

THE ABANDONED *DANTHONIA ALPINA* - GRASSLANDS ON MONTE SAN GIORGIO: EVIDENCE OF FLORISTIC CHANGES AND SUGGESTED MANAGEMENT PRACTICES

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Abstract

The grasslands on Monte San Giorgio, Ticino, are recognized as a plant community unique to Switzerland (alliance: Mesobromion) containing many isolated, rare, and endangered taxa. The vegetation pattern reflects a gradient of soil depth probably caused by different dolomitic and tuffitic strata of the underlying bedrock.

Successional changes after abandonment and uncontrolled fires have favoured *Molinia arundinacea* on relatively deep soils, resulting in a general decrease of species richness. In field experiments *M. arundinacea* was reduced in abundance by mowing in early August but favoured by removing litter in early spring.

Suggested management practices are mowing, at various locally defined mowing regimes, or, limited to a few areas, grazing by donkeys in late summer, both combined with cutting of shrubs and trees. Controlled burning may also be recommended, but fires have to be set at very small scale, and at intervals of several years, and effects must be well studied over a long term. Removing litter by rake in spring and grazing by sheep or goats are not recommended.

Introduction

Reduction of species diversity in abandoned meadows and pastures is well known from many studies in different parts of Europe (BAKKER 1989). Rates of succession after abandonment (secondary succession) in such grasslands of marginal agricultural value vary a lot, depending on complex factors described by ZOLLER *et al.* (1984). Under the 'favourable' conditions of the Insubrian climate in southern Switzerland and northern Italy, these rates are believed to be relatively high. In the study area on Monte San Giorgio, however, succession has not yet led to a dense cover of forests, and a remarkable flora of former meadows and pastures is still preserved. As this state might change in the near future, measures are currently discussed to preserve the present landscape of exceptional amenity and its most interesting flora and fauna (STAMPFLI *et al.* 1992).

Monte San Giorgio is included in the inventory of Swiss 'Landscapes and Natural Monuments of National Importance' (BLN 1977). But until recently conservation or management concepts did not exist. Conservation planning requires prior knowledge of the present and past distribution and abundance of species, on threats to those species, and on effects of different management practices (MURPHY 1990).

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The objective of this paper is to summarize the current state of plant-ecological knowledge of the grasslands of Monte San Giorgio, to which several authors contributed from 1988 to 1992. Extensive field studies resulted in a map of grassland vegetation complexes based on detailed plant-sociological relevés (F. Guggisberg, unpubl. data), soil analyses (H. Pestalozzi, unpubl. data), and a description of the recent fire history (S. Berli, unpubl. data; BERLI & SCHWEINGRUBER 1992). Clonal growth studies of the competitive grass *Molinia arundinacea* have been carried out by A. Stampfli at yearly intervals. In 1988 experimental plots were established (STAMPFLI 1993) to observe secondary succession and to detect effects of mowing and removing litter on reproductive shoots (STAMPFLI 1992), and the species composition. The feeding behaviour of donkeys was observed in a two-months field study (A. Valsangiacomo & I. Visconti, unpubl. data). In order to get a more comprehensive idea about the ecological significance of the grasslands of Monte San Giorgio, the plant-ecological studies were accompanied by investigations of selected invertebrate groups, spiders (A. Hänggi), butterflies (M. Lörtscher) and grasshoppers (C. Antognoli).

The management practices suggested are based on our current understanding of the natural and cultural processes involved in the creation and maintenance of the grasslands of Monte San Giorgio. It has been a pleasure to remember Gerhard Lang's challenging ideas on the conservation of ecosystems (LANG 1983).

Study area

Environment

Monte San Giorgio (elev. 1097 m; 45°54'55"N, 8°57'03"E) is situated at the southern edge of the Alps in the very south of the canton Ticino (Switzerland), about 10 km S of Lugano. Triassic limestone and especially dolomite, alternating with fine layers of volcanic tuff (WIRZ 1945; KUHN-SCHNYDER 1974), widely known for their extraordinary richness of fossils (reptiles and fish), form the bedrock of the south-facing slope of the mountain. The study area is located at an elevation of 840-1080 m (Fig.1) within a transition from predominant deciduous mixed oak forest (*Fraxino orn-Ostryetum*) to beech forest (*Cephalanthero-Fagion*). The annual precipitation is about 1900 mm. Dry winter and wet spring are followed by relatively high and evenly distributed monthly rainfall in 'normal' years. Thunderstorms and heavy rains are usually frequent during summer and fall. A snow cover lasting longer than a few weeks is rare. The annual mean temperature is 8.2°C.

According to HANTKE (1983: 376), the study area was ice-free during the Würm (last) glacial. The nunatak of Monte San Giorgio probably exceeded 100 ha during the Würm maximum, but it had not exceeded 50 ha in the (previous) Riss maximum. Forests covered the area by about 12,000 years B.P. (SCHNEIDER 1985; WICK 1989), probably leaving very small openings along the rocky ridge. In the Lake of Lugano area, human activities since about 5000 years B.P. are recorded by palynologic investigations (WICK 1989). No historical evidence exists for the origin of the clearings on Monte San Giorgio.

Cultural history

Historical evidence of human activity on the mountain is given by a visiting clergyman in 1578, who ordered that the door of the small church on top of the mountain be closed to prevent the invasion of domestic animals ('...tener chiuso l'edificio invaso dalle bestie...' cit. in MARTINOLA 1975: 333). Hermits lived on the mountain before for centuries (SESTI 1917), and grazing by domestic animals and hay-making have most likely been a common practice at the same time. Hay was made until 1955 by people from the village of Meride, situated at a hiking distance of one hour from the mountain grasslands. The hay was transported on oxen-sledges to their homes. The farm of Forello (Fig.1) built in the 1920s, was inhabited until about 1955. During that time the northern part of Monti was grazed by cows, goats, and sheep; Forello and the southern part of Monti were used for hay production. Manure was distributed only in the meadows surrounding the farm, and here two hay cuts were made in favourable years (A. Doninelli, personal communication).

The economical development after World War II deeply altered land-use practices. The low productive and remote grasslands on Monte San Giorgio have been abandoned since 1955. The meadow of Cassina and some areas close to the top are maintained through mowing by a local non-profit society. A natural-history trail has been established (ANTONIETTI *et al.* 1980) and touristic activities are restricted to hiking. Open areas of abandoned grassland currently amount to about 10 ha, half of which is covered by isolated trees and small groups of shrubs.

