ForestBIOTA project

Forest Biodiversity Test-phase Assessments

Deadwood assessment

Work report

Davide TRAVAGLINI, Gherardo CHIRICI

May 2006

Accademia Italiana di Scienze Forestali

Introduction

In recent years, deadwood has become more and more considered as indicator in the assessment of the biodiversity and naturalness of forest systems (McComb and Lindenmayer 1999, Larsson et al. 2001, Kristensen 2003, Schuck at al. 2004).

Its occurrence, in an appropriate proportion according to forest use, is fundamental for the maintenance of biological diversity, since it represents a microhabitat for hundred of species of invertebrates (Heliövaara and Väisänen 1984, Kirby and Drake 1993, Samuelsson *et al*. 1994, Siitonen 2001), fungi (Rydin *et al.* 1997, Sippola and Renvall 1999, Heilmann-Clausen 2001, Mason 2003), bryophytes (Söderström 1988, Lesica *et al*. 1991, Ódor and Standovár 2001), lichens (Humphrey *et al*. 2002), amphibians (Raymond and Hardy 1991, Herbeck and Larsen 1999), small mammals (Harmon *et al.* 1986) and birds (Hunter 1990, Sandström 1992, Mikusinski and Angelstam 1997, McComb and Lindenmayer 1999).

The quantity of deadwood occurring in natural forests in the different European regions depends on many factors, and its correct estimation must consider forest type (species' composition and structure), development stage, type and frequency of natural disturbance in the region (Nocentini 2002), type of management, but also soil and climatic characteristics, which together contribute to complete the formation and decomposition cycle of deadwood (Christensen *et al* 2003).

Quantities of deadwood have strongly decreased since the middle of the nineteenth century due to intense forest exploitation (Linder and Ostlund 1998, Siitonen *et al*. 2000, Nilsson *et al.* 2001) and widespread burning of small wood pieces and other leftovers, and to the removal of all physical obstacles to sylvicultural activity.

Presence of deadwood can be related to the intensity of sylvicultural actions and the way these are carried out (Guby and Dobbertin 1996, Green and Peterken 1997). This is why deadwood quantities (woody necromass) in managed forests are considerably lower than in forests left to evolve naturally: it has been estimated that only 2 to 30% of the deadwood found in non-managed forests occurs in managed ones (Lesica *et al*. 1991, Green and Peterken 1997, Kirby *et al*. 1998, Jonsson 2000). Therefore, in the interest of conservation, attempts are being made to increase woody necromass in productive areas (Hodge and Peterken 1998, Harmon 2001, Mason 2003, Jonsell *et al*. 2004, Ranius and Kindvall 2004, Ranius *et al.* 2005, Abrahamsson and Lindbladh 2006).

The perspective of sustainable forest management is internationally recognized and fostered. On an European level, definition and effective implementation of the concept of sustainable forest management by specific criteria and indicators are mainly carried out through the Ministerial Conference on the Protection of Forests in Europe (MCPFE). In such a context, the relevance of deadwood for the assessment and monitoring of sustainable forest management is testified by the MCPFE indicator 4.5 Volume of standing deadwood and of lying deadwood on forest and other wooded land classified by forest type (MCPFE 2003). MCPFE underlines the need to improve and harmonise existing forest assessment and monitoring systems in the European countries, in order to have comparable data.

MCPFE targets are supported by the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), established in 1985 with the objective to «provide a periodic overview on the spatial and temporal variation in forest condition» in a European and national large-scale systematic network arranged in a 16x16 km grid (Level I) and «to contribute to a better understandanding of the relationship between the condition of forest ecosystems and stress factor, in particular air pollution» (UNECE 2003), within an Intensive Forest Monitoring Programme (Level II) by more than 860 plots (Hauβmann and Fisher 2004). Under the Regulation (EC) No 2152/2003 (Forest Focus) for the devolopment of forest biodiversity monitoring (Art 6 (2)), ICP Forests has launched the ForestBIOTA project, whose aim is to contribute to forest biodiversity assessments in Europe by (ForestBIOTA 2004) «I. further development and test wise implementation of monitoring methods for different aspects of forest biodiversity at intensive monitoring plots», including stand structure, deadwood, forest types, epiphytic lichens and ground vegetation; «II. correlative studies in order to determine relationships between some compositional, structural and functional key factors of forest biodiversity at the monitoring plots using existing intensive monitoring data as well as newly assessed data; III. recommendations for forest biodiversity indicators and surrogates that can be applied in the context of large scale inventories».

The report prepared by the Accademia Italiana di Scienze Forestali describes the methodology for surveying woody necromass within the ForestBIOTA project and results of its application on 91 Intensive Level II monitoring areas are presented.

Methods

Deadwood survey scheme

Survey unit for assessing woody necromass within EU/ICP Forest level-II monitoring areas consists of a magnetic north-oriented 50 m side square plot, within which is positioned a cluster of four circular subplots. As an alternative, the plot may be shaped as a moderate rectangle, preferably with a minimum width of 40 m (or a maximum length of 62.5 m).

The subplots, of 7 m radius, are centred on the corners of a magnetic north-oriented 26 m side square (Figure 1). If such a configuration is not feasible because the plot has a design different from that suggested, or because large parts of a subplot contain installed Level II measurement equipment, the four subplots should be arranged within the plot in such a way that distances between the subplot centers and plot borders are maximized.

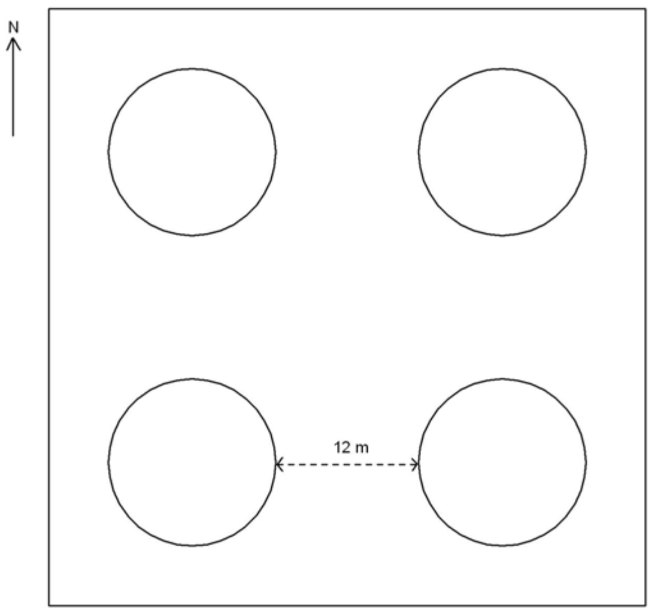

Figure 1. Survey unit for estimating woody necromass within EU/ICP Forest level II monitoring areas.

Inventoried attributes and measurement

Five deadwood components are considered by the ForestBIOTA protocol:

- standing dead trees (standing deadwood or snag);

- downed dead trees;
- lying deadwood pieces;
- stumps.

