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# Vegetation changes during a 30 year period in several stands above the forest line (Emilian-Apennines)

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**Abstract**
The study highlights the changes occurred in several stands of *Hyperico richeri-Vaccinietum* communities of the high Emilian Apennines after 30 years after the first phytosociological and phenological surveys. In 2012 the same types of surveys were repeated in the original stands, with the aim to detect any change in vegetation structure as well as in species composition and behaviour. The study has pointed out significant changes in all the vegetation stands over the last 30 years. The following trends are displayed in the stands analysed: A) a general decrease of species richness per stand; B) a slight increase of the shrubs/herbs cover ratio, with a significant spreading of *Juniperus communis* and of *Vaccinium uliginosum*, sometimes coupled with a reduction of *V. myrtillus* cover; C) a reduction of Orophytes and of many species belonging to the classes *Caricetea curvulae* and *Nardo Callunetea;* D) a xero-thermic trend of plant communities composition (index species analysis). It is noteworthy that many of the declining species flower in the dryest and hottest period of the year (July-August). The results seems to indicate that the changes in vegetation features are due only partly to human causes (lighter grazing) and more widely to climatic stress.

Key words: climate change, Northern Apennines, *Vaccinium* heath, vegetation dynamics.

## Introduction

The Apennines constitute the backbone of the Italian peninsula from Liguria Region, directly in contact with the Maritime Alps, to Calabria. This long chain of mountains is subdivided into several successive sectors and massifs. The Northern Apennines summit flora and vegetation have a higher similarity with the Alps than with the other sectors of the Apennines, as it is relatively rich in boreal and alpine taxa. The Tuscan-Emilian Apennines includes, as its name indicates, Tuscany and Emilia-Romagna regions: the ridgeline constitutes the administrative limit of these two areas. Dwarf shrublands dominated by *Ericaceae* occupy the undisturbed slopes of mountains above the timberline, together with pastures with *Nardus stricta*. The naturalistic importance of the area is linked to several geomorphological and geological features and to the presence of interesting flora and fauna (AA.VV., 1992; Alessandrini *et al*., 2003). In fact, this territory represents an important phytogeographic boundary, already identified by Adamović (1933) with the Reno valley, separating the North-Western sector of the Apennines, characterized by Eurosiberian features, from the Eastern (Romagna) and Southern mediterranean sectors. Here many species reach their southern geographic edge in Italy (e.g. *Diphasiastrum alpinum, Rhododendron ferrugineum, Homogyne alpina, Empetrum hermaphroditum, Vaccinium vitis-idaea, Leontodon helveticus, Lycopodium annotinum, Maianthemum bifolium, Pimpinella alpina, Viola calcarata, Stachys pradica*, etc.).

*Vaccinium* dwarf heaths are very common in the subalpine belt of the Alps, while, in the Apennines they occupy only the high ridges of the Northern sectors and have their southern edge in Central Italy on the Monti Reatini (Lazio), even if the range of the species *Vaccinium myrtillus* reaches as far as the Abruzzo National Park (Blasi *et al*., 1990).

In particular, the subalpine heaths of the summit Emilian Apennines, have in the past been the subject of many studies, which analyzed their floristic and phytogeographic importance as well as their ecology and phytosociology (Pirola & Corbetta, 1971; Credaro & Pirola, 1975; Ferrari, 1978; Credaro *et al*., 1980; Ferrari *et al*., 1994; Ferrari & Rossi, 1995; Ferrari & Piccoli, 1997; Poldini & Favretto, 1999); in the last years, several studies of experimental ecology were added, with the aim to highlight the influence of several environmental factors such as snow, frost, fertilization, etc. (Gerdol *et al*., 2000; Gerdol, 2005; Brancaleoni *et al*., 2007; Gerdol *et al*., 2013) and climate warming (Bertin *et al*., 2001; Rossi *et al*., 2004, Gervasoni *et al*., 2010, *Abeli et al*., 2012).

The majority of the *Vaccinium* dwarf–shrublands (Alps and Northern Apennines) were ranked into the *Vaccinio-Piceetea* Br.-Bl. 1939 phytosociological class, and more recently into the *Loiseleurio-Vaccinietea* Eggler 1952 (Ferrari & Piccoli, 1997), while the heaths with *Vaccinium myrtillus* and *Juniperus communis* of Central Italy were assigned to the *Pino-Juniperetea* class by Blasi *et al*. (1990). In the Northern Apennines three associations of dwarf–shrublands are recognized: the extremely localized *Rhododendretum*

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*ferruginei* Rubel 1911 (with *Rhododendron ferrugineum* as character species), the *Empetro-Vaccinetum* Br.-Bl. 1926 and the *Hyperico richeri-Vaccinietum gaultherioidis* Pirola et Corbetta 1971 nom. invers. (Ferrari & Piccoli, 1997).

The *Empetro-Vaccinietum* forms the core of the Northern Apennine summit heaths and is characterized by high contents of arctic-alpine species: these communities are frequent in the Emilian chain sector from M.La Nuda (RE) to M. Libro Aperto (MO); the sites have a climate with sub-continental features and with a snow coverage of about 5 months (Ferrari & Rossi, 1995).

The *Hyperico-Vaccinietum*, with a few arctic–alpine taxa, is frequently found below 1840 m asl and corresponds to the sites with a sub-oceanic climate, a snow cover of 5-6 months and high wind speed (Ferrari & Piccoli, 1997): a thermo-xerophilous variant of the *Hyperico-Vaccinietum* (subassociation *brachypodietosum* according to Pirola & Corbetta, 1971) is characterized by the high frequency of the endemic *Brachypodium genuense*.

*Vaccinium* heaths are dynamically related to *Nardus*-rich grasslands (*Geo montani-Nardetum* Lüdi 1948 and *Violo cavillieri-Nardetum* Credaro et Pirola 75 corr. Tomaselli 1994): in fact, they are generally replaced by *Nardus*-dominated pastures in consequence of regular grazing.

This study analyzes the changes occurred in several homogeneous stands both of *Vaccinium* and *Nardus* communities in the Emilian Apennines 30 years after the first surveys. For this purpose the vegetation structure and floristic composition were compared. Moreover, in order to single out possible causes of vegetation changes, phenology, climatic data and human impact were analysed.

## Study area

The stands are located above the forest line in the high Emilian Apennines (Bologna province) in the area of the "Corno alle Scale" Mountain, between 1600 and 1800 m asl, near the ridge separating Emilia and Tuscany regions. Almost all the stations are situated on the Emilian slope (Bologna province) and only one (st. 7) on the Tuscan slope (Pistoia province).

The Corno alle Scale (1945 m asl) is the southernmost high summit of the Tuscan-Emilian Apennines, and is included in a regional park, to which it gives its name. Topographically, the Corno alle Scale is a dissymmetrical mountain, its SE and E side constituting an abrupt wall whereas its NW side is a gentle slope.

Our study area is located almost entirely within the large, natural amphitheatre which fans out in the northern side between the summit of Corno alle Scale and Lake Scaffaiolo. It corresponds with the upper basin of the Dardagna creek, above the tree limit and near the mountain ridge. The substratum is a siliceous sandstone formed by aquatic sedimentation, very compact and with a rather fine granulometry. Between 1000-1600 m, the vegetation consists mainly of dense beech forests, including zones of conifers plantations. Above 1600 m, the forests generally give way to a low vegetation, constituted chiefly of pastures and bilberry heaths (*Vaccinium* spp.), rich in faunistic and floristic relicts of the glacial period. Wide secondary meadows (mostly dominated by *Nardus stricta*), mingled with bilberry heaths, were originated from fires set in the past by shepherds in order to enlarge pasture lands.

### *Climate*

The climate of the high northern Apennines can be described as a transition between sub-Oceanic and sub-Continental types, owing to the relatively high annual temperature range. The climate of the mountain ridges is well documented by the meteorological station of Mount Cimone (2165 m asl), except for precipitation records that unfortunately present numerous gaps.

As far as Temperature is concerned, in the summer time the lapse rate is estimated to be around 0,6 °C per 100 m of altitude; moreover, on the basis of the climatic data for the last thirty years, the average values of several climatic variables between 1600 and 1800 m asl have been estimated as follows: 16 °C annual temperature range; 140 days with min T >5 °C; 150 days with max T >10 °C (Mercalli *et al*., 2003).