Since 1888 about 9 fires have been recorded on Monte San Giorgio, but unfortunately there are no exact records of their locations. A fire at the upper NE slope of the mountain destroyed almost 300 ha of forest between 10 and 14 May 1965. This fire may also have affected the abandoned grasslands of the study area.

Methods

Nomenclature: for vascular plants BINZ & HEITZ (1990), for grassland syntaxa ELLENBERG (1978), for forest syntaxa ELLENBERG & KLÖTZLI (1972).

Species composition and soil

Plant-species composition and soil depths were recorded in 2 m x 2 m quadrats from 91 locations distributed throughout the whole study area and representing all vegetation types of the open abandoned grassland; three relevés from the maintained meadow of Cassina (Fig.1) were added. The areas for the quadrats had to fulfil the following requirements: no vegetation boundaries and no gradient in cover of dominant species should be obvious, and the size should considerably exceed 2 m x 2 m. Cover-abundance of each species was estimated in an extended Braun-Blanquet scale. Soil depths within 92 quadrats were measured with a pointed iron bar at five regularly arranged points.

The floristic difference of the study area from meadows in surrounding areas at the southern edge of the Alps was studied through comparison of the relevés with those of several other authors (KOCH 1943; LÜDI 1949; BRAUN-BLANQUET 1961; STUDER-EHRENSBERGER 1993; K. Studer-Ehrensberger, unpubl. data; S. Häfelfinger, unpubl. data).

Soil profiles were described in three different vegetation types (Fig.1). Chemical analyses from the different strata were carried out, and the potential water-retaining capacity was estimated. At a fourth location, a ditch about 2 m long was dug through the transition from dominant *Carex humilis* to dominant *Molinia arundinacea*, across high abundant *Danthonia alpina*.

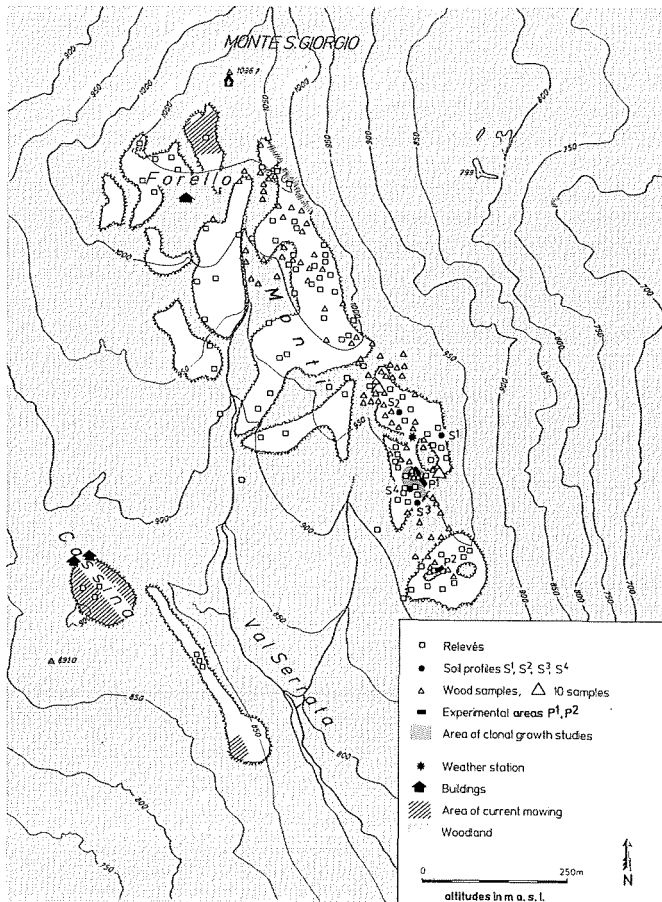


Figure 1. Map of the study site on Monte San Giorgio showing locations of different investigations.

Tree-ring analysis

In order to show the effect of fires on the woody flora, the ages of 111 shrubs and trees (Tab.1) throughout the study site were determined from basal cross-sections and cores (Fig.1). The plants were selected mainly from most frequent species. Stems of a wide range of diameters were chosen, and severely damaged examples as well as those showing no fire scars were included. The height of scars, which is considered to be a relative measure of fire intensity, and their orientation on the trunk were recorded.

Table 1. List of most frequent trees and shrubs selected for tree-ring analysis. Sample size and number of samples in different ways of survival: (A) survival of the wooden stems, (B) survival of the roots (sprouting), (C) germination from seed.

Species	Sample size	A	B	C
<i>Quercus pubescens</i>	31	22	7	2
<i>Tilia cordata</i>	12	3	8	1
<i>Laburnum anagyroides</i>	12	.	5	7
<i>Populus tremula</i>	10	.	.	10
<i>Fagus sylvatica</i>	8	5	3	.
<i>Ostrya carpinifolia</i>	8	3	4	1
<i>Betula pendula</i>	7	2	.	5
<i>Sorbus aria</i>	5	1	4	.
others	18	3	8	7

Clonal growth of *Molinia arundinacea*

Today *Molinia arundinacea* is very abundant in abandoned grasslands on Monte San Giorgio. The coexisting species are thought to be affected most strongly by this vigorously growing grass and its dead material, which is annually accumulated in a persisting layer of litter.

By yearly observation of single clones the expanding character of *M. arundinacea* was studied. Trends of growth in untreated clones are compared to trends of growth in treated clones (area of clonal growth study, Fig.1). Two different experimental set-ups were initiated in 1988 to investigate the effects of mowing and removing litter on the clonal growth of *M. arundinacea*:

Effect of mowing: Four *M. arundinacea* tussocks T₁-T₄ have been selected. Tussock T₁ (covering about 25 dm²) is a complex of about ten probably linked tussocks. It is bordered at one side by a partly shaded area densely covered by *M. arundinacea*. Tussocks T₂-T₄ are completely isolated from *M. arundinacea* patches. Tussocks T₂ (15 dm²) and T₃ (12 dm²) are compact and oval-shaped, tussock T₄ (5 dm²) is banana-shaped. The effect of mowing was investigated by clipping (with scissors) all the shoots of tussocks T₁ and T₂ at about 2 cm above the ground yearly in late August. No treatment operations were carried out on tussocks T₃ and T₄.

