UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE
CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

International Co-operative Programme on
Assessment and Monitoring of Air Pollution Effects on Forests

MANUAL

on
methods and criteria for harmonised sampling, assessment,
monitoring and analysis of the effects of air pollution on forests

Part IX

Phenological Observations

updated: 06/2004

Contents

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1. Introduction

Phenology is broadly defined as the study of visible life cycle events. Knowledge about the timing and the duration of certain life events provides valuable information in explaining the actual condition of the trees themselves, and about possible effects of environmental factors, like climate fluctuations and changes, on trees.

Within the aims of the Level II monitoring programme, forest phenology is defined as the systematic observation and recording of:

- the yearly development stages of forest trees.
- biotic and abiotic (e.g. damaging) events and phenomena

The main objective of phenological observations on the Level II plots is to provide supplementary and complementary information on the status and development of forest tree condition during the year. The data obtained will essentially contribute to estimating the effect of climate change on forest ecosystems.
The value of such information is enhanced when phenological data can be evaluated in combination with other parameters measured on Level II plots - in particular meteorological, deposition and soil solution, crown condition and increment parameters.

Further objectives of phenological monitoring are:

- to determine the course of the annual development stages of forest trees on the intensive monitoring plots and their dependence on local (e.g. meteorological and site) conditions, including damaging events, in order
- to document and explain possible changes in the timing of these stages (starting time, length of period and magnitude) in relation to environmental factors of natural and/or anthropogenic origin,
- to utilise this knowledge in interpreting observed changes in tree condition (e.g. crown condition, growth, nutritional status), and
- to evaluate the effects of air pollution on forest trees, especially with regards to the time and duration of exposure.

These objectives will be achieved by monitoring carried out at the plot level and at the individual tree level.

Technical details concerning observation, recording, evaluation and data submission are described in the technical annex.

Phenological Observations in the Intensive Monitoring Programme (Level II) are optional.

2. Observation and recording at the plot level

Further background information on ecological processes on the plot, as well as an early warning system on events affecting the condition of the trees, can be obtained by recording the most obvious effects of biotic and abiotic (damaging) events and phenological phenomena. This is of special interest for the evaluation of Level II data at the national level. A cursory examination on the plot and the buffer zone is recommended to be performed on those Level II plots where continuous measurements (e.g. meteorological observations, deposition and/or soil solution measurements) are being carried out.
The observations and recordings should be easy and simple, and limited to:

- Occurrence of flushing, colour change and leaf/needle fall
- Biotic damage (pests and/or diseases).
- Abiotic damage (e.g. frost, wind, hail)

A short explanation is necessary for the personnel making these observations but, in general, special in depth training will not be required.

3. Intensive phenological monitoring at the individual tree level

Intensive phenological monitoring, based on visual observations on individual trees on the plot or the buffer zone, is recommended to be performed at least on those Level II plots where continuous monitoring of meteorological parameters is carried out.

Since this monitoring is time consuming and needs well-trained staff, it is recommended to carry out in depth observations on a small number of plots. All species on the intensive monitoring plots are of interest; however, priority should be given to the main tree species on the plot.

The phases to be monitored (whenever applicable on the species) are: leaf/needle appearance, appearance of Lammas shoots, secondary flushing, flowering, autumn colouring, leaf/needle death and leaf/needle fall. The definition and determination of the individual phases on different tree species are described in detail in the technical annex.

The number of trees to be selected for phenological monitoring depends on the tree species and the stand conditions.

4. Additional monitoring techniques

Additional techniques (such as litterfall collection or girth band measurements) can provide supporting and supplementary information.

Litterfall sampling provides quantitative data, e.g. about flowering, seed production, leaf/needle shedding etc.

Girth bands. Continuous measurement of changes in girth can provide information on the onset and cessation of growth and on the response of trees to stress phenomena.

Throughfall chemistry can provide additional information on the occurrence of phenological phases through changes in nutrient fluxes.

5. Quality control, data processing, storage, submission and evaluation

In addition to fulfilling the above-mentioned objectives and aims, phenological data (biotic and abiotic events, as well as intensive phenological monitoring results) are required for integrated evaluations of different aspects of Level II plots (e. g. in connection with meteorological parameters, crown condition assessment, deposition, increment). This will contribute to a better understanding of their effects on the measured values of the various ecological parameters and stand characteristics on these plots.