Precipitations are abundant on the mountain ridges (about 2000 mm per year): in the whole commune of Lizzano in Belvedere (BO), the average amount is 1700-1600 mm, while at Madonna dell'Acero (1180 m asl), a site in the neighbourhood of the study area, even more than 3200 mm have been recorded in the past (Mennella, 1973). Above the tree line the snowfalls generally begin in November and finish in May. The monthly distribution of snowfalls (1982-2004) shows two peaks: the first in January and the second in April (Fazzini *et al*., 2005). At M.Cimone (2165 m asl), the snow cover thickness reaches its highest value in March (160 cm), then, in April decreases to 138 cm and in May to 56 cm (1961-90 average values, in De Bellis *et al*., 2010).

## Methods

### *Vegetation monitoring*

In the years 1981-1984, 12 stands of *Vaccinium* and *Nardus* communities were sampled by phytosociological and phenological methods (Puppi & Speranza, 1980; Puppi Branzi *et al*., 1994). At that time, the locations of sampling points were exactly recorded (CRT map 1:10000) and well documented by series of photos. In 2012 the original sites were relocated and the same types of surveys were repeated, with the aim to detect changes in vegetation structure, species composition and phenology. For vegetation assessment the phytosociological Sygmatist method was used (Braun-Blanquet 1965; Pott, 2011; Biondi, 2011), and for phenological monitoring the method proposed in Puppi & Speranza (1980) was used.

### *Climate change*

Climatic trends in the last 30 years were analysed on the basis of the literature (Mercalli *et al*., 2003; Fazzini *et al*., 2005; Govoni & Marletto, 2005; Marletto *et al*., 2010; De Bellis *et al*., 2010) and directly assessed by analizing data from the nearest meteorological stations: Mount Cimone (MO, 2165m asl) and in addition, Sestola (MO, 1020 m asl), Maresca (PT, 1043 m asl) and Cottede (PO, 850 m asl).

### *Disturbance assessment*

Anthropic impacts are difficult to quantify, for this reason we used different approaches in order to assess the "anthropic disturbance" and its trend in the period considered:

i) Estimating the risk of anthropic disturbance of the stands (low risk=1; medium=2; high risk=3) on the basis of slope (low risk: slope > 35°; medium and high risk: slope <35°;) and of proximity to footpaths (low risk: distance >200 m in plain or >100 m in altitude; medium risk: distance 100-200 m in plain or 50-100 m in altitude; high risk: adjacency): the stands were then ranked by the combination of the two scores.

ii) Collecting information about general trends of grazing and bilberry harvesting in the area, by means of interviews with shepherds and local collectors of bilberry.

iii) Estimating the disturbance trends in the studied stands (possibly due to grazing, N pollution, trampling and compaction of the soil) by means of an index species analysis (Landolt, 1977; Pignatti, 2005) of old and new relevés (therophytes and ruderal species, indicators of fertilized and compact soils).

## Results

### *Climatic trends*

With regards warming trend in the Northern Apennines (Mercalli *et al*., 2003), the annual mean temperature rose by 0,5°C in the period 1986-2002 compared to the years 1965-85 (the July temperature rose by 1,4 °C). With reference to the study area (Lizzano in Belvedere (BO)) in the period 1961-2008, an increase in the annual mean temperature of about 0,4 °C per decade was calculated (Marletto *et al*., 2010); in particular in the last 20 years, the mean annual temperature rose by about 1 °C compared to the period 1961-1990, and the mean temperature in summer rose more than that of the other seasons (+ 1,5 °C).

A comparison of monthly temperatures for the period 1965-1984 with those for 1985-2005 confirms the general trend already described (Fig.1). The annual

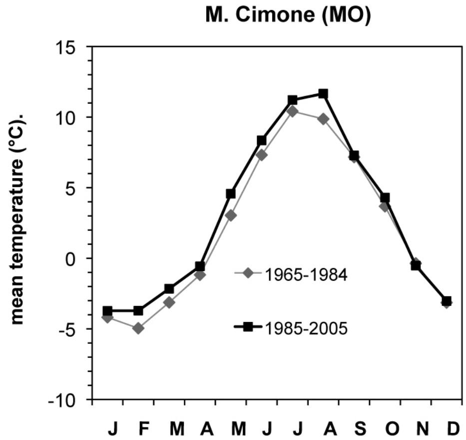


Fig. 1 - Climatic diagram of the meteorological station Mount Cimone (MO), 2165 m asl: mean temperatures of the periods 1965-1984 and 1985-2005 are compared.

temperatures rose by 0,8 °C on average: the highest increases occurred in the period January-August (+1,2 in February, +1,5 in May, +1,8 in August), the lowest in autumn, from September to December.

Marletto *et al*. (2010) reported a significant decrease in precipitations (-117 mm) in the last two decades with respect to the previous thirty years (Lizzano in Belvedere station). The annual and monthly trends of precipitations recorded in several neighbouring pluviometric stations (Sestola (MO), Maresca (PT), Cottede (BO)) show similar patterns. In the last decades there was a significant decline of precipitations in winter (December, January, February and March), May and August too become dryer, vice versa April and October become more rainy in all the stations.

As snow is a very important ecological factor for the summit vegetation (Sakai & Larcher, 1987; Ferrari & Rossi, 1995; Theurillat & Schlussel, 2000; Kreyling *et al*., 2012; Gerdol *et al*., 2013), the duration of snow cover together with the spatial distribution pattern and their variations, must be carefully considered in our analysis.

In the last decades several trends have been observed: in the Reno valley (BO), from the year 1922 onwards, the most snowy decade was 1977-86, whereas, the lowest values were recorded in 1927-36 and 1987-96 (Govoni & Marletto, 2005). With regards the amount of snow falling in the Northern Apennines, in the last 30 years the trend is negative for stations situated above 1000 meters: at Mount Cimone (2165m) a decrease of 3,3% between 1982 and 2004 has been observed (Fazzini *et al*., 2005): that is about –3,5 cm per decade (De Bellis *et al*., 2010). Moreover, the amount of snowfalls has a negative trend in winter (particularly in January and February) but increased in autumn (November) and spring (April) (De Bellis *et al*, 2010).

The prevailing winds (data from the Mount Cimone meteorological station) in all the seasons come from SW and are humid and relatively warm. On the contrary, the second principal wind direction varies with the season and the climatic period: in the years 1961-1990, the winds came mostly from NE (cold–dry winds) from September to March, and then blew from the S direction from May to August. However, in the following decades (1991-2005) the second principal wind direction was from NE-N only from January to March, while, in the greater part of the year (April-December) it came from W. The windiness too changed in the last decades: in fact the number of calm days clearly decreased throughout the whole year (Fig. 2).

In summary, the results of the climatological analyses confirm that over the last decades the study area has become warmer, more windy, less snowy and drier (lower rainfalls particularly in winter and summer). Moreover, periods of aridity (P/T<2) occurred recently in several summers.

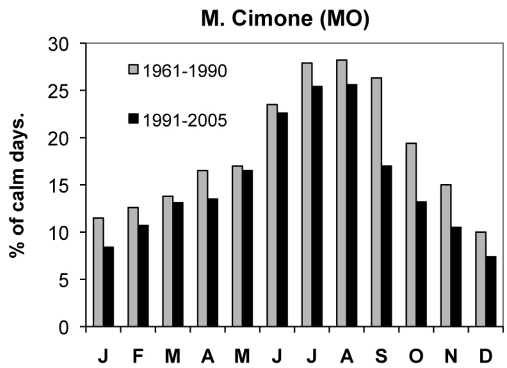


Fig. 2 - Trends in windiness at Mount Cimone (MO), 2165 m asl: mean number of calm days (%) are compared between the periods 1961-1990 and 1991-2005.

### *Human impact and disturbance*

i) The risk of direct human disturbance of the stands (estimated on the basis of slope and proximity to footpaths) is resumed in Tab.1, together with the data about topography and vegetation.

ii) The results of the interviews about grazing and berry picking can be summarized as follows. The area has been grazed, during the growing season (June-September), for many decades. In the '50s, two cowsheds (le Malghe) were built, but soon abandoned. Afterwards, during the period 1960-1980, a flock of about 700-1000 sheep was regularly led to pasture; later, the flock was reduced to 500-600 sheep until 1985, and then, from 1986 till now, to 370-390. Nearly all the study area is affected by a grazing impact of low and medium intensity (Tab.1). Pasture is fairly selective: the sheep prefer the young leaves of grasses such as *Phleum, Festuca, Anthoxanthum, Deschampsia*, and vice-versa avoid *Nardus*, *Brachypodium* and shrubs (*Vaccinium*, *Juniperus*, etc.). Thus, it is to be expected that the lowering of the grazing impact would have reduced the competitive advantage of the disliked plants: in fact the *Nardus stricta* cover dramatically decreased in some stands (31, 33, 35).

