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High mountain vegetation of the Apennines

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Abstract

This paper outlines the more significant plant communities of the subalpine and alpine belts in the Apennines (shrub formations of the subalpine belt, alpine grasslands, snowbed vegetation, scree and rock fissure vegetation). This overview highlights the coenological autonomy of the Apennine vegetation from the communities of the Alps and central European mountains, as well as the similarities with the high-mountain vegetation of South-Eastern Europe. The paper emphasises the biogeographical value of the Apennines, with its unique biogeographic pattern especially in the central Apennines, the high conservation value in terms of flora, vegetation and habitats, and the key role for monitoring climate change.

1. Introduction

The high altitude vegetation of the Apennines has been the subject of numerous studies (e.g. BIONDI et al. 1999, 2000, 2006; BLASI et al. 1989, 1990, 2003, 2005; DI PIETRO et al. 2008; DI PIETRO 2010; PETRAGLIA & TOMASELLI 2007; TOMASELLI 1994; TOMASELLI & ROSSI 1994; TOMASELLI et al. 2003, 2007), most of which have focused on the syntaxonomic features of these mountains. This paper does not focus on the syntaxonomy and taxonomy of the Apennine chain, but refers to the plant sociological studies with the aim to highlight its great biogeographic and conservation importance (BLASI et al. 2011; BIONDI 2011; IZCO & AMIGO 2011; POTT 2011).

The considerable lithological, morphological and climatic complexity of the Apennine chain has, together with its biogeographic factors, fostered floristic and vegetation diversity. Indeed, the vegetation of the Apennines, particularly that found in the high altitude plant communities, is quite different from the central European and alpine vegetation, and is related to the vegetation of south-eastern Europe for some formations (especially those in the central Apennines) and to that of western Europe for others.

The autonomy of the Apennine vegetation is due to the peculiar geomorphology and lithology of this chain of mountains. These peculiarities result from distinct orogenic processes, from the peninsula's geographical position and, consequently, from its unique climatic characteristics and complex paleogeographic and paleoclimatic history. This has, in turn, led to the arrival of floristic elements of various origins that make up the flora and vegetation now present in the Apennines, which are characterised by numerous endemics, relicts, vicariants, disjunctions and floristic and vegetation affinity.

2. The Apennine chain

2.1 Origin of the Apennines

The Apennines were formed during the Neogene. They are the result of the convergence of the African and Eurasian plates with the Adriatic microplate, which lies between them. The Apennines started forming in the Oligocene, when the Balearic-Provencal area broke away and started sinking, after which a smaller part broke off and rotated eastwards, with its hinge in the Genoa area (rotation of the Sardinian-Corsican block). This rotation caused the formation of a corrugated area (ancestral Apennines) where the plates collided. During the late Miocene, a new ocean basin (the Tyrrhenian sea) began to form. Its opening pushed the future Italian peninsula eastwards, causing the detachment of large masses of sedimentary rocks from their substrate, which in turn piled up and gave rise to the Apennine chain itself.

During the Messinian (late Miocene), the closure of the Strait of Gibraltar caused the evaporation of the waters in the Mediterranean sea and the formation of evaporite deposits. At the end of the Miocene, the Strait of Gibraltar once again opened up and the Atlantic flooded the Mediterranean Basin, leaving deep sea deposits on top of the salt deposits. The Pliocene witnessed a rise in sea level and a further shift eastwards of the Apennine chain, which also involved the Messinian salt deposits (from BOSELLINI 2005).

2.2 Physical geography and climate

The Apennine chain is currently about 1300 kilometres long. It has historically been divided geographically and morphologically in northern, central and southern. From a strictly geological point of view, the chain is 1000 kilometres long. It starts near Genoa and ends when it reaches the Calabro-Peloritan Arc, which links the Apennines to the ranges of northern Sicily (Nebrodi and Madonie). From a geographical and morphological point of view, the chain instead also includes the structural connection between Calabria and Sicily. This connection is a fragment of the Sardinian-Corsican block that broke away during the shift eastwards.

For the purposes of this description, we will adopt a geographical-morphological subdivision and divide the Apennines in northern, central and southern Apennines.

The highest peaks lie in the central Apennines, i.e. in the Abruzzi region (Gran Sasso 2912m and Majella 2793m; Fig. 1).

From a geological point of view, the Apennines are clearly distinct from the Alps: the former are dominated by sedimentary substrates (above all by Mesozoic and Tertiary sedimentary rocks), while the latter are dominated by metamorphic and plutonic rocks, with sedimentary rocks accounting for a small part of the Alps.

The lithology of the Apennine chain is very heterogeneous, ranging from the metamorphic calcareous substrates of the Alpi Apuane, to the arenaceous flysch, marly-arenaceous and marly-clay of the northern Apennines and the calcareous substrates of the central and southern Apennines.

