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**Ecology and sociology of macromycetes in snow-beds
with *Salix herbacea* L. in the alpine Valley of Radönt
(Grisons, Switzerland)**

A

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Preface

L' HOMME QUI PLANTAIT DES ARBRES

Pour que le caractère d' un être humain dévoile des qualités vraiment exceptionnelles, il faut avoir la bonne fortune de pouvoir observer son action pendant de longues années. Si cette action est dépouillée de tout égoïsme, si l' idée qui la dirige est d' une générosité sans exemple, s' il est absolument certain qu' elle n' a cherché de récompense nulle part et qu' au surplus elle ait laissé sur le monde des marques visibles, on est alors, sans risque d' erreurs, devant un caractère inoubliable.

(Jean GIONO 1980)

The present work is the result of the author's idea to support efforts in restoration in the alpine zone with convenient ectomycorrhizal plants.

The mycosociological part of the study was well looked after by Prof. Dr. E. Horak. I express my thanks especially for his support in taxonomy and for critically reading the manuscript. Special thanks are due to Dr. Ivano Brunner, who supported the author' s ideas throughout the project and energetically assisted the ectomycorrhizal part of the study. Thanks are also due to Prof. Dr. E. Landolt and Dr. W. Huber for attentively reading the section plant sociology. I am grateful to Mr. H. Dissing (*Neottiella*), PD. Dr. A. Baici (Aphyllophorales) and M. Poulain (Myxomycetes) for the determination of uncertain taxa. Furthermore, I express my thanks to Dr. Ch. Scheidegger for checking the determined lichens and to PD Dr. Orlando Petrini for inspecting the moss taxa and for giving helpful advices in statistical evaluation. Thanks to Mr. Benno Mengis, software problems for evaluation of mapped data never became serious. I also appreciate the supervision of the soil analysis by Miguel Baldoma and the introduction by Bettina Schneider for microtome cutting and further processing of ectomycorrhizal material. For attentively reading the manuscript and correcting the English I am greatly indebted to Mr. Charles Gallo, and for interesting suggestions to Dr. R. Watling and Prof. Dr. M. Moser. Although Dr. Matthias Baltisberger was not professionally involved in this project he deserves my warmest gratitude for having offered financial support in form of a post in the herbarium during the last two years of the study.

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1. INTRODUCTION

In the northern hemisphere the genus *Salix* L. (willows) is distributed from the arctic belt throughout the temperate zones. The number of taxa ranges between 300 and 500 depending on the interpretation of the species definition (LAUTENSCHLAGER 1989). In Europe more than half of the known taxa are inhabitants of the Alps growing under harsh climatical conditions. In the alpine zone of the Swiss Alps, above treeline, four typical dwarf willows, characterized by their creeping growth habit dominate the snow-bed communities. Among them, *Salix herbacea* L. is restricted to acid soil conditions, whereas the others, viz. *S. reticulata* L., *S. retusa* L. and *S. serpyllifolia* Scop. are predominantly found on base-rich substrate (LANDOLT 1984). To enhance survival under the severe regime of the alpine zone, these dwarf willows are entering into a mutualistic relationship with different macromycetes, mostly represented by taxa of the Agaricales. The existence of ectomycorrhizae on rootlets of dwarf willows was first detected by FRANK (1888). Numerous fungal representatives in association with alpine *Salix* spp. (FAVRE 1955, KÜHNER & LAMOURE 1986, WATLING 1992) have been reported since but only in a few cases ectomycorrhizal symbiosis was proven with laboratory synthesis experiments (DEBAUD et al. 1981 a & b, ANTIBUS et al. 1981). Due to this plant-fungus interface the unfavourable climatic and environmental conditions are better endured and furthermore, enable the dwarf willows to colonize habitats inaccessible to other competing plant species. This fact, and the high capacity for rooting and producing cuttings, explain why willows are preferred plants used in organic architecture, e.g. restoration, safeguarding slopes and river shores from landslides (SCHIECHTL 1992).

1.1. PRESENTATION OF OBJECTIVES

The main objective of this study was to gain information about *Salix herbacea* and its ectomycorrhizal partners with the prospect of laying the foundations for restoration projects in the alpine zones with this plant- and fungus-system (PFS). In this context ecology and sociology of the macromycetes in snow-bed communities with *S. herbacea* and closely related associations were investigated during a three year period. From 1988 to 1990 during the snow-free vegetation periods, all observed macromycetes in 13 permanent investigation plots of 50 m² each were noted on excursions in weekly intervals whenever possible. Besides the list of the registered taxa, the main goal of this work was to record abundance, frequency and periodicity of the macromycetes. Furthermore, relationships between carpophore productivity of selected taxa and the

course of climatical parameters (microclimate) and soil properties were subjects of this study. The mapping of the carpophores and the snow-melting zones (isochiones) in 11 of the 13 permanent plots was carried out to better understand distribution patterns and association behaviour, especially between ectomycorrhizal taxa accommodated by the dwarf willow. It was further attempted to cultivate typical ectomycorrhizal macromycetes from fungal tissue (axenic cultures) and from the host plant *S. herbacea* from seeds as well as from cuttings. With these materials it was predicted to carry out ectomycorrhizal synthesis experiments, to produce inoculum and host plants and to provide basic knowledge about the PFS for future restoration projects, especially in the Swiss Alps.

1.2. BASICS

1.2.1. *Salix herbacea* L.

Salix herbacea is a representative of the genus *Salix* (*Salicaceae*). The distribution area of this dwarf willow is restricted to the northern hemisphere where this species predominantly occurs in the northernmost regions of America, Asia, Europe as well as in the Alps. There, *S. herbacea* can be found up to 3350 m, whereas in western Ireland it grows even at sea-level (HULTÉN 1958). At places with long snow covering (9 - 10 months), this dwarf shrub dominates snow-beds as the characteristic plant of the *Salicetum herbaceae* Br.-Bl. association (LANDOLT 1984). Its caulines and branches have subterranean growth and, therefore, only the leaves are visible, covering the soil with a low carpet. With this unique growth habit and its restriction to acid snow-bed communities in the alpine zone, *S. herbacea* is easily separated from the three other dwarf willows in Switzerland, viz. *S. reticulata*, *S. retusa*, and *S. serpyllifolia* occurring not strictly tied to habitats above treeline. The flowering season of *S. herbacea* commences shortly after the leaves have developed and lasts from the end of July until the end of August.

1.2.2. Mycoecology and mycosociology in alpine snow-beds

The alpine zone is defined as the region above treeline which in the research area is between 2100 and 2250 m and further characterized by the occurrence of closed patches of meadows on condition that soil properties are stable and snow covering lasts not too long. The upper limit coincides with the isotherme

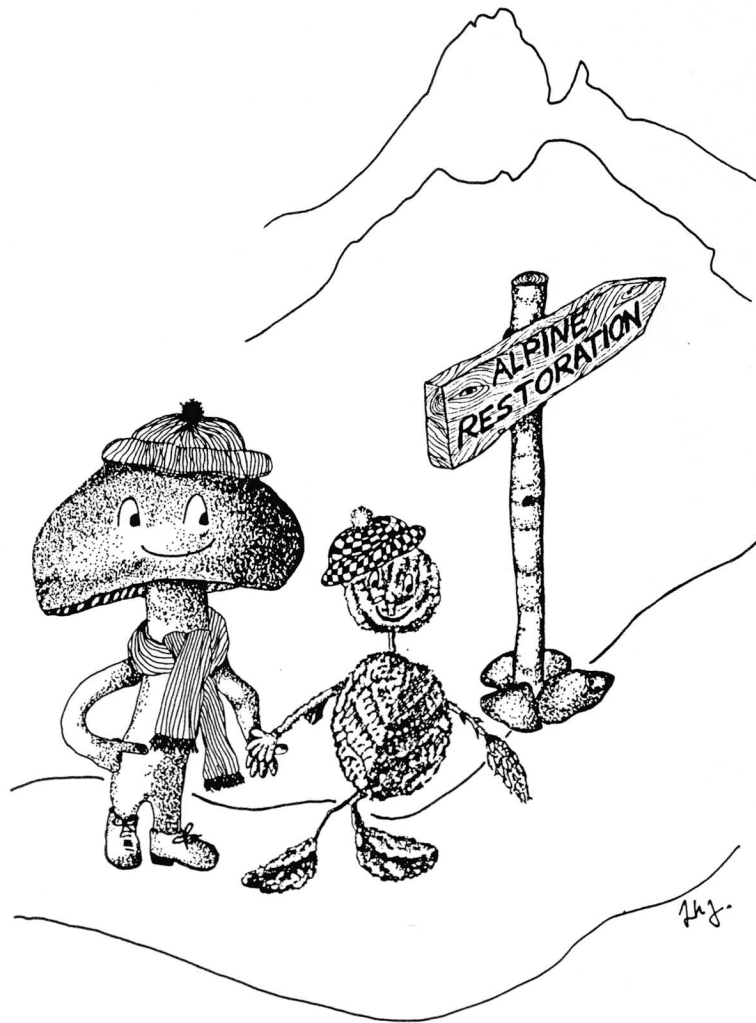
of the mean July temperature with about 5°C (LANDOLT 1984). In the actual research area this is situated about 2600 to 2700 m.

Studies about ecology and sociology of macromycetes in the alpine zone are rather rare. Investigations encompassing several years are known of the Alps from EYNARD (1977) and SENN-IRLET (1987). Whereas the former author restricted his study to macromycetes occurring in plant associations with *Salix herbacea* at two alpine localities in close neighbourhood in the French Alps, the latter observed different plant communities at numerous sites distributed over the Swiss Alps. Jules FAVRE (1955), the promotor of the alpine mycology, who investigated the Swiss National Park (SNP), situated in close vicinity to the research area of this study, also included ecological and sociological information in his otherwise more taxonomically oriented work. Furthermore, several studies were carried out in arctic regions. LANGE (1948-57) investigated the mycoflora of West Greenland and OHENOJA (1971) reported about the ecology of the larger fungi in Svalbard. PETERSEN (1977) studied the phenology of macromycetes in relation to different environmental factors and various other aspects of ecology in the arctic Godhavn area in West Greenland.

1.2.3. Ectomycorrhizae of alpine plants

Since FRANK (1888) described for the first time ectomycorrhizal symbiosis of alpine dwarf willows, viz. *Salix reticulata* and *S. retusa* the reports of further arctic-alpine plants with comparable symbiotic structures found in arctic and alpine habitats were appended. HESSELMAN (1900) detected on his polar expedition ectomycorrhizal rootlets not only on 15 different species of *Salix* (among them also *S. herbacea* L., *S. reticulata* L. and *S. rotundifolia* Trautv.), but also on *Betula nana* L., *Dryas octopetala* L., as well as on herbaceous *Polygonum viviparum* L. However, it was not before 1930 when PEYRONEL, based on more than 15 years of field experience, pointed to the relationship between ectomycorrhizal rootlets of alpine plants and the carpophores of macromycetes of *Amanita*, *Cortinarius*, *Lactarius*, *Russula* and others. Although his conclusions were convincing there was no definite proof of the mentioned relationships between plants and macromycetes. Only decades later successful laboratory synthesis experiments for ectomycorrhizae between alpine plants and macromycetes were realized. HACSKAYLO & BRUCHET (1972) were able to show the ability of alpine *Hebeloma* spp. to form ectomycorrhiza with *Pinus virginiana* Mill., a system not found in nature. ANTIBUS (1980) demonstrated the ectomycorrhizal relationships under laboratory conditions between *Salix rotundifolia* Trautv. and *Cenococcum*

geophilum Fr., *Entoloma sericeum* (Bull.) Quél. and *Hebeloma pusillum* J. Lange, which were also observed in nature. DEBAUD (1983) synthesized the ectomycorrhiza between *Dryas octopetala* L. and *Hebeloma alpinum* (J. Favre) Bruchet and *H. marginatulum* (J. Favre) Bruchet, two well known partnerships throughout the alpine zones.



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Fig. 1: New perspectives in alpine restoration ?! Reproduced with kind permission of V. Morgen, 19.2.1994.