In summer, the local population and tourists habitually pick up the bilberries, for personal use and also for commercial purposes. Since the end of the 70's (LR 2/1977) the picking of bilberries has been regulated (allowed only with a permit, by hand, without rakes). Commercial harvesting by hand rakes, that don't damage the plants, is permitted, although at present, only few official collectors are working in the studied area. Official collectors use woody hand-rakes and are requested to collect the bilberries of *Vaccinum myrtillus* in a strictly selective way, carefully avoiding the berries of *Vaccinum uliginosum*, although the heaths are often made up of both species. The harvest season begins at the end of July and takes about two months. Over the last decades the amount of the harvest could be estimated at approximately 1-1,5 tons/year on average; however, in recent years (from 2009 till now) the picking intensity has increased to 3,5-7,5 tons/year. It is noteworthy that the year 2012 had a very scarce harvest (only 0,8 tons/year), maybe owing to the frost damage caused to V. myrtillus by a very cold period without snow, occurred in February 2012.

Tab. 1 - The table summarizes the main data regarding the 12 stands under study. Topography (latitude, longitude, altitude (m asl), exposure, slope (degrees)); Vegetation physiognomy (G grassland, V= Vaccinium heath, G/V = open heath); Disturbance risk (low risk = 1; medium = 2; high risk = 3); Grazing impact (low-medium frequency = 1; high frequency = 2); Number of species recorded in the two years 1981 and 2012.

| stand | latitude | longitude | altitude | exposure | slope ° | physiognomy | trampling risk | grazing impact | n. of species in 1981 | n. of species in 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 44° 07.410' N | 10° 48.932' E | 1610 | NE | 25 | V | 3 | 1 | 30 | 31 |
| 3 | 44° 07.408' N | 10° 48.898' E | 1620 | WSW | 35 | G/V | 3 | 1 | 37 | 14 |
| 4 | 44° 07.218' N | 10° 48.719' E | 1710 | NE | 40 | V | 1 | 1 | 37 | 22 |
| 6 | 44° 07.032' N | 10° 48.679' E | 1800 | NE | 40 | V | 3 | 1 | 30 | 25 |
| 7 | 44° 06.963' N | 10° 48.737' E | 1800 | S | 35 | G/V | 3 | 1 | 36 | 34 |
| 30 | 44° 07.358' N | 10° 49.161' E | 1650 | SW | 25 | V | 1 | 1 | 23 | 18 |
| 31 | 44° 07.225' N | 10° 49.349' E | 1740 | W | 10 | G | 1 | 1 | 31 | 18 |
| 32 | 44° 07.219' N | 10° 49.384' E | 1740 | WSW | 10 | V | 1 | 1 | 23 | 16 |
| 33 | 44° 07.070' N | 10° 49.035' E | 1680 | NNE | 25 | G | 2 | 1 | 28 | 35 |
| 34 | 44° 07.073' N | 10° 49.025' E | 1680 | NNE | 25 | V | 2 | 1 | 17 | 22 |
| 35 | 44° 07.132' N | 10° 49.255' E | 1680 | SW | 25 | G | 3 | 2 | 29 | 20 |
| 36 | 44° 07.143' N | 10° 49.249' E | 1670 | SW | 25 | V | 3 | 2 | 30 | 26 |

In summary, in the last decades grazing impact has been lighter than before 1985 (about 2/3), while the picking impact on *V. myrtillus* became heavier than in the past, particularly since 2009.

iii) The results of the index species analysis are reported in the next sub-section.

***Changes in plant communities***

The comparisons between the new surveys (2012) and the old phytosociological relevés performed in 1981 (published in Puppi Branzi *et al*., 1994) are here summarized. The two sets of relevés (years 1981 and 2012) are reported side by side in a phytosociological table (Tab.2). Both sets of relevés are ordered according to the results of the cluster analysis (plant cover data) for the year 1981 (Fig.3), which is the same sequence as adopted in Puppi Branzi *et al*. (1994).

The comparison of groups of species, shows that some interesting changes occurred. In general, we note a decrease of common herbaceous species and on the other hand, a new entry of sporadic shrubs and herbs. The character species of *Vaccinium* heaths (*Hyperico-Vaccinietum, Vaccinio-Piceetea*) remain constant or are reinforced, while other groups such as *Caricetea curvulae, Nardo-Callunetea* and *Arrhenatheretea* sharply decreased in frequency and cover.

The dendrograms of the two sets of relevés (Fig. 3), obtained using plant cover data (transformed according to Van der Maarel 1979), show some changes. In 1981 we can see 2 main groups: a small group of 3 stands, composed of *Nardus stricta* grasslands, is clearly distinguished from the main group of the *Vaccinium* heaths: particularly noteworthy is the isolated position of an open heath (st. 7) sited near the ridge on the Tuscan side.

In 2012 the two original groups are fused and the similarity levels between the stands have mostly changed; moreover, the stand 7, on Tuscan slope (now become a grassland with a few *Vaccinium myrtillus*, dominated by *Brachypodium genuense, Festuca ovina* (s.l.) and *Carex sempervirens*), appears still more isolated.

Analyzing the similarity matrix based on binary data (presence of species, Jaccard index) we can observe that the similarity beween relevés is quite high in both years: in 1981 the mean value (J=0,45) is higher than in 2012 (J=0,34) and the average similarity between the years is J=0,36.

Besides, there are few cases of low values (J<0,15) referring only to one station (st.7) in 2012.

To sum up, the studied vegetation is floristically quite homogeneous in both years; on the basis of the character species, as previously assessed (Puppi Branzi *et al*., 1994), the relevés of 1981 can be assigned to the association *Hyperico richeri-Vaccinietum*, except for the *Nardus* grasslands (st.35, st.33, st.31), which

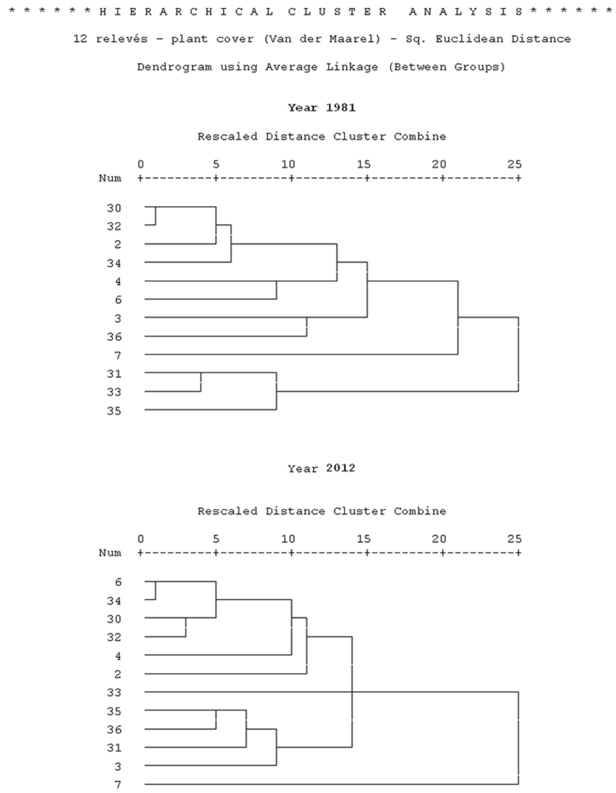


Fig. 3 - Dendrograms of the two sets of relevés (1981 and 2012). Plant cover data (Van der Maarel 1972 transformation) and Euclidean Distance are used.

can be considered a transition with the association *Violo cavillieri-Nardetum*. However, all the relevés of 2012 can be assigned to the association *Hyperico richeri-Vaccinietum*. The *Brachypodium* grassland of the station st.7 could be assigned to the sub-association *Hyperico-Vaccinietum* subass. *brachypodietosum* in both years.

In order to assess the vegetation changes after 30 years, it is interesting to compare the intra-station similarities (between 1981 and 2012 in the same stand) with the inter-stations similarities (Tab. 3): if the intra-station similarity is high, the community can be considered stable, on the contrary, if the value is low, the community underwent significant changes in its floristic composition.