The yearly observations include: a count of numbers of vegetative and reproductive shoots in tussocks T₁-T₄, a determination of dry weight of total vegetative and reproductive shoots of tussocks T₁ and T₂, and length measurements of vegetative and reproductive shoots of tussock T₁.

Effect of removing litter: Three pairs of experimental plots (A_{1/2}, B_{1/2}, C_{1/2}), 50 cm x 100 cm in size, were selected in dense *M. arundinacea* patches. The distance between plots in each pair is 50 cm, between pairs more than 20 m.

Litter was removed on one plot in each pair every March since 1989. Vegetative and reproductive shoot modules have been counted every year in September.

Results

Soil

The soils are classified as Rendzina (according to the system of Arbeitsgruppe Bodenkunde, BENZLER *et al.* 1982), showing in the deeper profiles a more distinctive Bv-horizon than in the shallower ones. Deeper profiles include a few weathered layers of volcanic tuff in addition to the underlying dolomite, which is the only rock material found in the shallower profiles and at the soil surface throughout the study area (Fig.2). The top samples of deep soils can be distinguished from samples of shallow soils by somewhat lower pH-values (Tab.2). All soils are completely leached of carbonate. Nevertheless 95-99% of the sum of extractable cations are Ca and Mg. Phosphorus is very low here compared to other Mesobromion meadows in Ticino (H. Pestalozzi, unpubl. data). In addition to the relatively high content of organic matter in the upper stratum, the soils are remarkably rich in clay. Dolomite blocks indicate the lower limit of weathered soil and roots beyond that limit extend into narrow clefts between the blocks. At the time when the profile was dug in fall 1988 these clefts still retained humidity after a long dry period.

Table 2. Soil characteristics from profiles in three different vegetation types, S₁, S₂, S₃, dominated by *Carex humilis*, *Danthonia alpina*, and *Molinia arundinacea*, respectively.

		S ₁	S ₂	S ₃
Depth of soil profile (cm)		25	45	85
Estimated potential water-retaining capacity (mm)		46	91	96
pH* at different depth of soil:	10 cm	6.4	5.8	5.7
	20 cm	7.0	5.8	5.8
	35 cm	.	6.7	7.2
	70 cm	.	.	7.7
P** (mg/kg), samples of different soil strata:	< 10 cm	45.6	39.2	24.4
	10-25 cm	25.6	7.6	19.0
	25-50 cm		9.2	13.2
	> 50 cm			15.8

* pH: 1 part soil and 2.5 parts 0.01 M CaCl₂

** P (extractable inorganic phosphorus): 1 part soil and 50 parts 0.5 M H₂SO₄ (16 h)

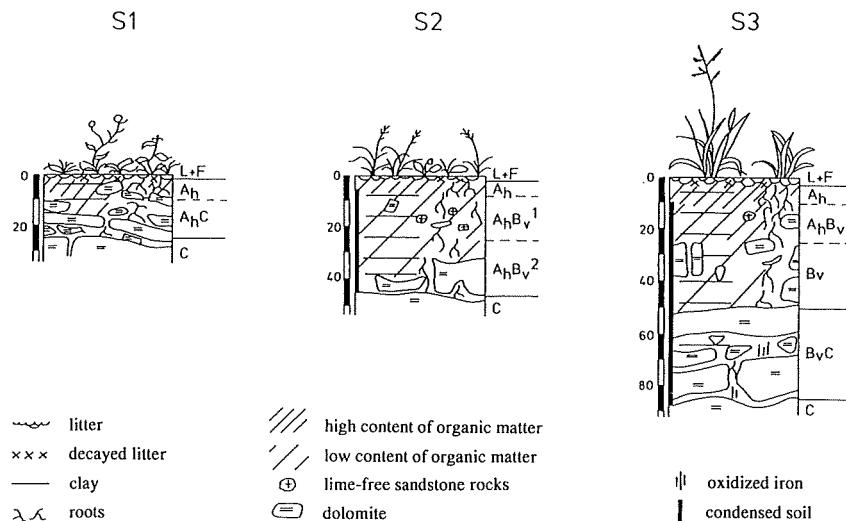


Figure 2. Soil profiles S₁, S₂, S₃.

Species composition

The number of species recorded per relevé (2 m x 2 m) ranged between 12 and 32. The total list of herb species in relevés and experimental plots, completed with rare species (Tab.4) amounts to 131. Additionally, at least 25 species of trees and shrubs are present in the study area.

The species composition is clearly related to differences in soil depth (Fig.3). Of the 136 species recorded for the 91 relevés, 57 show a preference for a particular soil depth; the five most abundant grasses and sedges and three different groups of species (A, B, C) are presented along a gradient of soil depth (Fig.3).

The 20 species of group A are restricted to extremely shallow soils:

Teucrium montanum
Asperula purpurea
Aster amellus
Allium pulchellum
Sanguisorba minor
Potentilla neumanniana
Bupleurum ranunculoides
Globularia cordifolia
Asperula cynanchica
Cuscuta epithymum

Sesleria varia
Thesium linophyllum
Silene insubrica
Scabiosa columbaria
Leontodon tenuiflorus
Fumana procumbens
Sedum album
Dianthus monspessulanus
Anthyllis vulneraria s.l.
Lilium croceum