2. MATERIAL AND METHODS

2.1. ABBREVIATIONS

The following abbreviations are used in text, Tables and Figures:

A	: first soil section (0/-4 cm)	min.	: minimum
ad int.	: ad interim	ml	: milliliter
ap.	: apud	mm	: millimeter
B	: second soil section (-4/-8 cm)	µm	: micrometer
b.p.	: before present	MMN	: modified Melin Norkrans (agar)
cf.	: refer to	OI	: Ochiai index
d	: day	org.	: organic
E	: Evenness index	PFS	: plant- and fungus-system
f.	: forma	rec.	: record (carpophore group)
FAA	: Formaldehyd	sl.	: sensu lato
Fig.	: figure	SLF	: Institut für Schnee- & Lawinen Forschung
GR	: Graubünden (Grisons)	SMA	: Schweizerische Meteorologische Anstalt
H'	: Diversity index	SNP	: Schweizer Nationalpark
J	: Jaccard index	sp.	: species
diam.	: diameter	ss.	: sensu
m	: meter	Tab.	: table
max.	: maximum	var.	: variation
Met.	: meteorological (stations)	WSL	: Institut für Wald, Schnee & Landschaft
mg	: milligramme	X ²	: chi-square value

2.2. RESEARCH AREA: VALLEY OF RADÖNT (GR)

2.2.1. Geographical location

The research area is located between Davos (1560 m) and Susch (1426 m) south-east of the Flüela Pass (2383 m) in the valley of Radönt, in the canton of Grisons, Switzerland (Fig. 2).

2.2.2. Climate

The nearest climate stations (Fig. 3) of the SMA net (Schweizerische Meteorologische Anstalt) are situated in Davos (1590 m; 12 km WNW) and on the Weissfluhjoch (2690 m; 16 km WNW). The Flüela Pass marks a rather weak weather divide between the Landwasser Valley and the Lower Engadine which is characterized by comparatively low precipitation (Tab. 1), higher temperatures and wind calm. Therefore, the side valleys south-east of the Flüela Pass are already influenced by the more continental climate of the Lower Engadine

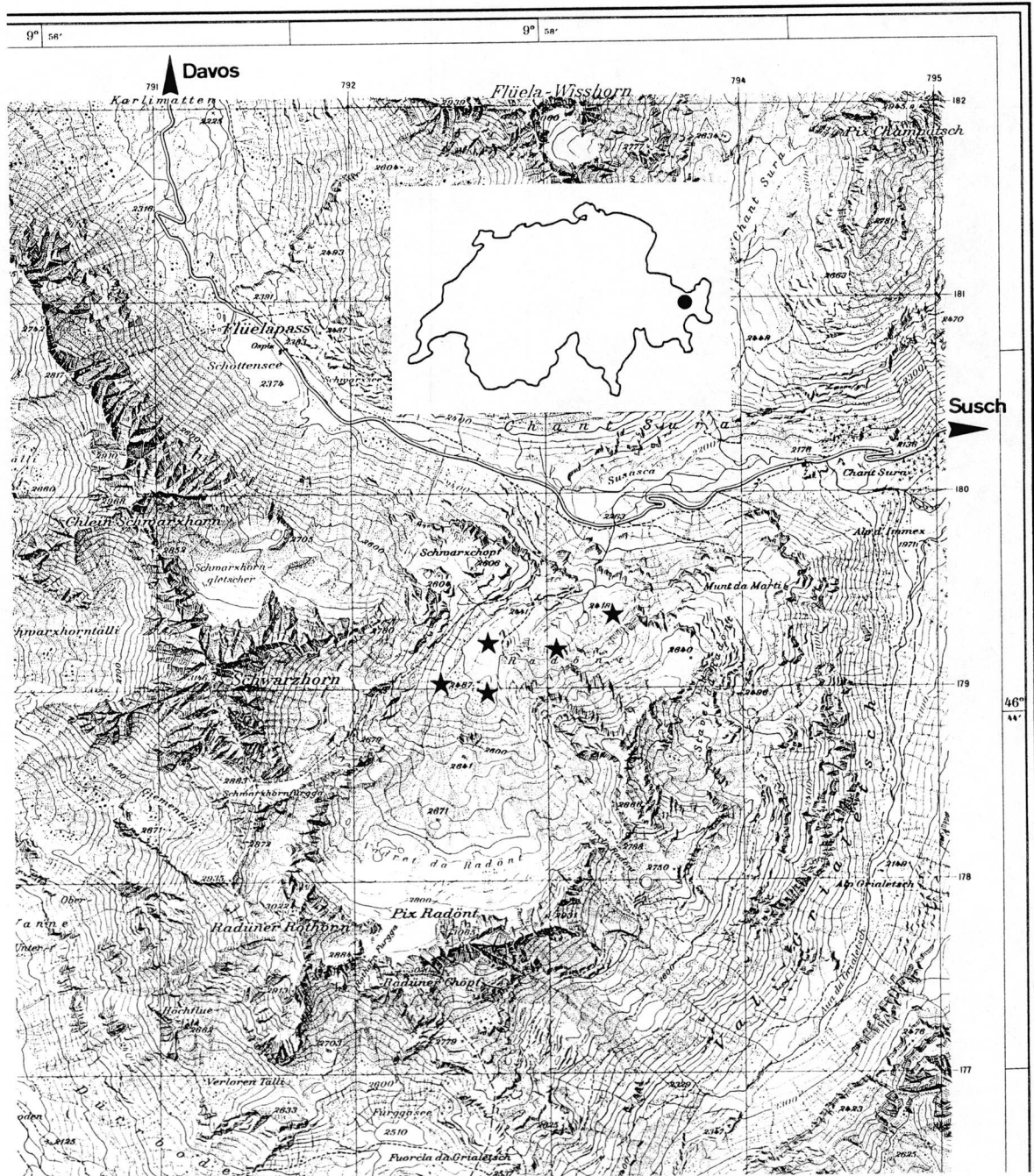


Fig. 2: Geographical location of the research area (●) in Switzerland and location of the five investigation sites (★) near the Flüela Pass in the Valley of Radönt (cf. Fig. 4). Reproduced with kind permission of the "Bundesamt für Landestopographie" (31.1.1994).

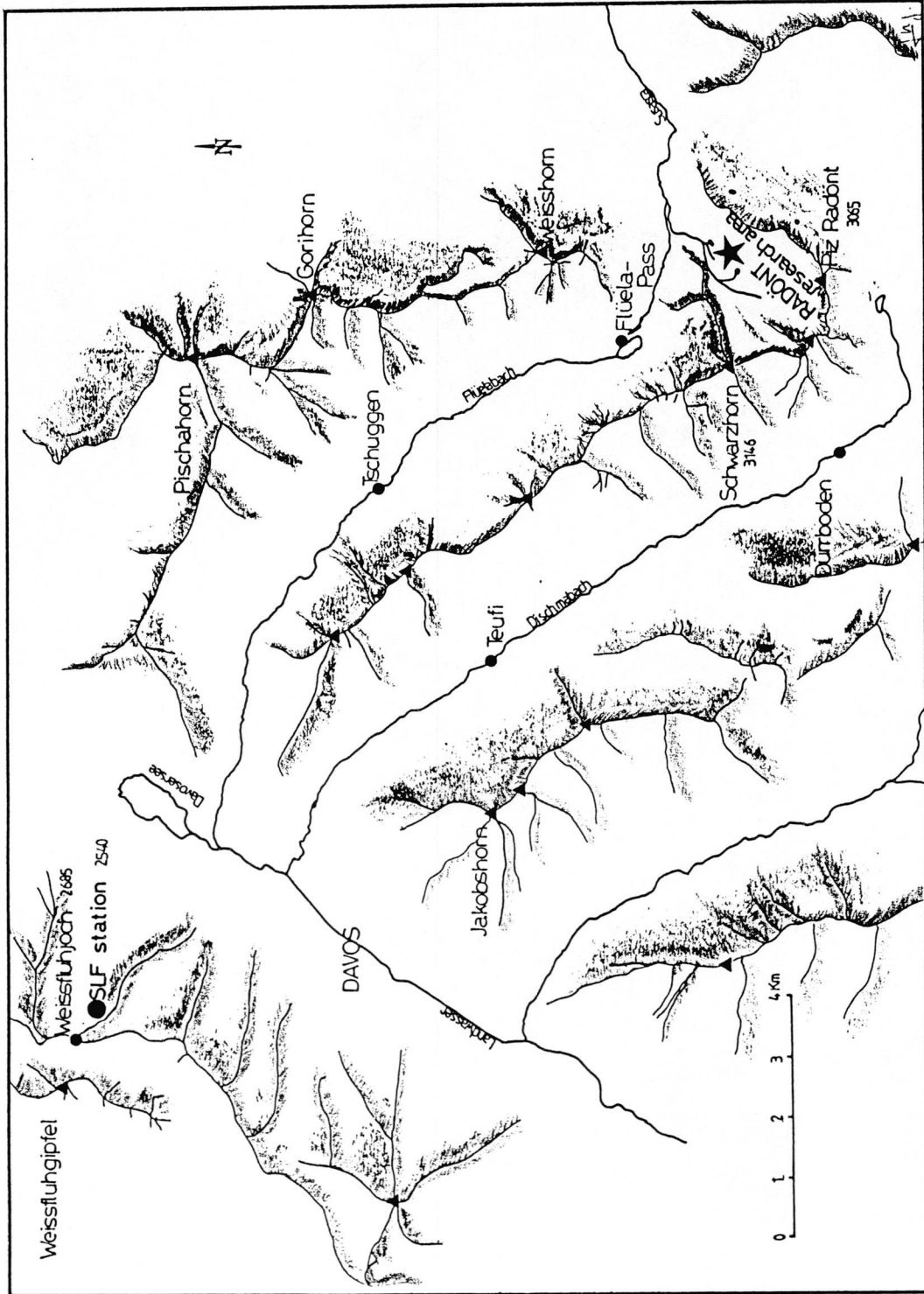


Fig. 3: Geographical situation of the research area (★) in the Valley of Radont and the reference meteorological station SLF (●) on the Weissfluhjoch (Davos).

(MÖRIKOFER 1935, SCHÜEPP 1967). On the other hand, in winter time Radönt has above average snowfall carried in from the side of the Landwasser Valley (GENSLER 1978, VUAGNEUX 1983). These climatic facts combined with the altitude (2383 m) are responsible for the Flüela Pass being a dangerous Alp traverse because of avalanches.

Table 1: Comparison of precipitation [mm] east of the Flüela Pass in the Lower Engadine (Scoul) and west in the Landwasser Valley (Davos) and Prättigau (Klosters), respectively. Numbers are mean values based upon data registered during the period from 1931-1960 (GENSLER 1978).

Precipitation in mm from 1931-1960	Klosters 1200 m	Davos 1560 m	Scoul 1253 m
Winter	295	212	131
Spring	279	191	122
Summer	454	391	261
Fall	296	224	181
year (Total)	1324	1018	695

2.2.3. Geology

The bedrock of the research area belongs to the Silvretta formation (VUAGNEUX 1983) which is dominated in the Valley of Radönt by ortho- and paragneiss. Of the 13 permanent investigation plots, 11 (plot 3-13) are situated on mixed gneiss with low content of ortho material ($\text{pH}_{[\text{H}_2\text{O}]}$ 3.5-4.2), whereas two (1 and 2) are located on moraine deposits, dating from the Quaternary glaciation ($\text{pH}_{[\text{H}_2\text{O}]}$ 4.9-5.4) of the glacier of Radönt (HANTKE 1978, 1980, SPAENHAUER et al. 1935).