We note that the intra-station similarities are higher than the inter-stations ones only in 5 stands (less than 50% of cases): these quite stable communities, apart from the already mentioned st.7, are closed heaths (st.2, st.4, st.30, st.36). In the other cases, the relevés performed in 2012 are more similar to those of other stands than to the same station in 1981. The lowest intra-stations values (J<0,39) occurred in the *Nardus* pastures (st.31, st.35) and in an open heath (st.3).

***Diversity, physiognomy and chorotypes***

i) Plant species richness in most stands is lower than 30 years ago with a significant trend of about –2 spe-

Tab. 2 - Phytosociological table for the two sets of relevés (years 1981 and 2012). All the relevés are ordered following the results of the cluster analysis (Fig.3) of the year 1981 (plant cover data).

| Year | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of stand | 2 | 30 | 32 | 34 | 4 | 6 | 3 | 36 | 7 | 35 | 33 | 31 | 2 | 30 | 32 | 34 | 4 | 6 | 3 | 36 | 7 | 35 | 33 | 31 |
| *Hyperico richeri-Vaccinietum* | | | | | | | | | | | | | | | | | | | | | | | | |
| Vaccinium uliginosum L. subsp. microphyllum Lange (Tolm.) | 3 | 4 | 3 | 2 | 3 | 2 | 1 | 2 | . | . | . | . | 3 | 4 | 5 | 4 | 4 | 5 | + | 3 | . | + | 2 | . |
| Hypericum richeri Vill. subsp. richeri | 1 | 1 | 1 | + | 1 | 1 | 1 | + | 1 | . | . | + | 2 | + | . | + | 2 | + | 1 | + | + | + | . | . |
| Geum montanum L. | 1 | + | + | 1 | + | 2 | + | 1 | 1 | 1 | 1 | 1 | + | . | . | 1 | + | + | . | + | + | 1 | 2 | + |
| *Vaccinio-Piceetea* | | | | | | | | | | | | | | | | | | | | | | | | |
| Vaccinium myrtillus L. | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | + | . | + | 4 | 3 | 1 | 3 | 2 | 3 | 2 | 1 | 1 | + | 2 | 2 |
| Juniperus communis L. var. saxatilis Pall. | 1 | 2 | 1 | . | . | . | 2 | . | . | . | . | . | 3 | 2 | 1 | + | 1 | 1 | 4 | 2 | . | 2 | 1 | 1 |
| Luzula sylvatica (Huds.) Gaudin subsp. sieberi (Tausch) K. Richt | 2 | + | 1 | 1 | 1 | . | 1 | 1 | . | 1 | 1 | 1 | 1 | + | 1 | + | . | 1 | 1 | 1 | . | 1 | 2 | 1 |
| Homogyne alpina (L.) Cass. | 1 | + | + | + | + | . | + | . | . | . | + | + | 1 | + | + | + | + | + | . | . | . | . | + | . |
| Rosa pendulina L | . | 1 | + | . | 1 | . | . | . | . | . | . | . | . | . | + | . | 1 | . | . | . | . | . | . | . |
| Vaccinium vitis-idaea L. | . | 1 | + | . | . | . | . | 2 | . | . | . | . | . | . | + | . | . | . | . | 1 | . | + | . | + |
| Lycopodium annotinum L. subsp. annotinum | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . |
| *Caricetea curvulae* | | | | | | | | | | | | | | | | | | | | | | | | |
| Phyteuma haemisphaericum L. | . | . | . | + | + | + | 1 | + | + | . | + | + | . | . | . | . | + | . | . | . | + | . | + | . |
| Agrostis rupestris All. | + | . | . | . | . | . | + | + | . | 2 | 2 | + | + | . | . | . | . | . | . | + | . | 2 | . | . |
| Euphrasia minima Jacq. ex DC. | . | . | . | . | + | . | + | + | + | + | + | + | . | . | . | . | . | . | . | . | . | . | . | . |
| Juncus trifidus L. subsp. trifidus | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | + | . |
| Festuca paniculata (L.) Schinz & Tell. subsp. paniculata | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | 2 | . |
| *Violo cavillieri-Nardetum* | | | | | | | | | | | | | | | | | | | | | | | | |
| Nardus stricta L. | + | + | + | . | . | + | 1 | 2 | + | 4 | 4 | 4 | . | 1 | . | . | . | . | + | 2 | . | 1 | + | 3 |
| Viola calcarata L. subsp. cavillieri (W. Becker) Negodi | + | . | . | . | + | + | 1 | 1 | 1 | 1 | 1 | + | + | . | . | . | + | . | 1 | . | + | . | + | + |
| *Nardo-Callunetea* | | | | | | | | | | | | | | | | | | | | | | | | |
| Leontodon helveticus Mèrat emend. Widder | 1 | 2 | + | 1 | 1 | + | 1 | + | . | . | + | 1 | . | + | + | + | + | + | . | + | . | . | + | + |
| Alchemilla transiens Buser (Buser) (A. alpina) | + | . | + | . | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | + | . | . | + | + | + | . | 1 | 1 | 2 | 2 | 2 |
| Potentilla aurea L. subsp. aurea | + | . | . | + | + | + | + | 1 | + | 1 | 1 | 1 | + | + | . | + | . | + | . | + | . | . | + | + |
| Genista tinctoria L. | 1 | 1 | + | . | + | . | 2 | 2 | . | 1 | . | . | + | . | . | . | . | . | . | . | + | . | 1 | . |
| Potentilla erecta (L.) Raeusch. | + | 1 | + | . | . | . | + | . | + | . | . | 1 | + | . | . | + | . | + | . | . | + | . | + | . |
| Pseudorchis albida (L.) A. & D. Love | + | + | . | . | + | + | + | . | . | . | . | . | + | . | . | + | . | + | . | . | + | . | . | . |
| Gentiana acaulis L. | + | + | . | . | . | . | + | . | + | . | . | . | + | + | . | . | . | . | . | . | + | . | + | + |
| Galium anisophyllon Vill. | + | . | . | . | . | . | . | . | 1 | + | + | . | . | . | . | . | + | . | . | . | . | . | + | . |
| Antennaria dioica (L.) Gaertn. | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | . |
| Calluna vulgaris (L.) Hull | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | + | + | . | + | . |
| *Molinio-Arrhenatheretea* | | | | | | | | | | | | | | | | | | | | | | | | |
| Anthoxanthum alpinum Love et Love | 2 | 1 | + | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | + | + | 1 | + | 1 | 1 | + | . | . | 1 | + |
| Festuca rubra L. | + | 1 | 1 | 1 | 2 | + | 1 | 2 | + | 2 | 2 | 2 | 1 | . | + | . | 1 | + | + | 1 | + | 2 | 1 | 1 |
| Crocus vernus (L.) Hill | . | . | . | + | . | + | 2 | 2 | + | 1 | 2 | 1 | + | + | + | . | . | + | + | . | . | . | + | + |
| Phleum alpinum L. | + | . | . | + | + | . | . | . | + | 1 | + | + | . | . | . | . | . | + | . | + | . | + | + | . |
| Trifolium repens L. | . | . | . | . | . | . | . | . | + | + | 1 | + | . | . | . | . | . | . | . | . | . | . | . | . |
| Deschampsia caespitosa (L.) P. Beauv. | . | . | . | . | . | . | . | + | . | + | + | + | . | . | . | . | . | . | . | + | . | . | . | . |
| Bistorta officinalis Delarbre | . | . | . | . | + | + | . | . | . | . | . | . | . | . | + | 2 | + | 1 | . | . | . | . | . | . |
| other herbs | | | | | | | | | | | | | | | | | | | | | | | | |
| Campanula scheuchzeri Vill. subsp scheuchzeri | + | *1* | *1* | + | + | + | + | *1* | + | + | + | + | . | . | . | . | . | . | + | + | . | . | . | . |
| Festuca riccerii Foggi & Graz. Rossi | . | . | + | + | 1 | 1 | 1 | + | + | 1 | 1 | 1 | + | . | . | 1 | . | + | . | + | 3 | . | . | . |
| Solidago virgaurea L. subsp. minuta (L.) Arcang. | 1 | 1 | 1 | + | + | + | 1 | + | . | . | + | + | + | + | + | . | . | . | + | + | . | . | . | . |
| Brachypodium genuense (DC.) Roem. & Schult. | + | . | + | . | 1 | 1 | 1 | + | 2 | 1 | + | . | . | . | + | . | 2 | . | + | + | 3 | 2 | 1 | 1 |
| Carex sempervirens Vill. | . | + | . | . | . | 1 | 1 | 1 | 2 | 2 | 1 | + | + | + | . | + | + | + | . | 1 | 2 | + | + | + |
| Anemonoides nemorosa (L.) Holub | + | 1 | . | 1 | 1 | + | + | 1 | . | . | 1 | . | + | + | + | 2 | 1 | + | 1 | . | + | . | 2 | . |
| Deschampsia flexuosa (L.) Trin. subsp. montana (L.) K. Richter | 2 | 1 | 1 | . | + | 2 | 1 | . | + | . | . | 1 | 1 | + | . | 1 | . | + | . | + | . | + | 1 | . |
| Agrostis capillaris L. (A. tenuis) | + | . | . | . | . | + | 1 | + | + | 1 | 1 | 1 | . | . | . | . | . | . | . | + | . | 1 | . | . |
| Polygala vulgaris L. + P. alpestris Rchb. | + | . | . | . | + | . | + | + | + | + | . | + | . | . | . | . | . | . | . | . | + | . | + | . |
| Plantago maritima L. subsp. serpentina (All.) Arcang. | . | . | + | . | . | . | . | 1 | . | . | 1 | + | + | . | . | . | . | . | . | + | + | + | + | . |
| Luzula multiflora (Ehrh.) Lej. | . | + | + | . | . | . | + | . | . | . | . | + | . | . | . | . | + | . | . | . | . | . | . | . |
| Dianthus deltoides L. subsp. deltoides | . | . | . | . | + | + | . | + | 1 | . | . | 1 | . | . | . | . | . | . | . | . | + | + | . | . |
| Thymus praecox Opiz | . | . | . | . | + | + | . | 1 | 1 | 2 | . | . | . | . | . | . | . | . | . | + | 1 | + | . | . |
| Lotus corniculatus L. subsp. alpinus (DC.) Rothm. | . | . | . | . | 2 | 1 | . | . | 1 | . | 1 | . | . | . | . | . | + | . | . | . | 1 | . | 1 | . |
| Bellidiastrum michelii Cass. | . | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . | . | + | . | . | + | . | . | . |
| Ajuga reptans L. | . | . | . | . | + | + | + | . | . | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . |
| Pimpinella alpina Host. (P. saxifraga) | . | . | . | . | + | . | + | . | + | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . |
| Cruciata glabra (L.) Ehrend. subsp. glabra | . | . | . | . | + | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . |
| Alchemilla glaucescens Wallr. | . | . | . | . | + | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | + | . | + | . |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Luzula nivea (L.) DC. | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | 2 | . | . | . | + | . | . | . |
| Scorzonera purpurea L. subsp. rosea (Waldst. & Kit.) Nyman | . | . | . | . | + | . | 1 | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Sagina glabra (Willd.) Fenzl. | . | . | . | . | . | + | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | + | . |
| Cerastium arvense L. subsp. suffruticosum (L.) Ces. | . | . | . | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . |
| Rumex acetosella L. | . | . | . | . | . | . | . | . | . | + | . | + | . | . | . | . | . | . | . | . | + | . | + | . |
| Veratrum lobelianum Bernh. | . | . | . | . | . | . | . | . | . | . | . | . | 1 | + | . | . | . | . | . | . | . | . | . | . |
| Poa alpina L. subsp. alpina | . | . | . | . | . | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . |
| Dactylorhiza maculata (L.) Soó subsp. fuchsii (Druce) Hyl. | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | . |
| sporadic shrubs and trees | 1 | . | . | . | . | . | . | . | . | . | . | . | 3 | . | 1 | . | . | . | . | . | . | . | . | 1 |
| sporadic herbs | 1 | . | . | . | 1 | . | 1 | . | 4 | 1 | . | . | 1 | . | . | 1 | 1 | 2 | . | . | 5 | . | 2 | 1 |