The Apennines also vary greatly from a bioclimatic point of view. The Phytoclimatic map of Italy (BLASI & MICHETTI 2007), based on the classification of monthly raw data (precipitation, maximum and minimum temperatures) collected from as many as 400 weather stations over a period of 30 years, clearly shows the wide range of bioclimatic conditions: 28 phytoclimatic types, referred to 9 bioclimatic types included in 2 climatic regions and additional transitional regions. The temperate bioclimate prevails in Italy (over 55%), while the presence of Mediterranean climate is relatively scarce (only 20%), and the remaining 25% is characterised by a transitional bioclimate. Eight bioclimate types, most of which belong to the temperate region, have been identified in the Apennine chain.

3. High mountain vegetation of the Apennines

3.1 Vegetation series of Italy

An ecological land classification approach was applied to the physical and climatic data as the abiotic model to create the Map of Vegetation Series of Italy (BLASI ed. 2010a; BLASI & FRONDONI 2011), which summarises the heterogeneity of the vegetation in Italy (print scale



Fig. 1: Main mountain peaks of the Apennines and spatial and percentage distribution of the phytoclimatic regions in Italy (from BLASI & MICHETTI 2007).

1:500,000; scale of analysis 1:100,000 and 1:250,000). The Map identifies 240 vegetation series, 37 series-based mosaics and 39 geosigmeta (classified according to types of Potential Natural Vegetation), all of which are found in Italy in the various dynamic stages described in the monography (BLASI ed. 2010b).

The Apennines contain more than 50 legend types, 8 of which consist of high mountain vegetation. Six vegetation series linked to the subalpine shrublands and to the communities above the timberline and 2 geosigmeta make up the natural vegetation in the alpine belt. Fig. 2.

3.2 Subalpine belt

The Apennine subalpine shrublands are clearly distinct from those in other central and southern European regions. The Greek coenoses are more xeric and are characterised by endemic *taxa*, the largest islands being dominated by communities of the *Genista* and *Astragalus* genera, whereas the southeastern European communities bear some similarities in physiognomic terms alone.

There are phytogeographic similarities between communities in the central Apennines and other communities in western Europe (especially for the *Juniperus* communities), both of which lie on the border between the Euro-Siberian and Mediterranean regions. Indeed, the high altitude vegetation in the central and southern Apennines and in the mountains in Spain and southern France is dominated by coenoses of the *Pino-Juniperetalia* order, dominated by



Fig. 2: Map of vegetation series in Italy (from BLASI ed. 2010b).

Pinus and *Juniperus* genera, and does not contain *Rhododendron*, *Picea* or *Vaccinium* communities (STANISCI 1997).

The Apennine shrublands are, however, dynamically linked to grasslands described by alliances and suballiances that are endemic to the Apennines, particularly in the central and southern Apennines (*Seslerion apenninae*, *Phleo-Bromion*, *Linario-Festucion dimorphae*, *Brachypodenion genuensis*, *Asperulenion calabricae*).

The subalpine belt of the northern Apennines is characterised by the widespread presence of *Vaccinium* sp.pl. communities on deep acid soils, whereas peculiar *Pinus mugo uncinata*¹

¹ Taxonomic nomenclature follows CONTI et al. 2005 and focused taxonomic studies.

Altitudial belt	Apennine sector	Prevalent Series and Geosigmetum
Subalpine belt	N	Vaccinium myrtillus heaths (Northern Apennines hypsophilous oligo- trophic series)
		Carex sempervirens grasslands (Apuan hypsophilous series)
	С	Vaccinium myrtillus heaths (Central Apennines oligotrophic series)
		<i>Pinus mugo mugo</i> shrublands (Central Apennines neutrobasiphilous series)
		Juniperus communis alpina shrublands (Central-Southern Apennines neutrobasiphilous series)
	S	Juniperus communis alpina shrublands (Central-Southern Apennines neutrobasiphilous series)
		<i>Pinus leucodermis</i> communities (Southern Apennines neutrobasi- philous serie) in mosaic with <i>Juniperus communis alpina</i> shrublands series
Alpine belt	N	Geosigmetum of high altitude primary acidophilous vegetation of Northern Apennines
	С	Geosigmetum of high altitude primary vegetation of Central Apennines

Tab. 1: Series and Geosigmeta prevailing in the Apennine sectors.

formations or *Juniperus communis alpina* communities are found on shallow soils. Communities dominated by *Rhododendron hirsutum* or *R. ferrugineum*, which are common in the Alps, are instead rare. Very limited areas contain communities dominated by *Genista radiata*.

These communities bear some similarities to the Alpine communities, though with considerably fewer arctic-alpine species. The subalpine belt represents the southern distribution limit for some of these species (*Seslerio caeruleae-Pinion uncinatae, Loiseleurio-Vaccinion* and *Rhododendro-Vaccinion*).

