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Correlation between floristic and structural features of plant communities. An example concerning lithophytic vegetation in the Julian Alps (NE-Italy)

MICHELE CODOGNO (*), DUILIO LAUSI (**) and PIER LUIGI NIMIS (**)

ABSTRACT. This study is based on a set of 37 phytosociological relevés of lithophytic vegetation taken in the Western Julian Alps. This has been submitted to multivariate analysis. The results are as follows:
- Six vegetation types have been identified on the basis of floristic composition.
- Floristical variation and vegetation types are related to two main parameters: type of substrate and potential solar irradiation.
- These two main ecological factors are related also to structural variation.
- Differences in potential solar irradiation are more important than differences in substrate as far as structural variation is concerned.
- A high correlation exists between floristic and structural variation.
- The structural variation is highly predictive with respect to typification.

CORRELAZIONE TRA CARATTERI FLORISTICI E STRUTTURALI DELLE COMUNITÀ VEGETALI. UN ESEMPIO RELATIVO ALLA VEGETAZIONE LITOFITICA DELLE ALPI GIULIE (ITALIA NORD-ORIENTALE)

RIASSUNTO. Questo studio è basato su un campione di 37 rilievi fitosociologici di vegetazione litofitica delle Alpi Giulie Occidentali. I rilievi sono stati sottoposti a metodi di analisi multivariata. I risultati sono:
- *In base alla composizione floristica sono stati identificati sei tipi di vegetazione.*
- *La variazione floristica e i tipi di vegetazione sono correlati a due parametri principali: tipo di substrato e irradiazione solare potenziale.*
- *La variazione di questi fattori ecologici è correlata alla variazione strutturale della vegetazione.*
- *Le differenze nell'irradiazione solare potenziale sono più importanti delle differenze in substrato nel determinare la variazione strutturale della vegetazione.*
- *Esiste una correlazione significativa tra variazione floristica e variazione strutturale.*
- *La variazione strutturale ha un alto valore predittivo nella tipizzazione della vegetazione.*

Introduction

Structural characters were used for the description of vegetation since the earliest times of vegetation science. In the last decades the interest in structural analysis of vegetation considerably decreased, at least in Europe, as a consequence of the generalized adoption of a floristic-statistic classification-oriented methodology were structural characters play a very little role in the establishment of vegetation types. Structural characters are still considered as an useful tool for describing vegetation types in areas that are little known floristically, or for comparing plant communities that grow under

(*) Botanical Garden, University of Calabria.
(**) Department of Biology, University of Trieste.
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similar ecological conditions in different phytogeographical subdivisions of the globe (see Parsons & Moldenke, 1975; Parsons, 1976; Cowling & Campbell, 1980).

Furthermore, the fact that structural characters are directly linked to adaptive processes allows to relate the study of their variation in different plant communities to ecological differences between the communities themselves (see Cody & Mooney, 1978; Barkman, 1979; Beard, 1973; Feoli & Scimone, 1984). Following this approach, it has even been attempted to predict the vegetation structure in a given area on the basis of the knowledge of the climate in that area (Box, 1981 a, b). Finally, the structural description of vegetation is considered by some authors (see Werger & Sprangers, 1982) as being a less laborious and generally applicable approach, since it does not require a detailed floristic knowledge.

The present study is concerned with the following problems:

- Identification of structural characters whose variation may be explained in adaptive terms.
- Quantification of the correlation between compositional and structural variation along gradients.

The study is based on a set of relevés of lithophytic vegetation, taken in such a way as to reflect the broadest possible ecological variation, i.e. at different exposures and inclination (variation in solar irradiation), and on different types of substrate (compact rock versus scree slope).

Data and methods

The vegetation survey was carried out in the calcareous Western Julian Alps (NE-Italy). 37 phytosociological relevés of lithophytic vegetation were taken following the Braun-Blanquet method. The station-types selected for sampling are rock outcrops and adjacent scree slopes, at different exposures, within an elevation range of 600 m (between 1400-2000 m). The relevés have been taken in randomly selected sites. The location of relevés is reported in the Appendix (Fig. 6).

The main outlines of data analysis are as follows:

1) Classification of the relevés on floristic data (Tab. 1), to detect floristically different vegetation types.

2) Ordination of the relevés on floristic data (Tab. 1), to analyze the compositional variation in the data set, and to detect possible ecological gradients related to it.

3) Classification of life-form types, on the basis of their relative frequencies in the relevé groups (Tab. 2), to detect groups of life-form types with similar occurrencies in the relevé groups.

4) Concentration analysis based on the contingency table of the life-form type groups and relevé groups (Fig. 1), to quantify their correlations.

5) Ordination of the relevés, on the basis of structural data (Tab. 2), in order to analyze the structural variation in the data set.

6) Comparison between the ordination of relevés on floristic data and the ordination of relevés on structural data, in order to quantify the correlation between floristic and structural variation in the data set.

Life-forms spectra have been calculated on the basis of cover data. The life-forms (for vascular plants) are as in Ellenberg & Mueller-Dombois (1967).

