DIVERSITY OF SAPROXYLIC BEETLES (HEXAPODA: COLEOPTERA) IN CLEAR-CUT SITES WITH REMOVED AND RETAINED STUMPS IN CENTRAL LATVIA

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Saproxylic insects represent an important part of forest biodiversity and have functionally significant role in the forest ecosystems. They are species-rich organisms that depend upon the dead or dying wood or upon the presence of other saproxylic species. In this study we investigated whether stump harvesting affects saproxylic beetle assemblages in the clear-cut of managed forest in Latvia. We used pitfall traps and window traps for sampling beetles in the clear-cut sites with removed and retained stumps. Overall, these two sampling sites shared a similar number of beetle species. However, there were significant differences between two sampling methods with more species from window traps. Saproxylic species were more abundant in site with retained stumps.

Key words: saproxylic beetle, stump harvesting, clear-cut, Hylocomiosa, window traps, pitfall traps.

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INTRODUCTION

Saproxylic or dead wood inhabiting insects comprise a significant proportion of the biodiversity of most forest ecosystems (Jackson et al. 2009, Stenbacka et al. 2010). They are vitally important in the initial fragmentation and breakdown of dead woody debris and comprise a food base for other organisms (Warriner et al. 2004). A radical decline in the abundance of saproxylic insects and threatened species is a direct outcome of the large reduction of dead, decaying wood and old living trees in the forest landscape by modern forestry and agricultural practices (Martikainen et al. 2000, Siitonen 2001, Hjalten et al. 2007). To predict extinction risks and to evaluate the efficiency of conservation efforts, we need to understand the ecology of saproxylic species and to study the dynamics of the habitats and the inhabiting populations.

Stumps are homogenous key alternative microhabitats for saproxylic organisms in managed forests (Gibb et al. 2006, Franc et al. 2007, Lindbladh et al. 2007, Jonsell 2008). Globally growing interest for forest biofuels such as slash (branches and tops) and stumps significantly increases intensity of stump and root harvesting in clear-cuts (Hakkila 2004, Björheden 2006, Walmsley & Godbold 2009). Stump extraction has also been used as a silvicultural treatment method to control post-harvest root-rot fungi in forests (Chapman & Xiao 2000, Chapman et al. 2004, Cleary et al. 2013) and to improve site preparation for re-growth or re-planting of forest. The removal of stumps and roots negatively affects fauna and flora that use them as a food sources, platforms, dens, nest sites, habitats or refuges (Davis 1996, Keisker 2000, Waldien et al. 2000, Bunnell & Houde 2010). In Finland, Sweden and the UK stump harvesting is performed only during final felling (not during thinning) to exclude risk of damaging adjacent trees (Forestry Commission 2009, Swedish Forest Agency 2009, TAPIO 2010). In Nordic region, the stump retention guidelines state that minimum number of retained stumps is 20/ha (50/ha on finer-textured soils) (Stupak et al. 2008), whereas in the UK about 20-30% of the forest surface should be left undisturbed by stump removal (Forestry Commission 2009). However, in practice small pine stumps are retained at the expense of large spruce stumps because spruce stumps are more easily pulled from the ground than pine stumps (Kalliola & Markkila 2004). In Latvia, spruce, birch and aspen stands are more appropriate for stump removal, but pine stands are more protected by technical constraints and legislation of environmental protection. The main resources for forest fuels are stumps from private and national Latvian forests (Lazdāns et al. 2008). The effects of increasing forest fuel harvesting on the forest ecosystems are poorly understood (Koistinen & Äijälä 2005, Rudolphi & Gustafsson 2005, Äijälä et al. 2005, Eräjää et al. 2010).

Stumps produce similar amounts of saproxylic species as snags and logs and only some differences in species composition could be observed (Dahlberg & Stokland 2004, Wikars et al. 2005, Abrahamsson & Lindbladh 2006, Hedgren 2007, Jonsell & Hansson 2011). However, contradictory results may be found (Kruys & Jonsson 1999, Franc 2007, Bässler et al. 2010, Bouget et al. 2012, Brin et al. 2012). Andersson et al. (2012) found that stump removal had non-significant long-term effect on beetle abundance, species richness and species composition, although several groups of beetles were strongly affected by characteristics of the surrounding forest. Investigations on the effects of stump harvesting on forest biodiversity and on possible long-term effects are rare.