The central Apennines, from a bioclimatic and biogeographic point of view, have always been considered one of the most interesting areas in the Italian peninsula. The presence of very high peaks in this range, besides allowing the development of a peculiar flora, has played an important role in the preservation of species (and, in some cases, of whole plant community types) with typical endemic or circumboreal/arctic-alpine features (e.g. *Juniperus communis alpina, Moneses uniflora, Dryas octopetala, Vaccinium myrtillus, V. uliginosum microphyllum, Arctostaphylos uva-ursi*), which spread down the peninsula following the Quaternary cold periods (BLASI et al. 2003). Furthermore, the central Apennine subalpine shrublands are rich in southern and south-eastern European orophytes and in endemic species (e.g. *Sorbus chamaemespilus, Rosa pendulina, Lonicera alpigena*).

The central Apennine subalpine shrublands are mainly composed of *Juniperus communis alpina* coenoses, with *Rhamnus alpina* and *Daphne oleoides* (BLASI et al.1989). Of particular interest is the thick pinewood of *Pinus mugo mugo* found in the Abruzzo and Majella National Parks, while local formations of *Arctostaphylos uva-ursi* and fragments of *Vaccinium myrtillus* and *V. uliginosum microphyllum* (=*V. gaultherioides*) communities are found on deep, acid soils (Laga Mountains and Terminillo; BLASI et al. 1990).

The altitudes in the southern Apennines do not favour the presence of extensive areas above the timberline. There are, however, *Juniperus communis alpina* formations and, on the Pollino massif, *Pinus leucodermis* wooded lands. These communities are enriched with endemic *taxa* such as *Viola aetnensis messanensis*, *Campanula pollinensis* and *Asperula cal-*

abra, whereas the more characteristic elements of the central Apennines disappear. They are closed shrublands dominated by *Juniperus communis alpina*, with *Daphne oleoides* and *Rhamnus alpina*.

The Pollino massif is characterized by scattered *Pinus leucodermis* trees, which occur in the Balkan peninsula and in a few massifs in southern Italy (Pollino, M. Alpi and M. La Spina). *P. leucodermis* dominates open woodland on dry pastures with prostrate *Juniperus communis alpina* shrubs between 1800 and 2200 m, in rupicolous stations with a limestone or dolomitic substrate and poorly evolved soils.

In phytosociological terms, Apennine shrublands are referred to the *Vaccinio-Piceetea* class (with the alliance *Seslerio caeruleae-Pinion uncinate*) and *Loiseleurio-Vaccinetea* class (represented by the alliances *Loiseleurio-Vaccinion* and *Rhododendron-Vaccinion*) in the northern sector, and to the *Pino-Juniperetea* class (endemic alliances *Daphno oleoidis-Juniperion alpinae* and *Epipactido atropurpurae-Pinion mugo*) in the central and southern sectors.

3.3 Alpine belt

Although the Apennine chain stretches from the north of Italy (Liguria) to the southernmost part of Calabria, it is only in the high mountains of the central Apennines (Gran Sasso, Laga, Majella) that there is an actual alpine bioclimatic belt, which allows high-altitude vegetation to exist.

The northern Apennines are not high enough to provide the conditions required for the preservation of high-altitude vegetation, though some scattered stands of alpine vegetation, dominated by the orophilous central-European, boreal and Eurasiatic species, as well as a few limited endemics, are found in this sector. The summit area of the northern Apennines has, owing to its floristic similarity to the Alps, been considered as the southernmost part of a larger phytogeographic unit that also includes the main central-European massifs.

Grasslands

The high-mountain grasslands in this sector cover very limited areas because there are very few stations above 2000 metres (Monte Cimone 2165 metres): there are discontinuous acidophilus grasslands of the association *Sileno exscapae-Trifolietum alpini (Caricion curvulae)*, whose southernmost distribution limit is reached here, basiphilous closed grasslands of *Aquilegio-Anemonetum narcissiflorae (Caricion ferrugineae)*, which are represented even less and are often limited to ledges, and basiphilous open grasslands dominated by *Sesleria juncifolia* and *Carex mucronata (Seslerio tenuifoliae-Caricetum sempervirentis, Seslerion caeruleae*) that grow on the outcrops of the transition zone between the subalpine belt and the alpine belt of the Apuan Alps.

In the central Apennines, the occurrence of a true alpine belt and the wide range of lithological and morphological conditions allow the development of various types of primary grasslands. Some examples are:

- Kobresia myosuroides (= Elyna myosuroides) grasslands (Leontopodio-Elynetum, Leontopodio-Elynenion), which occur exclusively in the central Apennines (Gran Sasso massif, Laga Mountains and Majella); they prevail along mountain ridges where the constant action of the wind does not allow the snow to lie, causing extreme variations in temperature, on both arenaceous and calcareous substrates;
- *Carex rupestris (taxon* only found in the Gran Sasso range for the Apennines) communities (*Caricetum kitaibelianae-rupestris, Leontopodio-Elynenion*), with *Carex kitaibeliana, Poa alpina* and *Edrajanthus graminifolius*, are typical of rocky ridges or windy plateaux with abundant fine-textured debris;