cies/decade.

In order to identify correlations between the species richness and the topographic and ecological features of stands, a multiple regression analysis was performed (Tab. 4); For this purpose the exposure of stands was factorized in W-E (sine of degrees from N) and N-S (cosine of degrees from N) gradients. The best result, besides the quoted temporal trend (years), shows a significant positive correlation only with the W-E gradient, while the S-N does not reach the significance threshold; moreover, relations with slope, altitude, vegetation structure are all not significant.

It is noteworthy that, in a study carried out recently in the alpine belt of the central Apennines (Stanisci *et al*., 2005) the greatest species richness was similarly found in the eastwards aspects.

An other interesting analysis was carried out to understand the temporal trend of species richness (number of species (2012) - number of species (1981)). A declining trend is observed in most of the studied cases: the number of species increased only in a pair of bordering stands (st.33, st.34) NNE facing (with low-medium grazing impact and low trampling risk), while the highest losses are recorded in the W and WSW aspects (Fig. 4).

Thus, the variation of the plant richness seems to be chiefly related to the exposure. To test the significance of this relationship, a multiple regression analysis between the richness variation (number of species difference: 2012-1981) of each stand and its topographic factors, was effected (Tab. 4b). The results pointed out a significant relation with W-E gradient and with slope; however, no significant relationship with S-N gradient, nor altitude was detected; other factors were tested, such as shrub cover variation, but again no significance was found.

ii) As far as the physiognomy of stands is concerned, a slight advancement of shrubs and a reduction of herbs is observed. The comparison of life-forms cover (%) according to Raunkiaer, shows that increasing values of Phanerophytes, Chamaephytes and Geophytes are balanced by the decrease of Hemicryptophytes (Fig. 5). Analyzing the variations of dominant species between 1981 and 2012, we observe significant

Tab. 3 - Similarity matrix on binary data (presence of species) by Jaccard index. J similarity values between relevés of 2012 and 1981 are reported in the upper part of the matrix: the intra-station similarities (diagonal cells) are higher than the inter-stations ones only in 5 sites.

| Year | | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 1981 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stand | *2* | *3* | *4* | *6* | *7* | *30* | *31* | *32* | *33* | *34* | *35* | *36* | *2* | *3* | *4* | *6* | *7* | *30* | *31* | *32* | *33* | *34* | *35* | *36* |
| 2012 | *2* | 0,53 | 0,51 | 0,33 | 0,36 | 0,26 | 0,46 | 0,41 | 0,42 | 0,34 | 0,37 | 0,28 | 0,42 | | 0,32 | 0,29 | 0,47 | 0,27 | 0,48 | 0,32 | 0,27 | 0,43 | 0,43 | 0,31 | 0,39 |
| 2012 | *3* | 0,42 | 0,38 | 0,28 | 0,38 | 0,21 | 0,42 | 0,29 | 0,42 | 0,31 | 0,48 | 0,26 | 0,42 | 0,32 | | 0,33 | 0,30 | 0,14 | 0,45 | 0,39 | 0,50 | 0,29 | 0,24 | 0,31 | 0,38 |
| 2012 | *4* | 0,37 | 0,37 | 0,44 | 0,41 | 0,26 | 0,41 | 0,29 | 0,41 | 0,35 | 0,34 | 0,21 | 0,33 | 0,29 | 0,33 | | 0,38 | 0,27 | 0,29 | 0,33 | 0,41 | 0,39 | 0,38 | 0,27 | 0,30 |
| 2012 | *6* | 0,45 | 0,48 | 0,44 | 0,49 | 0,27 | 0,45 | 0,40 | 0,41 | 0,33 | 0,50 | 0,29 | 0,34 | 0,47 | 0,30 | 0,38 | | 0,23 | 0,43 | 0,34 | 0,37 | 0,40 | 0,62 | 0,32 | 0,42 |
| 2012 | *7* | 0,23 | 0,34 | 0,39 | 0,36 | 0,45 | 0,21 | 0,25 | 0,21 | 0,22 | 0,16 | 0,24 | 0,31 | 0,27 | 0,14 | 0,27 | 0,23 | | 0,11 | 0,18 | 0,09 | 0,35 | 0,19 | 0,26 | 0,22 |
| 2012 | *30* | 0,41 | 0,41 | 0,25 | 0,33 | 0,20 | 0,52 | 0,32 | 0,37 | 0,28 | 0,46 | 0,18 | 0,33 | 0,48 | 0,45 | 0,29 | 0,43 | 0,11 | | 0,38 | 0,42 | 0,36 | 0,43 | 0,27 | 0,38 |
| 2012 | *31* | 0,37 | 0,38 | 0,22 | 0,33 | 0,31 | 0,37 | 0,32 | 0,37 | 0,35 | 0,30 | 0,34 | 0,41 | 0,32 | 0,39 | 0,33 | 0,34 | 0,18 | 0,38 | | 0,36 | 0,39 | 0,29 | 0,36 | 0,42 |
| 2012 | *32* | 0,31 | 0,29 | 0,29 | 0,28 | 0,10 | 0,44 | 0,21 | 0,44 | 0,26 | 0,43 | 0,15 | 0,31 | 0,27 | 0,50 | 0,41 | 0,37 | 0,09 | 0,42 | 0,36 | | 0,28 | 0,31 | 0,24 | 0,31 |
| 2012 | *33* | 0,48 | 0,44 | 0,36 | 0,35 | 0,41 | 0,38 | 0,40 | 0,38 | 0,43 | 0,33 | 0,33 | 0,38 | 0,43 | 0,29 | 0,39 | 0,40 | 0,35 | 0,36 | 0,39 | 0,28 | | 0,39 | 0,31 | 0,39 |
| 2012 | *34* | 0,41 | 0,40 | 0,34 | 0,37 | 0,20 | 0,45 | 0,33 | 0,41 | 0,25 | 0,39 | 0,19 | 0,30 | 0,43 | 0,24 | 0,38 | 0,62 | 0,19 | 0,43 | 0,29 | 0,31 | 0,39 | | 0,27 | 0,37 |
| 2012 | *35* | 0,39 | 0,36 | 0,27 | 0,35 | 0,30 | 0,34 | 0,38 | 0,43 | 0,30 | 0,23 | 0,36 | 0,47 | 0,31 | 0,31 | 0,27 | 0,32 | 0,26 | 0,27 | 0,36 | 0,24 | 0,31 | 0,27 | | 0,64 |
| 2012 | *36* | 0,51 | 0,47 | 0,37 | 0,47 | 0,37 | 0,44 | 0,54 | 0,58 | 0,50 | 0,43 | 0,45 | 0,65 | 0,39 | 0,38 | 0,30 | 0,42 | 0,22 | 0,38 | 0,42 | 0,31 | 0,39 | 0,37 | 0,64 | |