Studies on stump harvesting effect on saproxylic beetle species in Latvia are lacking. In this study we investigated differences in the saproxylic beetle assemblages in two clear-cut sites with removed and retained stumps. Both sampling sites are characterized by significant ecological differences in vegetation and site conditions. These and other factors may play important roles in forming the saproxylic beetle fauna of both sites. We predicted lower numbers of dead wood dwelling species in stumped area than in non-stumped site. Two types of traps were used in this study and capture effectiveness of each sampling method was established.

MATERIALS AND METHODS

Study site

Research area, *Hylocomiosa* forest type, was located in central Latvia, in Ogresgals rural municipality (N: 56°46'57.8" E: 24°45'18"). The selection criteria for forest site were: dominance of *Picea abies*, high rot incidence (> 50%) and weak regeneration of *Populus tremula*. The chosen forest site which fulfilled these criteria was dominated by *P. abies* (60% of stand volume) with admixture of *Pinus sylvestris* and *Betula pendula*. The forest site was 98 years old with size 3 ha. This site had been felled in autumn 2010. In 2012, clear-cut was divided into two separate sample plots: plot with removed stumps and plot with retained stumps. Each area was 0.5 ha in size with buffer zone between them. On one plot (O1) stumps were removed in November 2012 using caterpillar excavator New Holland E215B with stump extractor MCR-500 prototype. On second plot (O2) stumps were left intact. The collection of beetles was done in 2013.

Characterization of vegetation before stump removal in 2012

O1 – plot with removed stumps (Fig. 1). The clear-cut area was covered by naturally regenerated young *Betula pendula, Picea abies, Pinus sylvestris, Populus tremula*, *Quercus robur* and *Sorbus aucuparia* trees and some shrubs: *Corylus avellana, Frangula alnus* and *Rubus idaeus*. The herb species were abundant, dominating by *Calamagrostis arundinacea, Chamaenerion angustifolium*, *Erigeron canadensis, Juncus effusus, Galeopsis bifida*, *Impatiens parviflora, Luzula pilosa, Mycelis muralis*, *Molinia caerulea, Oxalis acetosella* and *Vaccinium myrtillus*. Mosses were abundant; in total 10 moss species were registered. Most of stumps were low and shaded. Soil lichens were not found. Some lichens were found only on stumps with bark - mostly *Cladonia* spp. and *Lepraria incana.*

O2 – control plot with retained stumps (Fig. 2). The clear-cut area was also covered by naturally regenerated young *Betula pendula, Picea abies, Pinus sylvestris, Quercus robur, Salix caprea, Sorbus aucuparia* trees and some shrubs: *Corylus avellana, Frangula alnus, Rubus idaeus*. The herb species were abundant, dominating by *Calamagrostis arundinacea, Erigeron canadensis, Galeopsis bifida, Impatiens parviflora, Luzula pilosa, Mycelis muralis, Pteridium aquilinum, Oxalis acetosella* and *Vaccinium myrtillus*. Mosses were abundant; in total 7 moss species were registered. Lichens were rare, found only on some stumps with bark – *Cladonia* spp. and *Lepraria incana.*

Characterization of vegetation after stump removal in 2013

O1: shrubs and young trees were cut down, herbs were mowed down. Stump removal promoted formation of furrows and soil outcrops.

O2: shrubs and young trees were cut down, herbs were mowed down. The whole area was mounded.

Both sample plots (O1 and O2) were replanted in June 2013 with 2-year-old nursery cultivated bare-root seedlings of *P. abies* with improved root system.

Insect sampling

Beetles were sampled using pitfall traps and window traps. Window trap consisted of transparent Plexiglas sheet (L x W, 60 x 40 cm) attached with a nylon rope to a plastic container (L x W x H, 50 x 20 x 15 cm). Ethylene glycol diluted with water was used as a preservative in a collecting container. Window traps were hung between two artificially placed wooden poles close to stumps. A total of ten traps were placed at each sampling site.

As pitfall traps we used transparent plastic glasses filled with ethylene glycol diluted with water. Trap was dug into the ground so that the rim was in one level with the ground surface. These traps were used to catch mobile ground-dwelling insects. Sixteen traps were placed in each sampling site. Pitfall traps were slightly covered with pieces of bark from neighbouring stumps to protect traps from destruction or flooding.