The protocol asks for a complete census of all standing and downed dead trees within the 50-m plot, whereas stumps and lying deadwood pieces are surveyed within the four circular subplots.

A standing dead tree (including snag) is surveyed if its diameter at breast height (dbh) is equal to or greater than 5 cm and its stem base lies within the boundary of the plot. In contrast to stumps, snags are required to have a height equal to or greater than 1.3 m.

A downed dead tree (in one piece or in more pieces unambiguously recognizable as a single tree) is surveyed if its diameter at breast height (dbh) is equal to or greather than 5 cm and the thickest part of its stem lies within the boundary of the plot.

A lying deadwood piece is measured if its diameter at thicker end is equal to or greather than 5 cm and its thicker end lies within the boundary of the subplot (if the piece contains several branches, then all the branches are considered and measured as separate deadwood pieces if their diameter is equal to or greater than 5 cm at the thicker end).

A stump is inventoried if its diameter at the level where the tree was cut (or where the stem broken off) is equal to or greather than 10 cm and if more than 50% of the stump lies within the boundary of the subplot.

The protocol asks for the survey in the field of the following attributes:

a. dbh and height of all standing dead trees within the 50-m plot (for snag, also stem diameter at half snag height, only in the case of snag height equal to or smaller than 4 m);

b. dbh and length of all downed dead trees within the 50-m plot;

c. length and diameter at half length of all lying deadwood pieces within the four circular subplots (length is measured from the thicher end of the piece until the point where the diameter size is equal to or smaller than 3 cm);

d. height and diameter at the level where the tree was cut (or where the stem broken off) of all stumps within the subplots;

e. species and decay level of all deadwood components. Decay levels are assessed according to the five decomposition classes (Figure 2) proposed by Hunter (1990).

Estimation procedure

The volume of each standing and downed dead tree is calculates using double-entry volume tables (in the case of snag, if the snag height is greater than 4 m, the snag volume is estimated by applying a reduction factor[1] to the intact volume obtained by double-entry tables, otherwise the snag volume in m^3 is estimated by formula [1]); volumes in m^3 are then added up at plot level and transformed into m^3ha^{-1}.

The volume of each lying deadwood piece and stumps is calculated by means of formulas [1] and [2]; volumes in m^3 are then added up at subplot level and transformed into m^3ha^{-1}.

[1] The reduction factor is defined based on a height-dbh relationship obtained from surrounding trees of the same species.

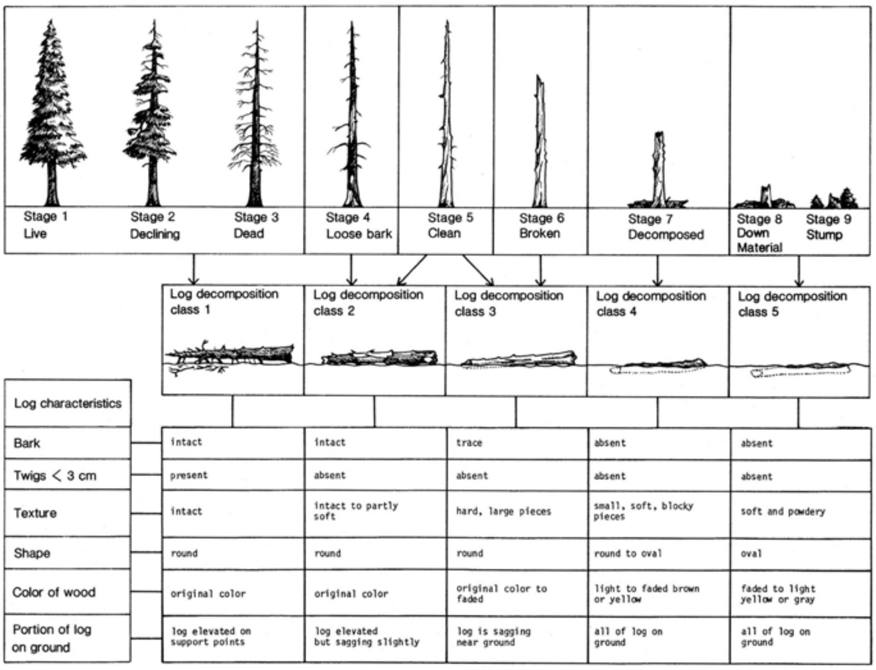

Figure 2. Decay levels according to the five decomposition classes proposed by Hunter (1990).

$$V = \frac{\pi}{4} d^2{}_{0.5l}\, l \qquad [1]$$

where: V = volume; $d_{0.5l}$ = diameter at half length/height; l = length/height.

$$V_{stump} = \frac{\pi}{4} d^2 h \qquad [2]$$

where: V_{stump} = volume of the stump; d = diameter of the stump at the cutting or breaking point; h = height of the stump.

The volume of stumps and lying deadwood pieces in m^3ha^{-1} is calculated for the whole plot, as an average of estimates for each of the four subplots. If X_i is the volume figure (in m^3ha^{-1}) estimated on the i-th subplot, then the averaged overall value at the plot level (X_{pp}, in m^3ha^{-1}) is equal to:

$$X_{pp} = \frac{1}{4}\sum_{i=1}^{4} X_i \qquad [3]$$

with a variance ($(m^3ha^{-1})^2$) equal to:

$$S^2 x_{pp} = \frac{\sum_{i=1}^{4}(X_i - X_{pp})^2}{12} \qquad [4]$$

Total deadwood volume at plot level (TV_{dead}, in m^3ha^{-1}) is equal to the sum of volumes from standing deadwood (V_{st_tr}), downed dead trees (V_{down_tr}), lying deadwood pieces (V_{lying}) and stumps (V_{stump}).

Total deadwood volume can be considered as the sum of true measured values (i.e., standing deadwood and downed dead trees) and values estimated by sampling (i.e., lying deadwood and stumps). Assuming no covariance between V_{lying} and V_{stump}, the standard error (in m^3ha^{-1}) of TV_{dead} is equal to:

$$S_{TV_{dead}} = \sqrt{S^2{}_{V_{lying}} + S^2{}_{V_{stump}}} \qquad [5]$$

where $S^2{}_{V_{lying}}$ and $S^2{}_{V_{stump}}$ are, respectively, the variances of V_{lying} and V_{stump}, estimated according to formula [4].

Material

The survey scheme described in the preceding section was applied to the 91 EU/ICP Forest Level II monitoring areas distributed over 11 European countries (Figure 3).

Figure 3. Distribution of the 91 EU/ICP level II plots.

For each EU/ICP level II monitoring area information on total deadwood volume, deadwood decay levels and number of deadwood pieces was compiled.

The distributions of total deadwood volume among the five deadwood components (standing dead trees, snags, downed dead trees, lying deadwood pieces and stumps) and between coarse (deadwood elements with diameter grater than 10 cm) and fine (deadwood elements with diameter equal to or lower than 10 cm) woody necromass were also recorded.