- the dwarf-cushions dominated by *Silene acaulis (Galio magellensis-Silenetum acaulis, Leontopodio-Elynenion)*, that are the most evident expression of the "alpine tundra" in the Apennines, mainly occur in the proximity of screes or in sites characterised by abundant superficial debris;
- Sesleria juncifolia continuous grasslands (*Leontopodio nivalis-Seslerietum juncifoliae*, *Leontopodio-Elynenion*) found in areas over 2300 metres in the Majella massif, where the substrate is subjected to the action of winds and frequent cryoturbation processes, with relatively deep soils that are rich in calcareous skeletons but have scarce surface debris;
- the discontinuous grasslands dominated by *Helianthemum oelandicum alpestre* and *Festuca violacea italica* (*Helianthemo alpestris-Festucetum italicae*, *Leontopodio-Elynenion*) that colonize the slightly sloping stretch connecting the lower part of the slope to the bottom of the karst basin;
- the open, basophilous, xerophytic grasslands dominated by *Sesleria juncifolia (Seslerietum apenninae, Seslerion apenninae)* that are widespread on the rocky ridges of the highest peaks;
- the Sesleria juncifolia and Dryas octopetala (Seslerio apenninae-Dryadetum octopetalae, Seslerion apenninae) chamaephytic grasslands that occur in stations with strong winds and cryoturbed soils.

In the southern Apennines, where an actual alpine belt is absent, there are fragments of primary vegetation in small, isolated areas (Pollino and Sirino Papa).

Primary grasslands can be found in the subalpine belt of the highest peaks in the Pollino National Park (Serra Dolcedorme), where their presence is confined to windy ridges and steep screes. These are dry grasslands dominated by *Sesleria calabrica*, with *Carex kitaibeliana*, *Anthyllis montana atropurpurea*, *Sempervivum tectorum* and *Festuca bosniaca* referred to *Seslerion apenninae (Anthyllido atropurpureae-Seslerietum calabricae)*. They typically contain several south-eastern European orophytes (e.g. *Carex kitaibeliana, Pedicularis comosa*), endemics (e.g. *Sesleria calabrica*, which is endemic to Pollino and Orsomarso, and *Asperula calabra*) and amphi-adriatic *taxa* (e.g. *Sesleria juncifolia*).

In phytosociological terms, these alpine grasslands can be referred to the *Elyno-Seslerietea* and *Caricetea curvulae* classes. The former is present in the northern Apennines and in the Apuan Alps with the *Seslerietalia caeruleae* order and with the *Seslerion caeruleae* alliance, which includes xerophytic vegetation of the order, and the *Caricion ferrugineae* alliance, which includes the mesophytic vegetation of the order. In the central and southern Apennines we instead find the *Seslerietalia tenuifoliae* order, which is represented by the endemic alliance *Seslerion apenninae*, which is subdivided in two suballiances: *Leontopodio nivalis-Elynenion myosuroidis*, which includes natural communities growing in the alpine belt in the central Apennines and is rich in circumboreal and arctic-alpine species, endemics and southeastern European orophytes, and *Seslerenion apenninae*, which consists of the natural or semi-natural communities characterized by subalpine and high mountain species. The *Caricetea curvulae* class, which is widely represented in the Alps, occurs in only a scattered fashion (sporadically) in the northern Apennines with *Caricion curvulae* alliance, consisting of acidophilous grasslands such *Sileno excapae-Trifolietum alpini*.

Snowbed vegetation types

The Apennine alpine belt also contains examples of snowbed vegetation. The snowbed vegetation types in Italy are distributed mainly in the Alps, becoming increasingly rare in the Apennines the further south one goes. This is largely due to a climatic gradient, though the prevailing geological conditions are also responsible (calcareous bedrock). The gradual impoverishment of the floristic composition in the arctic-alpine and alpine species is accom-

panied by an enrichment in other endemic and oromediterranean chionophilous species. Moreover, there is a gradual decline in the *Salicetea herbaceae* species (PETRAGLIA & TOMASELLI 2007). Although they are still present in the northern Apennines on account of this sector's position between the Alps and the central Apennines (geographically) and between the Eurosiberian and Mediterranean regions (biogeographically), the number of chionophilous plants is significantly lower than in the snowbeds in the Alps. Several snowbed vegetation types can, however, be identified, such as *Salix herbacea* communities, *Luzula alpinopilosa* communities, *Poa supina* and *Cerastium cerastioides* communities, *Carex foeti-da* communities and the bryophytic communities of *Polytrichetum sexangularis and Oligotricho-Gnaphalietum*.