changes in many stands (Fig. 6): plant cover increased in *Juniperus, Brachypodium* and *Vaccinium uliginosum*, while it decreased in *Vaccinium myrtillus*, *Nardus stricta* and *Anthoxanthum alpinum*. Among the *Vaccinium* species, *V. uliginosum* is tending to prevail on *V. myrtillus*. In fact, many plants of *V. myrtillus* seem to have been damaged by the shortening of the snow cover duration, as well as by the scarcity of snowfalls in winter.

iii) A chorotypes analysis was carried out on the old and new relevés both for the species increasing in frequency and those decreasing (Fig.7). The difference between the two spectra is highly significant ($\chi 2$ test: P < 0.002). Of particular note are the Orophytes species. This group shows a marked decline, counterbalanced by the increase of the less specialized Circumboreals and Eurosiberian. In fact Orophytes are species strictly connected to the high Apennine environment and include many micro-thermophilous plants (Alessandrini *et al*., 2003). Their decline could be directly caused by the environmental warming over the last decades.

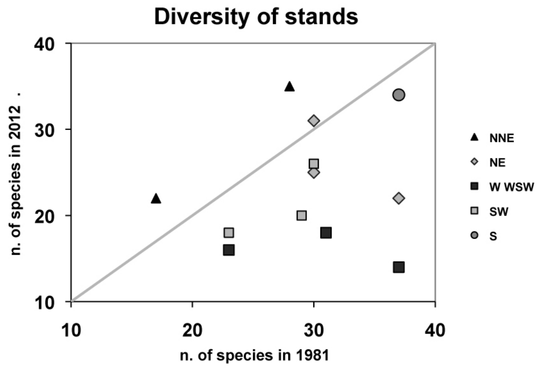


Fig. 4 - Species richness of stands in 1981 and 2012. For each stand the number of species recorded in 1981 is plotted versus the number of species found in 2012. The stands are grouped by exposure.

Tab. 4 - Multiple regression analysis on species richness. The first frame (a) shows the best results taking as dependent variable the “number of species of each relevé”: the regression coefficient B of the independent variables “year” and “W-E gradient” are both significant, while the “S-N” gradient does not reach the significance threshold.
The second frame (b) shows the best results for the dependent variable “difference in number of species of each stand between the years” (2012-1981): the regression coefficient B of the independent variables “slope” and “W-E gradient” are both significant, while the “S-N” gradient does not reach the significance threshold.

a) Dependent Variable: number of species per relevé

R = 0,61 total df= 23 Sig. F = 0,020

| | Coefficients | | | |
|---|---|---|---|---|
| Model | B | Std. Error | t | Sig. t |
| (Constant) | 403,25 | 155,89 | 2,59 | 0,018 |
| year | -0,19 | 0,08 | -2,41 | 0,026 |
| W-E | 6,90 | 2,72 | 2,53 | 0,020 |
| S-N | -4,59 | 2,64 | -1,74 | 0,097 |

b) Dependent Variable: n. species difference (2012-1981)

R= 0,78 total df= 11 Sig. F = 0,046

| | Coefficients | | | |
|---|---|---|---|---|
| Model | B | Std. Error | t | Sig. t |
| (Constant) | 17,22 | 8,09 | 2,13 | 0,066 |
| slope | -0,75 | 0,27 | -2,80 | 0,023 |
| W-E | 17,11 | 5,62 | 3,04 | 0,016 |
| S-N | -6,98 | 4,53 | -1,54 | 0,162 |

### *Comparison of species abundance*

The abundance of species in the set of stands, was measured by frequency (presence or absence) and plant cover (expressed according to Van der Maarel, 1979).

The frequency and the plant cover of each species between 1981 and 2012 were compared. In order to combine the two aspects of abundance, we plotted the differences (2012-1981) in plant cover and frequency (Fig.8).

The graph allows us to single out three groups of species: a small group (7 taxa) increasing in cover and frequency, 17 species that are quite constant showing no clear variations, and then a large group of 24 “decreasing species”. In particular among the decreasing species, a significant reduction in cover and frequency: *Campanula scheuchzeri, Agrostis capillaris, Festuca ovina* (s.l.), *Solidago virgaurea* subsp. *minuta*, and then, *Euphrasia minima, Agrostis rupestris, Phyteuma hemisphaericum* (*Caricetea curvulae*) as well as *Nardus stricta*, *Viola calcarata, Leontodon helveticus, Potentilla aurea, Genista tinctoria* (*Nardo Callunetea*) and *Anthoxanthum alpinum, Festuca rubra, Phleum alpinum, Trifolium repens, Deschampsia caespitosa* (*Arrhenatheretea*).

On the other hand, the increasing species are few: only *Juniperus communis* and *Vaccinium uliginosum* show a significant trend; furthermore we note some new entries, especially at the tree line altitude: *Sorbus aucuparia, S. chamaemespilus, S. aria, Salix caprea, Veratrum lobelianum, Dactylorhiza maculata, Maianthemum bifolium, Poa alpina*, etc..

### *Index species*

The indirect ecological analysis by means of index species shows a clear xerothermic trend. In fact, a decrease in the psychrophilous species frequency (Pignatti’s (2005) low scores: T (Temperature) = 1-2) is coupled with an increase in that of the thermophylous species (high scores: T= 5-7). Moreover, a decreasing trend in the meso-hygrophilous species (Pignatti’s high scores: U (Humidity) = 6-8) is coupled with an increase in that of the xerophilous species (low scores: U= 2 - 3). Using the cover data, the same results are obtained. The regression analysis shows that these trends are significant.

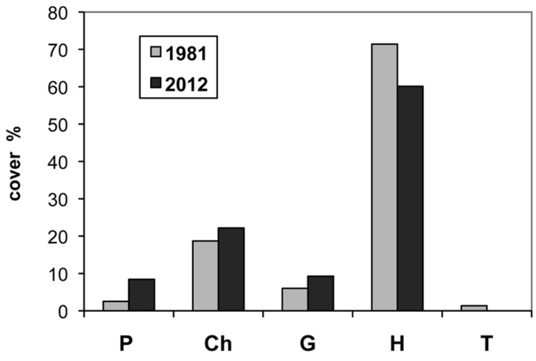


Fig. 5 - Life-form spectrum according to Raunkiaer: the cover (%) of life forms is compared. In 2012, increasing cover values of Phanerophytes, Chamaephytes and Geophytes are balanced by the decrease of Hemicryptophytes.

