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Supplementary Data S3. Formal definition of the *Montio-Cardaminetea* class and list of spring-positive species and neutral species.

The formal definition is written as logical formula in an editable script stored as a TXT file (the *expert system* file: Supplementary material S7). The computer program JUICE (Tichý 2002) runs the expert system and checks whether the plot meets the conditions of the formal definition of *Montio-Cardaminetea* in this script. The plot that matches the definition is assigned to the unit. For a general description of expert systems, formal definitions, the protocol of JUICE software etc., see Landucci et al. (2015), Fischer (2015), Tichý et al. (2019) or Chytrý et al. (2020).

The formal definition of *Montio-Cardaminetea*:

<#TC +01 Spring-positive-species GR #TC +01 Spring-negative-species> NOT ((<#TC +01 Spring-negative-species GR50> OR <#TC Fen-not-spring GR05>) OR (<#TC Cliff-ferns GR05> OR (<#TC Moist-or-wet-mesotrophic-to-eutrophic-hay-meadow GR15> OR <#TC Small-helophyte-bed GR25>)))

Operators:

#TC: the total cover of the members of functional species group (according to Landucci et al. 2015) is used as an assignment rule

GR: greater than (followed by threshold cover value expressed in percentages)

OR: at least one of two elements must be present

NOT (= AND NOT): element(s) must not be present

Examples:

<#TC +01 Spring-positive-species GR #TC +01 Spring-negative-species>: the total cover of *spring-positive species* must be greater than the total cover of *spring-negative species*

NOT <#TC Fen-not-spring GR05>: the total cover of the species group must not exceed 5 %.

Species groups:

Spring-positive species (*spring indicators*): Species indicating springs and spring-like habitats (see below).

Neutral species: Species that can be present in spring vegetation but also frequently occur in other habitats (see below). They indicate springs neither positively nor negatively.

Spring-negative (*other*) *species*: Negative indicators of spring vegetation (and environment). This group contains all other species present in the initial dataset of vegetation plots; the group contains thousands of species (see the expert system file; Supplementary material S7). It can theoretically contain the rest of European flora.

The total cover of other species groups (e.g. *Cliff ferns*, *Fen not spring*; see below) were used as negative criterion in the definitions. These species lists were adopted from species groups used in the EUNIS classification (Chytrý et al. 2020) but revised and optimised with respect to evaluation of the results of successive classification trials.

Examples of how the formal definition of *Montio-Cardaminetea* works:

Plot 1: *Palustriella commutata* agg. 80 %, *Pellia endiviifolia* 10 %, *Deschampsia cespitosa* +, *Urtica dioica* +.
This plot is classified to *Montio-Cardaminetea* because *spring-positive species* (*Palustriella commutata* agg., *Pellia endiviifolia*) reach higher total cover than *spring-negative species* (*Urtica dioica*).

Plot 2: *Palustriella commutata* agg. 40 %, *Pellia endiviifolia* 10 %, *Deschampsia cespitosa* 65 %, *Urtica dioica* +.
This plot is classified to *Montio-Cardaminetea* because *spring-positive species* (*Palustriella commutata* agg., *Pellia endiviifolia*) have higher total cover than *spring-negative species* (*Urtica dioica*). Although *Deschampsia cespitosa* has higher cover than all the *spring-positive species*, the plot still fits *Montio-Cardaminetea* because *Deschampsia cespitosa* is a *neutral species*.

Plot 3: *Palustriella commutata* agg. 1 %, *Pellia endiviifolia* 1 %, *Deschampsia cespitosa* 1 %, *Urtica dioica* 95 %.
Although some *spring-positive species* (*Palustriella commutata* agg., *Pellia endiviifolia*) occur in the plot, the plot is not classified to *Montio-Cardaminetea* because *spring-negative species* (*Urtica dioica*) have greater cover than all the *spring positive species*.

Spring positive species:
Bryophytes are marked with asterisk (*).