In the central Apennine alpine belt (Sibillini, Laga, Gran Sasso), the snowbed vegetation is generally located on northern slopes, in depressions or along drainage lines. In these habitats, Salix herbacea, whose southern distribution limit is reached here, forms communities referred to Armerio majellensis-Salicetum herbaceae (Salicion herbaceae), which replaces the association Salicetum herbaceae that is typical of the Alps and northern Apennines. Other snowbed communities that are found in the Gran Sasso and Majella massifs are those dominated by Plantago atrata and Trifolium thalii. On decarbonated soils found at the bottom of dolines, where snow lies most of the year, Plantago atrata form small-sized carpets (referred to the association Gnaphalio-Plantaginetum atratae, Ranunculo-Nardion) with other species such as Ranunculus sartorianus, Trifolium thalii, Gnaphalium hoppeanum magellense, Taraxacum apenninum and Botrychium lunaria. On the slopes of the dolines we may also find Salix retusa, which plays a primary role in the colonization and stabilization of substrates, whereas the microconcavities are characterized by the presence of Taraxacum glaciale. In the central area of the largest dolines, when calcareous debris is absent, and even along the drainage lines, we find Trifolium thalii communities that belong to the association Taraxaco apennini-Trifolietum thalii (Ranunculo-Nardion), which may be considered a geovicariant association of the northern Apennine and the Apuan Alps Trifolio thalii-Festucetum puccinellii (Caricion ferruginae).

The snowbed habitats in the southern Apennines host plant communities that are completely different from those found in the northern and central Apennines belonging to the *Salicetea herbaceae* class, which reaches its southernmost distribution limit in the central Apennines. These communities in the southern Apennines are referred to *Ranunculo-Nardion*, an endemic alliance of the central and southern Apennines.

In the highest areas of the Pollino and Sirino-Papa massifs, where the snow cover remains for much of the year, we find *Nardus* communities of the *Nardo-Luzuletum pindicae* in the Pollino massif, formations in which *Nardus stricta* is codominant with *Festuca rubra micro-phylla* and *Plantago serpentina* (*Plantagini serpentinae-Nardetum strictae*) on the steep slopes of the Sirino-Papa massif, and communities dominated by *Crepis aurea glabrescens* and *Plantago atrata* (*Bellidi pusillae-Alopecuretum gerardi*) at the bottom of karstic depressions.

Salix retusa communities

Salix retusa communities (Carici-Salicetum retusae, Arabidion caeruleae) in the central Apennines occur in various environmental conditions, ranging from snowbeds to scree: they occupy the micro-convexities of the north-facing slopes of gullies, they may represent differential species in the Salix herbacea stands and at higher altitudes (over 2600m) where the amount of debris and rock markedly increases, and they assume an important role in the colonisation and consolidation of north-facing scree slopes characterised by prolonged snow cover.

Scree vegetation types

The northern Apennine sector contains a range of scree vegetation types that vary according to the lithology and to the characteristics of the clasts. In the Apuan Alps the most common scree-vegetation type on calcareous substrata is the Heracleo-Valerianetum montanae, whereas at the edges of the talus slopes colonized by these coenoses we may find communities of Saxifraga aizoides and Leontodon hyoseroides (Saxifrago-Leontodontetum hyoseroidis). Both these communities belong to the Apuan endemic suballiance Aquilegienion bertolonii, referred to Linario-Festucion dimorphae, an endemic Apennine alliance that includes communities growing on screes in calcareous mountains between 1500 and 2500 m. On the marly and marly-arenaceous talus slopes of the Tuscan-Emilian Apennines, we find formations dominated by Arenaria bertolonii, with Rumex scutatus, Robertia taraxacoides and Arabis alpina (Arenarietum bertolonii, Linario-Festucion dimorphae). Fern communities dominated by Cryptogramma crispa develop in the spaces among the arenaceous clasts of inactive or recently stabilised talus. These communities are referred to the association Cryptogrammo-Dryopteridetum abbreviatae of the alliance Dryopteridion oreadis, which include all the acidophilous herbaceous communities that grow among stones from the montane to the alpine belt.

The most widespread scree vegetation types in the central Apennines are the communities of Isatido-Thlaspietum stylosi and of Galio magellensis-Festucetum dimorphae (Linario-Festucion dimorphae), both of which are characterized by many endemic taxa such as Isatis apennina, Thlaspi stylosum, Galium magellense, Festuca dimorpha, Robertia taraxacoides and Cerastium tomentosum. The former community (i.e. Isatido-Thlaspietum stylosi) is a paucispecific pioneer community that colonizes loose and very steep scree slopes with mediumand large-sized debris, in the subalpine and alpine belts. The latter community (i.e. Galio magellensis-Festucetum dimorphae) develops on unstable slopes with medium- and smallsized clasts, mainly in the montane and subalpine belts, though it also occurs in the alpine belt. Scree vegetation in the highest altitudes is characterized by small rosulate hemi-cryptophytes, such as Papaver alpinum ernersti-mayeri and Draba aspera, and nano-chamaephytes, such as Cerastium thomasii. This vegetation is referred to the Thlaspienion stylosi suballiance, i.e. endemic syntaxon of the central Apennines that include high altitude communities of the Linario-Festucion alliance. The highest altitude communities in the Gran Sasso massif (between 2600m and 2914m, i.e. the height of the Corno Grande, the summit) are referred to the association Arabido-Cerastietum thomasii. The communities in the Majella massif are instead referred to Saxifrago speciosae-Papaveretum julici and to the Ranunculo seguierii-Adonidetum distortae, which form scattered stands of limited size, dominated by the central Apennine endemic Adonis distorta.

