of records separately. The  
365 effect size was slightly stronger when only data of mean number of species was  
366 analyzed (mean effect size 0.32, 95% Bootstrap CI 0.12 to 0.45) compared to mean  
367 number of records (mean effect size 0.23, 95% Bootstrap CI 0.07 to 0.46). Therefore,  
368 we concluded it to be safe to use both indicators in our analyses.

369

370 For each data point we calculated the difference between the mean value of the  
371 WKHs and the mean value of mature production forests. Thus, positive effect size  
372 denotes that the biodiversity quantity is more abundant in WKHs. Since the summary  
373 information is presented in different forms in different studies a common currency is  
374 needed. We first calculated student's t-value for each difference if means and their  
375 standard deviations were available. Then we transformed these parameters to a  
376 product moment correlation and calculated effect sizes from correlation coefficients  
377 (Cooper and Hedges, 1994). Fisher's z-transformations were used during the  
378 calculations as recommended (Rosenthal, 1991; Sokal and Rohlf, 1995). If standard  
379 deviations were missing we calculated the effect size using data on sample size and p-  
380 values of the primary study (see, Rosenthal, 1991, p. 19).

381

382 We fitted random-effects models with the data. In this way, we consider the  
383 correlation coefficient estimated for each experiment to be drawn from an underlying  
384 distribution of correlations rather than considering each experiment as providing an  
385 estimate of a single common value (Cooper and Hedges, 1994; Hedges, 1994;

386 Raudenbush, 1994). Mean effect size can be considered significantly different from  
387 zero if its 95% confidence interval (derived by bootstrapping) does not include zero.

388 The presence of publication bias was examined by analyzing a rank correlation (effect  
389 size vs. sample size). A significant correlation may indicate a publication bias where  
390 only larger effect sizes are likely to be published with small sample sizes (Rosenberg  
391 et al., 2000; Kotiaho and Tomkins, 2002, Tomkins and Kotiaho, 2004). We also  
392 calculated fail-safe numbers to estimate the magnitude of the publication bias. Fail-  
393 safe number is the number of unpublished, missing or non-significant studies that  
394 would need to be added to a meta-analysis so that the result of the meta-analysis  
395 would change from significant to non-significant (Rosenberg et al. 2000). Rosenthal  
396 (1979) suggests that the fail-safe number should be at least  $5n + 10$  (where  $n$  is the  
397 original number of studies). In addition to the calculation of fail-safe number of the  
398 entire data set, we calculated fail-safe numbers also separately for each of the  
399 analyzed effect size.

400

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## 402 **4. Results**

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### 404 **4.1 Review statistics**

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406 Searching was conducted during April and May 2009. Additional searches were  
407 conducted in November 2009. The main results from the search are shown in Table 1.  
408 Forty studies remained after abstract filter stage from which 35 were found via  
409 database searches. In addition, the number of hits gained from the Google Scholar  
410 search was in total 8080. However, the relevant studies found from Google Scholar  
411 search did not contribute to the final number of relevant studies since all of the studies  
412 were already found previously from database searches. We found two relevant  
413 abstracts from The Finnish Google Scholar search and we did not find any relevant  
414 studies from the Swedish Google Scholar search. The consultation of the main authors  
415 increased the number of relevant studies by two and the consultation of institutions  
416 increased the number of relevant studies by two.

417

418 Most of the relevant studies included to this review were comparing WKHs to  
419 production forests. We only found two relevant studies comparing WKHs surrounded  
420 by production forests and WKHs surrounded by clear cuts. Therefore we were only  
421 able to find answers to the question number 1: “Are Woodland Key Habitats (WKH)  
422 biodiversity hotspots (i.e. do they have higher biodiversity qualities) compared to the  
423 surrounding production forests?”. Most of the studies were conducted in Sweden and  
424 Finland, and there were two studies conducted in Norway. We did not find any  
425 relevant studies conducted in Baltic countries or in Russia.

426

427 **Table 1.** Number of studies included during each of the systematic review filtering stages.

428

Systematic review stage	No. studies
Studies captured using search terms in electronic databases* (including duplicates)	1443
Studies captured using search terms in electronic databases* (excluding duplicates)	404
Studies remaining after abstract filter	40
Studies remaining after full text filter i.e. relevant studies (from databases, Google Scholar, and consultations)	16

429 \*(excludes hits from Google Scholar search)

430

431

## 4.2 Meta-analysis

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### 3.3.1 Dead wood

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When comparing the dead wood volume in WKHs and production forests between-country heterogeneity was not significant ( $Q = 0.95$ , d.f. = 1,  $P = 0.379$ ) suggesting that the studies from different countries provide consistent results. Likewise, the heterogeneity among vegetation zones was not significant ( $Q = 1.44$ , d.f. = 2,  $P = 0.576$ ). The mean effect size for dead wood volume was significantly different from zero (mean effect size = 0.41; 95% Bootstrap CI 0.26 to 0.52, figure 1.) indicating that the volume of dead wood is significantly higher in WKHs (mean in the original data  $19 \text{ m}^3 \text{ ha}^{-1}$ ) than in production forests (mean in the original data  $11 \text{ m}^3 \text{ ha}^{-1}$ ).