Adequate Quality Assurance is of great importance, especially for the monitoring at the individual tree level. The phenological data at the plot level are mainly intended for use at the national level and their use is therefore the responsibility of the NFC's. For the monitoring at the individual tree level (annual), instruction and intercalibration of the field staff by the NFC is required. Further tools to assist the field staff are photo guides and the web pages on phenology monitoring. Also, external field control by an independent observer is recommended.

The National Focal Centres (NFC) are responsible for quality control, data processing, data storage and submission and also for evaluations at the national level.
To ensure adequate quality assurance, annual training and intercalibration of the observers are necessary at the national and international level.

Annex 1: Technical Instructions for the Phenological Observations on Level II Plots (Optional)

A1.1. Observation and recording at the plot level.

A1.1.1 Introduction

The observation and recording should concentrate on the obvious effects of the events by on the basis of a cursory examination. If these observations and recordings are performed by the same person responsible for other routine activities on the plot (e.g. collection of deposition or soil solution samples) then the costs, both in labour and money, will be very low.

A1.1.2 Location

The observations should be made on the plot and/or the buffer zone of all those Level II plots where continuous measurements are carried out.

A1.1.3 Frequency

Observation dates may coincide with the collection of deposition samples or soil solution. A frequency of at least once every second week during the growing period is recommended.

A1.1.4 Observation and recording

All species on the intensive monitoring plots are of interest, however priority should be given to the main tree species on the plot. NFC's are free to include more species. In this case, however, each species should be recorded separately. Only events that have occurred and/or have changed their frequency/intensity since the last visit should be recorded. As the individual phases of phenological phenomena occur, assessments need to be repeated until the phase is completed

The event codes for the monitored effects and phenological phenomena are:
1 = Flushing;
2 = Colour changes;
3 = Leaf/needle fall;
4 = Significant signs of leaf or crown damage (e.g., eaten leaves or bare crown parts);
5 = Other damage (breakage, uprooted trees).
6 = Lammas shoots / secondary flushing
7 = Flowering

In case significant signs of leaf or crown damage (event code 4) or other damage (event code 5) are observed, an additional assessment should be made according to the submanual on crown condition and its guidelines for the assessment of the cause of damage.

It is recommended to use field forms for the assessments at the plots. From these field forms information can be condensed for submission using the submission forms in the annex of this submanual. Field forms are available at the ICP Forests phenology webpage (http://www.metla.fi/eu/icp/phenology).

A1.1.5 Data processing, validation and analysis

The NFC is responsible for the proper use of the data. If the field staff observes any damaging (biotic or abiotic) event, this should be reported immediately to the responsible person, who should decide on further actions. For the submission of the data form 11b should be used.

A1.2 Observation and recording at the individual tree level

A1.2.1 Introduction

Intensive phenological monitoring on the Level II plots is concerned with observations on individual trees of the major species or group of species, and on a limited set of phenological phases.

A1.2.2 Location

A1.2.2.1 Selection of species and plots

Priority should be given to:

- those plots where (at least) meteorological measurements are carried out.
- the most important species on the plot, which is already reported as the main species (other species on the same plot may be added),

A1.2.2.2 Criteria for the selection of sample trees

Criteria for selecting trees are:

- Trees should be selected from those on which crown condition assessments are carried out. Preference should be given to trees that are clearly visible when standing outside the plot, because the high frequency of the observation may affect the condition of the ground vegetation on the plot.
- If there is an insufficient number of crown condition trees visible, it will be necessary to select additional trees from the plot or from the buffer zone. In this case:
  - trees should be dominant or co-dominant,
  - trees on which periodical measurement of DBH and height is (planned to be) made should be preferred,
  - trees selected for leaf/needle sampling and analysis are not to be included.

Between 10 and 20 trees per species on a plot are generally recommended as the norm. All trees should be numbered. If they already have numbers (e.g. for crown condition or increment assessment) these numbers should be kept and used. If there is no number, a new range may be started e.g. 901, 902, etc. Do not start with already existing numbering series (1,2,3 etc.).

Basic information on each tree has to be submitted using form 12a.

If a selected tree dies or is removed it can be replaced. The newly selected tree should be given a new number and it should be registered using form 12a.

A1.2.2.3 Crown to be assessed
Preferably the top of the crown (light crown) should be visible from one observation point. If this is not possible, then the middle part of the crown is also acceptable. The same part of the crown should be considered for subsequent phenological observations throughout the whole year, as well as for subsequent years. The part of the crown observed should be reported on form 12a at the time the trees are selected, or whenever it changes, using the following codes:
1 = top of the crown
2 = middle of the crown
3 = top and middle of the crown.