Tab. 1 — Structured table of *species* and *relevés*. Relevé group numbers are as in the dendrogram of Fig. 1. Sporadic species are reported in the Appendix.

Relevé group no.			1						2						3						4						5						6			
Relevé no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Poentilla caulescens		1	1	2	2																																
Aquilegia einseleana	+		1	+	1																																
Physoplexis comosa	+			1	2																																
Hieracium porrifolium		+	+	+																																	
Valeriana saxatilis	1			+	+	+	+																														
Kernera saxatilis		+		+	1		+																														
Didymodon luridus		+	1		+				+										+																		
Ditrichum flexicaule	+	1	+			+													+											+						+	
Trisetum argenteum				1	2														+																		
Campanula cespitosa				+	1									+																							
Salix glabra			+		+																																
Asplenium ruta-muraria	+	+																																			
Carex firma			+	+			+	2	1	1	2	2																								1	
Sesleria sphaerocephala		1				+	1	1	1	+	1	2																									
Primula auricula						1	+	+		+	+	+																									
Helianthemum alpestre						+		+	+	+	+	+																									
Potentilla nitida							2		+	2	+	+																									
Saxifraga crustata						+	1	+																													
Anthyllis vulneraria ssp. alpestris								+			+	+	+																								
Saxifraga burserana										1	+																										
Gentiana terglouensis									+		+																										
Lecidea decipiens										+		+																									
Cetraria tilesii										+		+																									
Fulgensia bracteata							+	+																													
Festuca calva							+						3	3	2	1	1	1																			
Thymus alpigenus													+	+	+			+	+																		
Helianthemum grandiflorum													1	+	1	+			+																		
Acinos alpinus													1	+		+			+																		
Laserpitium peucedanoides														+	+	+		+																			
Athamanta cretensis													+	+			+	1		+																	
Galium anisophyllum													+	+				+	+	+																	
Tortella fragilis															+		+		+											+	1						
Hieracium villosum								+							+		+	+																			
Ptychodium plicatum													+			+		+												1							
Senecio abrotanifolius													+		+	+																					
Lotus corniculatus													+			+			+																		
Polygala alpestris															+	+		+																			
Campanula scheuchzeri													+	+																							
Oxytropis pyrenaica													+			+																					
Leucanthemum maximum													+			+																					
Scabiosa lucida															+	+																					
Cerastium arvense ssp. strictum													+			+																					
Scrophularia juratensis																	+	+																			
Rumex scutatus																				+	1	1		1													
Silene vulgaris ssp. glareosa															+					+	1	1		+		+											
Cratoneurum commutatum v. sulcatum						+															+	1		1							+				+		
Hutchinsia alpina ssp. austro-alpina																								+	+	+	+	+	+	+	r						
Thlaspi rotundifolium																							+	+	2	+		1		+							
Achillea atrata																							+	+	+	+		+	+		+		+				+
Saxifraga aizoides																	+						+					+	+	+							
Saxifraga hohenwartii																											2	+	+	+							
Saxifraga stellaris																									+		+	+	+							+	
Saxifraga sedoides																											1	+			+	+					
Arabis alpina																													+	+	+						
Taraxacum alpinum																							+						+	+							
Papaver julicum																									1	1											
Soldanella minima																																+	+	+	+	+	+
Cystopteris regia																																+	1	1	1	+	+
Viola biflora	+																														+	+		+	+		
Paederota lutea	1																															+			+	1	1
Asplenium viride																																+		1	+	1	
Ranunculus traunfellneri																														+		+	+	+	+		
Orthothecium rufescens					+																										+		+			+	
Valeriana elongata																														+	+	+	+	1			
Aster bellidiastrum										+															+					+		+	+		+	+	
Cratoneurum decipiens																																				+	1