Each monitoring area was classified according to the forest type classification proposed by the EU/ICP Forests Biodiversity Test-Phase (ForestBIOTA 2005): fluvial and riparian woodland (FT1N.1); lowland beech forest (FT1N.3a); mountain mixed beech forest (FT1N.3b); thermophilous deciduous woodland (FT1N.4); acidophilous oak-dominated woodland (FT1N.5); meso and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland (FT1N.7);

natural and semi-natural broadleaved mediterranean and macaronesian sclerophyllus woodland (FT2N); coniferous plantations (FT3A); fir and spruce woodland (FT3N.1); alpine larch-arolla and mountain pine woodland (FT3N.2); scots pine woodland (FT3N.3); black pine, mediterranean and macaronesian pines or pine-juniper woodland (FT3N.4); taiga woodland (FT3N.6); hemiboreal forest (FT4N.2); mixed fir-spruce-beech woodland (FT4N.5).

Statistical differences among forest types as concerns the total deadwood volume and its distribution within deadwood components were assessed by single-factor analysis of variance, verifying the variance homogeneity by the Levene test and carrying out multiple comparison by the HSD Tukey test (Zar 1996). In the case of the volume distribution within deadwood components, the arcsine transformation was applied to the percentage values.

Main results

Summary details of deadwood volume in each EU/ICP level II monitoring areas are given in the Annex 1. Total deadwood volume range is large within the 91 monitoring areas, varying between 0 and 258 m^3ha^{-1}. However most of the examined plots have a volume less than 25 m^3ha^{-1} (Figure 4-5).

Highest values occur on plots in central Europe. Volumes greater than 100 m^3ha^{-1} have been found in two fir-spruce forests and in one lowland beech forest; all such three forests have an age over 100 years.

Albeit, as expected, total volume in young forests is lower than that of the older ones, woody necromass distribution among age classes shows a high variability (Figure 6).

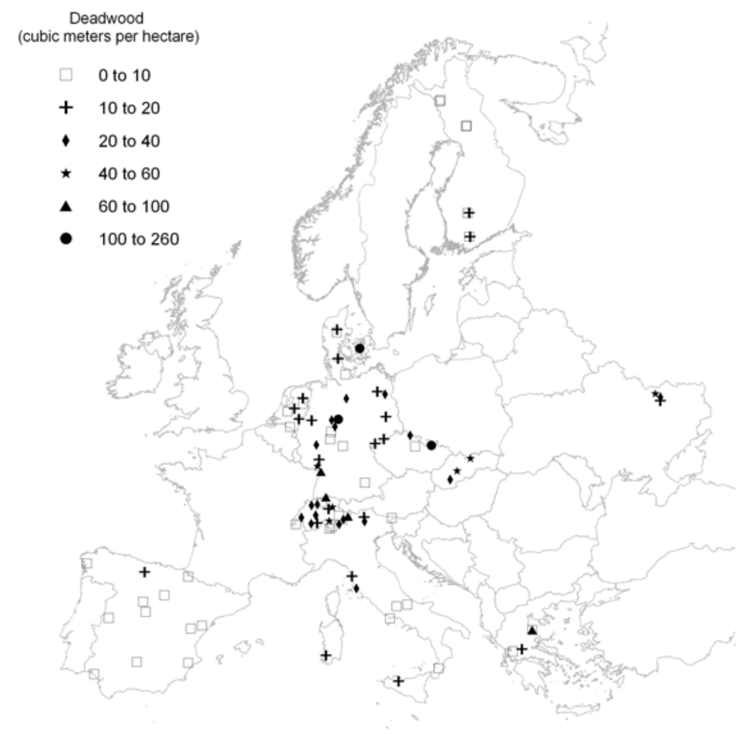

Figure 4. Distribution of the EU/ICP level II monitoring areas labeled with respect to their total deadwood volume.

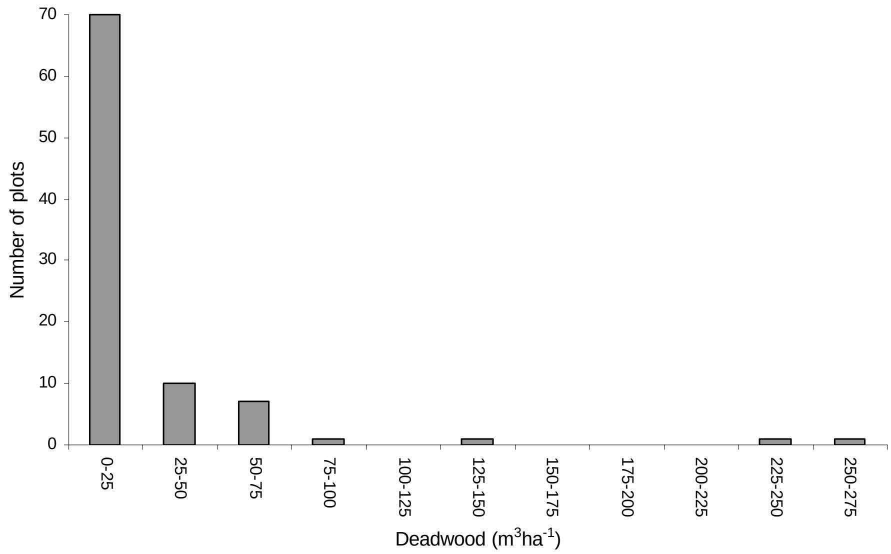

Figure 5. Frequency distribution of monitoring areas according to total deadwood volume classes (m^3ha^{-1}).

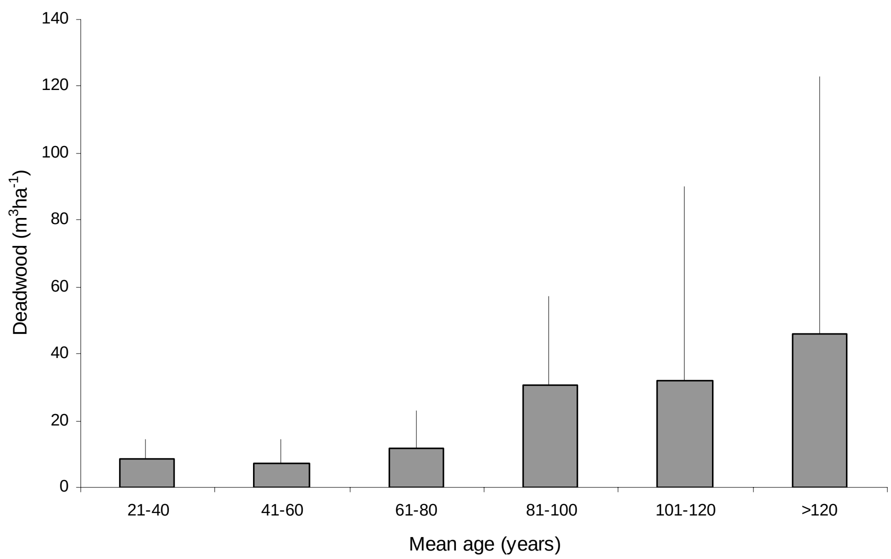

Figure 6. Total deadwood volume (m^3ha^{-1}) vs. age classes. Mean values and standard deviation are given.