Where more water is available on calcareous screes of the Gran Sasso massif, Saxifraga aizoides forms communities with *Bellidiastrum michelii* and *Parnassia palustris (Astero bellidiastri-Saxifragetum aizoidis, Linario-Festucion dimorphae)*, whereas in the wettest spots on the arenaceous screes of the Laga Mountains we find communities referred to *Achilleo mucronulatae-Saxifragetum aizoidis (Linario-Festucion dimorphae)*, a silicicolous vicariant of the *Astero-Saxifragetum*.

The only areas in the southern Apennines where high elevation scree vegetation can be found are the Monte Cervati, Pollino and Sirino-Papa massifs. Small stands of communities with *Linaria purpurea*, *Senecio scopolii* and *Festuca dimorpha* (*Linario-Festucion dimorphae* alliance) are present on Monte Cervati. Screes in the the Sirino-Papa summit area are colonized by paucispecific communities with *Festuca dimorpha* and *Rumex scutatus*, which belong to *Galio magellensis-Festucetum dimorphae* (*Linario-Festucion dimorphae*). In the

Pollino massif, which represents the southernmost massif with landforms deriving from the Würm glaciation, the scree vegetation is confined to the northeast slopes and is characterized by *Laserpitium siler siculum*, *Leucanthemum laciniatum*, *Silene multicaulis* and *Lomelosia crenata*.

Vegetation of rock fissure

The rock fissure vegetation of the Apennine alpine belt varies considerably and is characterised by a wide range of endemic *taxa* and *syntaxa*. In the northern Apennine sector, the occurrence of lithoid substrates of varying origin favours the development of different types of chasmophytic vegetation. In fissures on the arenaceous cliffs of the Tuscan-Emilian Apennines, the endemic *Primula apennina* forms paucispecific communities (*Drabo aizoidis-Primuletum apenninae*, *Androsacion valdellii*) with other chasmophytic and comophytic species. Rupicolous fern communities of the *Asplenio-Cystopteridetum fragilis* (*Cystopteridion*) are present in shaded niches where the microclimate is cold and moist, on calcareous or arenaceous substrates. Communities of *Silenetum saxifragae* occur exclusively on outcrops of sandstone and jasper (*Globularienion incanescentis*).

On the southern slopes of carbonate outcrops of the Apuan Alps, it is possible to find communities dominated by the *Silene lanuginosa* (*Artemisio nitidae-Silenetum lanuginosae*, *Globularienion incanescentis*), which is endemic to the Apuan Alps, whereas communities dominated by *Valeriana saxatilis* of the *Valeriano-Saxifragetum* (*Globularienion incanescentis*) develop in more shaded areas on the northern slopes.

In the central Apennines, the cliffs of the highest peaks of the Gran Sasso massif are colonised by *Festuca alfrediana* communities. In areas in which the rocks are still compact, there are very few species, besides *Festuca alfrediana*, that are closely linked to cliff environments, such as *Campanula tanfanii*, *Saxifraga sedoides*, *S. paniculata*, *S. exarata ampullacea*, *Potentilla apennina* (*Potentillo apenninae-Festucetum alfredianae*, *Saxifragion australis*). In areas in which the rocks are fissured, *Campanula cochlearifolia*, *Arabis alpina* and *Papaver alpinum ernersti-mayeri* may be well represented in the community.

Crevice vegetation is rarely present in the southern Apennines, though few investigations have been conducted on this vegetation type.

The calcareous rocks close to Monte Cervati (1898m) contain two communities with *Primula auricula* and *Saxifraga paniculata*: xerophytic formations with *Anthyllis montana* and *Oxytropis campestris* and formations with *Cystopteris fragilis* and *Doronicum columnae* in moist and shady sites.

Above 1600 metres on Monte Alpi there are interesting communities (referred to the association *Saxifrago-Achilleetum lucanae*) characterized by endemic *taxa* such as *Saxifraga australis* (incl. in *S. callosa callosa*) and *Saxifraga porophylla*, both of which are endemic to the central and southern Apennines, and *Achillea rupestris calcarea* (= *A. lucana*), which is endemic exclusively to the Lucania region.

From phytosociological point of view, these Apennine chasmophytic vegetations of calcareous cliffs belong to the *Potentilletalia caulescentis* order. The *Saxifragion lingulatae* alliance and the *Globularienion incanescentis* suballiance, which is an endemic *syntaxon*, are references for the communities of the Tuscan-Emilian Appennines and Apuan Alps. The alliance *Saxifragion australis* is a central Apennine endemic alliance that also occurs very locally in the southern Apennines. It is related to ecological conditions similar to those of the *Potentillion caulescentis* in the Alps and includes *Potentillo apenninae-Festucetum alfredianae* in the Gran Sasso as well as lower altitude communities, such as *Potentilletum apenninae* in the Majella massif. The alliance *Violo-Cystopteridion alpinae* instead groups the rupestral communities of moist, dripping and shady calcareous rocks of the Apuan Alps and the northern and central Apennines.