All traps were checked, and all insects removed from traps, on a bimonthly basis. Traps were exhibited 60 days from August to September in 2013. Collected insects were placed in marked plastic containers, sorted by collecting type and date, and frozen in portable car refrigerator. All samples were transported to Daugavpils University and placed in the large-volume refrigerator (temperature -15°C) for further analysis. All insect species were identified by

Fig. 1. Window traps in clear-cut area with removed stumps (Plot - O1).

Fig. 2. Window trap in clear-cut area with retained stumps (Control plot – O2).

the same person (A.B.) in Coleopterological Research Center, Institute of Life Sciences and Technology, Daugavpils University (Ilgas, Daugavpils Municipality, Latvia). Almost all trapped insects were identified to the genus or species level. Collected beetles were defined as saproxylic species by authors and according to Alexander (2002), Nieto and Alexander (2010), Lachat et al. (2012), Olsson et al. (2012).

RESULTS AND DISCUSSION

By using two types of traps, we collected 2132 individual beetles. 41 family and 163 species were identified (Table 1). Eleven of all collected species were identified only to the genus level: *Phylonthus* sp. (21 individual), *Quedius* sp. (3), *Meligethes* sp. (27), *Cryptophagus* sp. (2), *Atomaria* sp. (2), *Enicmus* sp. (2), *Corticaria* sp. (2), *Cis* sp. (6), *Mordellistena* sp. (20), *Corticeus* sp. (8), *Psylliodes* sp. (2) and were used as separate species (due to morphological similarity of individuals) in further data analysis. Several individuals were identified to family level: Staphylinidae (51 individual), Chrysomelidae (54), Curculionidae (72), but 98 individuals were identified only as representatives of Coleoptera order. Many beetle species accidentally flew into the clear-cut and could not be considered as resident species.

The time of beetle collecting is an important factor because occurrence of beetles differ between months. Our results show, that species richness did not differ significantly between site with removed stumps (120 species) and site with retained stumps (132 species) (Table 1). These non-significant differences could be explained by comparatively small size of sampling plots and active migration of insects. Moreover, 90 species overlapped in both sampling sites. 30 species from stumped site and 42 species from non-stumped site were collected only in particular site and were not present in opposed site. These species in each sampling site were represented by one to seven individuals (most of them occurred in single specimen). The number of specimens collected in site without stumps (1097 individuals (51.5%)) was also similar to number from site with stumps (1035 individuals (48.5%)). Most frequent species in non-stumped area were *Hylobius abietis* (67 individuals), *Anoplotrupes stercorosus* (55), *Pterostichus oblongopunctatus* (55), *Pterostichus niger* (44), *Stictoleptura rubra* (40), *Mordella holomelaena* (33), *Hylobius pinastri* (30), but in stumped site: *H. abietis* (81), *S. rubra* (58), *P. oblongopunctatus* (49), *A. stercorosus* (43), *H. pinastri* (39), *Adrastus pallens* (32), *P. niger* (31).

Beetle families with largest number of species from site with stumps (SS) and site without stumps (WS) were: Carabidae (SS = 28 species (207 individuals); WS = 25 species (222 individuals)), Staphylinidae (SS = 6 (29); WS = 6 (20)), Elateridae (SS = 6 (38); WS = 6 (48)), Nitidulidae (SS = 8 (42); WS = 7 (58)), Coccinellidae (SS = 5 (17); WS = 6 (18)), Cerambycidae (SS = 8 (82); WS = 7 (106)), Chrysomelidae (SS = 6 (16); WS = 7 (17)) (Table 1).

In overall, our results show that window traps were more effective (1337 individuals (62.7%), 126 species) than pitfall traps (795 individuals (37.3%), 74 species) in this study (Table 1). Comparing both sampling sites, we did not find significant differences in the number of specimens (window traps: SS = 628 individuals (47%), WS = 709 (53%); pitfall traps: SS = 407 (51.2%), WS = 388 (48.8%)) and species (window traps: SS = 102 species, WS = 96; pitfall traps: SS = 59, WS = 52).