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452

We could not analyze the differences between WKHs and production forests in respect of the diversity of dead wood with country as a grouping variable since there was not enough data from each of the countries. However, we were able to analyze the data with vegetation zone as a grouping variable. The heterogeneity was not significant ( $Q = 0.007$ , d.f. = 1,  $P = 0.934$ ) indicating that studies from the different vegetation zones provide consistent results. The mean effect size differed significantly from zero (mean effect size = 0.33; 95% Bootstrap CI 0.19 to 0.46, figure 1) suggesting that the diversity of dead wood is significantly higher in WKHs compared to the production forests. In the original data, dead wood diversity was 1.67 times higher in the WKHs than in the production forests.

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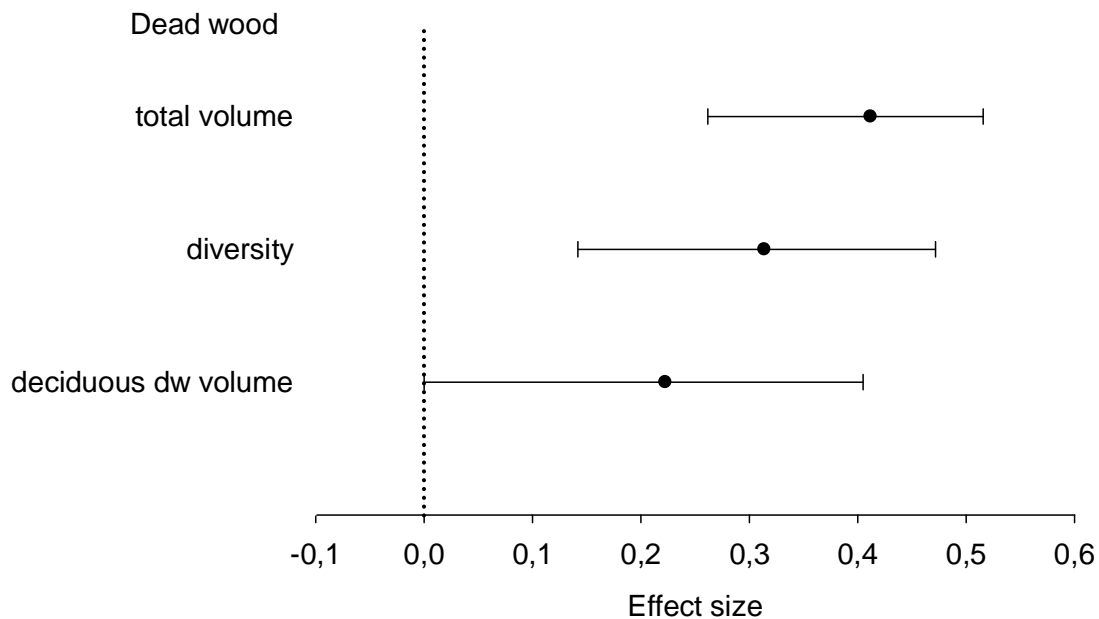
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There was not enough data to analyze differences of deciduous dead wood volumes in WKHs and production forests with country or vegetation zone as a grouping variable. Therefore, we compared differences between WKHs and production forests for all studies combined. There was no significant heterogeneity among the studies ( $Q_T = 1.65$ , d.f. = 2,  $P = 0.438$ ), and the mean effect size was positive (mean effect size 0.23; Bootstrap CI 0.00 to 0.41, figure 1), suggesting greater deciduous dead wood volumes in WKHs.



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464

465 **Figure 1.** Effect sizes for dead wood variables (differences in dead wood variables between  
 466 WKHs and production forests). Dots represent the mean effect sizes and the error bars are  
 467 equivalent to 95% Bootstrap confidence intervals. The dashed vertical line represents no  
 468 difference i.e. if the confidence interval bracket zero the difference is not significant.