Within the examined plots, the means of deadwood total volume vary greatly, but not significantly, among forest types (Table 1), ranging from an average of 1 m^3ha^{-1} in black pine, mediterranean and macaronesian pines or pine-juniper woodland (FT3N.4) to an average of 43 m^3ha^{-1} in fir and spruce woodland (FT3N.1). Values of about 60 m^3ha^{-1} are reported for the hemiboreal forest (FT4N.2) and the fluvial and riparian woodland (FT1N.1), but only one monitoring area occurs in each of such forest types. A mean of total deadwood volume equal to 20-40 m^3ha^{-1} has been found on plots in lowland beech forest (FT1N.3a), mountain mixed beech forest (FT1N.3b), mixed fir-spruce-beech woodland (FT4N.5), meso and eutrophic oak forest (FT1N.7) and Alpine larch-arolla and mountain pine woodland (FT3N.2). All other forest types have a mean of total deadwood lower than 20 m^3ha^{-1}.

Forest type *code*	*description*	*Number of EU/ICP level II plots* *n*	*Total deadwood volume* m^3ha^{-1}
FT1N.1	Fluvial and riparian woodland	1	64
FT1N.3a	Lowland beech forest	16	36 (63)
FT1N.3b	Mountain mixed beech forest	8	22 (24)
FT1N.4	Thermophilous deciduous woodland	1	3
FT1N.5	Acidophilous oak-dominated woodland	5	7 (5)
FT1N.7	Meso and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland	8	24 (19)
FT2N	Natural and semi-natural broadleaved Mediterranean and Macaronesian sclerophyllus woodland	8	9 (10)
FT3A	Coniferous plantations	5	10 (4)
FT3N.1	Fir and spruce woodland	15	43 (59)
FT3N.2	Alpine larch-Arolla and mountain pine woodland	3	38 (28)
FT3N.3	Scots pine woodland	4	17 (4)
FT3N.4	Black pine; Mediterranean and Macaronesian pine or pine-juniper woodland	5	1 (0)
FT3N.6	Taiga woodland	8	7 (7)
FT4N.2	Hemiboreal forest	1	59
FT4N.5	Mixed fir-spruce-beech woodland	1	34
-	Not defined	2	0 (0)

Table 1. Deadwood volume (m^3ha^{-1}) in relation to forest types. Mean value, standard deviation (in brackets) and number of EU/ICP level II monitoring areas are given.

As expected, coarse necromass contributes more to the total deadwood volume than the fine one (Figure 7). Differences of the mean percentages for both coarse and fine necromass are very highly significant among forest types (p<0.001). Differences of the mean percentages among forest types are highly significant (p<0.01) also for the deadwood components, except for snags (Table 2-3).

In most cases, ground deadwood (downed dead trees, lying deadwood pieces and stumps) contibutes more to the total deadwood volume than standing deadwood (standing dead trees and snags).

Total number of deadwood pieces tends to increase as the quantity of woody necromass increases (Table 4).

As far as deadwood decay levels is concerned, decay classes 1, 2 and 3 prevails together on more than 75% of the monitoring areas. Class 3 prevails on plots where more than 50% of total deadwood volume is composed by only one decay class (Figure 8).

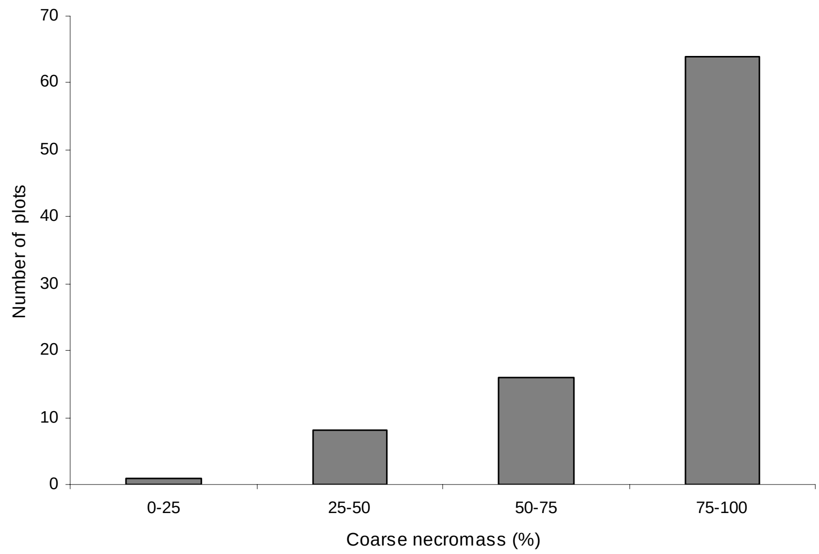

Figure 7. Frequency distribution of monitoring areas according to the percentage of coarse necromass with respect to total deadwood volume.

Forest types code	*Coarse material volume %*		*Fine material volume %*	
FT2N	45.4	A	54.6	CD
FT1N.5	60.2	AB	39.8	D
FT3A	69.6	ABC	30.4	BCD
FT1N3.a	80.3	ABC	19.7	BCD
FT1N3.b	82.6	ABCD	17.4	ABCD
FT3N.2	85.3	BCD	14.7	ABCD
FT1N.7	90.8	BCD	9.2	ABCD
FT3N.6	94.1	CD	5.9	ABC
FT3N.3	94.4	CD	5.6	ABC
FT3N.1	96.5	CD	3.5	AB
FT3N.4	99.9	D	0.1	A

Table 2. Mean percentage value of coarse and fine necromass across forest types. Means with different letters are statistically different at p=0.05.

Forest types *code*	*Standing deadwood volume* %		*Snags volume* %		*Downed dead trees volume* %		*Lying deadwood pieces volume* %		*Stump volume* %	
FT3N.4	0.2	A	0.1	A	0.0	A	0.1	A	99.6	B
FT3N.1	2.3	AB	21.8	A	10.0	ABC	34.6	B	31.3	A
FT1N.3a	2.6	AB	19.3	A	2.7	AB	46.8	B	28.6	A
FT3N.6	10.4	AB	24.9	A	25.2	ABC	12.9	AB	26.6	A
FT1N.3b	12.7	AB	24.4	A	10.0	ABC	33.5	AB	19.4	A
FT3N.2	13.4	AB	15.7	A	33.4	BC	23.8	AB	13.7	A
FT1N.7	19.3	AB	17.7	A	15.4	ABC	34.8	B	12.8	A
FT3A	19.4	AB	11.2	A	20.2	ABC	38.9	B	10.3	A
FT3N.3	22.6	AB	5.3	A	42.8	C	26.0	AB	3.3	A
FT2N	29.7	AB	38.4	A	6.7	ABC	3.6	AB	21.6	A
FT1N.5	42.1	B	12.4	A	9.0	ABC	24.5	AB	12.0	A

Table 3. Mean percentage value of deadwood components across forest types. Means with different letters are statistically different at p=0.05.