In total, we recorded 62 saproxylic species in this study (Table 1). 10 species are included in the European Red List of Saproxylic Beetles in category "Least Concern": *Microrhagus pygmaeus*, *Melanotus villosus*, *Ostoma ferruginea*, *Triplax aenea*, *Tritoma subbasalis*, *Dacne bipustulata*, *Mycetophagus quadripustulatus*, *Mycetophagus multipunctatus*, *Litargus connexus*, *Pytho depressus* (Nieto & Alexander 2010). The number of saproxylic individuals was similar in both sampling sites: SS = 379, WS = 384, but the number of species differed between sites: SS = 53, WS = 36. 647 saproxylic individuals (62 species) were

Table 1. Collected specimens in sampling sites with removed and retained stumps depending on type of traps

Order, family	**Genus, species**	**Number of individuals sampled**			
		Site with stumps		**Site without stumps**	
		Pitfall traps	**Window traps**	**Pitfall traps**	**Window traps**
COLEOPTERA					
Dytiscidae					
1.	*Hydroporus palustris*				1
2.	*Ilybius fuliginosus*		1		
3.	*Ilybius ater*				1
4.	*Cilius canaliculaus*				1
Carabidae					
5.	*Carabus cancellatus*	5		9	
6.	*Carabus granulatus*	8		13	
7.	*Carabus nemoralis*			2	
8.	*Carabus glabratus*	3			
9.	*Cychrus caraboides*	2		1	
10.	*Cicindela hybrida*			3	
11.	*Loricera pilicornis*	4		2	
12.	*Patrobus atrorufus*	1			
13.	*Trechus secalis*	4		2	
14.	*Trechus quadristriatus*	8		11	
15.	*Bembidion lampros*	2		1	
16.	*Bembidion quadrimaculatum*	7		14	
17.	*Bembidion tetracolum*	1			
18.	*Bembidion femoratum*	3		6	
19.	*Agonum sexpunctatus*	6		5	
20.	*Poecilus coereleus*	9		17	
21.	*Pterostichus niger*	43	1	31	
22.	*Pterostichus melanarius*	7		12	
23.	*Pterostichus minor*	2		4	
24.	*Pterostichus oblongopunctatus*	53	2	48	1
25.	*Pterostichus rhaeticus*	1			
26.	*Calathus melanocephalus*	6		9	
27.	*Calathus micropterus*	7		7	
28.	*Anchomenus dorsalis*	1			
29.	*Oxypselaphus obscurus*	7		4	
30.	*Amara familiaris*			1	
31.	*Amara communis*	1			
32.	*Amara spreta*			1	
33.	*Amara aenea*	1		2	
34.	*Amara fusca*	2			
35.	*Harpalus rufipes*	7	1	13	
36.	*Anisodactylus binotatus*	1			1
37.	*Acupalpus parvulus*			1	1
38.	*Dromius agilis* *		1		
Histeridae					
39.	*Plegaderus vulneratus* *		1		

Order, family	Genus, species	Number of individuals sampled			
		Site with stumps		Site without stumps	
		Pitfall traps	Window traps	Pitfall traps	Window traps
40.	*Saprinus semistriatus*	1			
Cholevidae					
41.	*Sciodrepoides watsoni*	2			
42.	*Apocatops nigritus*	1			
43.	*Agathidium atrum* **		2		
Silphidae					
44.	*Thanatiphilus sinuatus*	3	1	2	
45.	*Thanatophilus rugosus*			2	
46.	*Oiceoptoma thoracica*	7	3	4	3
47.	*Nicrophorus vespilloides*	14	11	8	13
48.	*Nicrophorus vespillo*				1
49.	*Nicrophorus investigator*		2		
Staphylinidae					
50.	*Xantoholinus tricolor*	1			
51.	*Ontholestes murinus*	1	2		1
52.	*Staphylinus erythropterus*	9		6	
53.	*Phylonthus sp.*	11	1	8	1
54.	*Quedius sp.*	3			
55.	*Phaederus riparius*			1	
56.	*Lordithon lunulatus* *			1	1
57.	*Aleochara curtula*	1			1
	Staphylinidae not det.	17	4	21	9
Geotrupidae					
58.	*Anoplotrupes stercorosus*	41	14	36	7
Scarabaeidae					
59.	*Cetonia aurata* *	2	5	3	3
60.	*Protaetia metallica* **	3	8	1	9
61.	*Oxythyrea funesta* *		3		1
62.	*Trichius fasciatus* *		15		10
63.	*Serica brunnea*	2	6		11
Scirtidae					
64.	*Cyphon variabilis*		6		4
65.	*Cyphon pubescens*	1	5		6
66.	*Cyphon padi*	3	17	1	12
Buprestidae					
67.	*Agrilus viridis* *				1
68.	*Agrilus roberti*		2		
69.	*Anthaxia quadripunctata* *		3		1
70.	*Anthaxia godeti* **				1
71.	*Trachys minuta*		2		3
Eucnemidae					
72.	*Microrhagus pygmaeus* *		1		
Throscidae					
73.	*Trixagus dermestoides* **				2
Elateridae					
74.	*Agrypnus murinus*		1		1