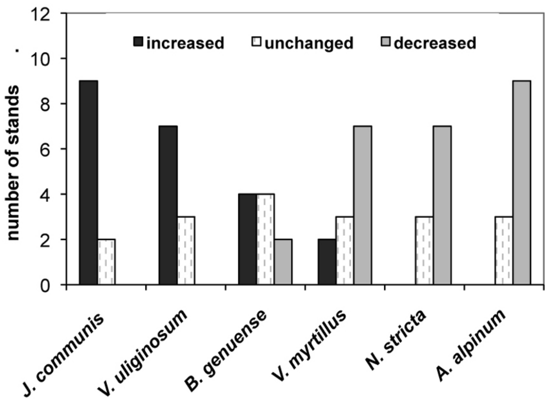


Fig. 6 - Changes in physiognomy of stands between 1981 and 2012. On ordinates the number of stands where the cover of dominant plants increased, decreased or remained unchanged: the cover trend is clearly increasing in *Juniperus* and *Vaccinium uliginosum,* while it is decreasing in *Vaccinium myrtillus, Nardus stricta* and *Anthoxanthum*.

Regarding the soil features, changes in reaction (pH) and nutrient values (N) are displayed: in particular, a slight tendency toward a greater oligotrophy can be observed.

The indicators of the nitrogen content in soils can be used as a proxy of anthropic and livestock organic pollution. Among the species of rich soils are *Heracleum sphondylium, Trifolium repens, Ranunculus platanifolius, Poa alpina, Phleum alpinum, Geranium sylvaticum, Crepis aurea, Chaerophyllum hirsutum* and *Crocus vernus*; on the other hand, *Calluna vulgaris* and *Juncus trifidus* are known to have an oligotrophic behaviour (Landolt, 1977; Pignatti, 2005). The comparison between the years, shows a slight decrease of the nitrophilous species in frequency and cover (Fig. 9). The trend is evident in the station n.7 (a *Brachypodium* grassland with a scarce *Vaccinium* cover) and in the st. 31, 33, 35 (all these stands were *Nardus* pastures in 1981, but are now are partly colonized by *Juniperus* and *Vaccinium*). The decrease of vegetation nitrophily is consistent with the lowering of the grazing impact.

As regards the assessment of disturbance, among the indicators of disturbed stands, we singled out only one Therophyte, *Euphrasia minima,* and some species of compact soils (Landolt 1977); on the other hand, some species are known to avoid disturbance, being sensitive to trampling (Grabherr 1982), as *Leontodon helveticus, Phyteuma hemisphaericum* and *Anthoxanthum alpinum*.

The comparison between the years, shows a decrease of the disturbance index species (in frequencies and cover) in most stations, except for some heaths (st.2, st.6, st.34) dominated by *Vaccinium myrtillus* and sited

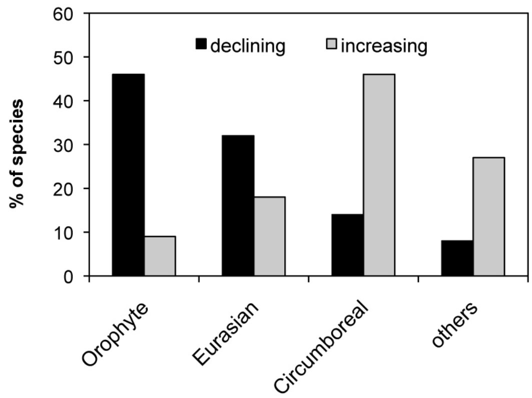


Fig. 7 - Chorological spectra of increasing and declining species (1981 vs. 2012).

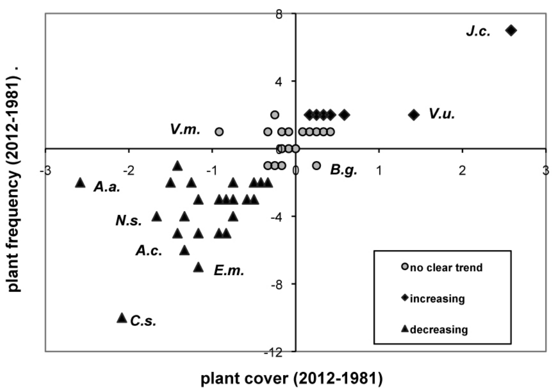


Fig. 8 - Difference in frequency and abundance of species between 1981 and 2012.
For each species, differences of frequencies between the two years (2012-1981) are plotted versus differences in average plant cover (the numerical values of plant cover are expressed according to the Van der Maarel method). The graph allows to us to single out three groups of species: above on the right, a small group of species increasing in frequency and cover, as *Juniperus communis* (J.c.) and *Vaccinium uliginosum* (V.u.); in the center a number of species quite constant or showing no clear variations, as *Brachypodium genuense* (B.g.) and *Vaccinium myrtillus* (V.m.); below on the left, a large group of "decreasing species", as *Campanula scheuchzeri* (C.s.), *Euphrasia minima* (E.m.), *Agrostis capillaris* (A.c.), *Nardus stricta* (N.s.) and *Anthoxanthum alpinum* (A.a.).

near the footpaths (medium-high trampling risk).

Since the results seem to indicate a lowering of disturbance, we can argue that the berry harvesting in the last years does not display any visible impact on the vegetation.

***Phenology***

In Fig. 9 the full bloom times of species decreasing in frequency and cover are represented in comparison with those of the increasing ones (new entries and spreading species). It is noteworthy that many of the declining species (chiefly *Caricetea curvulae* and *Arrhenatheretea*) flower in mid summer (July-August); on the other hand, the flowering period of the increasing species takes place principally in June, at the beginning of the growing season. The data seem to point to a relation between the flowering period and the "species fitness". In fact, xerothermic stress suffered in July-August could damage flowering and fruiting structures of sensitive species, affecting their reproductive efficiency as assessed in several studies (Abeli *et al*., 2012a; Abeli *et al*., 2012b).

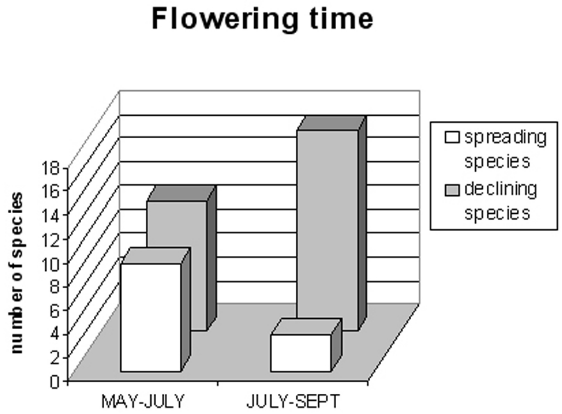


Fig. 9 - Full bloom time of the species showing changes in frequency and cover with respect to thirty years ago. The flowering season is divided into two periods: from the end of May to the beginning of July (MAY-JULY) and from mid July to the beginning of September (JULY-SEPT).

**Discussion**

As reported above, the new relevés detected significant changes in the structure and composition of the stands. Among the dominant species, an increase of *Juniperus communis* and *Vaccinium uliginosum* and *Brachypodium genuense* has been obseved alongside a reduction of *Nardus stricta* and *Anthoxanthum alpinum*. The behaviour of *Vaccinium myrtillus* is apparently contrasting: increasing in frequency and decreasing in cover.

The spread of *Vaccinium* species in the old pastures (stands 31, 33, 35) coupled with the decrease of *Nardus*, is probably a consequence of the reduction of the grazing pressure: also the decrease of the indicators of nitrophily, compact soils and disturbance can be related to this process.

We note that the spread of new plants of *V. myrtillus* in the old pastures gives evidence of a good colonizing aptitude by their seeds. As regards the anthropic impact, we can conclude that the berry picking and harvesting did not till now limit the renovation of bilberry.

On the other hand, the decrease of *V. myrtillus* cover in the mixed heaths, could be related to a competitive disadvantage, maybe caused by a selective environmental stress. At this regard, in the last springs, we observed extensive frost damages to bilberry plants in many stands, while the co-dominant *V. uliginosum* was not visibly affected.

It is well known that *V. myrtillus* populations living at high altitude benefit from the snow protection in winter and early spring (Ferrari & Rossi, 1995; Gerdol *et al*., 2013) and are more sensitive to late frosts than other *Vaccinium* species (Kreyling *et al*., 2012, Taulavuori *et al*., 2013). Beside this, in the current less fertilized conditions, the growth of *V. myrtillus* could be P-limited, while that of *V. uliginosum* is not (Gerdol, 2005).