Carex mucronata	1	1	1	1	2	1	1	1	1	1	1	1																									
Paederota bonarota			1	2	2	+	+	1	+	+	+	+																									
Asperula aristata		+			+										+			+																			
Gypsophila repens						+		+		+			1	+	+																						
Leskeella nervosa								1			+			+			+																				
Pedicularis rostrato-capitata									+			+	+	+						+																	
Tortella tortuosa	+		+	+	1	+		+	+	+	+	+	+		1	1		+			+												1		1		
Sesleria varia	1		1		2		1	+	1				1	1	1			1	1	+	+	+															
Achillea clavenae			+			+			+		+			+	+	+	+	+	+	+	+	+															
Carex sempervirens				1	1		+						+	1	1	+	+			+		+															
Draba aizoides							+				+	+							+																		
Cerastium carinthiacum															+					+		1		+	+	1				+							
Poa minor																		1	+	+				+	1	+	1		+			1					
Moehringia ciliata																				+				1	+		+	+	1	+	+		+	+			
Festuca nitida																		1		+	1	2	1	1			+	1	+	+		+		+		1	+
Poa alpina															+				1	1					+			+	1	+	1		1	+	+	1	1
Rhodothamnus chamaecistus	+	+	+	+		+	1		+	+	1	1																								+	+
Saxifraga caesia							1		1	+	-	1																			+	+	+	+			+
Phyteuma sieberi	+							+		+																					+			+	1	+	
Campanula cochleariifolia	+	+						+					+																			+			+		
Arabis pumila											+	+														+								+	+	+	+
Mniobryum carneum																		+	+	+							1					1		+			+
Distichium capillaceum										+		+								+				+								1					+
Polygonum viviparum										+				+								+							+	+				+			
Stellaria graminea															+			1	+		+		+														
Minuartia austriaca							+							1	+																		+				
Campanula zoysii	1								+																											+	
Euphrasia salisburgensis								+			+							+																			
Globularia cordifolia		+													+	+																					
Gentianella anisodonta		+													+			+																			
Dryas octopetala										+		1							+																		
Gentiana clusii							+	+					+																								
Linum catharticum				+	1													+																			
Calamagrostis varia		+	+																																		
Adenostyles glabra																	+				+																
Crepis kerneri																						+							+								+
Sedum atratum																			+				+						+								
Juncus monanthos														+							+	1															
Biscutella laevigata														+						+		+															
Silene alpestris														+					+		+		+														
Bartsia alpina			+												+						+																
Bryum elegans						+																+		+													
Lepraria incana			+				+																											+			
Dacampia hookeri						+																										1	+				
Papaver kerneri																								+				1									
Minuartia verna											+										+																
Ranunculus hybridus						+							+																								
Linaria alpina																			+										+								
Pedicularis verticillata																			+			+															
Leptodontium flexifolium																						+	+														
Cladonia pyxidata							+										+																				
Myosotis alpestris													+										+														
Polystichum lonchitis																																+	+				
Veronica aphylla																												+	+								
Scapania aspera																	+																			+	
Lepraria crassissima																															+				+		
Solorina bispora						+			+																												

Growth-forms have been utilized in the case of bryophytes (Gimingham & Robertson, 1950) and lichens (Mattick, 1951, modified).

In the analysis of floristic data (Tab. 1), only those species have been retained, whose frequency within the data set was more than 3%.

Data analysis is based on the following methods:

- Classifications: Complete Linkage Clustering on quantitative data, similarity measure: Correlation Coefficient (Anderberg, 1973).

Tab. 2 — Structured table of *life-forms* and *relevés*. Life-form group letters are as in the dendrogram of Fig. 1. The relative frequency-classes are:
1: from 1% to 10%
2: from 11% to 20%
3: from 21% to 30%
4: from 31% to 40%
5: from 41% to 50%
6: from 51% to 60%

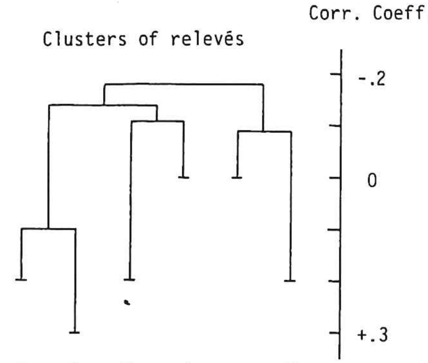
Group of l. f.	Relevé no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
d	a NP caesp			1		1																																
d	a G bulb			1	1																																	
d	e H scap			1																																		
c	a T scap				1	1			1			1							1																			
c	Squamulose (L)					1	1	1	1		1		1																									
e	Broad-lobed Foliose (L)						1			1	1		1																									
g	Large Cushion (B)							1																														
f	m Ch frut rept										1		1							1																		
e	m Ch suff caesp						1		1	1	1	1	1	1	1	1	1			1																		
c	Thread-like Form (B)					1			1			1			1			1																				
g	Fruticose (L)							1						1				1																				
f	Ch herb rept													1	1	1			1	1																		
b	a H sem														1						1		1															
f	Compact Mat (B)																			1																		
a	met T scap																			1				2						1								
a	t Ch herb caesp																			1		1		2				4	2	1	1	1	1					
a	t Ch herb rept																	1						2					1	1	1							
a	Ch herb scap																													1	1	1						
a	t Ch herb scap		1		1	1		1				1	1							1					1	2	3	2	2	2	1	1			1	1	2	1
e	m Ch frut caesp	1	1	1	1		1	1		1	1	1	1																								1	1
d	Leprose (L)			1				1																								1			1	1		
d	e H ros	2	1																														1	1				
e	g Ch herb pulv						1	2	1	1	2	1	1																			1	1	1	1			1
d	Narrow-lobed Foliose (L)						1					1																					1	1				
e	e H caesp	1	1	2	2	2	1	2	2	2	2	2	2	1	1	1	1	1			2		1		1	1		1	1	1	1	1		1	1		1	
b	a H ros		1				1	1	1	2	1	1	1	1	1	1			1		1		1	2	1				1	3	1		2	2	2	2	2	2
c	a H scap	6	2	3	4	4	2	1	3	2	2	2	1	4	3	3	5	5	4	3	3	4	3	2	2	2	2		1	2	2	3	3	2	4	4	2	2
b	a H caesp	1	2	2		1	1	2	2	2	1	1	2	2	3	3	1	2	4	3	4	4	3	3	3	3	3	3	2	2	2	2	2	3	3	2	2	3
d	Small Cushion (B)	1	1	2	1	2	1		1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1			1	1		1	2	1	2		2	1	1
b	Short Turf (B)	1	1	1			1					1		1			1		1.	1	2		1		1			2	1		2		1		1		1	1
a	t Ch suff scap		1	1	2	1								1		1	1							2	1	1	2		1	1		1					1	1
g	t Ch suff rept		1					2		1	2	1	1	1	1	1	2			1				2	1	3	2		1		1							
g	t Ch suff caesp						1	1	1		1	1		1	2	2	1				1	1	1		1	1	2				1			1				
f	a G rhiz				1	1	1							1	1					1		1	1															
b	Tall Turf (B)						1															1	1		1							1				1	1	2
c	Spreading-branch Weft (B)											1						1																			1	