The communities that develop in the fissures of siliceous rocks in the northern Apennines are referred to the *Androsacetalia vandellii* order and *Androsacion vandellii* alliance.

4. Conclusion

This overview on the subalpine and alpine Apennines vegetation allows us to highlight:

- a) The biogeographic value and in particular of the Apennines particularly of the central Apennines;
- b) The high conservation value of the Apennine;
- c) The role of the Apennines in the climate change monitoring.

4.1 Biogeographic value of the Apennines

The chorological spectra of the central Apennine communities clearly show the presence of a circumboreal component. However, both the southeastern European orophytes and endemic species always exhibit very high values, in some cases becoming dominant. The high number of central Apennine endemic *taxa*, the abundance of southern and southeastern European orophytes (which highlight the link with Balkan communities), and the occurrence of arctic-alpine elements further contribute to the special significance of the unique biogeographic pattern found in this area.

The northern Apennines can, in view of their low degree of floristic independence from the Alps (see FOGGI, 1990; TOMASELLI & GUALMINI, 2000), instead be considered as the southernmost part of a larger central-European phytogeographical unit, as is suggested by the chorological analysis and the very low number of species that are endemic solely to this area. Fig. 3.

4.2 Conservation value of the Apennine

Besides the afore-mentioned examples, several studies have also previously highlighted the importance of the Apennines as a mountain area of high conservation concern in southern Europe for both animal and plant species (e.g. STANISCI et al. 2005, 2011; MAIORANO et al. 2006; FATTORINI 2010), with numerous sites containing 'priority habitats' defined according to the European Habitats Directive (EEC Directive 92/43; BIONDI et al. 2009, 2012).

Furthermore, the conservation value of mountain areas is recognized by a range of international strategies: by the Chapter 13 of Agenda 21 (the United Nations programme on Sustainable Development launched at the 1992 Earth Summit), which recognizes the essential role of mountains as a "a major ecosystem representing the complex and interrelated ecology of our planet" for the survival of our planet's ecosystems; by the Convention on Biological Diversity (UNEP), Programme of Work on Mountain Biological Diversity COP 7 Decision VII/27; by the UE, which has supported environmental and nature conservation projects by funding more than 40 LIFE (Environment and Nature) projects regarding mountain ecosystems in Italy (approx. 25% of all funded projects on mountainous areas); by the Global Strategy for Plant Conservation through one of its main goals, i.e. affording a high degree of protection for Important Plant Areas, which in Italy correspond to many Apennine high altitude areas.

As a consequence, in Italy, the alpine and subalpine belts are the most widely protected environmental units by Italian parks and the Natura2000 network (ROSATI et al. 2008).



Fig. 3: Chorological spectra calculated on the frequency values of Central Apennines communities of alpine belt (from BLASI et al. 2003).

4.3 Monitoring climate change

A project highlighting the threat posed by climatic change to subalpine and alpine vegetation was presented more than 10 years ago (BLASI 2001). This study indicated that an increase of 1.5° C (suggested by the Geophysical Fluid Dynamic Laboratory model) would raise the subalpine and alpine belts by about 300 m. Such changes would, given their intensity and speed combined with the relatively low altitude of the Apennine mountains, have a very detrimental effect on the flora.

Over the last ten years, the GLORIA program, which is aimed at establishing and maintaining a world-wide long-term observation network in alpine environments, has achieved significant results.

Italy takes part in this program, with as many as 45 permanent plots along an altitudinal gradient (20 for the northern Apennines, 15 for the central Apennines and 10 for the southern Apennines).

This scenario is experimentally confirmed by Pauli's work (PAULI et al. 2012), which analyzes recent changes (2001-2008) in vascular plant species richness observed in a standardized monitoring network across Europe's most important mountain ranges. This study shows that a rise in the altitude of the alpine belt would lead to an increase in the number of species (both total and endemic) in the temperate regions and in the northern Apennines but to a reduction in the Mediterranean area, whereas in the central and southern Apennines the situation would remain stable. These findings confirm the phytogeographic and bioclimatic autonomy of the central and southern Apennines as well as the weak presence of the Mediterranean climate in these sectors of the Apennines (BLASI et al. 1999).