For these reasons we argue that the reduction of *V. myrtillus* could be caused by the lowering of the snow cover and also by the less fertilized soils: therefore, the spread of *V. uliginosum* is favoured by the *V. myrtillus* reduction. In many stations we observed a significant decrease in biodiversity and a high turn-over of species.

Regarding the biodiversity, two apparently contrasting trends coexist: a decline of the average number of species per relevé (29,3 in 1981 and 23,4 in 2012) and an increase of the total number of species detected (64 in 1981 and 72 in 2012). Contrary to the findings of Jurasinski and Kreyling (2007), our results point out an increasing heterogeneity of the community set (the inter-stations similarity J is higher in 1981 than in 2012), due, on the one hand to the decreasing frequency of many species and, on the other, to the entry of new species. So, in the 2012 relevés there are more sporadic species than thirty years before. Note that in changing environments, vegetation can show high biodiversity until old declining species coexist with the new entries. With regards the vegetation stability, it is noteworty that the intra-station similarities (Jaccard index) are lower than those of the inter-stations in 7/12 stands. In conclusion, this situation can be interpreted as a "dynamic syndrome" caused by a decrease in pasture and/or climate changes.

Even though it is well known that lower grazing should cause the spread of shrubs, the phytodiversity trend cannot be easily predicted: the lowering of pasture disturbance could cause a diversity loss, however the lowering of soil fertilization could have an opposite effect: in fact, an experimental study carried out on some *Hyperico-Vaccinietum* communities highlighted that species richness decreased as an effect of increased fertilization (Gerdol *et al*., 2000).

So, the decline of the average number of species per relevé cannot be clearly explained by the the reduction of pasture; moreover, this trend seems to be related to grazing-unrelated factors.

As stated above, the variation of species richness does not show any significant relationship with altitude, disturbance risk, nor with the shrub cover variation, but displays a clear E–W gradient.

As for the gain of species occurred in NE facing stations and the higher losses occurred chiefly in stands with steep slopes and western exposures (W and WSW), we suppose that the biodiversity losses could be related chiefly to the worsening of summer dryness, caused by several interacting conditions: rising temperatures, decreasing rainfalls and reinforcing of winds (in particular the W direction has reinforced from April to December over the last decades).

In fact, in the study area, the climatic trends over the past 30 years brought about an average increase in temperature of about 0,4°C per decade (in summer the value is higher) coupled with a significant decline of precipitations, especially in winter and summer: in summary, the climate has become warmer and dryer, with mild winters and dry summers.

So, in the last decades, sensitive species of the *Vaccinium* heaths probably suffered both in consequence of dryness in summer (also increased by the high windiness), and because of fewer snowfalls in winter. In this scenario, we can expect that Orophytes, psychrophilous and hygrophilous species would be damaged by the recurrence of water stress; in fact, in our data these species are declining (Fig. 7), together with many herbs flowering from mid-July to August (Fig. 9).

With regards the turn-over of species, the variations appear to be related in part to the lowering of the anthropic impact (chiefly in three *Nardus* pastures, st.31, 33, 35) and in part to the climate change. Many herbaceous species became rarefied or disappeared (mostly belonging to the classes *Caricetea curvulae, Nardo-Callunetea* and *Arrhenatheretea*): in particular Orophytes, meso-hygrophilous species were reduced, and on the other hand some other species increased their frequency and cover. Even if the tree line did not advance in this area (Corazza, 2010; Pezzi *et al*., 2008; Mognol *et al*., 2008; Palombo *et al*., 2013), the new entry of some phanerophytes (*Sorbus aucuparia, Sorbus aria, Sorbus chamaemespilus, Salix caprea*) in the lower stations, as well as the spread of some nemoral species (*Dactylorhiza maculata, Maianthemum bifolium, Anemonoides nemorosa, Luzula nivea*) could be a consequence of the climate warming. We notice that, among these species, only *Sorbus aucuparia, Anemonoides nemorosa* and *Luzula nivea* were already reported in the past in the Emilian *Vaccinium* heaths (Pirola & Corbetta, 1971; Credaro *et al*., 1980 (see the phytosociological table in Ubaldi, 2008); Puppi *et al*., 1983). Moreover, the also quoted *Brachypodium* and *Juniperus* spread could be caused by the climate warming over the last decades. In fact their ecology is known to be associated with the most xero-thermophilic *Vaccinium* heaths (Pirola & Corbetta, 1971; Puppi *et al*. 1983.

## Conclusion

The study highlighted significative changes in the *Vaccinium* and *Nardus* communities over the last 30 years. The community's structure has become more complex: in particular, *Juniperus communis* cover has significantly increased; moreover, among the *Vaccinium* species, *V. uliginosum* is tending prevail on *V. myrtillus*, which was probably damaged by the shortening of the snow cover duration.

In general, the species richness (per stand) is lower than 30 years ago, chiefly in western faced sites exposed to the prevailing winds (from SW and W): many herbaceous species became rarefied or disappeared (in particular Orophytes and meso-hygrophilous), and on the other hand, new less specialised species appeared.

Thus, the following trends are displayed in the stands analysed: a) a decrease of species richness per stand coupled with an increase of the floristic heterogenity of the whole set of stands; b) a slight increase of the shrubs/herbs cover ratio; c) a spreading of *Juniperus* and of *Vaccinium uliginosum*, sometimes coupled with a reduction of *V. myrtillus* cover; d) a decline of species of *Caricetea curvulae, Nardo-Callunetea* (chiefly *Nardus stricta*) and *Arrhenatheretea*; e) a decline of many species flowering in the dry period (July-August); f) a xerothermic trend of communities composition (index species).

In summary, the observed changes in vegetation features seem to be due only in part to a lighter grazing pressure and mostly to climatic stresses. In fact, the climate of the area has become warmer and drier (less snow, less rainfalls and more wind) over the last 2 decades. Recently, scanty snow cover caused chilling damages to *V. myrtillus*. On the other hand, periods of aridity (P/T<2) that occurred in several summers, may be the main causal factor for the population decline of sensitive species; in fact, drought can affect the primary productivity, the reproductive success (most declining species are summer-flowering) and the survival rate (Abeli *et al*., 2012).

The monitoring of these *Vaccinium* heaths should be continued also in the future because of the peculiarity of this vegetation type and its high vulnerability due to their phytogeographic isolation. In a climate warming scenario, the low extension of this sub alpine island leads to a high extinction risk for most sensitive species, together with elevated difficulties of recolonization.

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**Appendix: Sporadic species**

Table 2:
Sporadic shrubs and trees: Year 1981 stand 2 Fagus sylvatica L. subsp. sylvatica (+) Year 2012 stand 2 Fagus sylvatica L. subsp. sylvatica (+), Sorbus aucuparia L. subsp. aucuparia (+), Sorbus chamaemespilus (L.) Crantz (+), Year 2012 stand 32 Sorbus aria (L.) Crantz subsp. aria (+), Year 2012 stand 31 Salix caprea L. (+).

Sporadic herbs: Year 1981 stand 2 Crepis aurea (L.) Cass. subsp. glabrescens (Caruel) Arcang. (+), Year 1981 stand 4 Geranium sylvaticum L. (+), Year 1981 stand 3 Centaurea uniflora Turra subsp. nervosa (Willd.) Bonnier & Layens (+), Year 1981 stand 7 Carlina acaulis L. subsp. caulescens (Lam.) Schübl. & G. Martens (+), Gentiana verna L. subsp. verna (+), Trifolium pratense L. subsp. pratense (+), Carduus carlinifolius Lam. subsp. carlinifolius (+), Year 1981 stand 35 Ranunculus platanifolius L. (+), Year 2012 stand 2 Maianthemum bifolium (L.) Schmidt (1), Year 2012 stand 34 Heracleum sphondylium L. (+), Year 2012 stand 6 Festuca alfrediana Foggi & Signorini ? (F. alpina) (+), Chaerophyllum hirsutum L. subsp. magellense (Ten.) Pignatti (+), Year 2012 stand 7 Centaurea uniflora Turra subsp. nervosa (Willd.) Bonnier & Layens (+), Carlina acaulis L. subsp. caulescens (Lam.) Schübl. & G. Martens (+), Leucanthemum adustum (W.D.J. Koch) Gremli (+), Cirsium bertolonii Spreng. (+), Stachys pradica (Zanted.) Greuter & Pignatti (+), Year 2012 stand 33 Trifolium thalii Vill. (+) Minuartia verna (L.) Hiern subsp. verna (+), Year 2012 stand 31 Gentiana verna L. subsp. verna (+).