469

### 470 3.3.2 *Species richness*

471 There was no significant heterogeneity in mean number of species between WKHs  
 472 and production forests among the countries or vegetation zones ( $Q = 3.82$ , d.f. = 2,  $P$   
 473 = 0.184 and  $Q = 1.61$ , d.f. = 2,  $P = 0.451$ , respectively). Mean effect size was  
 474 significantly positive (0.35; 95% Bootstrap confidence interval 0.23 to 0.45, figure 2)  
 475 suggesting higher overall mean number of species in WKHs than in production forests  
 476 (WKHs had 1.5 times more species). We also studied whether different species  
 477 groups (beetles, bryophytes, lichens, polypores, and vascular plants) differed between  
 478 the two categories. There was significant heterogeneity among the groups ( $Q = 11.18$ ,  
 479 d.f. = 4,  $P = 0.041$ ) suggesting that there are differences in the occurrence of different  
 480 species groups. All of the effect sizes were positive and most of the species groups  
 481 were significantly more abundant in WKHs than in production forests (Figure 2),  
 482 most pronounced for vascular plants (1.3 times more species in WKHs than in  
 483 production forests) while for beetles the difference was not statistically significant.

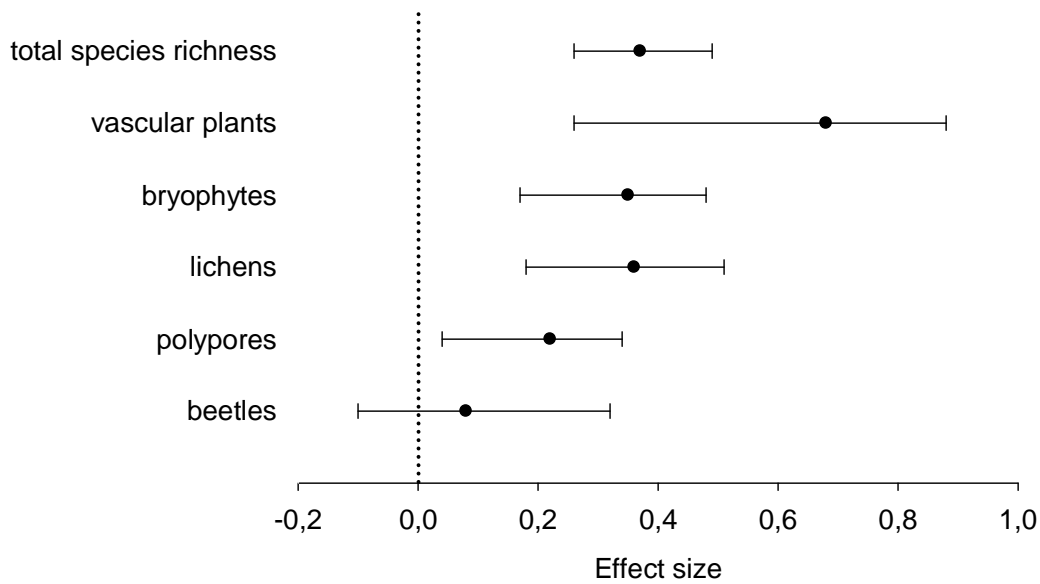
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**Figure 2.** Effect sizes for total species richness and separately for different taxonomic groups. For explanations, see Fig 1.

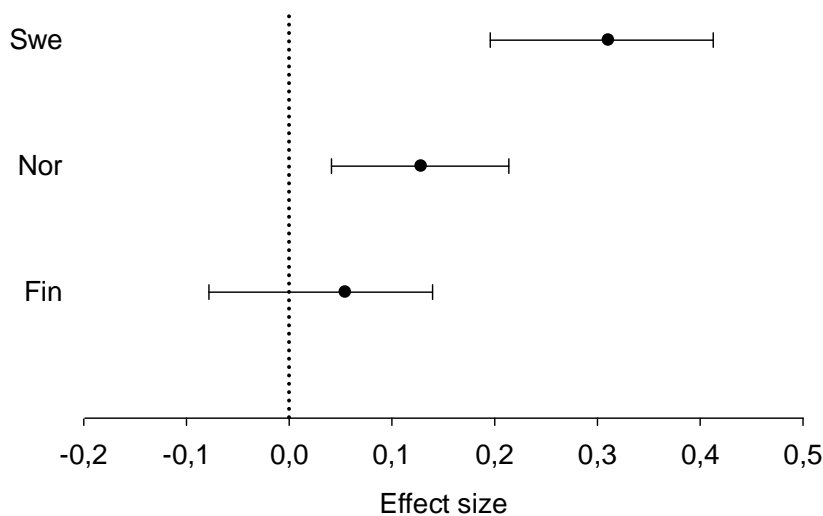
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### 3.3.3 Red listed species

For red-listed species richness between WKHs and production forests there was a nearly significant heterogeneity among the countries ( $Q = 8.22$ , d.f. = 2,  $P = 0.051$ ) indicating a country-specific effect sizes. In all countries, the mean effect size was positive indicating that more red-listed species were found in WKHs than in production forests, but the difference was not significant in studies from Finland (Figure 3). In Sweden the mean effect size was more pronounced and highest (WKHs had twice as much red-listed species than production forests) than in Norway (WKHs had 1.3 times more red-listed species) or Finland (1.4 times more red-listed species).