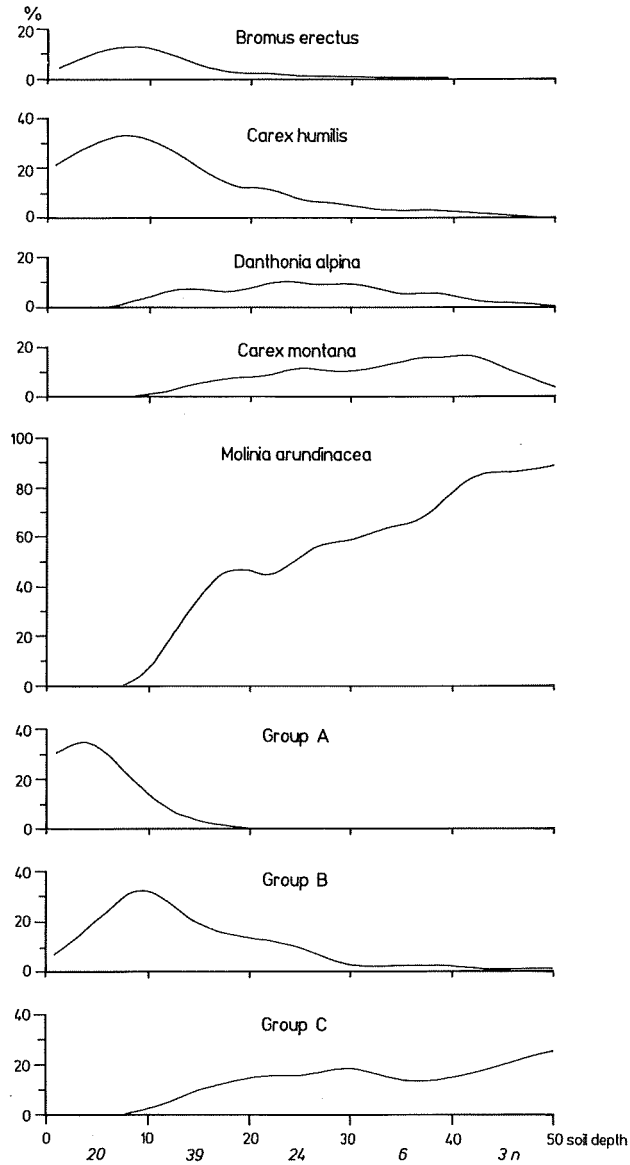


Figure 3. Cover (%) of most abundant grasses and sum of cover (%) of all the species in groups A, B, and C along a gradient of soil depth. Values of cover (estimated) and soil depth (mean of five measurements) of 91 relevés are smoothed by a quadratic multiple regression (distance weighted least squares, WILKINSON 1988). n is the number of samples within categories of soil depth (1-10 cm, 11-20 cm, etc.) along the gradient.

Carex humilis and *Bromus erectus* occur on a wide range, but their maximum cover is distinctly on shallow soils. The 24 species of group B show a similar range:

<i>Anthericum ramosum</i>	<i>Dorycnium herbaceum</i>
<i>Centaurea bracteata</i>	<i>Laserpitium siler</i>
<i>Carex flacca</i>	<i>Globularia punctata</i>
<i>Hippocrepis comosa</i>	<i>Melampyrum cristatum</i>
<i>Helianthemum nummularium</i> s.l.	<i>Viola hirta</i>
<i>Vincetoxicum hirundinaria</i>	<i>Geranium sanguineum</i>
<i>Teucrium chamaedrys</i>	<i>Campanula glomerata</i> s.l.
<i>Briza media</i>	<i>Melittis melissophyllum</i>
<i>Galium verum</i>	<i>Leontodon hispidus</i> s.l.
<i>Leucanthemum heterophyllum</i>	<i>Linum catharticum</i>
<i>Erica herbacea</i>	<i>Prunus spinosa</i>
<i>Salvia pratensis</i>	<i>Bupthalmum salicifolium</i>

Danthonia alpina does not occur on extremely deep or extremely shallow soils. *Carex montana* and the very abundant *Molinia arundinacea* are absent on extremely shallow soils, and their highest cover values are on deep soils. A similar range was found for the eight species of group C:

<i>Potentilla erecta</i>	<i>Succisa pratensis</i>
<i>Serratula tinctoria</i>	<i>Pteridium aquilinum</i>
<i>Aquilegia atrata</i>	<i>Calluna vulgaris</i>
<i>Iris graminea</i>	<i>Adenophora liliifolia</i>

For 79 species no conspicuous distribution along the gradient of soil depth was apparent.

Shallow soils, characterized by high cover of species of group A and low cover or lack of *Molinia arundinacea*, are estimated to include an area of about 2 ha; deep soils cover about 3 ha.

Most of the rare plants occurring in small populations on Monte San Giorgio (Tab.4) are either restricted to relatively deep soils or to the dry and rocky ridge.

Although the San Giorgio grasslands are not of an extraordinary species richness compared to regularly mown unfertilized grasslands elsewhere in the same region, they include a considerable number of 'differential' (Tab.3), rare, and endangered plant species (Tab.4). Grasslands of floristically more or less similar vegetation types can be found first at a distance of several hundred kilometres east of Monte San Giorgio, namely in Slovenia and Croatia. Most of the species differential for the Monte San Giorgio grasslands also occur in those Illyrian Bromion communities (HORVAT *et al.* 1974; PETKOVSEK 1974), e.g. *Danthonia alpina*, *Euphorbia verrucosa*, *Peucedanum cervaria*, *Potentilla alba*, *Dorycnium herbaceum*, and *Hypochoeris maculata*. Other differential species preferring deep soils on Monte San Giorgio are also reported from Molinion communities in northern Italy, e.g. *Serratula tinctoria*, *Succisa pratensis*, *Iris graminea*, and *Scorzonera humilis* (FORNACIARI 1986). A similar assemblage of taxa indicating periodically moist conditions was recorded by HORVAT (1962) from clay soils in Croatia (Molinio-Gladioletum), including *Molinia arundinacea*, *Succisa pratensis*, *Serratula tinctoria*, *Gladiolus illyricus*, *Danthonia alpina*, *Bromus erectus*, *Carex humilis*, and others.

There is a striking absence of many species that are very abundant on either traditionally managed or abandoned meadows elsewhere in southern Switzerland and in adjacent Italian areas (Tab.3), such as *Anthoxanthum odoratum*, *Festuca rubra*, *Agrostis tenuis*, *Trisetum flavescens*, *Plantago lanceolata*, *Trifolium pratense*, and *Rumex acetosa*. Some very common grassland species, *Centaurea nigrescens*, *Achillea millefolium*, and *Trifolium pratense* are only present within the study area on the mown meadow of Cassina.

Table 3. Differential species for grassland communities on Monte San Giorgio and other grasslands at lower elevations in the southern Alps: presence in single relevés (*) and percentage of presence in vegetation tables of different authors.