2.3. RESEARCH SITES WITH PERMANENT PLOTS

In the Valley of Radönt the 13 permanent plots are distributed among five different sites (Tab. 2, Fig. 4) between 2400 m and 2500 m. The main criterion for choosing the plots was to get the most possible homogeneity concerning the two dominating plant associations viz. *Salicetum herbaceae* Br.-Bl. and *Polytrichetum sexangularis* (Rübel) Br.-Bl. In addition, one plot each has been selected in pioneer vegetation, viz. *Eriophoretum scheuchzeri* (Brockm.-Jerosch) Rübel and *Oxyrietum digynae* (Lüdi) Br.-Bl., as well as in a *Caricetum curvulae* (Kerner) Brockmann-Jerosch, in a *Loiseleurio-Cetrarietum* Br.-Bl. (BRAUN-BLANQUET 1964) and two mixed plots with alternating,

Radönt

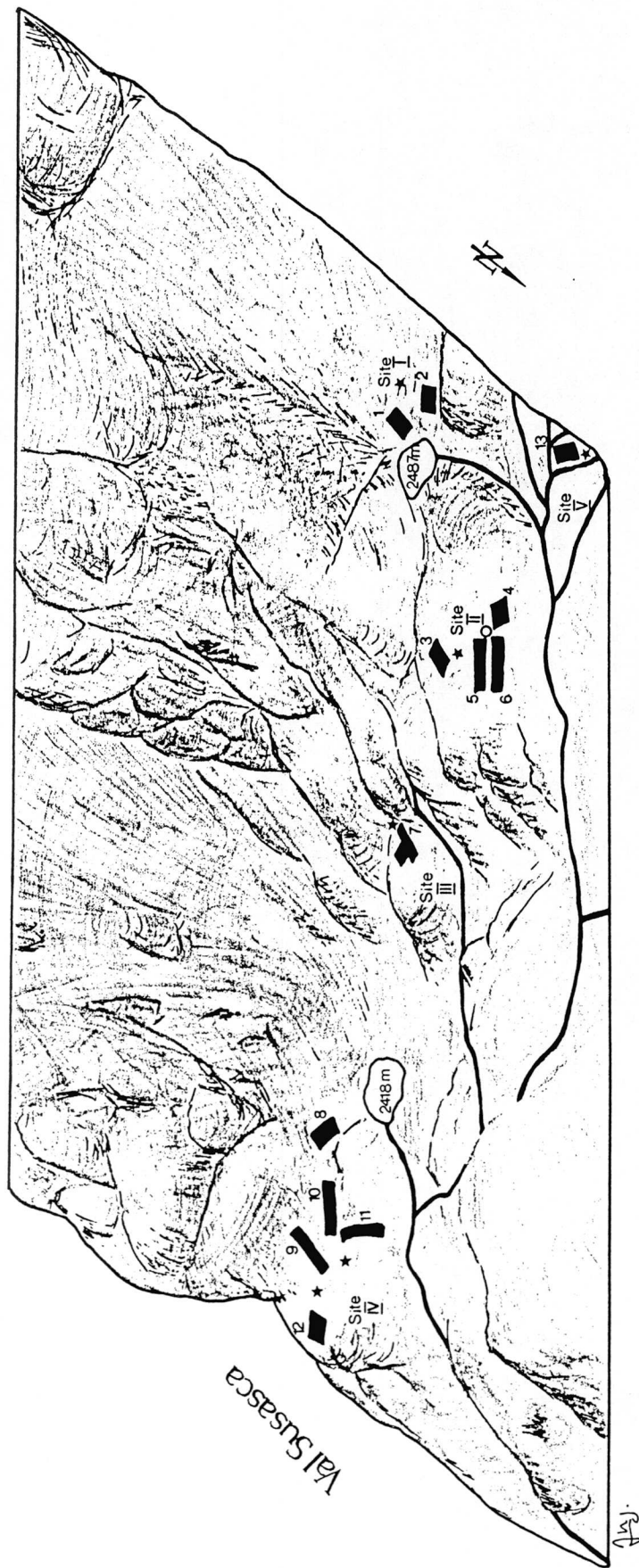


Fig. 4: Location of the five investigation sites (I- V) and the corresponding 13 permanent plots (■; 1-13) in the Valley of Radönt. ★ = met. station; ○ = additional max. -min. -thermometer.

Table 2: Characterization of the research sites (I-V) with the corresponding investigation plots (1-13) of 50 m² each.

sites	I	II	III	IV	V
m.a.s.l.	2488	2484-2490	2470	2420-2425	2484
coordinates	46°44'06"/ 9°57'43"	46°44'13"/ 9°57'42"	46°44'10"/ 9°58'6"	46°44'20"/ 9°58'11"	46°44'33"/ 9°57'43"
investigation plots	1+2	3-6	7	8-12	13
climate stations:					
-Min.-max.-therm.	1	2	1	2	1
-PVC rain gauges	1	1	1	2	1

heterogeneous plant associations, viz. *Polytrichetum*, *Salicetum* and *Caricetum* (Tab. 3).

Each of the rectangular plots covered an area of 50 m², viz. 2m x 25m or 4m x 12.5m (Tab. 3). An exception was plot 7 which forms a T (2m x 15m + 4m x 5m).

Table 3: Ecological and sociological characterization of the 13 permanent investigation plots.

plot	vegetation	shape (m) sum: 50 m ²	inclination	remarks
1	<i>Oxyrietum digynae</i>	4 x 12.5	flat	at shores of glacier lake
2	<i>Eriophoretum scheuchzeri</i>	4 x 12.5	flat	among brooklets
3	<i>Salicetum herbaceae</i>	4 x 12.5	flat	-
4	<i>Caricetum curvulae</i>	4 x 12.5	slight W-E	along a rib
5	<i>Polytrichetum sexangularis</i>	2 x 25	flat	palsa structures
6	<i>Salicetum herbaceae</i>	2 x 25	flat	along a rib
7	<i>Salicetum herbaceae</i>	2x15 + 4x5	flat	T-shaped
8	<i>Polytrichetum sexangularis</i>	4 x 12.5	slight S-N	ends avalanche channel
9	<i>Salicetum herbaceae</i>	2 x 25	slight E-W	-
10	<i>Salicetum herbaceae</i> / <i>Polytrichetum sexangularis</i>	2 x 25	slight S-N	transitional stage
11	<i>P. sex.</i> - <i>S. herb.</i> - <i>C. curv.</i> - <i>P. sex.</i> - <i>S. herb.</i>	2 x 25	depressions and ridges	transsect W-E, <i>S. herb.</i> dominant
12	<i>Loiseleurio-Cetrarietum</i>	4 x 12.5	slight E-W	-
13	<i>Salicetum herbaceae</i>	4 x 12.5	slight W-E	among brooklets

2.4. MICROCLIMATIC INVESTIGATIONS

2.4.1. Precipitation

In order to measure precipitation (rain and snow on soil surface), PVC funnels of 20 cm diam. tightly connected to 2-liter PVC bottles were buried into the soil (measure level at soil surface). These containers were emptied and the water content measured by using a 250 ml measuring cylinder (accuracy: $\pm 2\%$) during the visits at one or two week intervals. The loss of water through evaporation per week under laboratory conditions was found to be at the most 7% (BRUNNER 1987).

The registered precipitation captured by the funnel opening (314 cm²) was converted to m² values. The daily precipitation has been calculated by dividing by the number of days between two subsequent excursions. The weekly total sum results from the addition of the daily precipitation from Monday to Sunday (BRUNNER 1987, GRIESSER 1992).

2.4.2. Snow covering and mapping of snow-melting zones

During winter time (1988/89 and 1989/90) the research area was visited monthly (January to May) to measure the snow depth in all plots (Tab. 4). For this reason measuring poles, with a height of 1.5 m above ground each (with 10 cm measuring intervals), were hammered into the soil at every plot. Furthermore photographs were taken of every site. From mid-May to July investigation took place weekly to map and document the snow melting process.

Table 4: Excursion dates for measuring snow height (January to mid May) and mapping of snow-melting zones (mid May to July) in the permanent plots (1-13).

	1989	1990
January	4.	13.
February	13.	10.
March	25.	17.
April	27.	1./18.
Mai	14./22./28.	5./21./30.
June	3./10./17./25.	4./9./16./24./30.
July	2./7./9./13./16./23.	7./14./21./28.
August	---	3.

2.4.3. Maximum and minimum air temperatures

At the soil surface on each of the five sites the extreme air temperatures were registered using maximum-minimum thermometers. The standard deviation of the applied measuring instruments evaluated under laboratory conditions is $\pm 1\%$ (see also BRUNNER 1987). During the vegetation period (July to October) the maximum and minimum air temperatures were noted together with rain totalisator data on each excursion.

2.5. SOILS

2.5.1. Sampling and processing of soil cores

After mycological field work has ended in summer 1991, soil samples were taken from all plots by using a cylindric drill (diam.: 5 cm). The six samples, randomly distributed within a plot, have been split into two sections (A: 0/-4 cm and B: -4/-8 cm). For further processing in the laboratory the corresponding soil core sections were thoroughly mixed and have subsequently been used for analysis, following techniques proposed by STICHER et al. (1971) and SCHEFFER & SCHACHTSCHABEL (1984). In order to measure volume and density, separate soil samples of equal volume (157.1 cm³) were taken from each plot.

2.5.2. Physical and chemical analysis

All samples were air dried in the laboratory and subsequently separated into bulk and skeleton using a sieve of 2 mm mesh diam.

Physical soil parameters

Proportional volume (%V/V) of the skeleton and bulk density (%) were calculated (dry weight / volume) using the above-mentioned additional soil samples of equal volume. For further chemical analysis, only the bulk portion was examined.

Chemical soil parameters

Soil reaction (pH): The bulk pH was electrometrically determined with a Hach One analyzer (STICHER et al. 1971) of both, a watery suspension and a 0.01 M CaCl₂ solution (bulk : H₂O_{dest.}, 0.01 M CaCl₂, respectively = 1 : 2.5).

CaCO₃: The calcium carbonate content of the soil samples was disintegrated with a 1 M H₂SO₄ solution. The released CO₂ was determined after absorption on sodium asbestos.

Humus: The humus content was evaluated after reaction of the bulk samples with $K_2Cr_2O_7$ following the titration method (SCHLICHTING & BLUME 1966).

Organic C (C_{org}): Organic C was calculated as the difference of the total C amount ($\% \text{ humus} = \% C_{tot.} \times 1.724$) and the anorganic C number (from $CaCO_3$ experiment).

Nitrogen N (N_{total}): Determination of N_{total} after Kjeldahl, by disaggregation with H_2SO_4 (SCHLICHTING & BLUME 1966).

C/N ratio (C_{org}/N_{total}): The ratio between $C_{org.}$ and N_{total} indicates the biotic activity i.e. decomposition of dead organic matter in the soil (SCHROEDER 1984).

Phosphate (PO_4): Determination of extractable phosphate with bicarbonate after Olson (STICHER et al. 1971).

2.6. VEGETATION

2.6.1. Vegetation analysis

In spring 1990 and summer 1989 and 1990 the vegetation of each plot was studied and registered by employing the BRAUN-BLANQUET method (1964, 1971) in order to classify the plant communities. The frequency of the plant taxa was evaluated using the following scale: r: rare; +: <1%; 1: 1-5%; 2: 5-25%; 3: 25-50%; 4: 50-75%; 5: 75-100%. Taxonomy of the phanerogames follows HESS et al. (1976, 1977, 1980). Mosses and lichens were collected during two excursions in 1989 and 1990. Only fertile samples were taken for identification. Considering the large area investigated, the list of these cryptogams is only fragmentary. The nomenclature of the mosses follows FRAHM & FREY (1983) and SMITH (1980), whereas the lichens are determined after WIRTH (1980, 1987), POELT (1969) and POELT & VEZEDA (1977, 1981).

2.6.2. Evaluation of plant ecological indicator values

The environmental factors which influence a biocoenosis can be assessed with ecological indicator values of the plants present. The empirical values are based upon a scale divided into 5 parts (LANDOLT 1977):

F: humidity value [1: very dry, 5: wet, soaked soils]

R: reaction value [1: very acid, 5: alkaline (pH > 6.5)]

N: nutrient value [1: very poor soils, 5: over-rich supply of nutrients (nitrogen)]

H: humus value [1: raw soil, 5: raw humus, peat]

D: dispersion value [1: rocks, 5: clayey, peaty or poorly ventilated soils (poor in oxygen)]

L: light [1: very shady places, 5: full light]

T: temperature [1: cool areas, mostly alpine, 5: in warmest sites (southern Europe)]

K: continentality [1: oceanic, 5: continental]

The corresponding mean values for the plant sociological investigations were calculated after LANDOLT (1977). Taxa with frequency + were weighted once, with frequency 1 twice, with frequency 2 three times and so forth.