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We also analyzed the differences in red-listed species between WKHs and production forests with vegetation zone as a grouping variable. The heterogeneity was not significant ( $Q = 4.49$ , d.f. = 2,  $P = 0.136$ ), which indicates that the difference between WKHs and production forests is not dependent on vegetation zone.



**Figure 3.** Effect sizes for species richness of red-listed species in Sweden, Norway and Finland. For explanations, see Fig 1.

#### 4.6 Outcome of the review

Our results show that WKHs are hotspots of dead wood, diversity of dead wood, species richness and red-listed species. However, even though they now hold more of these attributes an open question that remains to be addressed is whether WKH's are able to retain their original species composition and support species persistence over time. Based on the two studies available it seems that species composition will alter when WKHs are surrounded by clear cuts. More information from this aspect is needed before the WKH's status as a functional conservation tool can fully be evaluated.

## 5. Discussion

### 5.1 Evidence of effectiveness

Based on the studies included into this review WKHs seem to be biodiversity hotspots of dead wood and species. All the biodiversity qualities that were used in comparisons were more abundant in WKHs than in production forests. The difference between WKHs and production forests varied with different species groups i.e. some species were more abundant in WKHs than others compared to the production forests.

### 5.2 Reasons for variation in effectiveness

The definitions of WKHs in all of the countries do underline the importance of structural elements (Timonen et al. unpublished manuscript) and thus the result of WKHs containing more dead wood could be expected. The average volume dead wood of  $19 \text{ m}^3 \text{ ha}^{-1}$  in the studied WKHs is notably more than the average volume of CWD (coarse woody debris) of production forest in general that varies between 2 and

541 10 m<sup>3</sup> ha<sup>-1</sup>, depending on the region (Siitonen, 2001). However, according to Siitonen  
542 (2001) the average volume of CWD in old-growth forests in southern Fennoscandia is  
543 60-90 m<sup>3</sup> ha<sup>-1</sup>. The definition of Finnish WKHs states that these habitats should be in  
544 natural or natural-like state (Meriluoto and Soininen, 1998) but the small volume of  
545 dead wood in Finnish WKHs compared to the old-growth forests suggests that these  
546 sites are not in natural state. The result of deciduous dead wood being more abundant  
547 in WKHs is only suggestive since the effect size was only indicative and the sample  
548 size was rather low.

549

550 WKHs did host more species than production forests in all of the countries. In one  
551 study, conducted in Finland, there were, however, more polypore species in  
552 production forests than in WKHs (Sippola et al. 2005, see Appendix). This could  
553 reflect the value of old-growth production forest or it could be a result of a poor  
554 implementation of WKH concept (Timonen et al. unpublished manuscript.). The study  
555 of Sippola et al. was conducted in a national park and therefore the result might not be  
556 unambiguously comparable.

557

558 WKHs seem to be hotspots of red-listed species (rarity hotspots) in Sweden and in  
559 Norway. However, in Finland WKHs did not differ significantly from production  
560 forests. These results are in line with the definition of WKHs in different countries.  
561 According to the Swedish definition red-listed species are likely to occur in WKHs  
562 (Nitare and Norén, 1992; Norén et al., 2002) and the Norwegian definition  
563 emphasizes habitat elements that are important for species. Finnish studies have been  
564 concentrating only on one sub-group of woodland key habitats, so called Forest Act  
565 habitats. In these habitats primary factors such as soil or bedrock properties are in  
566 focus and some weight has been put on secondary factors, such as successional stage  
567 and existence and attributes of dead wood (Timonen et al. unpublished manuscript).  
568 This more narrow definition of WKHs in Finland compared with the other Nordic  
569 countries is probably associated with the comparatively low occurrence of red-listed  
570 species in Finnish WKHs. However, the results from Finnish red-listed species were  
571 only from polypore species. The results from Norway should however be interpreted  
572 with caution due to the low sample size.

573

574

### 5.3 *Review limitations*

575 The status of WKH as a hotspot is species dependent and thus the results cannot be  
576 generalized into different species groups. Also, the only studied animal species group  
577 was beetles and therefore there is lack of knowledge on animal species richness in  
578 WKHs.