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Appendix

Syntaxonomic scheme NORTHERN APENNINES Vaccinio-Piceetea Br.-Bl. in Br.-Bl., Sissingh & Vlieger 1939 Piceetalia abietis Pawlowski in Pawlowski et al. 1928 Seslerio caeruleae-Pinion uncinatae Vigo 1974 Loiseleurio-Vaccinetea Eggler ex Schubert 1960 Rhododendro-Vaccinetalia Br.-Bl. in Br.-Bl. & Jenny 1926 Loiseleurio-Vaccinion Br.-Bl. in Br.-Bl. & Jenny 1926 Rhododendro-Vaccinion Br.-Bl. in Br.-Bl. & Jenny 1926 Elyno-Seslerietea Br.-Bl. 1948 Seslerietalia caeruleae Br.-Bl. in Br.-Bl. & Jenny 1926 Seslerion caeruleae Br.-Bl. in Br.-Bl. & Jenny 1926 Caricion ferrugineae G.Br.-Bl. & J.Br.-Bl. & Jenny 1931 Caricetea curvulae Br.-Bl. 1948 (= Juncetea trifidi Hadac, in Klika et Hadac 1944) Caricetalia curvulae Br.-Bl. in Br.-Bl. & Jenny 1926 Caricion curvulae Br.-Bl. 1925 Salicetea herbaceae Br -Bl 1948 Salicetalia herbaceae Br.-Bl. 1948 in Br.-Bl. & Jenny 1926 Salicion herbaceae Br.-Bl. 1948 in Br.-Bl. & Jenny 1926 Thlaspietea rotundifolii Br.-Bl. 1948 Thlaspietalia rotundifolii Br.-Bl. in Br.-Bl. & Jenny 1926 Linario-Festucion dimorphae Avena e Bruno 1975 Aquilegienion bertolonii Tomaselli 1994 Polystichetalia lonchitis Rivas-Martínez, Diaz, Prieto, Loidi & Penas 1984 Dryopteridion oreadis Rivas-Martínez 1977 Asplenietea trichomanis (Br.-Bl. in Meier & Br.-Bl. 1934) Oberd. 1977 Potentilletalia caulescentis Br.-Bl. in Br.-Bl. & Jenny 1926 Saxifragion lingulatae Rioux e Quézel 1949 Globularienion incanescentis Barbero & Bono 1973 Violo-Cystopteridion alpinae Fernandez Casas 1970 Androsacetalia vandellii Br.-Bl. in Meier & Br.-Bl. 1934 Androsacion vandellii Br.-Bl. in Br.-Bl. & Jenny 1926 CENTRAL APENNINES Junipero sabinae-Pinetea sylvestris Rivas-Martínez 1964 Pino-Juniperetalia Rivas-Martínez 1964 Epipactido atropurpurae-Pinion mugo Stanisci 1997 Daphno oleoidis-Juniperion alpinae Stanisci 1997 Elyno-Seslerietea Br.-Bl. 1948 Seslerietalia tenuifoliae Horvat 1930

Seslerion apenninae Furnari in Bruno & Furnari 1966 Leontopodio nivalis-Elynenion myosuroidis Blasi & Di Pietro 2003 Seslerenion apenninae Blasi & Di Pietro 2003 Salicetea herbaceae Br.-Bl. 1948. Salicetalia herbaceae Br.-Bl. 1948 in Br.-Bl. & Jenny 1926 Salicion herbaceae Br.-Bl. 1948 in Br.-Bl. & Jenny 1926 Nardetea strictae Rivas Goday in Rivas Goday & Rivas Martínez 1963 Nardetalia strictae Oberdorfer ex Preising 1949 Ranunculo pollinensis-Nardion strictae Bonin 1972 Thlaspietea rotundifolii Br.-Bl. 1948 Thlaspietalia rotundifolii Br.-Bl. in Br.-Bl. & Jenny 1926 Linario-Festucion dimorphae Avena & Bruno 1975 Thlaspienion stylosi Avena & Bruno 1975 Polystichetalia lonchitis Rivas-Martinez, T. E. Diaz, F. Prieto, Loidi, Penas 1984 Arabidetalia caerulae Rubel ex Br.-Bl. 1948 Arabidion caerulae Br.-Bl. in Br.-Bl. & Jenny 1926 Asplenietea trichomanis (Br.-Bl. in Meier & Br.-Bl. 1934) Oberd. 1977 Potentilletalia caulescentis Br.-Bl. in Br.-Bl. & Jenny 1926 Saxifragion australis Biondi & Ballelli ex Brullo 1993 Violo-Cystopteridion alpinae Fernandez Casas 1970 SOUTHERN APENNINES Junipero sabinae-Pinetea sylvestris Rivas-Martínez 1964 Pino-Juniperetalia Rivas-Martínez 1964 Daphno oleoidis-Juniperion alpinae Stanisci 1997 Elyno-Seslerietea Br.-Bl. 1948 Seslerietalia tenuifoliae Horvat 1930 Seslerion apenninae Furnari in Bruno e Furnari 1966 Seslerenion apenninae Blasi e Di Pietro 2003 Nardetea strictae Rivas Goday in Rivas Goday & Rivas Martínez 1963 Nardetalia strictae Oberdorfer ex Preising 1949 Ranunculo pollinensis-Nardion strictae Bonin 1972 Thlaspietea rotundifolii Br.-Bl. 1948 Thlaspietalia rotundifolii Br.-Bl. in Br.-Bl. & Jenny 1926 Linario-Festucion dimorphae Avena e Bruno 1975 Asplenietea trichomanis (Br.-Bl. in Meier & Br.-Bl. 1934) Oberd. 1977 Potentilletalia caulescentis Br.-Bl. in Br.-Bl. & Jenny 1926 Saxifragion australis Biondi & Ballelli ex Brullo 1993

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