2.7. MYCOLOGICAL INVESTIGATIONS

2.7.1. Methodical problems

Assessing of sociology and ecology of macromycetes (cap > 1 mm in diam.) within a defined association definitely depends on the occurrence of their reproductive carpophores. Only they do have (mostly) enough characteristics, necessary for a successful determination. On the other hand the main part of the individuals, the vegetative mycelium growing in the soil, is poorly differentiated and not available for direct observation. In addition, recording macromycetes is complicated by their sporadic and unpredictable fructifications and mostly short lifespan.

To receive a quite complete spectrum of the mycoflora it is therefore necessary to visit the research area weekly during the main fructification periods for several years (WINTERHOFF 1984). The situation in the alpine zone becomes more tiresome because one has to tackle snowfall as well as frequent frosts and desiccating winds during the vegetation period. These are all reasons that may prevent fructification or may be responsible for serious deformities on carpophores resulting in undefinable collections.

2.7.2. Literature used for determination of the macromycetes

The subsequent selected list of mycological literature represents the applied works for determination and is not necessary a citation of the most recent publications:

Agaricales, Russulales: BRESADOLA (1927-32), FAVRE (1948, 1955, 1960), HANSEN & KNUDSEN (1992), KÜHNER & ROMAGNESI (1953, 1977), LANGE (1935-1940), LANGE (1948-1957), MOSER (1983 a), ORTON (1960)

Agrocybe: WATLING (1982)

Amanita: BAS (1977, 1982), GERHOLD (1986), WATLING (1985)

Arrhenia: HØILAND (1976), KÜHNER & LAMOURE (1972), MILLER (1968)

- Astrosporina*: HORAK (1987 a), KÜHNER (1988), KÜHNER & BOURSIER (1932), KÜHNER & LAMOURE (1986), MILLER (1987), STANGL & VESELSKY (1974)
- Collybia*: BREITENBACH & KRÄNZLIN (1991), MOSER & RAMESEDER (1993)
- Cortinarius*: BON (1992 a), BRANDRUD et al. (1990), LAMOURE (1969, 1977 a, 1978, 1986, 1987, 1991), HORAK (1987 b), LAURSEN & AMMIRATI (1982, 1987), MOSER (1987)
- Dermocybe*: HØILAND (1983), LAMOURE (1984)
- Entoloma*: KÜHNER (1977 c) NOORDELOOS (1979, 1980, 1984, 1987), NOORDELOOS & GULDEN (1989)
- Galerina*: GULDEN (1980, 1987), KÜHNER (1935), SMITH & SINGER (1964)
- Hebeloma*: BRUCHET (1970), GROEGER (1987, 1988), RÜCKER (1987), VESTERHOLT (1989), VESTERHOLT & WEHOLT (1985)
- Hemimycena*: LAMOURE (1973)
- Hygrocybe*: GALLI (1985), KÜHNER (1977 a, b)
- Hypholoma*: WATLING & GREGORY (1987)
- Inocybe*: BON (1992), KÜHNER (1988), KÜHNER & LAMOURE (1986), KUYPER (1986), SENN-IRLET et al. (1990), STANGL (1989)
- Laccaria*: MUELLER (1991 a, 1991 b, 1992), MUELLER & VELLINGA (1986), SINGER (1977)
- Marasmius*: CLÉMENÇON (1982 a), BREITENBACH & KRÄNZLIN (1991)
- Mycena*: BREITENBACH & KRÄNZLIN (1991), GULDEN & JENSSEN (1982), MAAS GESTERANUS (1980 a & b, 1983, 1984, 1986, 1988)
- Naucoria*: KÜHNER (1981), MOSER (1978)
- Omphalina*: LAMOURE (1974, 1975, 1982 a), CLÉMENÇON (1982 b), POELT & JÜLICH (1969)
- Panaeolus*: WATLING & GREGORY (1987)
- Psilocybe*: LAMOURE (1977 b), ORTON (1969), WATLING & GREGORY (1987)
- Russula*: BON (1988 b, 1993), KNUDSEN & BORGES (1982, 1992), KÜHNER (1975 b), SKIFTE (1989)
- Lactarius*: KÜHNER (1975 a)
- Aphylophorales**: JÜLICH (1984), BREITENBACH & KRÄNZLIN (1986)
- Thelephora*: LARSEN (1968), SVRCEK (1960)
- Tomentella*: LARSEN (1968)
- Gastromycetes**: JÜLICH (1984), GROSS et al. (1980)
- Bovista*: KREISEL (1967)
- Hymenogaster*: GROSS (1980), SCHWÄRZEL (1975), SÖHNER (1962), HESSE (1891)
- Lycoperdon*: DEMOULIN (1972), JÜLICH (1984)
- Ascomycetes**: BREITENBACH & KRÄNZLIN (1981), DENNIS (1978), MAGNES & HAFELLNER (1991)
- Cheilymenia*: SCHUMACHER (1992)
- Mitruia*: DENNIS (1978)
- Neottiella*: DISSING & SIEVERTSEN (1983)
- Peziza*: MOSER (1963 a)
- Sclerotinia*: KOHN (1979)
- Scutellinia*: SCHUMACHER (1990, 1993)
- Myxomycetes**: MARTIN & ALEXOPOULOS (1969)
- Didymium*: MARTIN & ALEXOPOULOS (1969)

2.7.3. Observation period and excursion dates

During the vegetation periods (July to October) between June 1988 and October 1990 a total of 47 excursions took place, lasting 1 to 3 days, whenever possible in weekly intervals, to record ecology and sociology of macromycetes in the 13 permanent plots (Tab. 5).

In the first year of the study fructification in mass production, snowfall during summer time, and military manoeuvres declaring the research area as a closed region, prevented an unbroken weekly observation cycle of the plots.

Table. 5: Excursion dates (first day of 1 to 3 day trips) during the vegetation period of collecting macromycetes in the 13 permanent plots.

		1988	1989	1990
week	month			
27	July	10.7.	9.7.	7.7.
28		17.7.	16.7.	14.7.
29		24.7.	23.7.	21.7.
30		31.7.	29.7.	28.7.
31	August	7.8.	5.8.	4.8.
32		14.8.	12.8.	11.8.
33		21.8.	17.8.	19.8.
34		28.8.	24.8.	27.8.
35	September	4.9.	1.9.	1.9.
36		11.9.	9.9.	--
37		18.9.	16.9.	10.& 16.9.
38		25.9.	24.9.	22.9.
39	October	2.10.	1.10.	29.9.
40		9.10.	8.10.	6.10.
41		16.10.	--	12.10.
42		23.10.	--	20.10.
43		30.10.	--	--

2.7.4. Collecting, processing and determination of macromycetes

The carpophores of all larger Basidio- and Ascomycetes occurring within the plots and one meter outside their borders were registered and accurately mapped. During collecting, care was taken not to step onto the actual plot area, so that any trampling effect (especially concerning the vegetative mycelium in the soil) was avoided. The number of basidiomata and the names of taxa whose identification was unambiguous were noted already in the field. To avoid double counting the basidiomata were decapitated, leaving the pileus at the actual collecting spot. In case of uncertain and unknown taxa collections were mapped, macro features (veil, colour, smell, taste, substrate) noted, each

population packed with its appropriate collecting number separately in little plastic boxes padded with wet moss and taken to the laboratory. The relevant descriptions were completed with drawings of the carpophores (entire and in section; scale 1:1) and detailed data after examination with a Wild M3 dissecting microscope. On a drier the collections were dried at approximately 50°C, then packed in small paper bags and stored until microscopical analysis. Microscopic features of exsiccata (little pieces of cap cuticle, gills and stem cuticle) were soaked in 4% KOH and analysed with a Leitz Laborlux K microscope. As a rule the magnification of the original sketches was: Pileipellis structures 500 x, cheilo- and pleurocystidia 1000 x and spores 2000 x; all drawn with a Leitz drawing tube. Only after completing documentation it was possible to identify taxa using specialist literature (cf. chapter 2.7.2.). Determined specimens were compared with material from Herbarium Z-ZT and a few collections were sent to specialists. During the three year investigation period 1298 collections were documented and microscopically analysed. Representative exsiccata of each reported taxon are deposited in Herbarium Z-ZT.

2.7.5. Investigated taxonomic macromycete groups

In this work only macromycetes having carpophores visible with naked eye, are treated. Concerning Basidiomycetes the main attention was focused on Agaricales, although a few conspicuous representatives of Aphylophorales and Gastromycetes are also included. Ascomycetes were collected likewise and even one Myxomycete, *Didymium squamulosum* (Alb. & Schw.) Fr. is reported.

2.7.6. Mapping of macromycetes in permanent plots

Except for the the two pioneer plots (1 & 2) all observed macromycetes of the other plots (3-13) were mapped. Each collection (i.e. a group of basidiomata of the same taxon within a basal area of 5 cm in diam.; following designated as record) has been protocolled with its relative location and number of individual carpophores. During this procedure care was taken not to step onto the actual plot. Also taken into account was a 100 cm wide zone around the plot which was walked on for scanning for macromycetes (GRIESSER 1992) and, therefore, disturbed through soil condensation along the paths.

The result of this study related to an actual mapping area of 1073 m² composed of 5 x 108 m² (plot 5, 6, 9, 10, 11), 5 x 87 m² (plot 3, 4, 8, 12, 13) and 98 m² of plot 7 (cf. chapter 2.3.).

2.7.7. Ecological significance of macromycete mapping

The long term mapping of macromycetes occurring within defined permanent plots allows the assessment of different aspects regarding space and time, i.e. dispersion of basidiomata, productivity, spreading and competition of ectomycorrhizal mycelia associated with *Salix herbacea*.

2.7.8. Evaluation and presentation of mapping data

1. Association analysis of selected species pairs: Concerning the interspecific association analysis all six plots of the *Salicetum herbaceae* and plot 8 of the *Polytrichetum sexangularis* community were considered. The record data, the analysis is based upon are restricted to those records registered inside the actual plot borders to guarantee the same surface area of 50 m² in all plots. Furthermore only taxa with a frequency of at least 10% (20 records from 1988-90) were considered.

A net with a raster unit of 50 x 50 cm (sampling unit) was applied to each statistically investigated plot for checking the presence and absence of the selected pairs of macromycetes. The results of this check were registered in the following contingency or species association table (PIELOU 1977).

	species B		
	present	absent	
species A			
present	a	b	a+b = m
absent	c	d	c+d = n
	a+c = r	b+d = s	
			m+n = r+s = N

The 2 x 2 table contains observed values for each of the cells (a, b, c, d) from the sample of the size N. To test for association a chi-square (X²) test statistic can be used to test the null hypothesis of independence in the 2 x 2 table.

The chi-square test statistic is computed as

$$X^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

which is a summation over the four cells (**a**, **b**, **c**, **d**) of the above mentioned 2 x 2 contingency table. The expected value for cell **a** is given by

$$E(a) = \frac{(a+b)(a+c)}{mnrs}$$

We reject the null hypothesis that the co-occurrence of species A and B is independent and conclude that they are associated if:

$$> 3.82 \text{ (5\% significance level)}$$

$$X^2 = \frac{N(|ad - bc| - N/2)^2}{mnrs}$$

$$> 6.64 \text{ (1\% significance level)}$$

There are two types of associations:

1.) **Positive:** If observed $a > E(a)$, that is, the pair of species occurred together more often than expected if independent.

2.) **Negative:** If observed $a < E(a)$, that is, the pair of species occurred together less often than expected if independent.

The Index of OCHIAI (1957) was performed to test the relationships between species pairs without considering **d**, that is, the number of joint absences. The Ochiai Index is based on the geometric mean of a/m and a/r , that is the joint occurrences of the two species compared to the total occurrences of species A and species B, respectively.

$$OI = \frac{a}{\sqrt{(a+b)}\sqrt{(a+c)}}$$

The index is equal to 0 at "no association" and 1 at "maximum association".