-
- A** Abandoned grasslands on Monte San Giorgio, F. Guggisberg (unpubl. data):
A1 *Molinia arundinacea*-community [45]
A2 *Carex humilis*-community [45]
- B** Meadows in Southern Ticino and nearby North Italian areas:
B1 Denti della Vecchia [2], LÜDI (1949)
B2 *Andropogonetum grylli insubricum* 'basiphile Variante' [8], KOCH (1943)
B3 'Mesoxerophytic meadows':
Phyteumo-Mesobrometum [70] and *Coronilla - Bromus*-succession community [78],
 STUDER-EHRENSBERGER (1993)
B4 'Mesoxerophytic and calcareous xerophytic meadows' STUDER-EHRENSBERGER
 (1993): *Carex humilis - Chrysopogon gryllus* community [7], *Leucanthemum*
maximum - Sesleria varia community [3], *Helianthemum italicum - Xerobrometum*
condensati [49], *Bromo - Cleistogenetum* [17], Grasslands [96], K. Studer-
 Ehrensberger (unpubl. data)
B5 'Magerwiesen' S. Häfelfinger (unpubl. data): relevés of Val Blenio [5],
 Centovalli [1], Valle Morobbia [2], Val Colla [5], Monte Generoso [4]
- C** Abandoned meadows in Ticino, S. Häfelfinger (unpubl. data): relevés of Val Blenio [5],
 Centovalli [3], Valle Morobbia [8], Val Colla [4], Monte Generoso [8]
- D** Grasslands of Northwestern Italy: Danthonieto - Linetum [2], BRAUN-BLANQUET (1961)

in []: number of relevés

community	A1	A2	B1	B2	B3	B4	B5	C	D
number of relevés	45	45	2	8	148	172	17	28	2

frequently on Monte San Giorgio:

<i>Carex montana</i>	80	4	.	.	2	3	.	11	.
<i>Potentilla alba</i>	76	40	.	.	3	3	.	.	.
<i>Serratula tinctoria</i>	71	20	*	.	3	1	.	11	.
<i>Melampyrum pratense</i>	56	27	.	.	1	1	.	4	.
<i>Succisa pratensis</i>	20	.	.	.	3	3	.	7	.
<i>Peucedanum cervaria</i>	87	87	.	.	2	5	.	.	.
<i>Iris graminea</i>	18	16	.	.	.	.	.	.	.
<i>Carex flacca</i>	42	73	*	.	6	11	.	.	.
<i>Danthonia alpina</i>	27	53	*	13	.	1	.	.	*
<i>Euphorbia verrucosa</i>	36	56	.	.	2	3	.	.	.
<i>Dorycnium herbaceum</i>	4	24	.	.	.	5	.	.	.
<i>Prunus spinosa</i>	7	22	.	.	1	1	.	.	.
<i>Bupleurum ranunculoides</i>	.	22	.	.	.	.	.	.	.

frequently at other sites:

grasses and graminoids:

<i>Chrysopogon gryllus</i>	.	.	.	100	32	54	.	.	*
<i>Botriochloa ischaemum</i>	.	.	.	63	7	32	.	.	*
<i>Bromus condensatus</i>	.	.	.	38	3	32	.	.	.
<i>Carex caryophyllea</i>	.	.	.	75	36	13	82	25	.
<i>Anthoxanthum odoratum</i>	.	.	.	13	60	6	82	71	.
<i>Festuca rubra</i>	.	.	.	25	49	9	94	64	.
<i>Trisetum flavescens</i>	.	.	.	25	47	6	71	18	.
<i>Agrostis tenuis</i>	.	.	.	.	25	5	88	54	.
<i>Holcus lanatus</i>	.	.	.	.	34	1	65	14	.

forbs:

<i>Scabiosa columbaria</i>	.	4	*	75	45	20	65	7	.
<i>Anthyllis vulneraria</i> s.l.	.	2	*	100	26	43	24	.	.
<i>Clinopodium vulgare</i>	.	2	.	13	42	3	71	14	.
<i>Achillea millefolium</i> s.l.	.	.	*	25	70	13	100	82	.
<i>Plantago lanceolata</i>	.	.	*	63	64	11	94	25	.
<i>Stachys recta</i> s.l.	.	.	*	63	24	23	.	7	.
<i>Pimpinella saxifraga</i> s.l.	.	.	.	100	21	21	41	25	.
<i>Hieracium pilosella</i>	.	.	.	88	29	14	18	18	*
<i>Thymus pulegioides</i>	.	.	.	75	28	7	6	14	.
<i>Centaurea nigrescens</i>	.	.	.	50	58	1	82	29	.
<i>Trifolium pratense</i>	.	.	.	25	36	8	71	.	.
<i>Trinia glauca</i>	.	.	.	38	1	39	.	.	*
<i>Galium corrudifolium</i>	.	.	.	75	.	.	.	.	.
<i>Phyteuma betonicifolium</i>	.	.	.	.	20	4	71	64	.
<i>Rumex acetosa</i>	.	.	.	.	43	2	77	39	.
<i>Silene vulgaris</i> s.l.	.	.	.	.	60	4	94	46	.
<i>Galium lucidum</i>	.	.	.	.	20	55	.	.	.

Tree-ring analysis

58 samples were taken from shrubs and trees that sprouted before 1965 and 53 after 1965. As 93% of the former group showed fire-scars, it can be concluded that the 1965-fire covered approximately the entire area of Monti (Fig.1). Fire scars often reach a height of 4-5 m above ground; an oak (*Quercus pubescens*) east of Forello showed scars even up to 9 m. The sprouting activity increased in the period 1965-1967 directly after the fire (Fig.4). There is no evidence of increased sprouting in the years following the abandonment of the meadows and pastures in 1955; the sample size, however, is rather small. Shrub and tree species survived the fire in a variety of ways (Tab.1). Many individuals of *Quercus pubescens* and a few of most other species survived as standing trees. Sprouting from the roots was frequent in *Tilia cordata*, *Laburnum anagyroides*, and *Sorbus aria* but less frequent in others. Germination was most frequent in *Betula pendula* and *Laburnum anagyroides*.