Order, family	Genus, species	Number of individuals sampled			
		Site with stumps		Site without stumps	
		Pitfall traps	Window traps	Pitfall traps	Window traps
75.	*Athous vittatus*				1
76.	*Athous subfuscus* *		5		8
77.	*Prosternon tesselatum*		2		2
78.	*Melanotus villosus* *		1		
79.	*Dalopius marginalis*		5	1	3
80.	*Adrastus pallens*		24		32
Trogossitidae					
81.	*Ostoma ferruginea* *		3		
Dasytidae					
82.	*Dasytes niger* *				1
83.	*Dasytes plumbeus*		4		1
Kateretidae					
84.	*Brachypterus urticae*		8		11
Nitidulidae					
85.	*Meligethes aeneus*		5		9
86.	*Meligethes viridescens*		9		15
87.	*Meligethes sp.*		11		16
88.	*Soronia grisea* *				1
89.	*Cychramus luteus* *		6		9
90.	*Cychramus variegatus* *		2		
91.	*Glischrochilus quadripunctatus* *		2		2
92.	*Glischrochilus hortensis* *		5	2	4
93.	*Glischrochilus grandis* **		2		
Monotomidae					
94.	*Rhizophagus ferrugineus* **		1		
95.	*Rhizophagus dispar* *		3		
96.	*Rhizophagus bipustulatus* **		1		
Silvanidae					
97.	*Silvanus bidentatus* **		3		
Phalacridae					
98.	*Olibrus millefolii*				3
99.	*Olibrus bimaculatus*		4		8
Cryptophagidae					
100.	*Cryptophagus sp.*			1	1
101.	*Atomaria fuscata*		1		1
102.	*Atomaria sp.*		1		1
103.	*Antherophagus nigricornis*				1
Erotylidae					
104.	*Triplax aenea* *		1		1
105.	*Tritoma subbasalis* *		1		
106.	*Dacne bipustulata* *		2		
Byturidae					
107.	*Byturus tomentosus*		12		17
Cerylonidae					
108.	*Cerylon ferrugineum* *		1		1

Order, family	Genus, species	Number of individuals sampled			
		Site with stumps		Site without stumps	
		Pitfall traps	Window traps	Pitfall traps	Window traps
Endomychidae					
109.	*Endomychus coccineus* *		2		
Coccinellidae					
110.	*Propylea quatuordecimguttata*		3	1	4
111.	*Myrrha octodecimguttata*	1	2		
112.	*Calvia quqtuordecimguttata*				1
113.	*Hippodamia notata*		2		2
114.	*Thea vigintiduopunctata*				
115.	*Coccinella septempunctata*		4		4
116.	*Coccinella quinquepunctata*	2	3		5
117.	*Coccinella hieroglyphica*				1
Latridiidae					
118.	*Enicmus sp.*			1	1
119.	*Corticaria sp.*		1		1
120.	*Cortinicara gibbosa* *		6	8	14
121.	*Corticarina fuscula*		4	5	9
Mycetophagidae					
122.	*Mycetophagus quadripustulatus* *		6		1
123.	*Mycetophagus multipunctatus* *		1		
124.	*Litargus connexus* *		4		
125.	*Typhaea stercorea*		1		1
Ciidae					
126.	*Cis boleti* *				1
127.	*Cis sp.* **		6		
Melandryidae					
128.	*Serropaplpus barbatus* *		2		
Mordellidae					
129.	*Mordella holomelaena* **	1	32		29
130.	*Mordella aculeata* **		28		23
131.	*Tomoxia bucephala* *		1		
132.	*Hoshihananomia perlata* **		1		
133.	*Mordellistena sp.* **		9		11
Colydiidae					
134.	*Synchyta humeralis* *		1		
135.	*Bitoma crenata* *				1
Oedemeridae					
136.	*Oedemera lurida*		1		1
Pythidae					
137.	*Pytho depressus* *		7		
Salpingidae					
138.	*Sphaeriestes bimaculatus* **		2		
Anthicidae					
139.	*Omonadus floralis*			1	1
140.	*Notoxus monoceros*	1	8		12
Aderidae					