Total deadwood volume m^3ha^{-1}	*Number of deadwood pieces* nha^{-1}	*Standard deviation* nha^{-1}	*Number of EU/ICP level II plots* *n*
0-10	343	283	39
10-20	652	498	23
20-30	864	546	13
30-40	477	560	2
40-50	1311	619	3
50-60	641	420	4
60-70	1361	289	3
70-80	0	0	0
80-90	1942	0	1
90-100	0	0	0
> 100	2166	1730	3

Table 4. Number of deadwood pieces with respect to total deadwood volume. Mean value, standard deviation and number of monitoring areas are given.

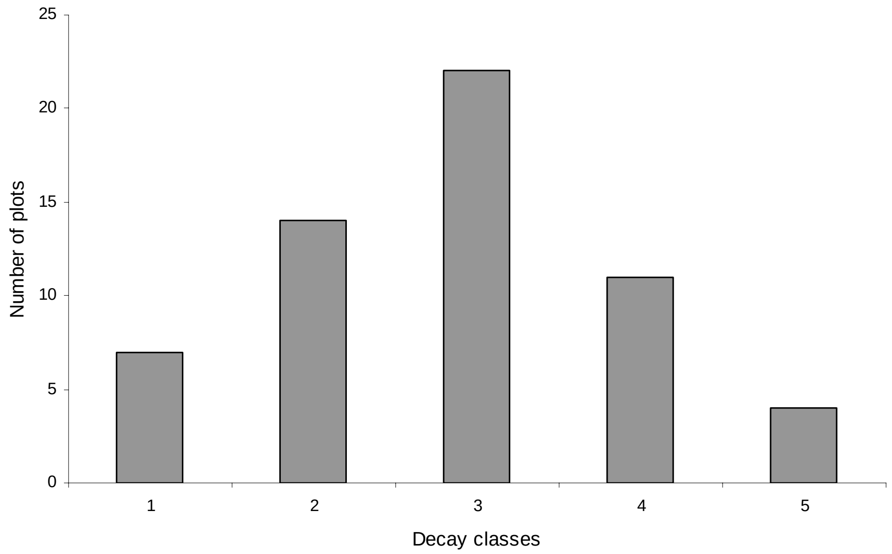

Figure 8. Frequency distribution of prevailing decay classes.

Conclusion

Total deadwood volume within the examined 91 EU/ICP Forest level II monitoring areas is generally low when compared with the amount of deadwood found in European forest reserves (e.g. Hahn and Christensen 2004). However, values higher than 25 m^3ha^{-1} are quite common on plots in Alpine and Central Europe, and in some scattered, but not rare cases, values higher than 50 m^3ha^{-1} can be found. On average, the Mediterranean plots contained relatively little deadwood.

In the examined areas, the total deadwood volume is not significantly different among forest types due to the high intra-type variability. On the contrary its distribution among coarse and fine necromass and among necromass components (except snags) is highly dependent on forest types. As a trend, coarse necromass tends to be relatively higher in coniferous than in broadleaf forests, except coniferous plantations, while fine woody material is distinctively important, in relative terms, in mediterranean forests managed as coppices. On average, standing deadwood contributes more than half to the total deadwood volume in natural and seminatural broadleaved mediterranean forests and in acidophilous oak-dominated forests, while ground deadwood prevails in all other forest types. Lying pieces are a relevant component of deadwood within plots classified as lowland beech forests. Black pine, mediterranean and macaronesian pines forests are poor of deadwood and woody necromass is mostly made up of stumps.

The quantity of deadwood occurring in forest depends on type and intensity of forest management. In managed stand, deadwood is often removed to avoid the outbreak of insect populations that could damage living trees, to remove all physical obstacle to silvicultural activity, or to reduce forest fire risk. Moreover, the number of old big trees in forest is usually poor, because classical forest management is based on rotations shorter than longevity of species (Nocentini 2003, Hahn and Christensen 2004, Montes and Cañellas, 2006). The influence of forest management on the total deadwood volume will be analysed in additional studies.

Several Authors underline the importance of large-sized deadwood for forest biodiversity, even though it has been demonstrated that smaller pieces are just as important (Nordén et al. 2004, Heilmann-Clausen and Christensen 2004). The species diversity related to deadwood depends also on type and decomposition stage of woody material. As an example, standing dead trees represent the habitat for many birds and lichens, whereas lying deadwood is utilized by other species, like fungi and mosses (Stokland et al. 2004).

The EU/ICP Forest level II plots constitutes an important source for further correlative enquiries aimed to determine relationships between compositional, structural and functional key factors of biodiversity in different forest ecosystems, through which recommendations can be provided for soundly guiding operational management to protect and foster forest biodiversity in Europe.

References

Abrahamsson M, Lindbladh M. 2006. A comparison of saproxylic beetle occurrence between man-made high- and low-stumps of spruce (*Picea abies*). Forest Ecology and Management. Article in press.

Christensen M., Hahn K., Mountford E. P., Wijdeven S. M. J., Manning D.B., Standovar T., Odor P., Rozenbergar D., 2003 - *Study on deadwood in european beech forest reserves*. Prepared by members of Work-package 2 in the Nat-Man project (Nature-based Management of beech in Europe) funded by the European Community 5th Framework Programme.

ForestBIOTA. 2004. ForestBIOTA (Forest Biodiversity Test-phase Assessments). Project Proposal under Regulation (EC) No 2152/2003 (Forest Focus) for the development of forest biodiversity monitoring (Art 6(2) monitoring test phase). Available: http://www.forestbiota.org/docs/ProjectProposal04.pdf via the INTERNET. Accessed 2006 April 24.

ForestBIOTA. 2005. Forest type classification within the EU/ICP Forests Biodiversity Test-Phase (ForestBIOTA). Available: www.forestbiota.org/docs/ForestTypeclassification2005.pdf via the INTERNET. Accessed 2006 April 24.

Green P, Peterken GF. 1997. Variation in the amount of deadwood in the woodlands of the Lower Wye Valley, UK in relation to the intensity of management. Forest Ecology and Management 98: 229-238.

Guby NAB, Dobbertin M. 1996. Quantitative estimates of coarse wooded debris and standing trees in selected Swiss forests. Global Ecology and Biogeography Letters 5: 327-341.

Hahn K, Christensen M. 2004. Dead Wood in European Forest Reserves – A Reference for Forest Management. In: Marchetti M, editor. Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI proceedings 51, 2004. p. 181-191.

Harmon M.E., 2001 - *Moving towards a new paradigm for woody detritus management*. Ecological Bulletins, 49: 269-278.

Harmon ME, Franklin JF, Swanson FJ, Sollins P, Gregory SV, Lattin JD, Anderson NH, Cline SP, Aumen NG, Sedell JR, Lienkaemper GW, Cromack K, Cummins KW. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15: 133-302.

Heilmann-Clausen J., 2001 - *A gradient analysis of communities of macrofungi and slime moulds on decaying beech logs*. Mycological research, 105(5): 575-596.