2. Correspondence analysis: For comparing the results of the X^2 test and the Ochiai indices a correspondence analysis was performed for three Salicetum plots (3, 7, 13) using the software package SIMCA-2 (GREENACRE 1986, 1988). The analysis is based on the same data set as used for the above mentioned statistics.

3. Qualitative comparison of taxa between the individual investigation years 1988-90: For all 13 investigation plots the qualitative comparison of the corresponding macromycete taxa was calculated for the three observation years (1988-90), comparing the three individual years among each other (88/

89, 88/89 and 89/90). For this reason the Jaccard index (JACCARD 1908) was performed, which is

$$J = \frac{a}{a+b+c}$$

where **a** is the number of common taxa in the pairs of years compared, **b** the number of taxa occurring only in the one year and **c** the number of taxa occurring only in the other year.

The mean value of all compared pairs of years is based on the equation

$$\bar{J} = \frac{1}{n} \sum_{i=1}^n \frac{a_i}{a_i + b_i + c_i}$$

where **n** is the total number of the year pairs compared.

4. Diversity and Evenness Indices: For all 13 investigation plots the diversity index following SHANNON & WIENER (1949) and the evenness index proposed by PIELOU (1977) were calculated.

The equation for the Shannon function, which uses natural logarithm (ln), is

$$H' = \sum_{i=1}^s (p_i \ln p_i)$$

where **H'** is the average uncertainty per species in an infinite community made up of **S*** species with known proportional abundances $p_1, p_2, p_3, \dots, p_{s^*}$. **S*** and the p_i 's are population parameters and, in practice, **H'** is estimated from a sample as

$$H' = \sum_{i=1}^s \left[\left(\frac{n_i}{n} \right) \ln \left(\frac{n_i}{n} \right) \right]$$

where n_i is the number of individuals belonging to the *i*-th of **S** species in the sample and **n** is the total number of individuals of the sample.

The evenness index is

$$E = \frac{H'}{\ln S}$$

which expresses **H'** relative to the maximum value that **H'** can obtain when all species in the sample are perfectly even with one individual per species (i.e., $\ln S$).

5. Mapping data in two-dimensional figures: All records of selected characteristic macromycetes in snow-bed associations (plot 3,6,7,8,9,11,13), registered during the three investigation years, are presented in individual figures true to scale. In a few interesting and typical examples the mapping patterns of the macromycetes are compared with those of the snow-melting zones (isochiones).

6. Mapping data in three-dimensional figures: The three-dimensional presentation is applied to demonstrate the productivity of selected characteristic macromycetes in snow-bed communities (plot 3,6,7,8,9,11,13). Furthermore, records of all species occurring in individual plots are submitted for each single year indicating eventual annual fluctuation. All figures are shown true to scale.

The presentation of the two-dimensional and three-dimensional figures of the macromycete mapping data was performed with the software package DOGMA (MENGIS & GRAF 1989).

2.8. ECTOMYCORRHIZA WITH *SALIX HERBACEA*

2.8.1. Natural ectomycorrhiza of *Salix herbacea*

2.8.1.1. Root sampling

After completion of field work in *Salix herbacea* carpets soil cores of 25 cm² surface and 5 cm depth were cut out in summer 1991. This process was carried out at locations where only one single macromycete species was registered during the investigation period, selected and based upon data evaluation of basidiomata mapping from 1988-1990. Such samples (Tab. 6) were packed in the field separately in plastic bags and transported the same day to the laboratory where further processing was carried out without delay.

2.8.1.2. Processing of root samples

Ectomycorrhizal rootlets of *Salix herbacea* were cleaned carefully under attentive observation of the mycelia of the carpophores leading to mycorrhizae which then were rinsed with sterile water, analysed under a Wild M8 dissecting microscope, subsequently morphologically described and photographed with a Wild MPS (MPS 46 & MPS 52) equipment. Afterwards the samples were fixed in 6% formaldehyde (FAA) and stored at 4°C in the dark.

Table 6: Mycorrhizal taxa considered for investigations of natural ectomycorrhiza of *Salix herbacea*, with the proportional share of carpophores in their originating plot and information about successful cultures and ectomycorrhiza synthesis experiments.

a) Found in nearly every soil sample of the above listed taxa.

species	origin plot	% occurrence of cp in plot	cultures on MMN	laboratory synthesis
<i>Cortinarius favrei</i>	7	9.9	+	-
<i>Dermocybe crocea</i>	9	0.3	-	-
<i>Entoloma alpicola</i>	13	6.0	-	-
<i>Hebeloma repandum</i>	7	12.2	+	+
<i>Laccaria bicolor</i>	3	0.9	-	-
<i>Laccaria montana</i>	7	10.7	-	-
<i>Russula norvegica</i>	13	4.9	-	-
<i>Cenococcum geophilum</i>	a)	?	-	-

2.8.1.3. Analysis of natural ectomycorrhiza

For analysis the root samples were dehydrated in alcohol, embedded in glycol-methacrylate, longitudinally sectioned (1.5 µm) with a Reichert-Jung 2050 microtome and stained with Giemsa for chitinous material. Such prepared sections were analysed with a Leitz Laborlux K microscope. Sketches were performed with the aid of a Leitz drawing tube. Photographs were taken on a Leitz Aristoplan microscope with an Orthomat camera system.

For comparison of different types of ectomycorrhiza of *Salix herbacea* emanating hyphae, the outer and inner layers of the mantle as well as the Hartig net of central longitudinal sections were taken into consideration.

2.8.2. Ectomycorrhizal synthesis experiments

2.8.2.1. Fungal material

Cultures of both *Hebeloma repandum* Bruchet and *Cortinarius (Myxaciium) favrei* M.M.Moser ex D.M. Hend. were isolated from basidiomata collected in the permanent plots. Under sterile conditions small tramal pieces were cut from fresh carpophores and placed in Petri dishes on modified Melin Norkrans (MMN) agar (MARX & BRYAN 1975). All fungal isolates were grown and maintained at 20°C in the dark. After several weeks of incubation the mycelium cultures were cut into small pieces and transferred into sterilized 500 ml Erlenmeyer flasks containing a MMN solution (including glucose: 10 g/l and malt: 3 g/l). For further processing 500 ml Erlenmeyer flasks with a

Vermiculite-peat moss mixture (200 ml : 30 ml) added with 150 ml MMN (pH 5.5) were autoclaved for 20 minutes at 120°C. Before introducing the fungal starters into these flasks the liquid mycelial cultures were homogenized with a blender and then injected with a pipette into the Vermiculite-peat moss mixture under sterile conditions (BRUNNER 1991).

2.8.2.2. Plant material

In fall 1989, 1990 and 1991 seeds of *Salix herbacea* were collected from the investigation plots (7, 9, 13) and stored at -20°C in the dark. After surface sterilisation for 3-5 minutes with H₂O₂ they were placed on water agar in Petri dishes for germination and incubated at room temperature in daylight. After the development of the cotyledons, the seedlings were transferred and maintained on MMN agar plates to screen for possible contaminants (BRUNNER & BRUNNER 1990). After 2 to 3 weeks the plantlets were ready for synthesis experiments, i.e. were added to the Vermiculite-peat moss Erlenmeyer flasks previously inoculated with the fungal mycelia.

2.8.2.3. Synthesis experiments

The fungal inocula were allowed to grow for 1 to 2 months prior to seedling introduction. Synthesis experiments were carried out in a growth chamber with a 16 hour day period (PAR: 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) at 20°C and 70% humidity (BRUNNER 1991). The duration of the syntheses were 11 months for *H. repandum* and 13 months for *C. favrei*, respectively. Ectomycorrhizal rootlets were then harvested and cleaned with sterile water, described, photographed under a Wild M8 dissecting microscope equipped with a Wild camera system, fixed in 6% FAA and finally stored at 4°C in the dark.

2.8.2.4. Analysis of synthesized ectomycorrhiza

For analysis the samples were treated as described in chapter 2.8.1.3.

2.8.3. Terminology

For the macroscopic description of ectomycorrhiza the terminology of ZAK (1973) is mainly followed. For the microscopic part the proposals of GODBOUT & FORTIN (1985) are applied.

2.8.4. Cuttings

Cuttings of *Salix herbacea* were made from plants grown under sterile conditions from surface-sterilized seeds and naturally grown plants respectively, both collected in the permanent plots. Each cutting, consisting of at least 3 leaves and with a minimal height of 15 mm, was put into a pot filled with a well watered Vermiculite-peat moss mixture to which 150 ml $\text{MMN}_{\text{anorg.}}$ solution was added. These systems were maintained under non-sterile conditions at 20°C and daylight in a greenhouse and weekly supplied with water. Furthermore, every third to fourth week 30 ml $\text{MMN}_{\text{anorg.}}$ were added to the pots.

2.8.5. Synthesis experiments with cuttings of *Salix herbacea*

The cuttings were left for 2½ months in the greenhouse for establishing. After this period 100 ml of homogenized mycelia of *H. repandum* and *C. favrei*, respectively were injected into one of the pots each. These pots were further maintained as described for the non-treated cuttings mentioned before.

Ten and 15 months later, respectively some of the rootlets were harvested for investigation of their ectomycorrhizal structures. Processing and analysis of the samples followed the descriptions in chapter 2.8.1.3.

The axenic cultures of *Cortinarius favrei*, *Hebeloma repandum* and *Hymenogaster saliciphilus* F. Graf & E. Horak are deposited in the mycological laboratory of the WSL in Birmensdorf (Switzerland).

Vital plantlets and cuttings of *Salix herbacea* are maintained in a greenhouse at the same institute.

3. RESULTS

3.1. CLIMATE

3.1.1. Precipitation

3.1.1.1. Description of precipitation patterns from 1987 to 1990 (region Davos)

From 1987 to 1990 the precipitation averages of the hydrological periods (Oct. to Sep.) were above the long term data. During all three winter periods the great snow masses arrived late i.e. mid-February to March.

Whereas in 1988 August was responsible for the highest summer precipitation it was July with values above average in 1990. Precipitation during the vegetation period (Jun. to Sep.) of 1989 was well balanced ranging between 93% in June and 89% in September. Precipitation in fall (Sep.) of 1988 was only half of the average but reached 110% in 1990 (Tab. 7).

Table 7: Comparison of long-term mean values of precipitation at the SMA station Flüela-Hospice (1901-40), Weissfluhjoch station (1901-40) and Weissfluhjoch SLF [*] research field (1901-60), as well as the proportional amounts of the years 1988-90 measured on the research field of the Weissfluhjoch SLF station (W.-Joch, 2540 m). Hatched = period of climate measurement in the Radönt Valley.

mean precipitation [mm/m ²]	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	year
Flüela-Hospice, 2383 m	85	75	84	86	110	148	181	179	121	105	100	96	1370
Weissfluhjoch, 2663 m	111	92	109	132	150	180	209	200	134	111	107	115	1650
Weissfluhjoch*, 2540 m	88	74	69	71	87	130	165	155	97	71	73	81	1153
precipitation [% of mean]													
Weissfluhjoch*, 1988	47	69	417	60	156	82	58	129	48	94	42	174	108
Weissfluhjoch*, 1989	12	43	78	108	48	93	92	92	89	67	32	68	73
Weissfluhjoch*, 1990	27	515	168	96	89	126	106	55	110	86	119	43	120

1987 (Oct.) to 1988 (Sep.): The total precipitation of the period under review amounted to 1323 mm meaning 114% of the long term average value. Until the beginning of March the height of the snow covering was distinctly below average. On January 20 only 83 cm (56%) was measured on the site of the Weissfluhjoch SLF station (SLF = Institut für Schnee und Lawinen Forschung). However, the situation changed to the opposite during March and at the end of the month 146% (334 cm) of the average snow amount was recorded. Although there was a record snowfall, the total water value was only

slightly higher than normal. Winter lasted for 244 days (11. November 1987 until 11. July 1988).

1988 (Oct.) to 1989 (Sep.): The annual precipitation was reported as 1203 mm which means 104% of the long term average. Whereas December and July were characterized by rich precipitation, the period from 21. December to the 12. February was extremely dry, resulting in only 20 mm of precipitation which equals about 22 cm fresh snow. The wintry maximum water value was recorded on the 1. Mai (691 mm = 80% of the long term average). The rather snow-poor winter extension ended on 9. July after a permanent snow covering of 248 days (3. November 1988 to 8. July 1989).