A1.2.2.4 Direction of assessment
The direction from which the observations on individual trees are made should be the same every time. It should be recorded using an eight-class system at the time the trees are selected and reported on form 12a. Any change in this position should be recorded and reported as well.
The codes for the direction **from** which observations are made are:
1 = North
2 = north-east
3 = East
4 = south-east
5 = South
6 = south-west
7 = West
8 = north-west

A1.2.3 Frequency of observations
At least during the periods from the beginning to the end of the phenological phases in question, at least weekly observation always at the same day of the week are advisable.

A1.2.4 Methods of assessment
Information and photographs of phenological events for the most important groups of species of the Level II plots can be found at the web page on phenology in the ICP Forests programme: http://www.metla.fi/eu/icp/phenology. This information can also be used as a guideline for monitoring other species. The photographs on the web pages may be printed and/or copied for internal use as field guides, however, without permission they may NOT be used for further publication.

A1.2.4.1 Phases to be monitored
In principle, all phenological phases are of interest for phenological monitoring. However, from the practical point of view (e.g. financial input, ease and reliability of the monitoring, European-wide comparability, compatibility with other surveys like crown condition) it is necessary to concentrate on a limited set of phases and on the major species or groups of species.
A distinction is made between conifers and broad-leaved species:

CONIFERS	BROAD-LEAVED SPECIES
Needle appearance	*Leaf unfolding*
Lammas shoots	*Secondary flushing*
Flowering	*Flowering*
	Autumn colouring
	Leaf death and leaf fall

For the flowering phase, only the beginning of opening of the male flowers (characterised by pollen shed) is to be recorded, whereas the other phases are to be recorded quantitatively. In addition, damage to needles, leaves or flowers caused by late frost in spring should also be recorded, as well as its intensity. The definitions and determinations of the individual phases are described hereafter.

The event codes for the monitored effects and phenological phenomena are:
1 = Needle appearance or leaf unfolding;
2 = Colour changes;
3 = Leaf/needle fall;
4 = Significant signs of leaf or crown damage (e.g., eaten leaves or bare crown parts);
5 = Other damage (breakage, uprooted trees).
6 = Lammas shoots / secondary flushing
7 = Flowering;

It is recommended to use field forms for the assessments at the plots. From these field forms information can be condensed for submission using the submission forms in the annex of this submanual. Field forms are available at the ICP Forests phenology webpage (http://www.metla.fi/eu/icp/phenology).

If significant signs of leaf or crown damage (event code 4) or other damage (event code 5) are observed, then an additional assessment should be made according to the submanual on crown condition and its guidelines for the assessment of the causes of damage.

For the submission of the data at the tree level, form 12c should be used for the phenological events, and 12d in case of damaging events.

A1.2.5 Quality Control

NFCs are responsible for Quality Control. Training should be provided to the field teams, and control assessment should be carried out by an independent control team, at least once a year on e.g. 10% of the plots. These data should be submitted. Training, as well as the preparation and use of a photo guide, could be organised on the European level in close connection with the Expert Panel on Crown Condition Assessment.

Annex 2: Forms

Form 11b
Submission Form
XX2004.PHE

Phenological phenomena and biotic and abiotic (damaging) events (plot level - extensive)

sequence	plot #	species	event	Phase/event happened between: date before (D D M M Y Y)	Phase/event happened between: date after (D D M M Y Y)	extent	symptom	cause	cause name	estimated starting date (D D M M Y Y)	estimated completion date (D D M M Y Y)	other observations
1 - - 4	6 - - 9	11 - 13	15	17 - - 22	24 - - 29	31	33-34	36 - - 41	43 - - 49	51 - - 56	58 - - 63	65 - - 80

column		*explanatory item # or chapter #*
1 - 4	sequence number record (1 to 9999)	
6 - 9	plot number (maximim 9999)	*(2)*
11 - 13	tree species	*(15)*
15	Event code 1 Flushing 2 Colour changes 3 Leaf/needle fall 4 Leaf or crown damage 5 Other damage	
17 - 22	date before = last date that the event/phenomena was not yet visible or had not yet occured	*(3)*
24 - 29	date after = first date of observation of completion or first date after the event had occurred	*(3)*
	columns 31 - 49 only to be completed in case of damaging events (if event code in column 15 = 4 or 5)	
31	extent of the damage using the codes: 2 infrequent or slight 3 common or moderate 4 abundant or severe	
33 - 34	symptom (01,..., 22)	A2.5.1.2 in the Crown Condition Manual
36 - 41	cause (e.g. 81001)	A2.5.2 in the Crown Condition Manual
43 - 49	Scientific name of cause (e.g. LOPHSED)	A2.5.2 in the Crown Condition Manual
51 - 56	stimated starting date = estimated date based on informations outside the plot	*(3)*
58 - 63	estmated completion date = estimated date based on informations outside the plot	*(3)*
65 - 80	Other observations (text)	*(99)*