*Anthelia julacea**
Arabis soyeri
Barbarea balcana
*Blindia acuta**
*Bryum cryophilum**
*Bryum schleicheri**
*Bryum weigelii**
Cardamine acris
Cardamine amara
Cardamine asarifolia
Cardamine nymanii
Cardamine raphanifolia
Cardamine rivularis
Carex remota
Chrysosplenium alpinum
Chrysosplenium alternifolium
Chrysosplenium oppositifolium
Cochlearia pyrenaica
*Cratoneuron filicinum**
*Dichodontium palustre**
Epilobium alsinifolium
Epilobium anagallidifolium
Epilobium hornemannii

Epilobium nutans
Epilobium obscurum
*Eucladium verticillatum**
*Hygrohypnum alpinum**
*Hygrohypnum mole**
*Hygrohypnum polare**
*Hygrohypnum smithii**
*Grimmia mollis**
Juncus biglumis
Juncus triglumis
Koenigia islandica
*Marsupella aquatica**
*Marsupella emarginata**
*Marsupella sphacelata**
Montia fontana
Myosotis stolonifera
*Nardia compressa**
Palustriella commutata agg.*
*Palustriella decipiens**
Pedicularis limnogena
Pellia endiviifolia
Pellia epiphylla agg.*
*Philonotis caespitosa**
*Philonotis calcarea**
Philonotis fontana agg.*
*Philonotis seriata**
Pinguicula alpina
Pinguicula balcanica
*Rhizomnium magnifolium**
Saxifraga aquatica
Saxifraga stellaris
*Scapania uliginosa**
*Scapania undulata**
Sedum villosum
*Seligeria oelandica**
Silene pusilla
Stellaria alsine
*Trichocolea tomentella**

Neutral species:

Bryophytes are marked with asterisk (*).

Agrostis canina
Adiantum capillus-veneris
Aegopodium podagraria
Agrostis mertensii
Agrostis rupestris
Agrostis stolonifera.
Ajuga reptans

Alchemilla fissa
Alchemilla vulgaris agg.
Allium schoenoprasum
Alopecurus magellanicus
*Amblyodon dealbatus**
*Amphidium mougeotii**
*Aneura pinguis**
Angelica archangelica
*Anthelia juratzkana**
Arabis alpina
Arctagrostis latifolia
Athyrium filix-femina
*Atrichum undulatum**
*Aulacomnium turgidum**
Bartsia alpina
Bellidiastrum michelii
Bistorta vivipara
Brachypodium sylvaticum
*Brachythecium rivulare**
*Bryum muehlenbeckii**
*Bryum pallens**
*Bryum pallescens**
Bryum pseudotriquetrum agg.*
*Bryum turbinatum**
Calamagrostis varia
Calamagrostis villosa
*Calliergon cordifolium**
*Calliergon giganteum**
*Calliergonella cuspidate**
Caltha palustris
*Calypogeia azurea**
*Calypogeia muelleriana**
Campylium stellatum agg.*
*Campylopus atrovirens**
Cardamine bellidifolia
Cardamine flexuosa
Cardamine pratensis agg.
Carex brachystachys
Carex brunnescens
Carex canescens
Carex echinata
Carex ferruginea
Carex flacca
Carex flava agg.
Carex frigida
Carex lachenalii
Carex paniculata
Carex pendula
Carex pyrenaica
Carex sylvatica
Carex vaginata
*Catoscopium nigritum**