579

580 There were only two studies (Appendix) comparing WKHs surrounded by mature  
581 forest with WKHs surrounded by a clear cut. Nevertheless, this is the comparison that  
582 should be considered when trying to assess the role of WKHs as a potential  
583 conservation tool. Since WKHs are small scale conservation areas in production  
584 forests it is expected that the surrounding forest will at some point be clear cut. Clear  
585 cut of the surrounding production forest will most likely cause changes in the WKHs  
586 due to e.g. isolation and edge effect. The edge effect causes changes in the  
587 microclimatic conditions due to increased exposure to sunlight and wind, thus  
588 changing species abundance and composition (Esseen and Renhorn, 1998; Snäll and  
589 Jonsson, 2001). Both of the studies reported change in the species composition in the  
590 WKHs surrounded by clear cuts (Vuorinen, 2007; Hartikainen, 2008, see Appendix).

591 Ylisirniö et al. (unpublished manuscript) found that WKHs surrounded by clear cuts  
592 had lower relative humidity compared to the old-growth spruce forest controls. Also,  
593 the mean number of polypore species was lower in WKHs than in control forests.  
594

## 595 **6. Reviewers' Conclusions**

596

### 597 **6.1 Implications for conservation**

598 WKH concept seems to protect biodiversity hotspots in production forests. However,  
599 there is a lack of knowledge of how WKHs are able to maintain their species  
600 composition in time. Moreover, in many cases WKHs do not have any statutory  
601 protection (Timonen et al. unpublished manuscript) and thus are susceptible to  
602 cutting. Hence, the continuity of their hotspot status is not guaranteed. Earlier research  
603 on edge effects (Esseen and Renhorn 1998; Snäll and Jonsson, 2001) suggests that for  
604 species persistence small remnant patches such as WKHs should at the minimum be  
605 surrounded by buffer zones to counterbalance the edge effects. Also, the protection of  
606 WKHs should be safeguarded by the forest legislation or forest certification.  
607

608

### 609 **6.2 Implications for research**

610 Research has almost solely concentrated on the differences between WKHs and  
611 production forests as they are. However, the question of whether WKH concept is a  
612 valid conservation tool is yet to be answered. Before we can fully answer that  
613 question we need to know whether WKHs are able to maintain their species  
614 composition under the prevailing forestry procedures i.e. when WKHs are surrounded  
615 by clear cuts.  
616

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618

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620

621

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623

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## 629 **9. References**

630

631 Cooper, H., Hedges, L.V. 1994. The handbook of research synthesis. Russell Sage  
632 Foundation, New York.

633

634 Esseen, P., Ehnström, B., Ericson, L., Sjöberg, K., 1997. Boreal forests. Ecol. Bull.  
635 46, 16-47.

636

637 Esseen, P., Renhorn, K., 1998. Edge Effects on Epiphytic Lichen in Fragmented  
638 Forests. Conserv. Biol. 12, 1307-1317.

639  
640 Gurevitch, J., Hedges, L.V., 1993. Meta-analysis: combining the results of  
641 independent experiments, in: Schiener, S., Gurevitch, J. (Eds), Design and analysis of  
642 ecological experiments. Chapman & Hall, New York, pp 378–398.  
643  
644 Hansson, L., 2001. Key habitats in Swedish managed forests. *Scand. J. for. Res.*  
645 *Suppl.3*, 52-61.  
646  
647 Hedges, L. V. 1994 Statistical considerations. *The Handbook of research synthesis*,  
648 in: Cooper, H., Hedges, L.V. (Eds), . Russell Sage Foundation, New York, pp 29-38.  
649  
650 Hottola, J., Siitonen, J., 2008. Significance of woodland key habitats for polypore  
651 diversity and red-listed species in boreal forests. *Biodivers. Conserv.* 17, 2559-2577.  
652  
653 Knight, R. L. 1999. Private lands: the neglected geography. *Conserv. Biol.* 13:223-  
654 224.  
655  
656 Kotiaho, J. S., Tomkins, J. L. 2002. Meta-analysis, can it ever fail? *Oikos* 96: 551-  
657 553.  
658  
659 Lindenmayer, D.B. Franklin, J.F. 2002. *Conserving Forest Biodiversity: A*  
660 *Comprehensive Multiscaled Approach*, Island Press.  
661  
662 Löfman, S., Kouki, J., 2001. Fifty Years of Landscape Transformation in Managed  
663 Forest of Southern Finland. *Scand. J. for. Res.* 16, 44-53.  
664  
665 Meriluoto, M., Soininen, T., 1998. *Metsäluonnon arvokkaat elinympäristöt.*  
666 *Metsälehti Kustannus & Tapio.* 192 p. (in Finnish).  
667  
668 Nitare, J., Norén, M., 1992. Nyckelbiotoper kartläggs i nytt projekt vid  
669 Skogsstyrelsen. *Svensk Bot. Tidskr.* 219-226. (In Swedish with English abstract).