1989 (Oct.) to 1990 (Sep.): The hydrological year brought a precipitation total of 1492 mm or 130% of the average. Heavy snowfalls in mid February, as well as precipitation in June and July were mostly responsible for the above average amount. Winter arrived on 7. October. As a result of deficiency in precipitation, the first stage of winter (30. Oct. to 12. Feb.) was very poor on snow. Between 15. January and 12. February, 29 days, the absolute minimum of snow covering was reported since records were started at the SLF station. However, on the 14. of the same month the situation changed abruptly with a new record maximum snowfall (within 24 hours) of 104 cm. Another new record with 229 cm was measured during the subsequent 3 days (14. to 16. Feb.). The monthly fresh snow total of 349 cm during February corresponded to 228% of the long term average. After these heavy snowfalls, winter continued more or less normally. With 885 cm total fresh snow (92.5%) during the period of permanent snow covering, winter ended after 274 days on 7. July.

3.1.1.2. Local precipitation patterns of the sites (I-V): Radönt

The fructification of macromycetes is influenced by precipitation patterns during the vegetation period regardless whether in meadows and fallowland (BRUNNER 1987, LANGE 1984), *Alnetum incanae* stands (GRIESSER 1992) or arctic (PETERSON 1977) and alpine areas (EYNARD 1977, DEBAUD 1983). Unlike lowland and temperate regions, snow is a very important ecological parameter in cold and high altitude zones. On the one hand the long presence of the winter snow pack limits the available time for reproduction, on the other hand during the period without permanent snow covering the water amount resulting from snow is substantial. Actually, it seems that melting snow, in combination with a temperature drop, is more stimulating for carpophore production (DEBAUD 1983). One reason may be the fact that humidity is more steadily available and lasts for a longer period than ordinary rainfall. In

addition snowfall in summer may protect basidiomata and primordia in the soil from violent and desiccating winds. During the three vegetation periods under review the average days with snowfall and lasting snow covering on the 13 permanent plots was 32 in 1988, 18 in 1989 and 22 in 1990 (Tab. 8). The overall precipitation patterns between the five measuring sites were similar during the three years of investigation but varied considerably from vegetation period to vegetation period. In 1988 there were two main precipitation periods during the second half of August and at the beginning of October respectively, separated by a dry September. The vegetation period of 1989, however, was rather well-balanced in rainfall except that the more or less uniform precipitation pattern was interrupted from 18. to 24. September by the absolutely driest week (0.3 mm). Although in 1990 precipitation was fluctuating, the values varied only little, showing more or less moderate amounts except during two dry weeks at the end of July (Fig. 5).

Table 8: Mean values of the 13 permanent plots in the Radönt Valley of snow-in, thaw and vegetation period compared with records of the SLF on Weissfluhjoch from 1988 to 1990 as well as with the long term average from 1961 to 1990. ** = data of the beginning of the winter in 1987 were not available.

results in days	1988		1989		1990		∅ 1961 - 1990
	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch	W.-Joch
thaw	13. Jul	11. Jul	10. Jul	8. Jul	9. Jul	7. Jul	16. Jul
snow-in	25. Oct	3. Nov	30. Sep	7. Oct	21. Oct	27. Oct	18. Oct
winter snowpack	**	244	259	248	283	274	271
vegetation period	104	115	82	91	104	112	-
summer snow	32	23	18	16	22	16	-
snow free v.-perio	72	92	64	75	82	98	-

3.1.1.3 Comparison of local precipitation with the SMA and SLF stations

The geographical location, the altitude and particularly the regional topography are very important parameters which deeply influence precipitation, both in quantity and from the technical point of view, especially in the higher mountain areas of the Alps (FRANZ 1979). The comparison of the long term averages from 1901 to 1940 of the SMA station on the Flüela Pass (2383 m) with those of the Weissfluhjoch about 15 km away, already demonstrates partially significant differences (cf. Tab. 7). The deviations of the two measurement series at the Weissfluhjoch station where the corresponding measuring sites are about 500 m apart from each other and are separated by an altitudinal difference of

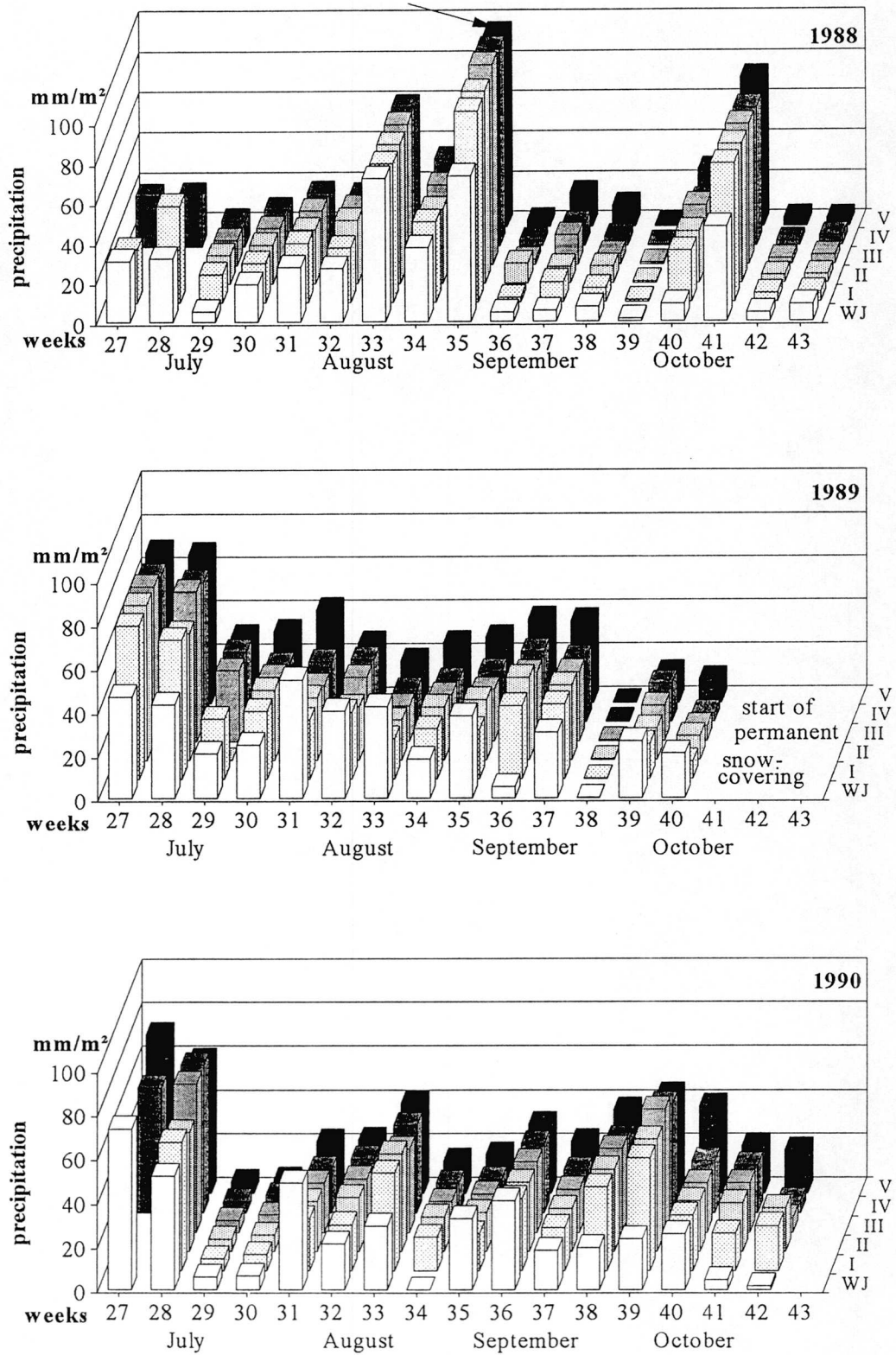


Fig. 5: Weekly precipitation measured at soil surface of the five sites (I-V) in the Radönt Valley compared with values of Weissfluhjoch SLF station (WJ) measured at 1.5 m above ground from 1988 to 1990. ↘ = Met. station V was installed on 28. August 1988.

123 m appear even more striking. Another reason for deviations of the results of the Met.-stations maintained in Radönt from the reference values of the Weissfluhjoch SLF station is the different methods used (Tab. 9) and technical installations. The SMA and SLF totalisators are situated 1.5 m above ground level in contrary the own recorded data correspond to precipitations taken at soil surface level. Furthermore the microclimate is dependent also on factors like exposure of the research site, topography of the nearest surroundings and last on the development of the vegetation (AULITZKY 1961), particularly in view of the humidity amount resulting from fog (MERRIAM 1973). Observed differences of the Met.-stations in Radönt among themselves result to a great extent from these micro habitat characteristics. In the same way, GRIESSER (1992) evaluated partially significant divergences between records of his measuring stations and also in comparison with the two nearest SMA facilities only between 3 km and 5 km apart. Aggravating circumstances in measuring precipitation above timberline are strong winds as well as heavy snowfalls (FRANZ 1979). Therefore, taking all these parameters and sources of interference into consideration it is absolutely essential for long term mycoecological and mycosociological research projects to maintain Met.-stations directly situated in the research area. Otherwise it is hardly possible to reconstruct relationships between fructification behaviour, fruit-body abundance, precipitation patterns or any other environmental parameters depending on climate. In many of the otherwise good mycosociological works these facts were not, or only inadequately, considered (HORAK 1963, 1985; SENN-IRLET 1987; OHENOJA 1993).

Table 9: Monthly precipitation of the research area in Radönt (average of the 5 meteorological stations) compared with values of Weissfluhjoch as well as total amounts of each vegetation period. * = until 20. Oct.; ** = until 8. Oct.

precipitation [mm/m ²]	1988		1989		1990		1988-90	
	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch
July	97	95	198	151	145	175	147	141
August	208	200	112	142	108	85	143	142
September	80	47	86	86	144	107	103	80
October	105	67	*10	*20	**62	**32	---	---
Total	490	409	*406	*399	**459	**399	393	363

3.1.2. Temperature

3.1.2.1. Description of temperature course from 1987 to 1990 (region Davos)

During the three year research cycle (1988-90) both July and August, the two months of the main vegetation period in the alpine zone, showed temperature surpluses between 1 and 2.5°C. This is also recorded for September in 1990. However, during the two previous years this month was cold, resulting in deficiencies of 0.4°C in 1988 and 1.5°C in 1989 respectively (Tab. 10).

Table 10: Long-term mean values of temperature at the research site of the SLF station Weissfluhjoch (1950-90) and the deviations of the monthly mean temperatures (1988-90). Hatched = period of climate measurement in the Radönt Valley.

mean temp. [°C] 1950-90	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	year
Weissfluhjoch, 2540	-9.2	-9.6	-7.8	-5.5	-1	2.4	5.1	5.1	3.3	0	-5	-7.6	-2.44
deviation [°C]													
Weissfluhjoch 1988	2	-0.9	-3	1.6	1.9	-0.7	1.4	1.1	-0.4	0.9	0.5	3.6	0.62
Weissfluhjoch 1989	3.1	4.8	2.6	-0.6	2	0.2	1.1	1.3	-1.5	1.8	-1.2	-2.3	0.90
Weissfluhjoch 1990	2.9	-1.5	3.2	-1.4	-4.1	-0.7	2.4	2.2	1.6	1.8	-0.4	-0.1	0.45

1987 (Oct.) to 1988 (Sep.): Temperatures during this hydrological period were reported with a total surplus of 0.72°C. Especially the first four months (Oct. to Jan.) of the period were responsible for this fact. With only one record of a value below -10°C in December, this month was 3.6°C too warm compared with the long term average (1950/51 to 1990/91). On the other hand, March was much too cold with a deviation of -3.1°C. During the first 12 days of this month temperatures never exceeded -10°C. The average day temperature of this period was -19.6°C with the absolute minimum on 9. March (-20.4°C). Concerning both, the monthly average and the absolute maximum (+19.6°C), July was the warmest month.