*Cephalozia bicuspidata**
Cerastium cerastoides
Cerastium fontanum
Chaerophyllum hirsutum
Chiloscyphus polyanthos agg.*
Chrysosplenium dubium
*Cinclidium subrotundum**
*Cinclidotus aquaticus**
*Cinclidotus fontinaloides**
*Cinclidotus riparius**
Circaea alpina
Circaea x intermedia
Circaea lutetiana
Cirsium oleraceum
Cirsium spinosissimum
Cochlearia officinalis
*Conocephalum conicum**
Cortusa matthioli
Crepis paludosa
Cryptotaenia thomasii
*Ctenidium molluscum**
Dactylorhiza cordigera
Dactylorhiza maculata agg.
Deschampsia cespitosa
*Dichodontium pellucidum**
*Didymodon tophaceus**
Doronicum austriacum
Doronicum carpaticum
Doronicum columnae
Dryopteris carthusiana
Dryopteris dilatata
Dryopteris filix-mas
Epilobium atlanticum
Epilobium davuricum
Epilobium montanum
Epilobium palustre
Epilobium parviflorum
Equisetum arvense
Equisetum palustre
Equisetum pratense
Equisetum scirpoides
Equisetum sylvaticum
Equisetum telmateia
Equisetum variegatum
Eupatorium cannabinum
Euphrasia scottica
*Eurhynchium angustirete**
*Eurhynchium striatum**
Ficaria verna
Fissidens adianthoides
*Fissidens crassipes**
*Fontinalis antipyretica**

Galium palustre agg.
Geranium robertianum
Geum coccineum
Geum rivale
Glyceria nemoralis
Gymnadenia conopsea
*Harpanthus flotovianus**
*Hookeria lucens**
Hornungia alpina
*Hygroamblystegium humile**
*Hygroamblystegium tenax**
*Hygrobiella laxifolia**
*Hygrohypnum diurusculum**
*Hygrohypnum eugyrium**
*Hygrohypnum luridum**
*Hygrohypnum ochraceum**
*Hylocomiastrum pyrenaicum**
*Hymenostylium recurvirostrum**
Impatiens noli-tangere
Jacobaea subalpina
Juncus alpinoarticulatus
Juncus articulatus
*Jungermannia atrovirens**
*Jungermannia exsertifolia**
*Kiaeria falcata**
Lactuca muralis
Lamium galeobdolon
Ligusticum mutellina
*Lophocolea heterophylla**
*Lophozia wenzelii**
Luzula alpinopilosa
Luzula confusa
Lysimachia nemorum
Maianthemum bifolium
*Marchantia polymorpha**
*Mesoptychia badensis**
*Mesoptychia bantriensis**
*Mnium hornum**
Myosotis secunda
Myosotis scorpioides agg.
Narthecium ossifragum
*Oncophorus virens**
*Oncophorus wahlenbergii**
*Orthothecium rufescens**
Oxalis acetosella
*Oxyrrhynchium hians**
*Oxyrrhynchium speciosum**
Parnassia palustris
Pedicularis sudetica
Persicaria hydropiper
Petasites albus
Phippsia algida

Phleum alpinum agg.
Pinguicula grandiflora
Pinguicula hirtiflora
Pinguicula leptoceras
Pinguicula longifolia
Pinguicula vulgaris agg.
*Plagiochila asplenioides**
*Plagiochila porelloides**
Plagiomnium affine agg.*
*Plagiomnium cuspidatum**
*Plagiomnium undulatum**
*Plagiothecium denticulatum**
Plagiothecium laetum agg.*
*Plagiothecium nemorale**
*Plagiothecium plathyphyllum**
*Plagiothecium succulentum**
*Plagiothecium undulatum**
Plantago gentianoides
*Platyhypnidium riparioides**
Poa alpina
Poa pratensis agg.
Poa remota
Poa trivialis
*Pohlia drummondii**
*Pohlia filum**
*Pohlia ludwigii**
*Pohlia obtusifolia**
*Pohlia wahlenbergii**
*Polytrichastrum alpinum**
*Porella cordaeana**
Potamogeton polygonifolius
*Preissia quadrata**
Primula elatior
Primula farinosa
Primula integrifolia
*Pseudobryum cinclidioides**
*Pseudoleskea incurvata**
*Pseudoleskea radicosa**
*Racomitrium aciculare**
*Racomitrium aquaticum**
*Racomitrium canescens**
*Racomitrium sudeticum**
Ranunculus hyperboreus
Ranunculus omiophyllus
Ranunculus reptans
Ranunculus repens
Ranunculus serbicus
Ranunculus sulphureus
Rhodiola rosea
*Rhizomnium punctatum**
*Rhizomnium pseudopunctatum**
*Riccardia chamedryfolia**