Heilmann-Clausen J, Christensen M. 2004. Does size matter? On the importance of various dead wood fractions for fungal diversity in Danish beech forests. Forest Ecology and Management 201: 105-117.

Heliövaara K., Väisänen R., 1984 - *Effects of modern forestry on northwestern European forest invertebrates: a synthesis*. Acta Forestalia Fennica, 189: 1-29.

Herbeck L.A., Larsen D.R., 1999 - *Plethodontid salamander response to selvicultural practices in Missouri Ozark forest*. Conservation Biology, 13 (3): 623-632.

Hodge S.J., Peterken G.F., 1998 - *Deadwood in British forests: priorities and a strategy*. Forestry, 71 (2): 99-112.

Hauβmann T, and Fisher R. 2004. The Forest Monitoring Programme of ICP Forests – A Contribution to Biodiversity Monitoring. In: Marchetti M, editor. Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI proceedings 51, 2004. p. 413-419.

Humphrey J.W., Davey S., Peace A.J., Ferris R., Harding K., 2002 - *Lichens and bryophyte communities of planted and semi-natural forests in Britain: the influence of site type, stand structure and deadwood*. Biological Conservation, 107: 165-180.

Hunter ML. 1990. Wildlife, forests, and forestry: principles of managing forests for biological diversity. Englewood Cliffs, N.J., Prentice Hall. p. 370.

Jonsell M, Nittérus K, Stighäll K. 2004. Saproxylic beetles in natural and man-made deciduous high stumps retained for conservation. Biological Conservation 118: 163-173.

Jonsson BG. 2000. Availability of coarse woody debris in a boreal old-growth Picea abies forest. Journal of Vegetation Science 11: 51-56.
Kirby K.J., Drake C.M., 1993 - *Deadwood Matters: The Ecology and Conservation of Saproxylic Invertebrates in Britain.* English Nature Science, 7, Peterborough. 22.
Kirby KJ, Reid CM, Thomas RC, Goldsmith FB. 1998. Preliminary estimates of fallen deadwood and standing dead trees in managed and unmanaged forests in Britain. Journal of Applied Ecology 35: 148-155.
Kristensen P. 2003. EEA core set of indicator. Revised version April, 2003. European Environment Agency, Copenhagen.
Larsson TB, Angelstam P, Balent G, Barbati A, Bijlsma R-J, Boncina A. 2001. Biodiversity evaluation tools for European forests. Ecological Bulletins 50: 237 p.
Lesica P., McCune B., Cooper S.V., Hong W.S., 1991 - *Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana*. Canadian Journal of Botany, 69: 1745-1755.
Linder P., Ostlund L., 1998 - *Structural changes in three midboreal Swedish forest landscapes, 1885–1996*. Biol. Conserv., 85: 9–19.
Mason F., 2003 - *Guidelines and aims of the Project Life NAT/IT/99/006245 "Bosco della Fontana: urgent conservation actions on relict habitat": 41-43.* In: Mason F., Nardi G., Tisato M. (eds.). Procedings of the International Symposium "Deadwood: a key to biodiversity", Mantova, May 29th –31th 2003. Sherwood 95, Suppl. 2.
McComb W, Lindenmayer J. 1999. Dying, dead, and down trees. In: Hunter ML, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge, UK: p 335–372.
MCPFE. 2003. State of Europe's Forests 2003 – The MCPFE Reports on Sustainable Forest Management in Europe. Vienna, Austria 2003.
Mikusinski G, Angelstam P. 1997. European woodpeckers and anthropogenic habitat change: a review. Vogelwelt 118: 277-283.
Montes F, Cañellas I. 2006. Modelling coarse woody debris dynamics in even-aged Scots pine forests. Forest Ecology and Management 221: 220-232.
Nilsson S.G., Hedin J., Niklasson M., 2001 - *Biodiversity and its assessment in boreal and nemoral forests*. Scand. J. For. Res. (Supplement 3): 10–26.
Nocentini S., 2002 - *Gli alberi morti in foresta: un principio biologico per la gestione forestale sostenibile*. In: Atti del Parco Nazionale delle Foreste Casentinesi : "Dagli alberi morti…la vita della foresta. La conservazione della biodiversità forestale legata al legno morto", Corniolo, 10/05/2002: 15-20.
Nocentini S., 2003 - *Alberi morti e selvicoltura: antitesi o armonia?* In: Atti del IV Congresso S.I.S.E.F.: "Meridiani Foreste", Rifreddo (Pz), 7-10 ottobre 2003: 95-99.
Nordén B, Ryberg M, Götmark F, Olausson B. 2004. Relative importance of coarse and fine woody debris for the diversity of wood-inhabiting fungi in temperate broadleaf forests. Biological Conservation 117: 1–10.
Ódor P, Standovár T. 2001. Richness of bryophyte vegetation in a near-natural and managed beech stands: the effects of management-induced differences in deadwood. Ecological Bulletins 49: 219-229.
Ranius T, Kindvall O. 2004. Modelling the amount of coarse woody debris produced by the new biodiversity-oriented sylvicultural practices in Sweden. Biological Conservation 119: 51-59.
Ranius T. Ekvall H, Jonsson M, Bostedt G. 2005. Cost-efficiency of measure to increase the amount of coarse woody debris in managed Norway spruce forest. Forest Ecology and Management 206: 119-133.
Raymond LR, Hardy LM. 1991. Effects of a clearcut on a popolation of the mole salamander (Ambystoma talpoideum) in an adjacent unaltered forest. Journal of Herpetology 25 (4): 509-512.

Rydin H., Diekmann M., Hallingbäck T., 1997 - *Biological characteristics, habitats associations and distribution of macrofungi in Sweden*. Conservation biology, 11: 628-640.
Samuelsson J., Gustafsson L., Ingelög T., 1994 - *Dying and Dead Trees: A Review of Their Importance for Biodiversity*. Swedish Threatened Species Unit, Uppsala.
Sandström U., 1992 - *Cavities in trees: their occurrence, formation and importance for hole-nesting birds in relation to silvicultural practise.* PhD thesis, Swedish University of Agricultural Sciences, Department of Wildlife Ecology, Uppsala.
Schuck A, Meyer P, Menke N, Lier M, Lindner M. 2004. Forest Biodiversity Indicator: Dead Wood – A Proposed Approach towards Operationalising the MCPFE Indicator. In: Marchetti M, editor. Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI proceedings 51, 2004. p. 49-77.
Siitonen J. 2001. Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecological Bulletins 49: 11-42.
Siitonen, J., Martikainen, P., Punttila, P., Rauh, J., 2000 - *Coarse woody debris and stand characteristics in mature, managed and boreal mesic forests in southern Finland*. For. Ecol. Manage., 128: 211–225.
Sippola A.L., Renvall P., 1999 - *Wood-decomposing fungi and seed-tree cutting: A 40-year perspective*. Forest Ecology and Management, 115: 183-201.
Söderström L., 1988 - *The occurence of epxylic bryophyte and lichen species in an old natural and a managed forest stand in Northeast Sweden*. Biological Conservation, 45: 169-178.
Stokland JN, Tomter SM, Söderberg U. 2004. Development of Dead Wood Indicators dor Biodiversity Monitoring: Experiences from Scandinavia. In: Marchetti M, editor. Monitoring and Indicators of Forest Biodiversity in Europe – From Ideas to Operationality. EFI proceedings 51, 2004. p. 207-226.
Zar JH. 1996. Biostatistical analysis (3rd ed.). Prentice-Hall International, New York, USA. p. 662.