670 Norén, M., Nitare, J., Larsson, A., Hultgren, B., Bergengren, I. 2002. *Handbok för*  
671 *inventering av nyckelbiotoper.* Skogsstyrelsen, Jönköping. 2<sup>nd</sup> edition 2005. (In  
672 Swedish).  
673  
674 Östlund, L., Zackrisson, O., Axelsson, A.-L. 1997. The history and transformation of  
675 a Scandinavian boreal forest landscape since the 19th century. *Can. J. for. Res. /Rev.*  
676 *can. Rech. for.* 27, 1198-1206.  
677  
678 Parviainen, J., Frank, G., 2003. Protected forests in Europe approaches-harmonising  
679 the definitions for international comparison and forest policy making. *J. Environ.*  
680 *Manage.* 67, 27-36.  
681  
682 Rassi, P., Alanen, A., Kanerva, T., Mannerkoski, I. (Eds.), 2001. *Suomen lajien*  
683 *uhanalaisuus 2000, Ympäristöministeriö ja Suomen ympäristökeskus, Helsinki.* (In  
684 Finnish).  
685  
686 Raudenbush, S.W., 1994. Analyzing effect sizes: Random effects models.  
687 In: Cooper, H., Hedges, L. V. (Eds.). *The Handbook of Research*

688 Synthesis. New York: Russell Sage Foundation. Chapter 20, pp.302-321.  
689  
690 Rosenberg, M.S., Adams, D.C., Gurevitch, J. 2000. Meta-Win: Statistical Software  
691 for Meta-analysis. Version 2.0. Sinauer Associates, Sunderland, Massachusetts.  
692  
693 Rosenthal, R. 1979. The “file drawer problem” and tolerance for null results. Psychol.  
694 Bull. 86:638-641.  
695  
696 Rosenthal, R. 1991. Meta-analytical procedures for social sciences. Revised edn.  
697 Applied Social Research Methods Series Volume 6. Sage Publications, London.  
698  
699 Siitonen, J., 2001. Forest management, coarse woody debris and saproxylic  
700 organisms: Fennoscandian boreal forests as an example. Ecol. Bull. 49, 11-41.  
701  
702 Snäll, T., Jonsson, B.G., 2001. Edge effects on six polyporous fungi used as old-  
703 growth indicators in Swedish boreal forest. Ecol. Bull. 49, 255-262.  
704  
705 Sokal, R.R., Rohlf, F.J. 1995. Biometry: the principles and practice of statistics in  
706 biological research. 3rd edition. W. H. Freeman and Co.: New York. 887 pp. ISBN: 0-  
707 7167-2411-1.  
708  
709 Timonen, J., Siitonen, J., Gustafsson, L., Kotiaho, J.S., Stokland, J.N., Mönkkönen,  
710 M. Woodland key habitats in northern Europe. Unpublished manuscript.  
711  
712 Tomkins, J. L., Kotiaho, J. S. 2004. Publication bias in meta-analysis: seeing the  
713 wood for the trees. Oikos 104: 194-196.  
714  
715 Wätzold, F., Schwerdtner, K. 2005. Why be wasteful when preserving a valuable  
716 resource? A review article on the cost-effectiveness of European biodiversity  
717 conservation policy. Biol. Conserv. 123, 327-338.  
718  
719 Wikberg, S., Perhans, K., Kindstrand, C., Djupström, L.B., Boman, M., Mattsson, L.,  
720 Schroeder, L.M., Weslien, J., Gustafsson, L., 2009. Cost-effectiveness of conservation  
721 strategies implemented in boreal forests: The area selection process. Biol. Conserv.  
722 142, 614-624.  
723  
724 Ylisirniö, A-L, Mönkkönen, M., Hanhimäki, T., Kouki, J. Importance of woodland  
725 key habitats in preserving polypore diversity in a boreal forest area –effects of patch  
726 size, microclimate and stand structure. Unpublished manuscript.  
727