1988 (Oct.) to 1989 (Sep.): The hydrological period 88/89 was characterized by a temperature surplus of 1.2°C. Only in June was it significantly colder, whereas in November, April and September the deficiency was low. A phenomenon, never reported before, was the three month period January, February and March with surpluses of more than 3°C each. In January for example, only four days were reported with a temperature below -10°C and during 16 days of this month the thermometer stayed above 0°C. Hence, it is not surprising that the annual minimum temperature was already measured on 22. November with -22.9°C.

1989 (Oct.) to 1990 (Sep.): The hydrological year 89/90 was very sunny and accordingly warm. Compared with the long term average values a temperature surplus of 1.5°C resulted. Only May and September were colder than normal. February, however, was about 5°C too warm. As in the year before the minimum temperature of the period was measured already at the end of November (-18.7°C). During the warm period from 12. July to 6. August the thermometer never recorded temperatures below 0°C. The absolute maximum was recorded as 18.5°C from 28. July.

3.1.2.2. Local temperature conditions on the sites (I-V): Radönt

In the research area the measured temperatures in connection with precipitation are two main parameters which are highly responsible for the fructification of fungi. In previous works dealing with mycoecology and mycosociology (BRUNNER 1987, GRIESSER 1992) it has been emphasized time and again that the minimum temperature is the important regulative factor for the seasonal occurrence of carpophores, in such a way that values below zero prevent fructification. This may be valid for investigated associations in low altitude and more temperate areas but has not such a striking impact in alpine or arctic habitats. In Greenland at the Godhavn area PETERSEN (1977) noticed formation of carpophores with temperatures at the soil-litter interface below zero and not exceeding 12.5°C. This is in perfect accordance with measurements and observations during the three year research in Radönt.

During the vegetation periods the weekly minimum temperatures were mostly below zero with measured mean values of -3.5°C in 1988, -3.0°C in 1989 and -3.8°C in 1990. In 1988 the quicksilver of the minimum thermometer climbed but once, in the week from 8. to 14. Aug. at three of the five Met.-stations in the research area above zero (+0.5 to +1°C). In the following year this phenomenon was noticed during two succeeding weeks (14. to 27. Aug.) at four sites in the first (+0.5 to +4.0°C) and at three in the second seven days (+0.5 to +1°C). From the 30. July to the 5. August in 1990 minimum temperatures above freezing were recorded at all sites with values between +0.5 and +3.5°C. Again, four weeks later positive extreme values (+0.5°C) were reported from two sites.

The absolute maximum temperature during investigation was measured in the week from 18. to 24. July 1988 at site I at 37°C. At the same time, the average value of this week of the five Met.-stations was the highest (34.4°C) for the whole research period (Figs. 6, 7).

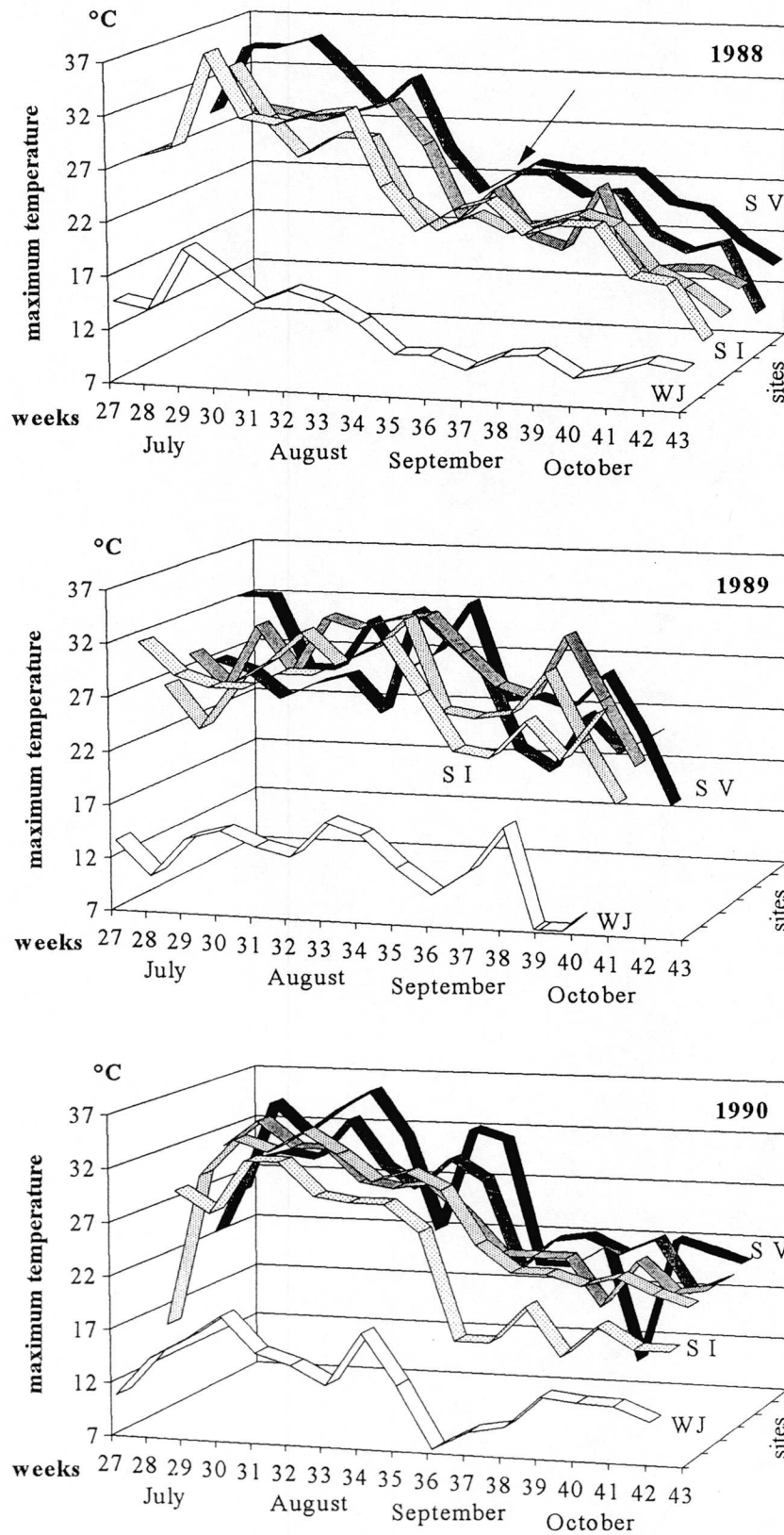


Fig. 6: Weekly maximum temperatures measured at soil surface of the five sites (SI-SV) in the Radönt Valley compared with official values of Weissfluhjoch SLF station (WJ) measured at 1.5 m above ground from 1988 to 1990. ⚡ = Met. station V was installed on 28. August 1988.

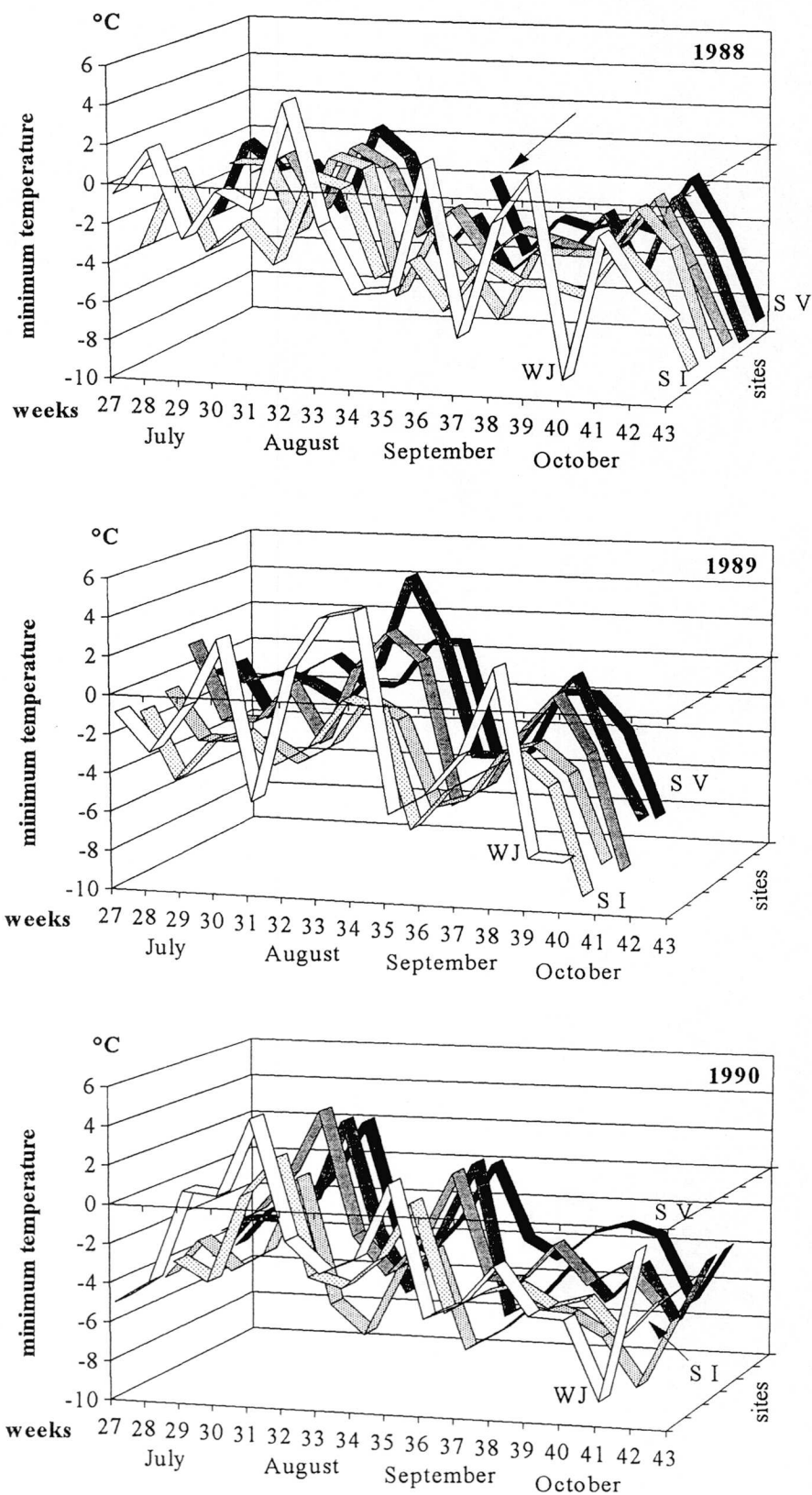


Fig. 7: Weekly minimum temperatures measured at soil surface of the five sites (SI-SV) in the Radönt Valley compared with official values of Weissfluhjoch SLF station (WJ) measured at 1.5 m above ground from 1988 to 1990. ↙ = Met. station V was installed on 28. August 1988.

3.1.2.3. Comparison of local maximum and minimum temperatures with SMA and SLF station records

Comparison between maximum and minimum temperatures measured at the five different sites in Radönt and the values from the official station on Weissfluhjoch (SLF) shows partially significant deviations especially considering maximum temperatures (Tab. 11, 12).

Table 11: Maximum temperatures of the Radönt Valley (average of the 5 measuring sites) compared with the SMA values of Weissfluhjoch. * = until 20. Oct.; ** = until 8. Oct.; # = mean value of Oct. (1988-90).

maximum temp. [°C]	1988		1989		1990		1988-90	
	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch
July	31.7	11	27.1	8.8	28.5	10.5	29.1	10.1
August	28.9	10.2	28.8	9.2	29.6	11	29.1	10.1
September	21.7	6.7	23.2	6.2	19.7	5.3	21.5	6.1
October	16.5	5	*19.1	*3.5	**19.6	**7.0	---	#4.9

One reason for these differences is found again in the different measuring methods. Whereas the SLF station values result from temperatures measured 1.5 m above soil level, the recorded maximum and minimum data of Radönt were taken directly at the soil surface. It is a proven fact that air layers at ground level warm up much more intensely during day time, and cool down faster at night. Therefore, it is not surprising that the weekly readings of the Met.-stations did result in mostly higher extreme values.