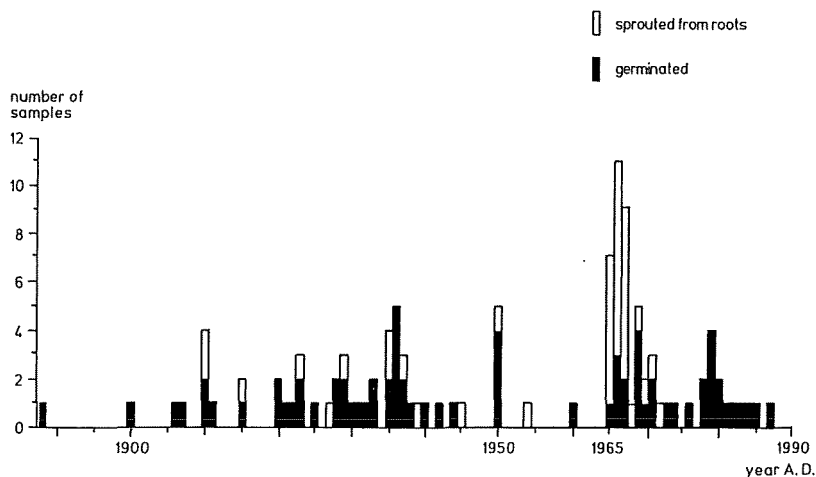


Figure 4. Year of sprouting from roots or germination of trees and shrubs sampled for tree-ring analysis.

Clonal growth of *Molinia arundinacea*

Far more vegetative than reproductive shoots were found in all the tussocks observed and on experimental plots. Effects of different treatments, as discussed here, are based on the sum of vegetative and reproductive shoots (Fig.5):

Within the five years 1988-1992 the size of untreated tussocks (T_3 , T_4) was relatively stable. In the same period clipping clearly affected tussocks T_1 and T_2 (Fig.5a): The number of shoots first increased but distinctly decreased after the second year of clipping; four years of successive clipping substantially damaged tussock T_2 .

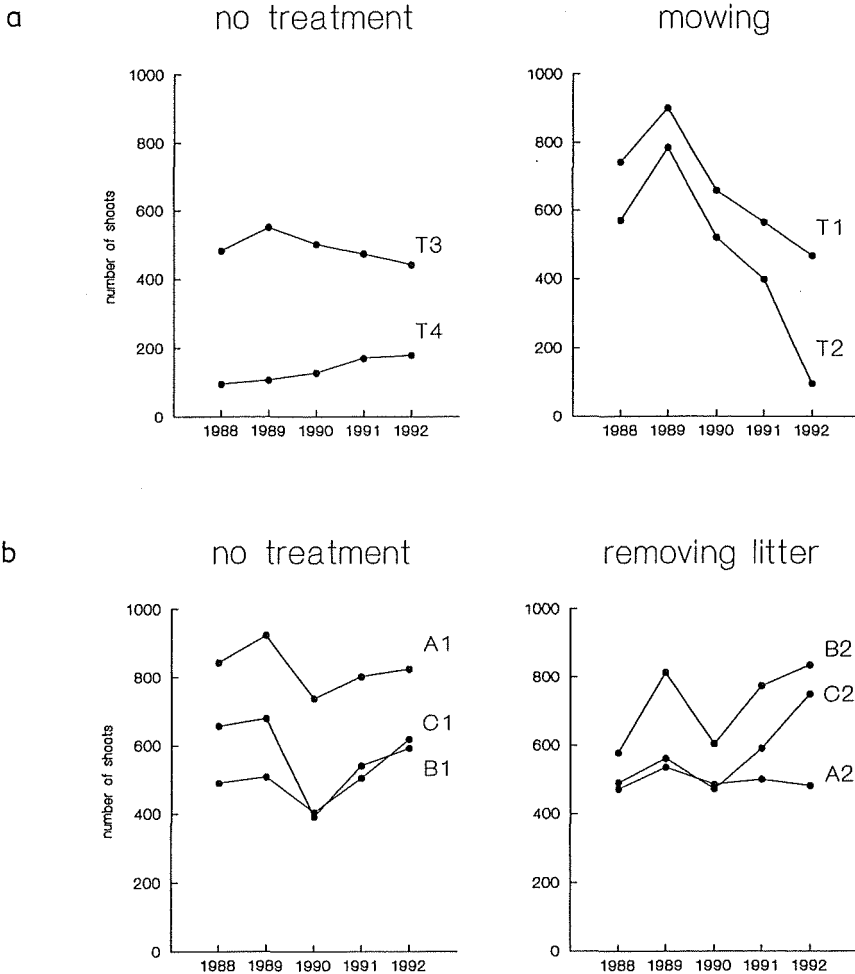


Figure 5. Different trends (1988-1992) in total shoot numbers of *Molinia arundinacea* for different managements (mowing, removing litter and no treatment):

a) tussocks (T₁-T₄).

b) pairs of small permanent plots (A₁/A₂, B₁/B₂, C₁/C₂).

Experimental plots on which litter was removed show fluctuations in shoot numbers similar to those on untreated experimental plots (Fig.5b): relative maxima in 1989 were followed by relative minima in 1990. However, different trends between pairs of differently treated experimental plots within a five-year period suggest that removing litter favours numbers of shoots. On plots A₁ (no treatment) and A₂ (litter removed) the trends are similar, both slightly decreasing; on plots B₁ and B₂ trends are different, distinctly increasing on plot B₂ (litter removed) and slightly decreasing on plot B₁ (no

treatment); on plots C₁ and C₂ trends are increasing, the increase is more pronounced C₂, where litter was removed.

The incisive effect of cutting on *M. arundinacea* tussocks is also demonstrated by shoot length and biomass of tussocks, already one year after cutting: the average length of vegetative shoots is reduced to about 50% (STAMPFLI 1992), the average dry mass per shoot is reduced to about 40% to 50% (Fig.6).

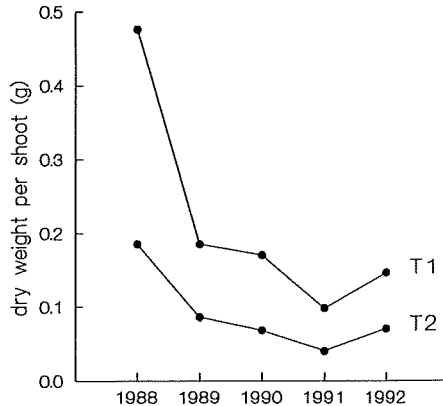


Figure 6. Average dry weight per shoot of *Molinia arundinacea* tussocks T₁ and T₂ in late August, before (1988) and after resumption of yearly mowing (1989-1992).

The preliminary conclusion from these experiments are: *M. arundinacea* tussocks reveal a negative growth rate as a result of mowing. When litter is removed in dense patches, growth rates of *M. arundinacea* clones are positively affected. Concerning *M. caerulea* the same effect of litter removal was found by GRANT *et al.* (1963).