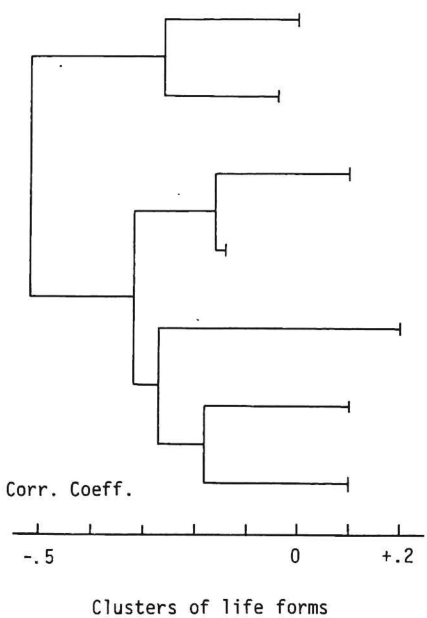
- Ordinations: Principal Component Analysis applied to the similarity ratio matrix of relevés after a logarithmic transformation (Feoli & Feoli Chiapella, 1980).
- Concentration analysis (AOC) (Feoli & Orlóci, 1979), with data adjusted to block size (Orlóci & Kenkel, 1983).

Results and discussion

Classification of relevés on floristic data.

The dendrogram of the relevés based on floristic data (Tab. 1) is in Fig. 1. At value -0.18 of the correlation coefficient two main clusters are formed, which respectively include relevés on South exposed stands and relevés on North exposed stands. At higher values of the correlation coefficient in each of





	1	2	3	4	5	6
a	7 *7*	3 *2*	4 *4*	8 *7*	26 *17*	7 *6*
b	8 *10*	17 *15*	11 *14*	18 *19*	18 *14*	19 *20*
c	8 *13*	12 *14*	8 *13*	7 *9*	7 *7*	7 *9*
d	13 *12*	9 *6*	5 *5*	6 *5*	6 *3*	11 *8*
e	10 *11*	35 *26*	9 *10*	3 *3*	8 *5*	9 *8*
f	2 *3*	3 *3*	5 *8*	7 *9*	0 *0*	0 *0*
g	1 *2*	12 *14*	10 *16*	5 *7*	9 *9*	1 *1*

Fig. 1 — Dendrograms of relevé groups and life-form groups. The contingency table gives the occupancy counts and their adjusted values (italics) in the blocks of the structured table of life-form groups and relevé groups based on binary data. Further explanations in text.

these clusters the relevés on rocks are separated from the relevés on scree slopes: altogether, six main relevé groups are formed, as follows (numbers as in Fig. 1):

Rel. group 1: on S-exposed rocks, subvertical, elevation under 1500 m.

Rel. group 2: on S-exposed rocks, average inclination 45°, elevation around 2000 m.

Rel. group 3: on S-exposed scree slopes, average inclination 35°, average elevation 1870 m.

Rel. group 4: on S- and N-exposed scree slopes, average inclination 35°, average elevation 1720 m.

Rel. group 5: on N-exposed scree slopes, average inclination 40°, average elevation 1850 m.

Rel. group 6: on N-exposed rocks, average inclination 45°, average elevation 1910 m.

The most important ecological factors related with the typification of vegetation on floristic basis are, in order: exposure, substrate, inclination. Exposure and inclination could be jointly expressed in terms of potential solar irradiation (Frank & Lee, 1966; Lausi & Codogno, 1984), so that the floristically defined types can be ecologically characterized by two main parameters, i.e. type of substrate and potential solar irradiation.