Order, family	Genus, species	Number of individuals sampled			
		Site with stumps		Site without stumps	
		Pitfall traps	Window traps	Pitfall traps	Window traps
141.	*Anidorus nogrinus*				2
Tenebrionidae					
142.	*Lagria hirta*	1	16		19
143.	*Uloma rufa* **	1	2		3
144.	*Corticeus sp.* **		4		4
Cerambycidae					
145.	*Rhagium inquisitor* *	1	12		13
146.	*Rhagium mordax* *				1
147.	*Leptura quadrifasciata* **		3		6
148.	*Anastrangalia reyi* **		7		7
149.	*Stictoleptura rubra* **	1	39	4	54
150.	*Paracorymbia maculicornis* **		6		8
151.	*Stenurella melanura* **		10		12
152.	*Acanthocinus aedilis* *		1		
153.	*Spondylis buprestoides* **		2		
Chrysomelidae					
154.	*Chrysomela populi*		2		2
155.	*Phratora vitellinae*		4		4
156.	*Galerucella lineola*		1		1
157.	*Lochmaea caprea*		5		5
158.	*Batophila rubi*		1		1
159.	*Cassida margaritacea*		3		3
160.	*Psylliodes sp.*			1	1
	Chrysomelidae *not det.*	3	18	5	28
Curculionidae					
161.	*Otiorhynchus ovatus*	2			2
162.	*Hylobius abietis* *	46	21	14	67
163.	*Hylobius pinastri* *	19	11	9	30
	Curculionidae *not det*	6	34	9	23
	Coleoptera *not det.*	7	42	11	38
TOTAL	**Specimens**	**407**	**628**	**388**	**709**
TOTAL	**Species**	**59**	**102**	**52**	**96**

* saproxylic species (according to references)

** saproxylic species (defined by authors)

caught by window traps, but 116 individuals (11 species) by pitfall traps. Comparing both sites, we found significant differences in the number of individuals (window traps: SS = 305, WS = 342; pitfall traps: SS = 74, WS = 42) and species (window traps: SS = 53, WS = 36; pitfall traps: SS = 8, WS = 8). Some of saproxylic species were found only in site with retained stumps, e.g., *Rhizophagus* spp., *O. ferruginea, S. bidentatus*, *L. connexus*, *Cis sp.*, *P. depressus*. In this study, we collected only species randomly creeping or flying along window traps and pitfall traps. It is necessary to include methods of collecting insects dwelling on/under bark, e.g. sieving bark from the stumps.

The greatest part of data from such studies in Latvia are available from research projects and are not easily accessible because they frequently remain unpublished. To get a complete picture of the differences in beetle fauna between sites with retained and removed stumps, long-term ecological monitoring must be made combining different sampling methods in the large-scale study sites. Finally, the sampling time must match to time when beetles are more diverse and abundant.

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REFERENCES

Abrahamsson M., Lindbladh M. 2006. Comparison of saproxylic beetle occurrence between man-made high- and low-stumps of spruce (*Picea abies*). F*orest Ecology and Management,* 226: 230-237.

Äijälä O., Kuusinen M., Halonen M. 2005. Metsäenergiapuun korjuu uudistushakkuualoilta-ohjeisto. Metsätalouden kehittämiskeskus Tapio, Helsinki. Pp. 14 (In Finnish).

Alexander K.N.A. 2002. The invertebrates of living and decaying timber in Britain and Ireland, A provisional annotated checklist. English Nature Research Report No. 467, Northminster House, Peterborough.

Andersson J., Hjältén J., Dynesius M. 2012. Long-term effects of stump harvesting and landscape composition on beetle assemblages in the hemiboreal forest of Sweden. *Forest Ecology and Management,* 271: 75-80.

Bässler C., Müller J., Dziock F., Brandl R. 2010. Effects of resource availability and climate on the diversity of wood-decaying fungi. *Journal of Ecology,* 98(4): 822-832.

Björheden R. 2006. Drivers behind the development of forest energy in Sweden. *Biomass Bioenergy,* 30: 289-295.

Bouget C., Lassauce A., Jonsell M. 2012. Effects of fuelwood harvesting on biodiversity - a review focused on the situation in Europe[1]. *Canadian Journal of Forest Research,* 42: 1421-1432.