*Riccardia multifida**
Rorippa islandica
Rumex acetosa
Rumex arifolius
Rumex sanguineus
Sagina nivalis
Sagina nodosa
Sagina saginoides
Sanicula europaea
Sanionia uncinata
Saxifraga aizoides
Saussurea alpina
Saxifraga cernua
Saxifraga clusii
Saxifraga foliolosa
Saxifraga hirculus
Saxifraga rivularis
Saxifraga rotundifolia
*Scapania irrigua**
*Scapania nemorea**
*Scapania paludicola**
*Scapania paludosa**
*Scapania subalpina**
Schedonorus pratensis
*Schistidium rivulare**
*Schljakovianthus quadrilobus**
*Sciuro-hypnum glaciale**
Scutellaria galericulata
Sedum lagascae
Selaginella selaginoides
*Seligeria patula**
Senecio nemorensis agg.
Silene asterias
Soldanella alpina
Soldanella carpatica
Soldanella pindicola
Soldanella villosa
*Solenostoma obovatum**
*Solenostoma sphaerocarpum**
Sphagnum auriculatum agg.*
*Sphagnum girgensohnii**
*Sphagnum fimbriatum**
Sphagnum palustre agg.*
*Sphagnum riparium**
*Sphagnum squarrosum**
*Splachnum vasculosum**
Stachys sylvatica
Stellaria calycantha
Stellaria crassifolia
Stellaria nemorum
Swertia perennis
Symphytum cordatum

Taraxacum sect. Crocea
Taraxacum sect. Fontana
*Tayloria lingulata**
Tephroseris crispa
Thalictrum alpinum
*Thuidium tamariscinum**
Tofieldia calyculata
Tofieldia pusilla
Triglochin palustris
Trollius europaeus
Tussilago farfara
Veratrum album
Veratrum lobelianum
Veronica beccabunga
Veronica montana
Veronica ponae
Veronica repens
Viola biflora
Viola palustris
*Warnstorfia exannulata**
Wahlenbergia hederacea
Willemetia stipitata

Trees and shrubs belong to neutral species because of the occurrence above forest springs (shoot presence).

Abies alba
Abies sibirica
Abies species
Acer campestre
Acer granatense
Acer heldreichii
Acer monspessulanum
Acer negundo
Acer obtusatum
Acer opalus
Acer platanoides
Acer pseudoplatanus
Acer species
Acer tataricum
Aesculus hippocastanum
Alnus cordata
Alnus glutinosa
Alnus incana
Alnus species
Alnus viridis
Alnus x pubescens
Betula pendula
Betula pubescens
Betula species
Betula x aurata
Carpinus betulus
Castanea sativa
Celtis australis

Corylus avellana
Fagus sylvatica
Fraxinus angustifolia
Fraxinus excelsior
Fraxinus ornus
Fraxinus pennsylvanica
Fraxinus species
Ilex aquifolium
Juglans nigra
Juglans regia
Larix decidua
Larix kaempferi
Larix species
Laurus nobilis
Malus species
Malus sylvestris
Ostrya carpinifolia
Picea abies
Picea obovata
Picea omorika
Picea pungens
Picea sitchensis
Picea species
Pinus cembra
Pinus halepensis
Pinus mugo agg.
Pinus nigra
Pinus peuce
Pinus pinea
Pinus species
Pinus strobus
Pinus sylvestris
Pinus uncinata
Pinus wallichiana
Pinus x rhaetica
Platanus hispanica
Platanus orientalis
Platanus species
Populus alba
Populus nigra
Populus species
Populus tremula
Populus x canadensis
Populus x canescens
Prunus avium
Prunus brigantina
Prunus cerasifera
Prunus cerasus
Prunus domestica
Prunus laurocerasus
Prunus padus
Prunus species