Ordination of relevés on floristic data

The results of the ordination of relevés on floristic data (Tab. 1) are in Fig. 2. In the ordination diagram of Fig. 2 the relevé points are circularly arranged

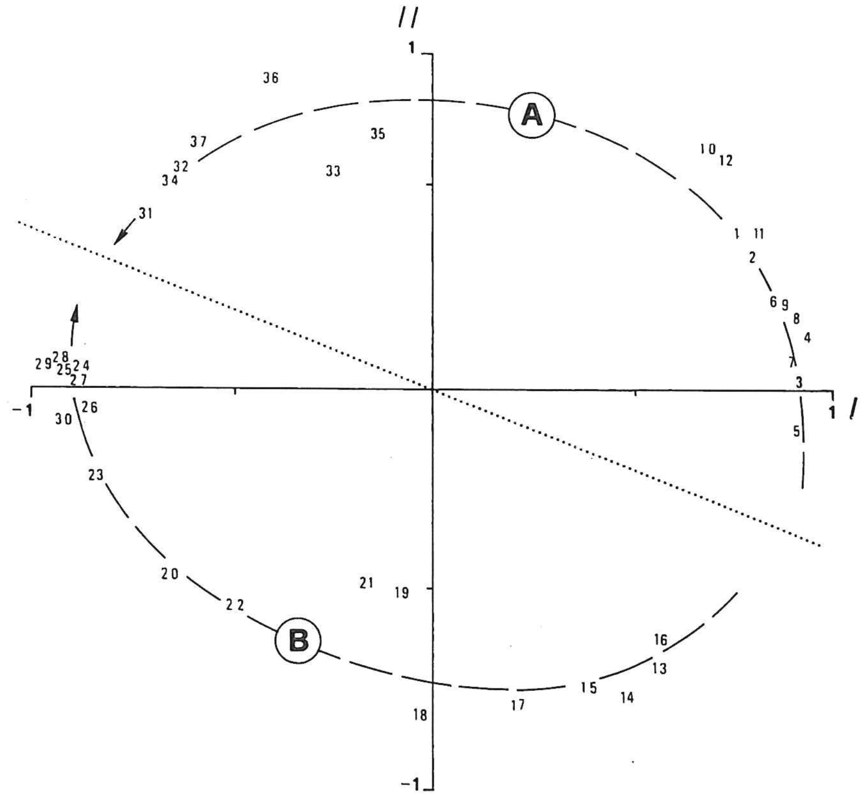


Fig. 2 — Ordination of relevés on floristic data. Relevé numbers as in Tab. 1. Dashed arrow A: sequence of relevés on rocks; dashed arrow B: sequence of relevés on scree slopes. Arrows A and B indicate a gradient from South to North exposure. Further explanations in text.

around the origin of the axes (first and second principal components). The relevé groups obtained by classification are still recognizable.

By informally rotating the axes of ca. 30°, the second axis separates relevés taken on rocks (positive scores) from relevés taken on scree slopes (negative scores). In this way two sequencies of relevé groups are obtained (dashed arrows in Fig. 2); they are: 1, 2, 6 (groups of relevés on rocks), and 3, 4, 5 (groups of relevés on scree slopes). From the typification of the relevé groups given above, both sequencies could be interpreted as revealing a topographic gradient of exposure (from S-exposed, to N-exposed stands).

Classification of life- and growth-forms

Tab. 2 contains the relative frequency-classes of life-forms in the relevés. The dendrogram of life-forms based on the data in Tab. 2, and the relative frequencies of life-form groups within the relevé groups based on binary data are in Fig. 1. Seven main groups of life-forms have been recognized; they are as follows (letters as in Fig. 1):

Group *a:* mostly includes herbaceous and deciduous chamaephytes.

Group *b:* includes deciduous hemicryptophytes and turf bryophytes.

Group *c:* includes scapose, deciduous hemicryptophytes and therophytes, and creeping bryophytes.

Group *d:* includes evergreen hemicryptophytes, nanophanerophytes, bulbose geophytes, leprose and narrow-lobed foliose lichens, bryophytes forming small cushions.

Group *e:* includes evergreen, mostly caespitose or pulvinate chamaephytes and hemicryptophytes, squamulose and broad-lobed foliose lichens.

Group *f:* includes creeping evergreen chamaephytes, rhizomatous geophytes and compact mat bryophytes.

Group *g:* includes deciduous, creeping or caespitose, suffruticose chamaephytes, large cushion bryophytes and fruticose lichens.

Concentration analysis

The results of concentration analysis performed on the contingency table in Fig. 1 are shown in Fig. 3. The percents of chi square accounted for by the two first canonical variates and the levels of influence of the variables are in Tab. 3.

Life-form groups *a* and *e* have the highest levels of influence on the first canonical variate. The first canonical variate separates relevé group 2, that is significantly correlated with life-form group *e,* from relevé group 5, that is significantly correlated with life-form group *a.* This arrangement shows a main difference in exposure between relevé group 2 (South exposed) and relevé group 5 (North exposed). This joint distribution between life-form groups and relevé groups reflects the higher frequency of evergreen, woody caespitose or pulvinate chamaephytes in relevé group 2 and of herbaceous, deciduous, scapose chamaephytes in relevé group 5. Xeromorphic characters prevail in South exposed stands (high frequency of stress periods), where the abundant availability of light and water immediately after the early melting of snow brings to positive selection of evergreen photosynthetic structures.