Discussion

Species composition

For an examination of the peculiar species composition of the grasslands on Monte San Giorgio we have to consider special soil properties, geographical isolation, and glacial history: special soil properties (*e.g.* a strong phosphorus limitation) seem to be the factors limiting the competitive vigour of plant species lacking on Monte San Giorgio, but highly abundant in other Mesobromion-meadows of Canton Ticino (southern Switzerland).

Meadows with similar environmental conditions (dolomite, similar elevation and exposure) are not known from Switzerland or adjacent Italy. The total size of the open areas on Monte San Giorgio is only 10 ha. This implies a high risk of extinction for small populations. The chance of spontaneous immigration of new species well adapted to the prevailing environmental conditions is probably extremely low.

The southern alpine endemic flora, having its centre of occurrence in prealpine areas east of Lake Como, is today represented on Monte San Giorgio only by *Leontodon tenuiflorus* and *Silene insubrica*; *Carex austroalpina*, listed by BECHERER (1972), has

not been found within the study area; *Gentianella insubrica* recorded by KOCH (1943) is now probably extinct. The populations of *Adenophora liliifolia*, *Bupleurum ranunculoides*, *Dianthus monspessulanus*, *Gentiana acaulis*, and *Leucanthemum heterophyllum* represent a group of taxa restricted to elevated areas in the southern Prealps. There are no indications of the time when these species invaded Monte San Giorgio. Were some of them already present during the last Glacial Period, surviving on the small nunatak of about 100 ha? The same applies to the isolated differential species: *Danthonia alpina*, *Potentilla alba*, *Dorycnium herbaceum*, *Euphorbia verrucosa*, and *Hypochoeris maculata*. The latter might have been more wide-spread in glacial times in the steppe that covered the lowlands of southern Europe (LANG 1994), from where they may have invaded and persisted because of special soil conditions, spontaneous fires, and human activity.

Secondary succession and threats to endangered plant populations

A depletion of species due to decreased human activity in recent times can be observed. There are some indications of disappearance of plant species within the last forty years. At times when farming was still common practice, open areas south of Cassina included *Carex tomentosa*, *Filipendula hexapetala*, some tussocks of *Chrysopogon gryllus*, and the endemic *Gentianella insubrica* (according to KOCH 1943: 592). *Crepis froelichiana* and *Gladiolus imbricatus* were recorded by H. Zoller (in LÜDI 1949). He observed hundreds of *Gladiolus* specimens growing in 1948 (personal communication). During six years of our extensive explorations, from 1988 to 1993, *Crepis froelichiana*, *Carex tomentosa*, and *Gentianella insubrica* have not been found in the study area. A small population of *Chrysopogon gryllus* was discovered on the experimental area P₂ (Fig.1) in 1990. The *Gladiolus imbricatus* population is estimated at a few dozen specimens, and *Filipendula hexapetala* is rare on the mountain today. Around 1985 *Epipactis palustris* was still observed in hundreds by E. Lienhard (personal communication) in small remaining open areas south of Cassina, where *M. arundinacea* is very abundant and *Rubus* spp., *Populus tremula*, and other shrubs and trees are now expanding. In 1993 just one flowering specimen of this orchid was surviving. The sites where *Epipactis palustris*, *Filipendula hexapetala*, and all the extinct populations once reported by KOCH (1943) and H. Zoller (in LÜDI 1949) are characterized by relatively moist soils. Obviously the process of succession has altered the species composition of these areas most thoroughly.

The joint effects of secondary succession and the 1965 fire on the composition of dominant species can roughly be reconstructed by comparing a relevé made by H. Zoller in 1948 (in LÜDI 1949) with the actual species composition. This relevé, with an area of about 200 m², included probably both deep and shallow soil conditions. H. Zoller considered it to be representative for the grasslands at the time. In 1948, *Bromus erectus* dominated, covering more than 50% of the relevé area, and *Molinia arundinacea* and *Danthonia alpina* were co-dominants with less than 25%; *Carex humilis* and *Carex montana*, with less than 5% each, were not as abundant as today. Obviously, secondary succession and fire led to the present predominance of *M. arundinacea* on deep and *Carex humilis* on shallow soils. No other documents are known with information on population size of other plant species at times of traditional farming. The performance of the other species under a traditional mowing regime is therefore hardly predictable, and only experimental plots will help to answer this question in the future.

The first air photograph of the study site dates from 1934. Later on, the area covered by wood gradually increased (STAMPFLI *et al.* 1992). The remaining open islets today represent about a quarter of the total open area of 1934. After the fire of 1965 open areas increased only temporarily, but the long-term effect of the fire was an accelerated spreading of the woody flora, particularly of *Quercus pubescens*, *Tilia cordata*, *Laburnum anagyroides*, and *Sorbus aria*. On more or less shallow soils, however, short shrubs have been observed to grow very slowly.

Today, after 35 years of abandonment, there is no evidence of further vigorous expansion of *M. arundinacea* clones; *M. arundinacea* seedlings have not been observed in most years. Within the remaining open grassland patches the process of secondary succession has reached a stage of relative stability, no changes in species composition can be observed within time intervals of five years. Dynamic changes are expected to occur at very slow rates. Major changes happen along the edges of the grassland patches, where shaded areas quickly increase because of fast growing shrubs and trees.

Even if there has been no drastic loss of species in the grasslands of Monte San Giorgio during the 35 years of abandonment, species diversity has declined, and populations of many plant taxa are today restricted to very small areas (Tab.4). There is a high risk that at least some of them may become extinct in the near future as a result of a further spreading of shrubs and trees or changed human activities. Once these populations are extinct on the mountain, there is very little chance of re-establishment, for the immigration rates will still be reduced by the progressive decline of unfertilized meadows in surrounding areas. Rare species have not immigrated a meadow nature reserve of about 1.5 hectares near Basel (Switzerland) that has been mown by conservationists and not fertilized for 15 years (BISCHOF 1992). Some of the threatened geographically isolated taxa of Monte San Giorgio may even represent unique relict populations.

Table 4. Rare, and (very) endangered plant species (LANDOLT 1991) in the grasslands on Monte San Giorgio.