Brin A., Bouget C., Valladares L., Brustel H. 2012. Are stumps important for the conservation of saproxylic beetle in managed forests? Insights from a comparison of assemblages on logs and stumps in oak-dominated and pine plantation forests. *Insect Conservation and Diversity,* 6(3): 255-264.

Bunnell F.L., Houde I. 2010. Down wood and biodiversity - Implications to forest practices. *Environmental Review,* 18: 397-421.

Chapman B., Xiao G. 2000. Inoculation of stumps with *Hypholoma fasciculare* as a possible means to control armillaria root disease. *Canadian Journal of Botany,* 78: 129-134.

Chapman B., Xiao G., Myers S. 2004. Early results from field trials using Hypholoma fasciculare to reduce Armillaria ostoyae root disease. *Canadian Journal of Botany,* 82: 962-969.

Cleary M.R., Arhipova N., Morrison, D.J., Thomsen I.M., Sturrock R.N., Vasaitis R., Gaitnieks T., Stenlid J. 2013. Stump removal to control root disease in Canada and Scandinavia: A synthesis of results from long-term trials. F*orest Ecology and Management,* 290: 5-14.

Dahlberg A., Stokland J.N. 2004. Vedlevande arters krav på substrat 7. Skogsstyrelsen, Jönköping, Sweden. (In Swedish).

Davis H. 1996. Characteristics and selection of winter dens by black bears in coastal

British Columbia. Unpublished Master's dissertation, Simon Fraser University. Retrieved June 12, 2012, from http://www.summit.sfu.ca/system/files/iritems1/7190/b18319129.pdf

Eräjää S., Halme, P., Kotiaho, J.S., Markkanen, A., Toivanen, T. 2010. The Volume and Composition of Dead Wood on Traditional and Forest Fuel Harvested Clear-Cuts. *Silva Fennica*, 44 (2): 203–211.

Forestry Commission 2009. Stump harvesting: Interim guidance on site selection and good practice. Edinburgh: Forestry Commission.

Franc, N. 2007. Standing or downed dead trees - does it matter for saproxylic beetles in temperate oak-rich forest? *Canadian Journal of Forest Research,* 37: 2494-2507.

Gibb, H., Hjältén, J., Ball, J., Atlegrim, O., Pettersson, R., Hilszczanski, J., Johansson, T., Danell, K. 2006. Effects of landscape composition and substrate availability on saproxylic beetles in boreal forests: a study using experimental logs for monitoring assemblages. *Ecography,* 29: 1-14.

Hakkila, P. 2004. Puuenergian teknologiaohjelma 1999–2003. Metsähakkeen tuotantoteknologia loppuraportti. Teknologiaohjelmaraportti 5/2004. Tekes, Helsinki. Pp. 135 (In Finnish).

Hedgren, P. 2007. Early arriving saproxylic beetles (Coleoptera) and parasitoids (Hymenoptera) in low and high stumps of Norway spruce. *Forest Ecology and Management,* 241: 155-161.

Hjältén, J., Johansson, T., Alinvi, O., Danell, K., Ball, J., Pettersson, R., 2007. The importance of substrate type, shading and scorching for the attractiveness of dead wood to saproxylic beetles. *Basic and Applied Ecology,* 8: 364-376.

Jackson, H.B., Baum, K.A., Robert, T., Cronin, J.T. 2009. Habitat-specific movement and edge-mediated behavior of the saproxylic insect *Odontotaenius disjunctus* (Coleoptera: Passalidae). *Environmental Entomology,* 38(5): 1411-1422.

Jonsell, M. 2008. The effects of forest biomass harvesting on biodiversity. In: Röser, D., Asikainen, A., Raulund-Rasmussen, K., Stupak, I. (Eds.), Sustainable Use of Forest Biomass for Energy – A Synthesis with Focus on the Nordic and Baltic Region. Springer, Pp. 129–154.

Jonsell, M., Hansson, J. 2011. Logs and stumps in clearcuts support similar saproxylic beetle diversity: Implications for bioenergy harvest. *Silva Fennica,* 45: 1053-1064.

Kalliola, T., Markkila, M. 2004. Stumps - An unutilised reserve. Newsletter on results 4/2004. Helsinki: Tekes.