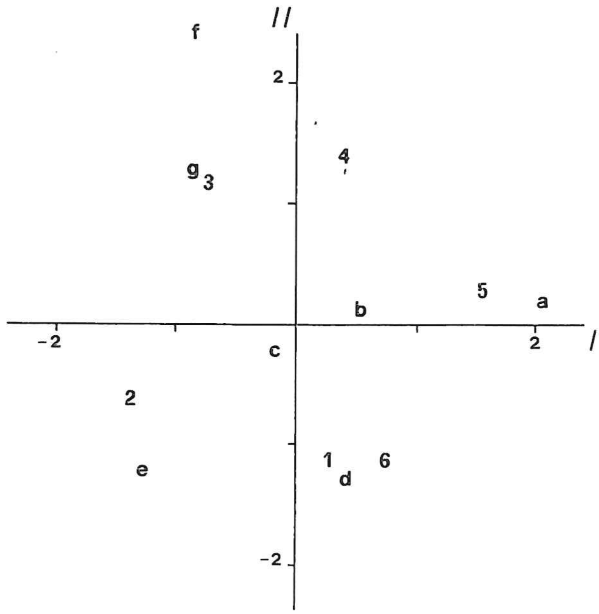


Fig. 3 — Joint distribution of relevé groups and life-form groups according to AOC performed on the contingency table in Fig. 1. Numbers are relevé groups as in Tab. 1. Letters are life-form groups as in Tab. 2. Further explanations in text.

Life-form Gr.	I Canonical variate		II Canonical variate	
	χ^2	%	χ^2	%
a	19.8	50	0.1	1
b	2.5	6	0.1	1
c	0.2	1	0.2	1
d	0.6	2	5.0	16
e	10.9	28	7.1	23
f	1.7	4	11.0	36
g	3.7	9	6.8	22
Total	39.4	100	30.3	100

Tab. 3 — Contribution of life-form groups to the chi square accounted for by the first and second canonical variates in AOC (see Fig. 3). Life-form group letters are as in Fig. 1. Further explanations in text.

The second canonical variate respectively separates the groups of relevés on scree slopes (3, 4, 5; positive scores) from the groups of relevés on compact rocks (1, 2, 6; negative scores). Life-form groups *f*, *e*, *g* and *d* have the highest levels of influence on the second canonical variate. The most significant correlations between relevé groups and life-form groups are: 3 and 4 with *f*, 3 with *g*, 1 and 6 with *d*, and 2 with *e*. This arrangement reflects differences both in substrate and in the degree of colonization.

The main structural differences concern:

(1) The creeping growth-form of bryophytes and chamaephytes, and the presence of rhizomatous geophytes on scree slopes.

(2) The presence of caespitose, suffruticose chamaephytes and fruticose lichens on scree slopes with higher plant cover (rel. gr. 3).

(3) The richness in chomophytes (hemicryptophytes, nanophanerophytes and geophytes) and the presence of a lot of hemicryptophytic chasmophytes (e.g. *Kernera saxatilis, Physoplexis comosa, Valeriana elongata, Asplenium viride)* on subvertical S-exposed rocks with little elevation (rel. gr. 1) and on N-exposed rocks (rel. gr. 6).

(4) The richness in chamaephytic chasmophytes (e.g. *Saxifraga* sp. pl., *Draba aizoides)* on S-exposed rocks at higher elevation (rel. gr. 2).

The chamaephytic chasmophytes with xeromorphic characters prevail on compact rocks subject to higher potential solar irradiation (exp. S and incl. 45°: rel. gr. 2), whereas hemicryptophytic chasmophytes and several chomophytes are present on the rocks subject to lower potential irradiation (exp. S and incl. 90°: rel. gr. 1; exp. N and incl. 45°: rel. gr. 6). The greater presence of chomophytes is probably linked to higher intensity of the cryoclastic action in the latter stands, that favours the production of detritus.

The results of AOC show that the two main ecological factors characterizing the floristically defined types, i.e. potential solar irradiation and substrate, are linked both to the variation of photosynthetic structures (evergreen versus deciduous) and to the variation of life- and growth-forms.

Ordination of relevés on structural data

The ordination of relevés based on structural data (Tab. 2) is shown in Fig. 4. The relevés are disposed along a semicircular line around the origin of the axes (first and second principal components). The sequence of the relevés along this line corresponds to a topographic gradient of exposure (from S- to N-exposed relevés). The arrangement of the relevés does not show a clear separation between relevés on compact rock and those on scree slopes. It seems therefore that differences in exposure, i.e. in potential solar irradiation, are more important than differences in substrate as far as structural variation is concerned.