Small populations growing on relatively deep soils:

<i>Adenophora liliifolia</i>	<i>Scorzonera humilis</i>
<i>Gladiolus imbricatus</i>	<i>Carex tomentosa</i> (extinct?)
<i>Filipendula hexapetala</i>	

Small populations growing on rocky or shallow soils:

<i>Bupleurum ranunculoides</i>	<i>Ophrys insectifera</i>
<i>Dianthus monspessulanus</i>	<i>Silene insubrica</i>
<i>Leontodon tenuiflorus</i>	<i>Gentianella insubrica</i> (extinct?)
<i>Lilium croceum</i>	

Endangered species still growing in great number:

<i>Asperula cynanchica</i>	<i>Fumana procumbens</i>
<i>Buphthalmum salicifolium</i>	<i>Hypochoeris maculata</i>
<i>Campanula glomerata</i> s.l.	<i>Inula hirta</i>
<i>Danthonia alpina</i>	<i>Iris graminea</i>
<i>Dorycnium herbaceum</i>	<i>Melampyrum cristatum</i>
<i>Euphorbia verrucosa</i>	<i>Potentilla alba</i>

Conclusions

Gerhard Lang has emphasized the high importance of ecosystems not affected by human activity (e.g. LANG 1983). Should seminatural ecosystems like the grasslands of Monte San Giorgio be conserved by human activities that have been resumed for this purpose? Or should such areas become 'passive' nature reserves in which human influence is reduced as much as possible?

In canton Ticino the area of seminatural grasslands containing rare species or a relatively high number of species has drastically declined and is estimated to amount to a few hundred hectares (based on 'Inventar der Tessiner Trockenstandorte', Systematisch-Geobotanisches Institut Universität Bern 1987). The few remaining unfertilized meadows at elevations below 1000 m are important environments for the survival of an increasingly threatened flora and fauna. Among them, the grasslands of Monte San Giorgio are of special importance, as they include a unique species composition. These species assemblages are probably very old. For hundreds of years they have been shaped by natural forces and human activity. The occurrence of a particular species can hardly be attributed to either natural or human forces, as we are not sure if grasslands species already existed in small open patches of the forests on very shallow soils before the forests were cleared the first time by humans.

We suggest that high priority be given to an effective conservation of the unusual flora and fauna on the one hand and that long-term studies be promoted to improve our understanding of human and natural processes that create and maintain these unique grasslands.

Three main goals of nature conservation have been suggested for different areas on Monte San Giorgio (STAMPFLI *et al.* 1992):

1. maintenance of the species diversity
2. restoration of *Danthonia alpina* - *Bromus erectus*-meadows
3. maintenance of the natural process of succession

These main goals will be implemented by five-year management concepts, which should be embedded in an overall conservation strategy including adjacent forests and grasslands. Different management practices will affect present plant and animal populations in different ways. The probable effects are listed here in the form of generalized hypotheses, which in turn are used as recommendations for future management practices:

No-management (abandonment, leading to secondary succession) raises the chance of destructive spontaneous fires. No mowing and occasional fires favour *Molinia arundinacea* and accelerate the process of the spreading of woody species, through which the areas of grassland species will further decline. This happens more rapidly on deep than on shallow soils; plant populations depending on relatively moist soils are most endangered.

No-management is therefore not recommended. However, some restricted areas where succession can be studied in the long-term would be of great value for further botanical and zoological research to improve future management practices.

Mowing increases the growth of reproductive shoots and species diversity in general, and cover proportions among dominant species are reversed, e.g. *Bromus erectus* and *Danthonia alpina* increase, *M. arundinacea* decreases. Mowing in August more efficiently affects *M. arundinacea* than mowing late in the season, as it prevents resource allocation to the roots.

Mowing is the most effective measure to guarantee a future existence of many rare grassland species and it is therefore strongly recommended; the date of mowing has to

be between July and October and the rhythm of mowing may be once a year or once every two or three years, both according to specially defined local conservation goals. Traditionally, most areas were probably mown once a year, however, the mowing rhythm of a particular area may have varied in time. The regularity of land-use activities has not been precisely documented nor have observations of its effects been made in the past. Therefore the long-term effects of different and variable mowing rhythms on single species are still unknown. Mowing at yearly intervals might be too intense on relatively shallow soils where the turf could be damaged, and, especially at unshaded sites, 'mesic' species (e.g. *Adenophora liliifolia*, *Succisa pratensis*, etc.) might decline as a consequence of increased drought stress; on the other hand, mowing at yearly intervals might not prevent the increase in dominance of grasses which benefit from elevated atmospheric nitrogen inputs (BOBBINK 1991). Long-term observations will provide the basis for a better understanding of these questions in the future.

Mowing has to be combined with wood cutting to prevent a further increase of shaded areas. After mowing and cutting the organic matter must be removed from the open grasslands.

Grazing donkeys prefer *M. arundinacea* and increase species diversity. The suggestion of using donkeys first arose from a discussion with a local farmer who argued that only donkeys would probably feed on the grasslands of Monte San Giorgio today. In an experiment (August and September 1989) donkeys preferably grazed on *M. arundinacea* and showed good adaptation to the local situation, where drinking water is scarce (A. Valsangiacomo & I. Visconti, unpubl. data). Certain areas on the mountain are suitable for grazing with donkeys, which should not be allowed prior to late August. Grazing intensity and grazing areas have to be well controlled to avoid damage of the sward. Grazing by other animals, however, is not recommended, as they might avoid *M. arundinacea* and select less abundant fodder plants. Grazing may easily cause undesired erosion on the slopes of Monte San Giorgio.

Removing litter in early spring favours *M. arundinacea*. It is not recommended. Controlled fire may be considered for management of open areas but it should not be used for maintaining a species composition typical of a meadow (BRIEMLE *et al.* 1987). Predictions of burning effects are extremely difficult, for conditions may vary a lot and cannot easily be controlled (SCHREIBER 1981). On the other hand it has been stated that various controlled burning techniques can be used that are cheaper than agricultural techniques (W. Riess, personal communication). Controlled burning requires well defined conditions of air temperature, air humidity, soil humidity, wind speed, and wind direction. Fire is therefore only recommended in the hands of a specialized fire-ecologist. It has to be used at a scale of ten by ten meters rather than of hectares. Fire effects have to be well studied.

Long-term financial contributions must be warranted for the management and the control of management effects. Scientific controls are essential for the improvement of management techniques and for the prevention of possible undesired changes resulting from suggested management practices or inappropriate application of management techniques.

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