Pyrus communis
Pyrus cordata
Pyrus spinosa
Quercus canariensis
Quercus cerris
Quercus coccifera
Quercus frainetto
Quercus ilex
Quercus petraea agg.
Quercus pubescens
Quercus robur
Quercus rotundifolia
Quercus rubra
Quercus species
Quercus suber
Quercus x rosacea
Salix alba
Salix caprea
Salix euxina
Sorbus aria
Sorbus aucuparia
Sorbus austriaca
Sorbus domestica
Sorbus chamaemespilus
Sorbus intermedia
Sorbus mougeotii
Sorbus species
Sorbus sudetica
Sorbus torminalis
Taxus baccata
Tilia cordata
Tilia platyphyllos
Tilia species
Tilia x europaea
Ulmus glabra
Ulmus laevis
Ulmus minor
Ulmus procera
Ulmus species
Juniperus communis
Ligustrum vulgare
Salix herbacea
Salix glauca
Salix lanata
Salix polaris
Salix lapponum
Salix hastata
Salix bicolor
Salix myrsinifolia
Salix myrsinites
Salix myrtilloides
Salix phylicifolia

Salix repens

Other species groups used in the definition of *Montio-Cardaminetea*

Fen-not-spring (species of fen habitats of the *Scheuchzerio-Caricetea* class)

Andromeda polifolia
Blysmus compressus
Carex atrofusca
Carex bicolor
Carex microglochin
Carex appropinquata
Carex capitata
Carex davalliana
Carex diandra
Carex dioica
Carex elata
Carex hostiana
Carex chordorrhiza
Carex lapponica
Carex lasiocarpa
Carex laxa
Carex limosa
Carex livida
Carex magellanica
Carex maritima
Carex rariflora
Carex tenuiflora
Carex trinervis
Centaurium littorale
Cinclidium arcticum
Cirsium heterotrichum
Cladopodiella fluitans
Comarum palustre
Dactylorhiza incarnata
Dactylorhiza majalis agg.
Dactylorhiza traunsteineri
Dicranum bonjeanii
Dicranum leioneuron
Drosera intermedia
Drosera longifolia
Drosera rotundifolia
Dupontia fisheri
Eleocharis quinqueflora
Eriophorum gracile
Eriophorum latifolium
Eriophorum russeolum
Eriophorum scheuchzeri
Festuca frigida
Gymnocolea inflata
Hamatocaulis lapponicus
Hamatocaulis vernicosus

Hammarbya paludosa
Liparis loeselii
Loeskypnum badium
Meesia hexasticha
Meesia longiseta
Meesia triquetra
Meesia uliginosa
Menyanthes trifoliata
Myrica gale
Paludella squarrosa
Pedicularis palustris
Polygala amarella
Polytrichum hyperboreum
Pseudocalliergon lycopodioides
Pseudocalliergon trifarium
Pseudocalliergon turgescens
Rhynchospora alba
Rhynchospora fusca
Scorpidium revolvens agg.
Scorpidium scorpioides
Scheuchzeria palustris
Schoenus ferrugineus
Schoenus nigricans
Sphagnum angermanicum
Sphagnum annulatum
Sphagnum balticum
Sphagnum capillifolium
Sphagnum contortum
Sphagnum cuspidatum
Sphagnum jensenii
Sphagnum lenense
Sphagnum lindbergii
Sphagnum majus
Sphagnum molle
Sphagnum obtusum
Sphagnum papillosum
Sphagnum pulchrum
Sphagnum recurvum agg.
Sphagnum rubellum
Sphagnum subfulvum
Sphagnum subnitens
Sphagnum subsecundum
Sphagnum warnstorfii
Spiranthes aestivalis
Succisa pratensis
Tomentypnum nitens
Triglochin maritima
Trichophorum pumilum
Typha lugdunensis
Typha minima
Typha shuttleworthii
Utricularia intermedia