Form 12a
XX2004.PLP

Form for registration of trees selected for intensive phenological monitoring

Sequence	Plot #	Species	Installation Date	Tree #	Visible part crown	direction	other observations
1 - - 5	7 - - 10	12 - 14	D D M M Y Y 16 - - 21	23 - - 26	28 - 29	31	33 - - 50

column		*explanatory item #*
1 - 5	sequence number record (1 to 99 999)	
7 - 10	plot number (maximim 9999)	*(2)*
12 - 14	tree species code	*(15)*
16 - 21	Installation date in DDMMYY date at which the trees for phenology monitoring were selected and the visible part of the crown and observation direction were defined.	
23 - 26	Tree number is the existing identification number on tree or newly given number preceded by an **M**	
28 - 29	Codes for visible part crown (during all year): 1 = top of the crown visible 2 = middle of the crown visible 3 = top and the middle of the crown visible	
31	Codes for visible direction crown (i.e. direction **<u>from</u>** where observations are made) 1 = north 2 = north-east 3 = east 4 = south-east 5 = south 6 = south-west 7 = west 8 = north-west	
33 - 50	other observations (text)	*(99)*

Form 12c
Submission Form
XX2004.PHI

Recording of phenological phenomena and biotic and abiotic (damaging) events (tree level - intensive)

Sequence	Plotnumber	Treenumber	Event	Starting date	Completion date	Spec. of affected part	Symptom	cause	Cause name	Extent	other observations
				D D M M Y Y	D D M M Y Y						
1 - - 4	6 - - 9	11 - - 14	16	18 - - 23	25 - - 30	32-33	35-36	38 - -43	45 - - 51	53	56 - - 70

column		*explanatory item # or chapter #*
1 - 4	sequence number record (1 to 9999)	
6 - 9	plot number (maximim 9999	*(2)*
11 - 14	tree number	*(14)*
16	event code 1 = Flushing 2 = Colour changes 3 = Leaf/needle fall 4 = Leaf or crown damage 5 = Other damage 6 = Lammas shoots / secondary flushing 7 = Flowering	
18 - 23	Starting date = last date that the event/phenomena was not yet visible or had not yet occured	*(3)*
25 - 30	Completion date = first date of observation of completion or first date after the event had occurred	*(3)*
	columns 32 - 53 only to be completed in case of damaging events (if event code in column 16 = 4 or 5)	
32 - 33	Specification of affected part (11, ..., 34)	A2.5.1.1 in the Crown Condition Manual
35 - 36	Symptom (01,..., 22)	A2.5.1.2 in the Crown Condition Manual
38 - 40	Cause (e.g. 81001)	A2.5.2 in the Crown Condition Manual
45 - 51	Scientific name of cause (e.g. LOPHSED)	A2.5.2 in the Crown Condition Manual
53	Extent (0,1,2,3,4,5,6,7)	A2.5.3.2 in the Crown Condition Manual
56 - 70	Other observations (text)	*(99)*

Annex 3: Explanatory items

(1) Country

1 France	13 Sweden	59 Estonia
2 Belgium	14 Austria	60 Slovenia
3 Netherlands	15 Finland	61 Republic of Moldova
4 Germany	50 Switzerland	62 Russia
5 Italy	51 Hungary	63 Bulgaria
6 United Kingdom	52 Romania	64 Latvia
7 Ireland	53 Poland	65 Belarus
8 Denmark	54 Slovak Republic	66 Cyprus
9 Greece	55 Norway	67 Serbia
10 Portugal	56 Lithuania	68 Andorra
11 Spain	57 Croatia	
12 Luxembourg	58 Czech Republic	

(2) Observation plot number

The observation plot number corresponds to a unique number given to the permanent plot during the selection or installation.