Annex 1

Country	*Forest type*	*Altitude*	*Mean age*	*Total deadwood volume*	*Standing deadwood volume*	*Snags volume*	*Downed dead trees volume*	*Lying deadwood pieces volume*	*Stumps volume*	*Coarse necromas volume*	*Fine necromass volume*
name	*code*	*m*	*years*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*
Czech Rep.	FT3N.1	1251-1300	101-120	129.7	30.5	20.2	17.5	59.5	2.0	128.6	1.1
Czech Rep.	FT4N.5	901-950	>120	34.3	0.0	3.1	29.1	0.7	1.4	34.0	0.3
Czech Rep.	FT1N.7	251-300	81-100	8.2	0.0	0.2	1.1	2.0	4.9	7.8	0.4
Denmark	FT3A	0-50	41-60	8.1	0.0	0.2	1.8	4.3	1.8	4.6	3.5
Denmark	FT1N.3a	0-50	81-100	11.6	0.0	0.0	0.0	7.2	4.4	10.4	1.2
Denmark	FT1N.3a	0-50	> 120	257.7	76.6	4.4	73.7	103.0	0.0	241.6	16.1
Denmark	FT1N.5	0-50	> 120	10.1	3.8	0.2	2.7	2.9	0.5	7.3	2.8
Finland	FT3N.6	301-350	41-60	3.7	0.7	0.2	0.7	0.0	2.1	3.6	0.1
Finland	FT3N.6	251-300	61-80	2.0	0.0	0.0	0.3	0.5	1.2	1.3	0.7
Finland	FT3N.6	251-300	61-80	4.1	0.0	0.1	0.6	0.0	3.4	3.8	0.3
Finland	FT3N.6	101-150	21-40	4.9	0.7	0.0	3.4	0.0	0.8	4.9	0.0
Finland	FT3N.6	151-200	61-80	4.3	0.0	0.0	3.1	0.9	0.3	4.0	0.3
Finland	FT3N.6	151-200	41-60	19.4	13.4	0.3	4.9	0.6	0.2	18.8	0.6
Finland	FT3N.6	101-150	41-60	6.1	2.6	0.0	1.3	1.1	1.1	5.0	1.1
Finland	FT3N.6	101-150	41-60	13.4	0.0	0.0	0.0	12.4	1.0	13.4	0.0
Germany	FT1N.3a	0-50	81-100	2.1	0.0	0.0	0.0	0.4	1.7	1.7	0.4
Germany	FT1N.3a	101-150	101-120	28.3	23.4	0.1	0.0	3.5	1.3	27.1	1.2
Germany	FT3N.1	501-550	101-120	225.7	11.1	2.1	43.5	164.0	5.0	225.3	0.4
Germany	FT1N.7	0-50	101-120	14.5	4.4	0.1	0.0	7.6	2.4	12.4	2.1
Germany	FT1N.3a	51-100	101-120	13.2	0.0	0.0	0.3	9.0	3.9	8.9	4.3
Germany	FT1N.3a	351-400	101-120	29.8	1.9	0.0	0.0	23.2	4.7	23.9	5.9
Germany	FT1N.3a	301-350	101-120	3.4	0.0	0.0	0.0	1.8	1.6	1.9	1.5
Germany	FT1N.3a	401-450	> 120	24.9	0.0	0.0	3.8	16.6	4.5	22.9	2.0

Table 5. Summary details of the EU/ICP level II monitoring areas.

Country	*Forest type*	*Altitude*	*Mean age*	*Total deadwood volume*	*Standing deadwood volume*	*Snags volume*	*Downed dead trees volume*	*Lying deadwood pieces volume*	*Stumps volume*	*Coarse necromas volume*	*Fine necromass volume*
name	*code*	*m*	*years*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*	*m^3ha^{-1}*
Germany	FT1N.3a	401-450	> 120	6.5	0.0	0.0	0.0	3.5	3.0	3.5	3.0
Germany	FT1N.3a	551-600	61-80	16.8	1.0	0.2	0.8	11.5	3.3	10.5	6.3
Germany	FT1N.3a	351-400	101-120	25.0	0.4	0.3	1.3	20.0	3.0	20.1	4.9
Germany	FT1N.1	101-150	81-100	63.9	30.6	0.0	9.9	20.9	2.5	58.8	5.1
Germany	FT4N.2	501-550	> 120	58.7	0.1	0.0	21.2	34.0	3.4	56.6	2.1
Germany	FT1N.3a	801-850	> 120	6.9	0.0	0.0	0.1	3.9	2.9	4.3	2.6
Germany	FT1N.3a	501-550	> 120	5.0	0.0	0.0	0.0	1.0	4.0	4.1	0.9
Germany	FT3N.3	0-50	61-80	17.8	7.0	0.0	4.9	5.0	0.9	16.5	1.3
Germany	FT3N.3	0-50	61-80	19.6	2.4	0.0	4.5	12.4	0.3	18.5	1.1
Germany	FT3N.3	0-50	61-80	12.1	2.3	0.0	9.3	0.1	0.4	11.8	0.3
Germany	FT3N.1	801-850	61-80	17.5	0.0	0.2	1.0	6.8	9.5	16.4	1.1
Germany	FT3N.1	701-750	101-120	12.7	0.0	0.0	0.0	10.6	2.1	12.6	0.1
Greece	FT2N	351-400	41-60	7.5	5.8	0.0	1.5	0.2	0.0	3.1	4.4
Greece	FT1N.4	701-750	61-80	3.4	1.6	0.0	0.3	0.8	0.7	1.8	1.6
Greece	FT1N.3b	851-900	81-100	68.2	15.6	0.0	18.8	27.8	6.0	65.8	2.4
Greece	FT3N.1	1151-1200	81-100	19.2	0.0	0.0	17.9	0.0	1.3	19.2	0.0
Italy	FT1N.3b	1451-1500	101-120	4.2	0.0	0.0	0.0	1.9	2.3	2.5	1.7
Italy	FT1N.3b	901- 950m	101-120	2.4	1.2	0.0	0.8	0.4	0.0	1.6	0.8
Italy	FT3N.1	801- 850m	61-80	2.8	0.0	0.0	0.0	0.0	2.8	2.8	0.0
Italy	FT3N.1	1151-1200	41-60	20.2	1.3	0.0	2.0	3.7	13.2	19.2	1.0
Italy	FT2N	651-700 m	101-120	15.8	8.2	0.3	2.6	3.7	1.0	8.1	7.7
Italy	FT1N.7	901-950 m	21-40	12.9	6.6	0.0	4.9	0.9	0.5	11.5	1.4
Italy	FT2N	101-150 m	21-40	16.4	7.1	0.0	5.8	3.3	0.2	6.1	10.3

Table 5 (Continued). Summary details of the EU/ICP level II monitoring areas.