Keisker, D.G. 2000. Types of wildlife trees and coarse woody debris required by wildlife of north-central British Columbia (Working Paper 50/2000). Victoria, BC: Government of British Columbia.

Koistinen, A., Äijälä, O. 2005. Energiapuu osana puuntuotantoa - taustaraportti. Metsätalouden kehittämiskeskus Tapio, Helsinki, Pp.15 (In Finnish).

Kruys N., Jonsson, B.G. 1999. Fine woody debris is important for species richness on logs in managed boreal spruce forests of northern Sweden. *Canadian Journal of Forest Research,* 29(8): 1295-1299.

Lachat T., Wermelinger, B., Gossner, M.M., Bussler, H., Isacsson, G. 2012. Saproxylic beetles as indicator species for dead-wood amount and temperature in European beech forests. *Ecological Indicators*, 23: 323-331.

Lazdāns V., Lazdiņš A., Zimelis A., Petersson, M. 2008. Celmu izstrādes tehnoloģijas enerģētiskās koksnes ražošanai [Stump harvesting technologies for production of forest fuels]. LVMI "Silava" (in Latvian), ISBN 978-9934-8016-0-0.

Lindbladh M., Abrahamsson M., Seedre M., Jonsell M. 2007. Saproxylic beetles in artificially created high-stumps of spruce and birch within and outside hotspot areas. *Biodiversity and Conservation,* 16(11): 3213–3226.

Martikainen P., Siitonen J., Punttila P., Kaila L., Rauh, J. 2000. Species richness of Coleoptera in mature managed and old-growth boreal forests in Southern Finland. *Biological Conservation,* 94: 199-209.

Nieto A., Alexander K.N.A. 2010. European Red List of Saproxylic Beetles. Luxembourg: Publications Office of the European Union, Pp. 45.

Olsson J., Johansson, T., Jonsson, B.G., Hjältén, J., Edman, M., Ericson, L. 2012. Landscape and substrate properties affect species richness and community composition of saproxylic beetles. *Forest Ecology and Management,* 286: 108-120.

Rudolphi J., Gustafsson, L. 2005. Effects on forestfuel harvesting on the amount of deadwood on clear-cuts. *Scandinavian Journal of Forest Research,* 20: 235-242.

Siitonen J. 2001. Forest management, coarse woody debris and saproxylic organisms. Fennoscandian boreal forests as an example. *Ecological Bulletins,* 49: 11-41.

Stenbacka F., Hjältén, J., Hilszczański, J., Dynesius, M. 2010. Saproxylic and non-saproxylic beetle assemblages in boreal spruce forests of different age and forestry intensity. *Ecological Applications,* 20(8): 2310-2321.

Stupak I., Asikainen, A., Röser, D., Pasanen, K. 2008. Review of recommendations for forest energy harvesting and wood ash recycling. In: D. Röser, A. Asikainen, K. Raulund-Rasmussen, & I. Stupak (Eds.), Sustainable use of forest biomass for energy: A synthesis with focus on the Baltic and Nordic regions, Pp. 155-196. Dordrecht: Springer.

Swedish Forest Agency. 2009. Stubbskörd - kunskapssammanställning och Skogsstyrelsens rekommendationer [Stump harvesting - Knowledge compilation and Swedish Forest Agency recommendations]. Meddelande 4: 2009. Skogsstyrelsen förlag, Jönköping (in Swedish).

TAPIO. 2010. Energiapuun korjuu [Harvesting energy wood] (in Finnish). Retrieved February, 2011, from http://www.forestenergy.org/openfile/152

Waldien, D.L., Hayes, J.P., Arnett, E.B. 2000. Day-roosts of female long-eared myotis in western Oregon. *Journal of Wildlife Management,* 64: 785-796.

Walmsley J.D., Godbold, D.L. 2009. Stump harvesting for bioenergy - a review of the environmental impacts. *Forestry*, 83(1): 17-38.

Warriner M.D., Nebeker, T.E., Tucker, S.A., Schiefer, T.L. 2004. Comparison of Saproxylic Beetle (Coleoptera) Assemblages in Upland Hardwood and Bottomland Hardwood Forests. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. Pp. 150-153.

Wikars L.O., Sahlin, E., Ranius, T. 2005. A comparison of three methods to estimate species richness of saproxylic beetles (Coleoptera) in logs and high stumps of Norway spruce. *Canadian Entomologist,* 137: 304-324.

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