## 10. Appendix

Study	Country & study area	Comparison between	Habitat size (ha)	Plot size (ha)	Hotspot Status (vote count) +/-	Study quality
Djupström et al. (2008)	Sweden, middle boreal vegetation zone	Nature reserves, WKH, retention patches, old managed spruce forest		Reserves, WKHs and old managed forest: min. 50m x 50m (0.25 ha) Retention patches: min. 25 x 25 m (0.07 ha)	Dead wood volume: ns Beetles diversity: + Deciduous dead wood volume: ns Diversity of dead wood: ns Red-listed beetles: ns	1
Froster (2005)	Sweden, boreal forest zone	WKHs, nature reserves, production forest >110 years and production forest 40-70 years		WKH: 0.25 PF: 0.5	Indicator bryophytes: + Indicator lichens: + Wood-living fungi: ns Vascular plants: ns	2
Gjerde (2007)	Norway,	WKHs compared to randomly selected sites		0.25	Red-listed species: +	1
Gustafsson (2000)	Sweden, hemi-boreal vegetation zone	WKHs and surrounding production forest	WKHs in Roslagen 2.7 ha (0.6-4.7), WKHs in Småland 1.2 ha (0.5-3.3)	WKH: 0.20 PF: 25	Vascular plant species richness: ns Red-listed vascular plants: ns Indicator vascular plants: ns	1
Gustafsson (2002)	Sweden, hemi-boreal vegetation zone	WKHs and production forest	WKHs in Örsundsbro 1.8 ha (0.5-2.7), WKHs in Roslagen 2.7 ha (0.6-4.7), WKHs in Småland 1.2 ha (0.5-3.3)	0.2	Tot. records of red-listed species: + Bryophytes: ns Lichens: + Red-listed vascular plants: ns	1
Gustafsson et al. (2004)	Sweden, hemi-boreal vegetation zone	WKHs and production forest	WKHs in Roslagen 2.7 ha (0.6-4.7), WKHs in Småland 1.2 ha (0.5-3.3)	0.2	Cumulative species richness: + Bryophyte species log ha <sup>-1</sup> : ns Bryophyte species records per hectare: + Indicator bryophytes record per hectare: + Red-listed bryophytes per hectare: ns	1

Study	Country & study area	Comparison between	Habitat size (ha)	Plot size (ha)	Hotspot Status (vote count) +/-	Study quality
Hartikainen (2008)	Finland, southern boreal vegetation zone	WKHs surrounded by clear cut and WKHs surrounded by mature forest	WKHs in clear cuts: 0.3 ha WKHs in mature forests: 0.2 ha		Vascular plants: -	2
Hottola and Siitonen, (2008)	Finland, in the border between southern boreal and middle boreal vegetation zones	WKHs and production forests	WKHs: average size 0.7 ha (0.2-2.5ha) Ordinary managed stands: 1.7 ha (0.3-7.6 ha)	0.2	Polypore species number: + Red-listed polypores: ns Diversity of dead wood: +	1
Johansson and Gustafsson, (2001)	Sweden, hemi-boreal vegetation zone	WKHs and surrounding production forest	WKHs in Roslagen 2.7 ha (0.6-4.7), WKHs in Småland 1.2 ha (0.5-3.3)		Red-listed lichen species number: ns Red-listed-lichens: ns Indicator lichens: ns	1
Junninen and Kouki (2006)	Finland, Southern boreal zone	WKHs and production forest	WKHs: mean 0.5 ha (0.28-0.65) Production forest: 1.52		Number of polypore species: +	1
Jönsson and Jonsson (2007)	All Sweden	WKHs, mature managed forest, overmature managed forest and old-growth forest		0.0314	Dead wood volume: +	1
Korvenpää et al. (2002)	Finland, south- and middle boreal zone				Vascular plants: + Bryophytes: + Liverworts: +	1
Perhans et al. (2007).	Sweden, middle boreal vegetation zone	WKHs, nature reserves and retention groups on clear-cuts			Bryophytes: + Red-listed bryophytes: + Indicator bryophytes: + Lichens: ns Red-listed lichens: ns Indicator lichens: ns Deciduous dead wood volume: ns	1

Study	Country & study area	Comparison between	Habitat size (ha)	Plot size (ha)	Hotspot Status (vote count) +/-	Study quality
Selonen and Kotiaho	Central-Finland	WKHs (according to the Finnish Forest Act , WKHs (not according to the Finnish Forest Act) and production forest	Study sites: 0.1 ha	0,1	Volume of dead wood: + Diversity of dead wood: + Deciduous trees: + Polypores: + Epiphytic moss species: + Beetles: ns	3
Siitonen et al. (2009)	Finland, in the border between southern boreal and middle boreal vegetation zones	WKHs and production forests	WKHs: average size 0.7 ha (0.2-2.5ha) Ordinary managed stands: 1.7 ha (0.3-7.6 ha)	0.2	Volume of dead wood: + Diversity of dead wood: + The number of large deciduous trees: +	1
Sippola et al. (2005)	Finland, at the transition border of the southern and middle boreal vegetation zones	WKHs and old-growth forests in the Koli National Park	3 classes of WKHS: a) <0.10 ha b) 0.15-0.50 ha c) >1 ha Old-growth forest: 6-15 ha		Total volume of CWD: + Polypore species number: - Red-listed and indicator polypore species number: -	1
Sverdrup-Thygeson (2002)	Norway, boreal forest	WKHs and production forest		PF: 0.16	Beetles: ns Red-listed beetles: ns Indicator beetles: ns Structural characteristics: ns	1
Vuorinen (2007)	Finland, southern boreal vegetation zone	WKHs surrounded by clear cut and WKHs surrounded by mature forest	WKHs in clear cuts: 0.3 ha WKHs in mature forests: 0.2 ha		Bryophytes: ns	2