Country name	Forest type code	Altitude m	Mean age years	Total deadwood volume m^3ha^{-1}	Standing deadwood volume m^3ha^{-1}	Snags volume m^3ha^{-1}	Downed dead trees volume m^3ha^{-1}	Lying deadwood pieces volume m^3ha^{-1}	Stumps volume m^3ha^{-1}	Coarse necromas volume m^3ha^{-1}	Fine necromass volume m^3ha^{-1}
Italy	FT3N.1	1751-1800	101-120	20.3	1.6	0.0	3.1	6.0	9.6	18.4	1.9
Italy	FT1N.7	951-1000	21-40	5.9	0.8	0.0	0.2	4.7	0.2	2.3	3.6
Italy	FT2N	151-200	21-40	3.7	3.2	0.0	0.0	0.4	0.1	1.0	2.7
Italy	FT2N	0-50	Irr. stand	27.4	14.0	3.4	8.5	0.1	1.4	6.6	20.8
Italy	FT3N.1	1701-1750	101-120	15.1	0.0	0.0	0.0	0.0	15.1	15.1	0.0
Netherlands	FT3A	0-50	61-80	6.9	1.7	0.0	0.4	3.9	0.9	3.3	3.6
Netherlands	FT3A	0-50	41-60	6.3	2.2	0.0	2.2	1.6	0.3	4.7	1.6
Netherlands	FT1N.5	0-50	61-80	3.1	2.2	0.0	0.0	0.9	0.0	2.2	0.9
Netherlands	FT3A	51-100	41-60	15.9	2.9	0.2	1.1	7.3	4.4	9.8	6.1
Netherlands	FT3A	0-50	41-60	10.8	4.3	0.0	4.8	1.7	0.0	10.5	0.3
Slovak Rep.	FT1N.7	201-250	61-80	20.5	2.5	0.0	1.7	16.1	0.2	19.2	1.3
Slovak Rep.	FT1N.3a	551-600	61-80	43.8	3.0	28.7	0.0	7.7	4.4	35.6	8.2
Slovak Rep.	FT3N.1	1101-1150	> 120	47.3	0.0	12.4	0.0	33.6	1.3	41.7	5.6
Spain	FT3N.4	1501-1550	101-120	2.2	0.0	0.0	0.0	0.0	2.2	2.2	0.0
Spain	FT2N	451-500	101-120	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Spain	FT1N.3b	851-900	81-100	2.5	0.0	0.0	0.0	0.0	2.5	2.5	0.0
Spain	FT3N.4	1401-1450	101-120	3.3	0.0	0.0	0.0	0.0	3.3	3.3	0.0
Spain	FT3N.4	751-800	41-60	0.3	0.0	0.0	0.0	0.0	0.3	0.3	0.0
Spain	FT2N	601-650	41-60	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Spain	FT3N.4	1101-1150	61-80	1.1	0.0	0.0	0.0	0.0	1.1	1.1	0.0
Spain	FT1N.5	1101-1150	41-60	14.1	5.0	0.0	3.2	0.4	5.5	6.9	7.2
Spain	FT3N.4	751-800	41-60	0.4	0.0	0.0	0.0	0.0	0.4	0.4	0.0
Spain	FT2N	7001-750	41-60	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0
Spain	-	51-100	41-60	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0
Spain	-	251-300	41-60	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0

Table 5 (Continued). Summary details of the EU/ICP level II monitoring areas.

Country	Forest type	Altitude	Mean age	Total deadwood volume	Standing deadwood volume	Snags volume	Downed dead trees volume	Lying deadwood pieces volume	Stumps volume	Coarse necromas volume	Fine necromass volume
name	*code*	*m*	*years*	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}	m^3ha^{-1}
Switzerland	FT3N.1	1151-1200	Irr. stand	13.9	0.0	4.4	1.7	1.2	6.6	12.9	1.0
Switzerland	FT3N.1	1551-1600	Irr. stand	26.6	0.1	0.0	2.6	22.4	1.5	24.1	2.5
Switzerland	FT1N.3b	1101-1150	Irr. stand	33.9	6.4	3.5	0.1	23.1	0.8	32.0	1.9
Switzerland	FT3N.2	1851-1900	Irr. stand	24.5	0.0	0.7	6.7	6.2	10.9	21.5	3.0
Switzerland	FT3N.1	1351-1400	Irr. stand	53.4	5.3	10.7	23.5	12.2	1.7	47.5	5.9
Switzerland	FT1N.3b	1201-1250	Irr. stand	3.8	1.2	0.3	0.0	1.5	0.8	1.9	1.9
Switzerland	FT1N.5	501-550	Irr. stand	3.8	1.5	0.1	0.8	1.1	0.3	2.2	1.6
Switzerland	FT1N.3b	801-850	Irr. stand	22.9	5.5	2.3	2.1	12.7	0.3	20.5	2.4
Switzerland	FT3N.2	1051-1100	Irr. stand	19.8	3.5	0.4	5.1	10.4	0.4	15.2	4.6
Switzerland	FT3N.2	1851-1900	Irr. stand	69.8	28.5	0.8	33.6	2.5	4.4	63.0	6.8
Switzerland	FT1N.3a	551-600	Irr. stand	89.0	0.0	0.0	56.2	31.2	1.6	80.8	8.2
Switzerland	FT1N.5	951-1000	Irr. stand	4.7	1.4	0.2	0.0	2.1	1.0	2.4	2.3
Switzerland	FT1N.3a	451-500	Irr. stand	8.3	0.0	0.0	0.0	2.3	6.0	7.5	0.8
Switzerland	FT3N.3	651-700	Irr. stand	19.4	4.2	0.2	8.8	5.3	0.9	17.8	1.6
Switzerland	FT3N.1	451-500	Irr. stand	25.0	5.0	0.3	1.1	14.2	4.4	22.6	2.4
Switzerland	FT1N.3b	751-800	Irr. stand	41.8	0.1	0.0	27.5	13.4	0.8	31.4	10.4
Switzerland	FT3N.1	1451-1500	> 120	8.3	0.4	0.0	0.1	6.0	1.8	7.9	0.4
Ukraine	FT1N.7	151-200	81-100	54.8	40.1	0.0	2.9	5.4	6.4	54.4	0.4
Ukraine	FT1N.7	not known	81-100	53.2	12.7	0.6	25.7	11.9	2.2	52.8	0.4
Ukraine	FT1N.7	not known	81-100	23.8	0.0	1.6	9.9	4.3	8.1	22.7	1.1

Table 5 (Continued). Summary details of the EU/ICP level II monitoring areas.