Correlation between floristic and structural variation

Already the similar data structure of Tab. 1 and Tab. 2 confirms the existence of a relationship between floristic and structural variation. For quantifying this correlation the results of the ordinations are compared in Fig. 5. This figure reports the relative positions of the relevés along the dashed line of Fig. 4 (ordination based on structural characters), plotted against the

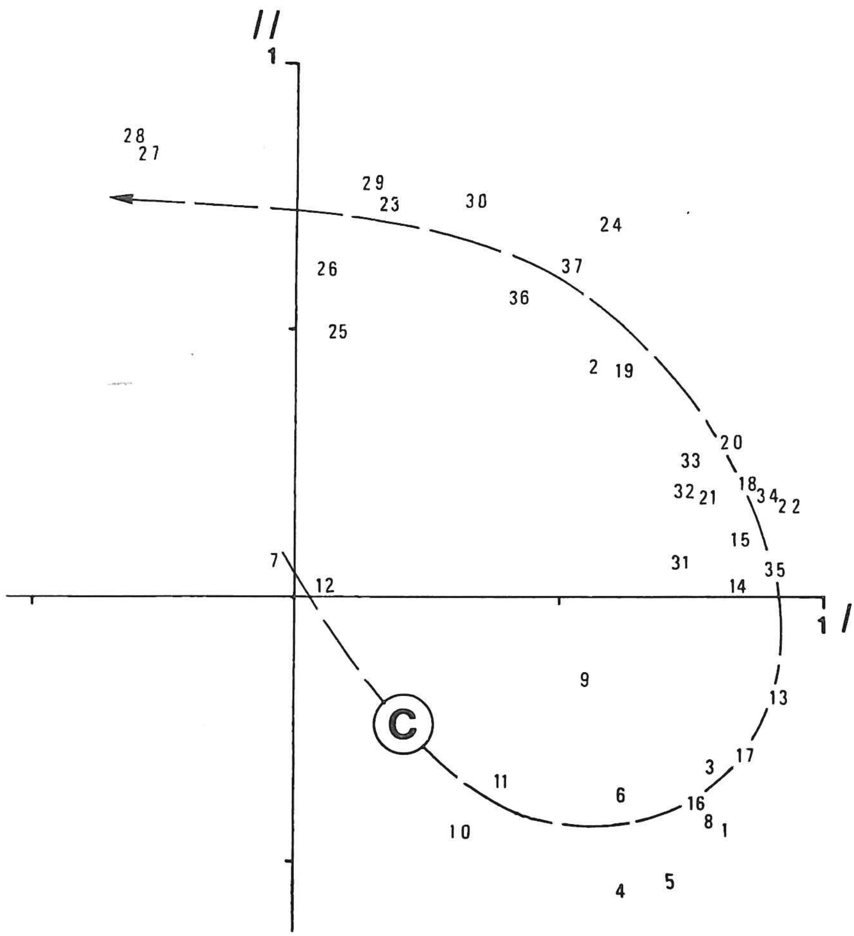


Fig. 4 — Ordination of relevés on structural data (life- and growth-forms). Relevé numbers as in Tab. 2. Dashed arrow C: gradient from South to North exposure.

positions of the relevés along the dashed lines of Fig. 2 (ordination based on floristic characters).

The correlation coefficients for the regression lines in Fig. 5 respectively are 0.78 and 0.88, and their significance is very high (the values of *t* are respectively 4.99 and 7.41, therefore higher than the critical values at the 1% level of significance for 17 and 16 degrees of freedom).

Concluding remarks

The results show that a high correlation exists between structural and floristic variation, both in the relevés taken on compact rocks and in the relevés taken on scree slopes. Furthermore it is noteworthy that the structural

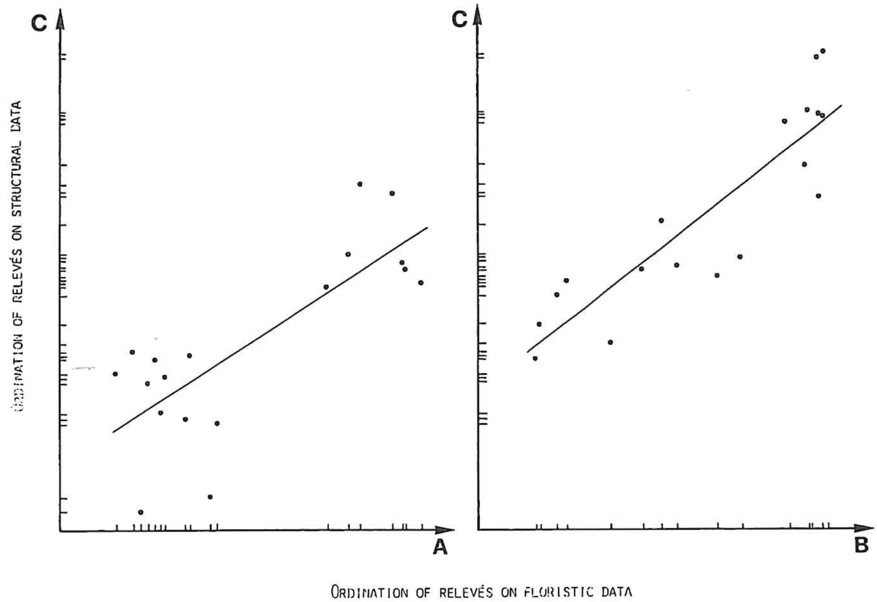


Fig. 5 — Correlation between floristic and structural variation.
C: sequence of the relevés along the gradient of Fig. 4.
A and B: sequencies of the relevés along the gradients of Fig. 2.
Further explanations in text.

variation seems highly predictive as far as typification of vegetation is concerned. This means that the floristic-ecological variation in the data set can be expressed by the variation of structural parameters with a high degree of predictivity.