(3) Date of observation, date of assessment, date of analysis

Dates shall be completes in the following order day, month and year:

Day	Month	Year
08	09	94

(4) Latitude-/ longitude coordinates:

Fill in the full six figure latitude and longitude coordinates of the centre of the observation plot, e.g:

	+/-	Degress		Minutes		Seconds	
— latitude	+	5	0	2	0	2	7
— longitude	-	0	1	1	5	3	2

the first box is used to indicate a + or - coordinate

(15) Species (Reference Flora Europaea)

Especially in mixed stands it is not possible to get just one value for the whole stand for e.g. flushing, but one has to assess each species separately. Thus it is important to indicate for which species the assessments are made

Broadleaves (= species to be used for the foliage inventory)*

001: Acer campestre*	046: Quercus ilex*
002: Acer monspessulanum*	047: Quercus macrolepis (Q. aegilops)
003: Acer opalus	048: Quercus petraea*
004: Acer platanoides	049: Quercus pubescens*
005: Acer pseudoplatanus*	050: Quercus pyrenaica (Q. toza)*
006: Alnus cordata*	051: Quercus robur (Q. pedunculata)*
007: Alnus glutinosa*	052: Quercus rotundifolia*
008: Alnus incana	053: Quercus rubra*
009: Alnus viridis	054: Quercus suber*
010: Betula pendula*	055: Quercus trojana
011: Betula pubescens*	056: Robinia pseudoacacia*
012: Buxus sempervirens	057: Salix alba
013: Carpinus betulus*	058: Salix caprea
014: Carpinus orientalis	059: Salix cinerea

015: Castanea sativa (C. vesca)*
016: Corylus avellana*
017: Eucalyptus sp.*
018: Fagus moesiaca*
019: Fagus orientalis
020: Fagus sylvatica*
021: Fraxinus angustifolia spp. oxycarpa (F. oxyphylla)*
022: Fraxinus excelsior*
023: Fraxinus ornus*
024: Ilex aquifolium
025: Juglans nigra
026: Juglans regia
027: Malus domestica
028: Olea europaea*
029: Ostrya carpinifolia*
030: Platanus orientalis
031: Populus alba
032: Populus canescens
033: Populus hybrides*
034: Populus nigra*
035: Populus tremula*
036: Prunus avium*
037: Prunus dulcis (Amygdalus communis)
038: Prunus padus
039: Prunus serotina
040: Pyrus coomunis
041: Quercus cerris*
042: Quercus coccifera (Q. calliprinos)*
043: Quercus faginea*
044: Quercus frainetto (Q. conferta)*
045: Quercus fruticosa (Q. lusitanica)
060: Salix eleagnos
061: Salix fragilis
062: Salix sp.
063: Sorbus aria
064: Sorbus aucuparia
065: Sorbus domestica
066: Sorbus torminalis
067: Tamarix africana
068: Tilia cordata
069: Tilia platyphyllos
070: Ulmus glabra (U. scabra, U. scaba, U. montana)
071: Ulmus laevis (U. effusa)
072: Ulmus minor (U. campestris, U. carpinifolia)
073: Arbutus unedo
074: Arbutus andrachne
075: Ceratonia siliqua
076: Cercis siliquastrum
077: Erica arborea
078: Erica scoparia
079: Erica manipuliflora
080: Laurus nobilis
081: Myrtus communis
082: Phillyrea latifolia
083: Phyllyrea angustifolia
084: Pistacia lentiscus
085: Pistacia terebinthus
086: Rhamnus oleoides
087: Rhamnus alaternus
088 Betula tortuosa
090 Crataegus monogyna
099: Other broadleaves

Conifers (= species to be used for the foliage inventory)*

100: Abies alba*
101: Abies borisii-regis*
102: Abies cephalonica*
103: Abies grandis
104: Abies nordmanniana
105: Abies pinsapo
106: Abies procera
107: Cedrus atlantica
108: Cedrus deodara
109: Cupressus lusitanica
110: Cupressus sempervirens
111: Juniperus communis
112: Juniperus oxycedrus*
113: Juniperus phoenicea
114: Juniperus sabina
115: Juniperus thurifera*
116: Larix decidua*
117: Larix kaempferi (L.leptolepis)
118: Picea abies (P. excelsa)*
119: Picea omorika
120: Picea sitchensis*
121: Pinus brutia*
122: Pinus canariensis
123: Pinus cembra
124: Pinus contorta*
125: Pinus halepensis*
126: Pinus heldreichii
127: Pinus leucodermis
128: Pinus mugo (P. montana)
129: Pinus nigra*
130: Pinus pinaster*
131: Pinus pinea*
132: Pinus radiata (P.insignis)*
133: Pinus strobus
134: Pinus sylvestris*
135: Pinus uncinata*
136: Pseudotsuga menziesii*
137: Taxus baccata
138: Thuya sp.
139: Tsuga sp.
140 Chmaecyparis lawsonia
199: Other conifers