Utricularia ochroleuca
Utricularia bremii
Utricularia minor
Vaccinium oxycoccos
Valeriana dioica

Cliff-ferns

Adiantum capillus-veneris
Adiantum hispidum
Adiantum reniforme
Asplenium adiantum-nigrum
Asplenium adulterinum
Asplenium ceterach
Asplenium fissum
Asplenium fontanum
Asplenium hybridum
Asplenium jahandiezii
Asplenium marinum
Asplenium ruta-muraria
Asplenium sagittatum
Asplenium scolopendrium
Asplenium seelosii
Asplenium septentrionale
Asplenium trichomanes
Asplenium viride
Cystopteris fragilis
Gymnocarpium robertianum
Polypodium cambricum
Polypodium interjectum
Polypodium vulgare

Moist-or-wet-mesotrophic-to-eutrophic-hay-meadow

Achillea millefolium agg.
Allium angulosum
Alopecurus arundinaceus
Alopecurus bulbosus
Alopecurus pratensis
Bistorta officinalis
Bromus racemosus
Cardamine pratensis
Carex melanostachya
Centaurea jacea
Centaurea nigrescens
Cerastium dubium
Cirsium canum
Cirsium heterophyllum
Cirsium rivulare
Colchicum autumnale
Dactylorhiza majalis
Elytrigia repens
Filipendula ulmaria

Galium debile
Galium uliginosum
Gratiola officinalis
Holcus lanatus
Inula britannica
Jacobaea aquatica
Juncus conglomeratus
Lathyrus palustris
Lathyrus pratensis
Leucojum aestivum
Lysimachia nummularia
Lysimachia vulgaris
Lythrum salicaria
Lythrum virgatum
Oenanthe fistulosa
Oenanthe silaifolia
Plantago altissima
Potentilla reptans
Ranunculus acris
Ranunculus ophioglossifolius
Rhinanthus angustifolius
Sanguisorba officinalis
Scirpus sylvaticus
Scutellaria hastifolia
Selinum dubium
Silaum silaus
Silene flos-cuculi
Stachys palustris
Symphytum officinale
Thalictrum flavum
Thalictrum lucidum
Thalictrum simplex
Trifolium michelianum
Trollius europaeus
Veronica longifolia
Viola elatior
Viola pumila

Small-helophyte-bed

Alisma gramineum
Alisma lanceolatum
Alisma plantago-aquatica
Alopecurus aequalis
Arctophila fulva
Beckmannia syzigachne
Berula erecta
Bolboschoenus glaucus
Bolboschoenus planiculmis
Bolboschoenus yagara
Butomus umbellatus
Calla palustris

Carex pseudocyperus
Carex reuteriana
Catabrosa aquatica
Cicuta virosa
Comarum palustre
Eleocharis mamillata
Eleocharis palustris
Eleocharis uniglumis
Festuca rothmaleri
Galium broterianum
Glyceria declinata
Glyceria fluitans
Glyceria nemoralis
Glyceria notata
Glyceria spicata
Helosciadium bermejoi
Helosciadium nodiflorum
Hippuris vulgaris
Hydrocotyle vulgaris
Hypericum undulatum
Juncus subnodulosus
Leersia oryzoides
Lycopus europaeus
Lysimachia vulgaris
Mentha aquatica
Menyanthes trifoliata
Nasturtium officinale
Oenanthe aquatica
Oenanthe crocata
Persicaria amphibia
Ranunculus flammula
Ranunculus gmelinii
Ranunculus lingua
Rorippa amphibia
Rumex hydrolapathum
Sagittaria sagittifolia
Scutellaria galericulata
Sium latifolium
Sparganium emersum
Thelypteris palustris
Veronica anagallis-aquatica

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