Appendix

Sporadic species in the relevés:

Rel. 1: *Peltigera rufescens.* Rel. 2: *Silene acaulis, Soldanella alpina.* Rel. 3: *Salix alpina, Catopyrenium lachneum.* Rel. 4: *Koeleria hirsuta, Picea abies* pl., *Pinus mugo* pl., *Myurella julacea, Squamarina gypsacea.* Rel. 5: *Carex brachystachys, Molinia caerulea.* Rel. 7: *Teucrium montanum.* Rel. 8: *Linum perenne* subsp. *alpinum, Rhamnus pumilus.* Rel. 9: *Festuca alpina, Grimmia apocarpa, Ctenidium molluscum, Plagiochila asplenioides, Solenostoma atrovirens, Physcia caesia.* Rel. 10: *Leontopodium alpinum, Daphne striata, Dicranum scoparium, Toninia caeruleonigricans.* Rel. 11: *Parnassia palustris, Cratoneurum commutatum* var. *falcatum, Hymenostylium recurvirostre.* Rel. 12: *Arctostaphylos uva-ursi, Erica herbacea.* Rel. 13: *Festuca valesiaca, Toninia diffracta.* Rel. 15: *Selaginella denticulata.* Rel. 19: *Camptothecium lutescens.* Rel. 21: *Encalypta streptocarpa.* Rel. 24: *Petrocallis pyrenaica.* Rel. 28: *Bryum pseudotriquetrum.* Rel. 29: *Cirsium spinosissimum, Arabis vochinensis, Valeriana montana.* Rel. 30: *Gentianella ciliata, Cladonia pyxidata* var. *pocillum.* Rel. 31: *Dianthus sylvestris, Pulsatilla alpina, Phyteuma orbiculare.* Rel. 32: *Tortula norvegica.* Rel. 33: *Hieracium bifidum, Silene nutans.* Rel. 34: *Cerastium holosteoides, Carduus defloratus.* Rel. 35: *Pedicularis rosea, Agrostis alpina, Mnium marginatum.* Rel. 37: *Festuca stenantha, Rhynchostegium murale* var. *julaceum.* Rel. 38: *Campanula carnica.*

Nomenclature follows Ehrendorfer (1973), Poelt (1969), Wirth (1980), and van Wijk, Margadant & Florschutz (1959-64).

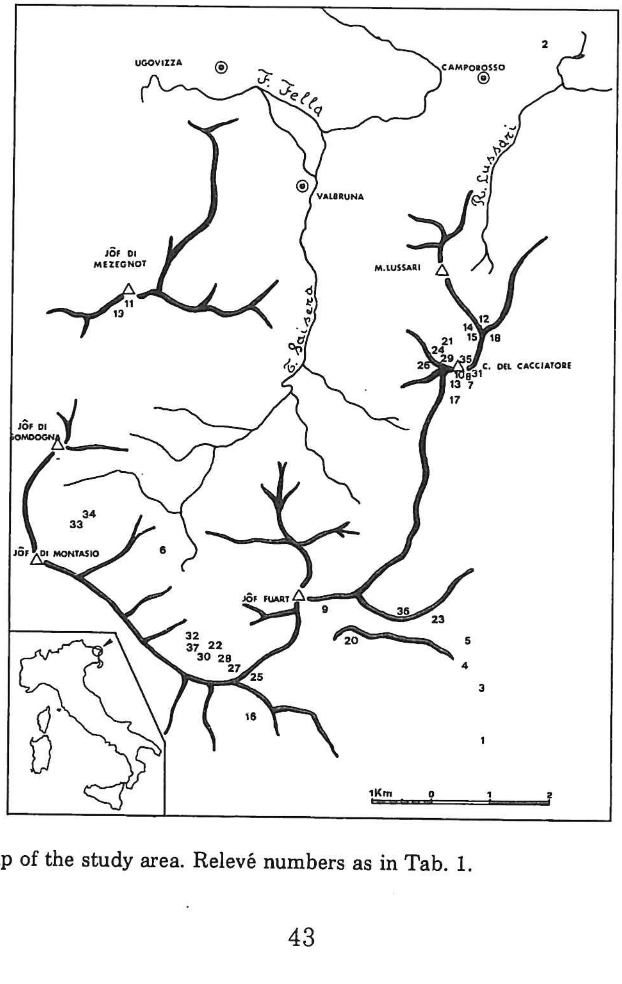


Fig. 6 — Map of the study area. Relevé numbers as in Tab. 1.

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