## References

Djupström, L.B., Weslien, J., Schroeder, L.M., 2008. Dead wood and saproxylic beetles in set-aside and non set-aside forests in a boreal region. *For. Ecol. Manage.* 255, 3340-3350.

This is a draft review for consultation. Additional work is in progress. Please do not quote this document or any part therein without prior consent of the authors.

Froster, A., 2005. Occurrence of signal species in woodland key habitats, nature reserves and production forest. Master's thesis. Department of Conservation Biology. Swedish University of Agriculture, Uppsala. 32 p.

Gjerde, I., Sætersdal, M., Blom, H.H., 2007. Complementary Hotspot Inventory—A method for identification of important areas for biodiversity at the forest stand level. *Biol. Conserv.* 137, 549-557.

Gustafsson, L., 2002. Presence and abundance of red-listed plant species in Swedish forests. *Conserv. Biol.* 16, 377-388.

Gustafsson, L., 2000. Red-listed species and indicators: vascular plants in woodland key habitats and surrounding production forests in Sweden. *Biol. Conserv.* 92, 35-43.

Gustafsson, L., Appelgren, L., Jonsson, F., Nordin, U., Persson, A., Weslien, J.O., 2004. High occurrence of red-listed bryophytes and lichens in mature managed forests in boreal Sweden. *Basic Appl. Ecol.* 5, 123-129.

Hartikainen, H., 2008. Importance of herb-rich forest habitats meant by forest law (1093/1996) 10 § to preserve biodiversity of vascular plants. Master's thesis. Department of Ecological and Environmental Science, University of Jyväskylä. 40p. (In Finnish with English abstract).

Hottola, J., Siitonen, J., 2008. Significance of woodland key habitats for polypore diversity and red-listed species in boreal forests. *Biodivers. Conserv.* 17, 2559-2577.

Johansson, P., Gustafsson, L., 2001. Red-listed and indicator lichens in woodland key habitats and production forests in Sweden. *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere* 31, 1617-1628.

Jönsson, M.T., Jonsson, B.G., 2007. Assessing coarse woody debris in Swedish woodland key habitats: Implications for conservation and management. *For. Ecol. Manage.* 242, 363-373.

Junninen, K., Kouki, J., 2006. Are woodland key habitats in Finland hotspots for polypores (Basidiomycota)? *Scand. J. for. Res.* 21, 32-40.

Korvenpää, T., Lehesvirta, T., Salpakivi-Salomaä, P., 2002. Pienvesien avainbiotoopit tärkeitä harvinaisille sammalille. *Luonnon Tutkija* 106, 144-154. (In Finnish).

Perhans, K., Gustafsson, L., Jonsson, F., Nordin, U., Weibull, H., 2007. Bryophytes and lichens in different types of forest set-asides in boreal Sweden. *For. Ecol. Manage.* 242, 374-390.

Selonen et al. Brook-side habitats of special importance: a way to preserve biodiversity in commercial forests. In preparation.

Siitonen, J., Hottola, J., Immonen, A., 2009. Differences in Stand Characteristics Between Brook-Side Key Habitats and Managed Forests in Southern Finland. *Silva Fenn.* 43, 21-37.

Sippola, A.-L., Mönkkönen, M., Renvall, P., 2005. Polypore diversity in the herb-rich woodland key habitats of Koli National Park in eastern Finland. *Biol. Conserv.* 126, 260-269.

Sverdrup-Thygeson, A., 2002. Key habitats in the Norwegian production forest: A case study. *Scand. J. for. Res.* 17, 166-178.

Vuorinen, M.-L., 2007. Importance of herb-rich forest habitats defined in the Forest Act (1093/1996) 10§ to preserve biodiversity of bryophyte vegetation. Master's thesis. Department of Ecological and Environmental Science, University of Jyväskylä. 40p. (In Finnish with English abstract).

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