Table 12: Minimum temperatures of the Radönt Valley (average of the 5 measuring sites) compared with the SMA values of Weissfluhjoch. * = until 20. Oct.; ** = until 8. Oct.; # = mean value of Oct. (1988-90).

minimum temp. [°C]	1988		1989		1990		1988-90	
	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch	Radönt	W.-Joch
July	-1.6	2.8	-2.1	2.8	-3.2	2.7	-2.3	2.8
August	-2.2	3.3	-2.1	2.4	-2.3	3.5	-2.2	3.1
September	-4.4	0.4	-3.7	0.3	-5.2	-1	-4.4	-0.1
October	-5.1	-0.7	*-9.3	*-3.6	** -5.5	**0.5	---	#-1.2

Whereas the maximum temperatures of Radönt showed positive deviation from official values without exception, the minima, however, varied positively as

well as negatively compared with reference values of Weissfluhjoch (Tab. 13). During the three field seasons the weekly minimum temperatures were reported with deviations between -7.3 and +4.2°C. On the whole the maxima on the other hand exceeded between +4.4 and +18.1°C.

Table 13: Monthly maximum and minimum temperatures at the five meteorological stations in the Radönt Valley (average of weekly readings) during the vegetation period compared with values of Weissfluhjoch SLF (1988-90), as well as amplitudes (range) for the same investigation period. * = measuring period until 8. Oct.; ** = measuring period until 20. Oct.; # = measuring period of site V started only from 28. Aug. 1988. Hatched = extreme values of the Met.-stations, viz. faint = maximum; diagonally = minimum.

min.- max. temp.		July			August			September			October		
[°C]		88	89	90	88	89	90	88	89	90	88	*89	**90
W.-Joch	min.	2.8	2.8	2.7	3.3	2.4	3.5	0.4	0.3	-1	-0.7	-3.6	0.5
	max.	11	8.8	10.5	10.2	9.2	11	6.7	6.2	5.3	5	3.5	7
ø site I-V	min.	-1.6	-2.1	-3.2	-2.2	-2.1	-2.3	-4.4	-3.7	-5.2	-5.1	-9.3	-5.5
	max.	31.3	27	28.5	28.9	28.8	29.6	21.7	23.2	19.7	16.5	19.1	19.6
site I	min.	-2.6	-3	-2.7	-2.6	-3.1	-1.9	-4.9	-4.1	-4.8	-5.6	-10	-5.2
	max.	30.8	28.3	29.3	29.8	29.2	28.8	22.2	22.5	16.6	17.1	26	16.7
site II	min.	0	-2.9	-4	-2.4	-3.9	-4	-4.7	-4.3	-6.6	-4.5	-9	-7.5
	max.	32.5	25.8	27.4	26.5	29.5	31	20.9	24.8	21.9	16.6	16.5	20.2
site III	min.	-0.5	-1.5	-1.7	-1.8	-1.7	-1.4	-3.9	-3.5	-4.5	-4.9	-10	-4.8
	max.	29.8	27.6	32.3	29.3	31.3	28.4	20.5	26.8	20.9	15.5	19	20.2
site IV	min.	-1.6	-1.3	-3.3	-2.1	-0.5	-1.9	-4.6	-3.1	-6.3	-5.8	-8	-5.3
	max.	33.6	24.9	27.6	30.1	26.9	29.5	22.4	19.4	21.6	15.8	21	20.2
site V	min.	#	-1.8	-3	#	-1.7	-2	-4.1	-3.4	-3.9	-4.9	-8.5	-4.8
	max.	#	28.5	30.9	#	27.3	30.3	22.7	22.6	17.3	17.6	13	21
W.-Joch	range	8.2	6	7.8	6.9	6.8	7.5	6.3	5.9	6.3	5.7	7.1	6.5
ø site I-V	range	32.9	29.1	31.7	31.1	30.9	31.9	26.1	26.9	24.9	21.6	28.4	25.1
site I	range	33.4	31.3	32	32.4	32.3	30.7	27.1	26.6	21.4	22.7	36	21.9
site II	range	32.5	28.7	31.4	28.9	33.4	35	25.6	29.1	28.5	21.1	25.5	27.7
site III	range	30.3	29.1	34	31.1	33	29.8	24.4	30.3	25.4	20.4	29	25
site IV	range	35.2	26.2	30.9	32.2	27.4	31.4	27	22.5	27.9	21.6	29	25.5
site V	range	#	30.3	33.9	#	29	32.3	26.8	26	21.2	22.5	21.5	25.8

3.1.2.4. Extreme maximum and minimum temperatures during a 28 hour period at plot 11

The present results of this measuring cycle again demonstrate impressively the need for direct measurement in the investigation area to assess the local climate for ecological research projects investigating alpine macromycetes.

During the two observation days (20./21. July 1990) the sky was absolutely cloudless. With sunrise at 06.¹¹ and sunset at 19.⁴⁷ on 21. July in the Radönt Valley, 13.6 hours of permanent sunshine resulted. At the SLF station on Weissfluhjoch the duration of sunshine was registered as 13.9 (maxima for 1990) and 13.8 hours on 20. and 21. July, respectively. The corresponding radiation values were 3400 Joule/cm² on 20. July and 3230 Joule/cm² on 21. July, whereas the maxima (3450 Joule/cm²) for 1990 was measured on 19. July.

One hour after installing the eight thermometers at plot 11 (Fig. 8, Tab. 14) the first reading took place at 17.⁰⁰ (20. July), when minima were between 16.5 and 22.5°C and maxima ranged from 22.5 to 26°C, followed by hourly reading intervals until 20.⁰⁰ on 21. July (Fig. 9). During the time interval of 19.⁰⁰ and 20.⁰⁰, with sunset at 19.⁴⁷, a remarkable drop (8.5-9.5°C) of the minimum temperature was noticed which was less distinct for the maxima (3-6.5°C) except at spot 6, where, because of shadowing one hour before sunset, a deviating temperature curve was registered in 1990.

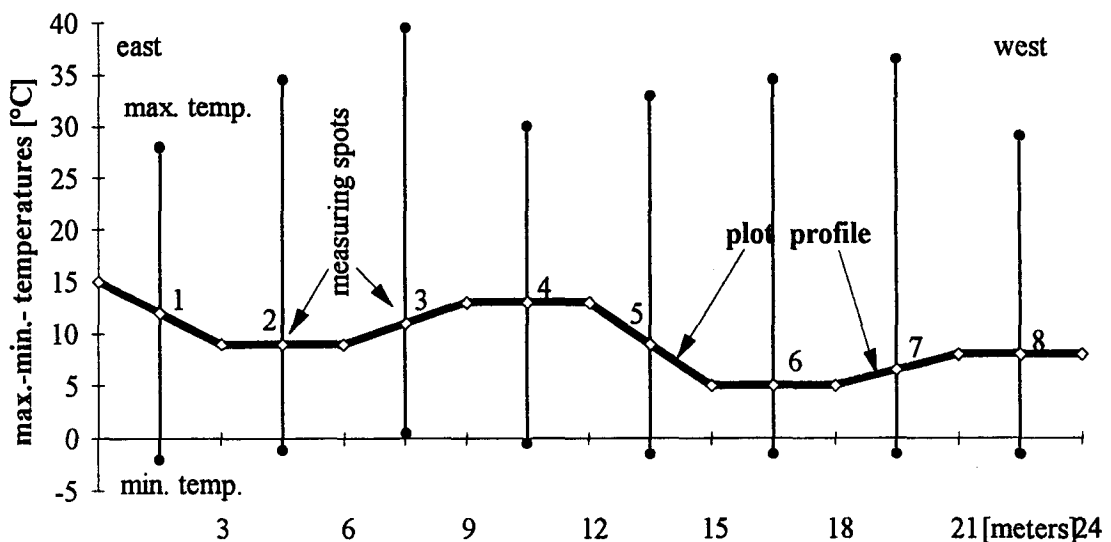


Fig. 8: Profile of plot 11 with the measuring spots (1-8) of the eight maximum-minimum thermometers and their corresponding extreme maximum and minimum temperatures during a 28 hour measuring cycle with one hour reading intervals from 20.7. until 21.7.

Except at spot 1, where the maxima decreased quite steadily to the lowest value, a distinct stagnation in the temperature drop was registered at all other measuring points from 20.⁰⁰ to 21.⁰⁰, when the decrease varied only slightly from 0°C to 1.5°C and even increased at plot 6 (+2.5°C). From 22.⁰⁰ (20. July) until 06.⁰⁰ (21. July) the course of the minima and maxima continued more or less parallel with the latter about 0.5 to 3°C higher.

Table 14: Spot characterization of the 8 thermometers measuring max.-and min. temperatures at plot 11 during a 28 hour cycle with one hour reading intervals from 20. to 21. July 1990. + = slight inclination, ++ = middle inclination, +++ = considerable inclination.

spot	1	5	2	6	3	7	4	8
exposition	W	W	—	—	E	E	—	—
inclination	++	+++	flat	flat	++	+	flat	flat
dominating plants	<i>Polytrichum sexangulare</i>	<i>Polytrichum sexangulare</i>	<i>P. sexang.</i> <i>S. herbacea</i>	<i>Luzula spadicea</i>	<i>Salix herbacea</i>	<i>S. herbacea</i> <i>L. spadicea</i>	<i>Carex curvula</i>	<i>Salix herbacea</i>
min. temp. °C	-2	-1.5	-1	-1.5	0.5	-1.5	-0.5	-1
max. temp. °C	28	33	34.5	34.5	39.5	36.5	30	29
temp. range °C	30	34.5	35.5	36	39	38	30.5	30

The absolute minima were reached between 04.⁰⁰ and 06.⁰⁰ and were below freezing (-0.5 to -2°C) at all except spot 3 (+0.5°C). After sunrise (6.¹¹) the maxima increased steadily to the highest value and with one hour delay also the minima. After 10.⁰⁰, readings revealed a more or less distinct interruption in the temperature rise at the measuring spots except at numbers 4 and 7. Later the temperature rose more slowly until the absolute maxima were reached between 12.⁰⁰ and 14.⁰⁰. After this culmination, temperatures dropped first gently until 17.⁰⁰ and then, faster and faster until the final reading at 20.⁰⁰.

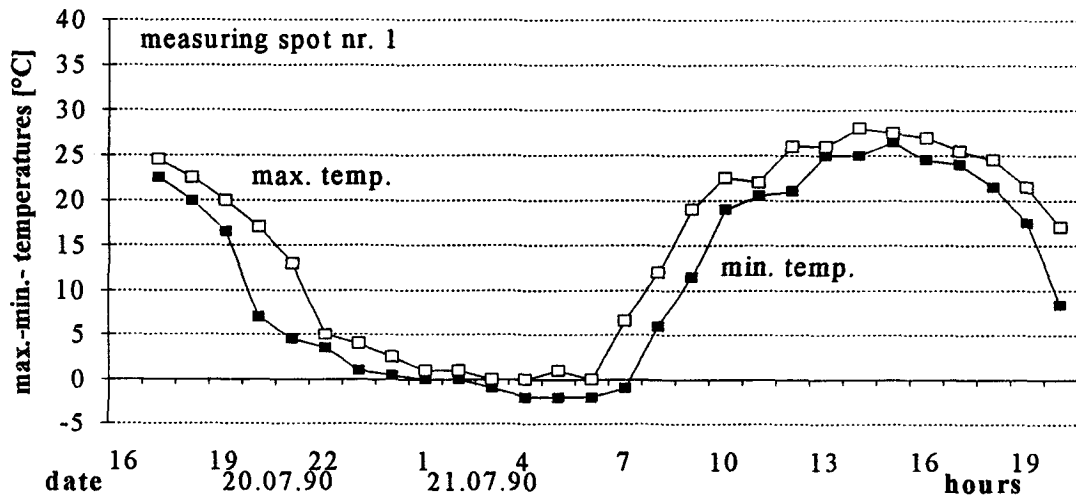


Fig. 9: Maximum and minimum temperature courses in plot 11 during a 28 hour measuring cycle with one hour reading intervals of 8 different measuring spots.

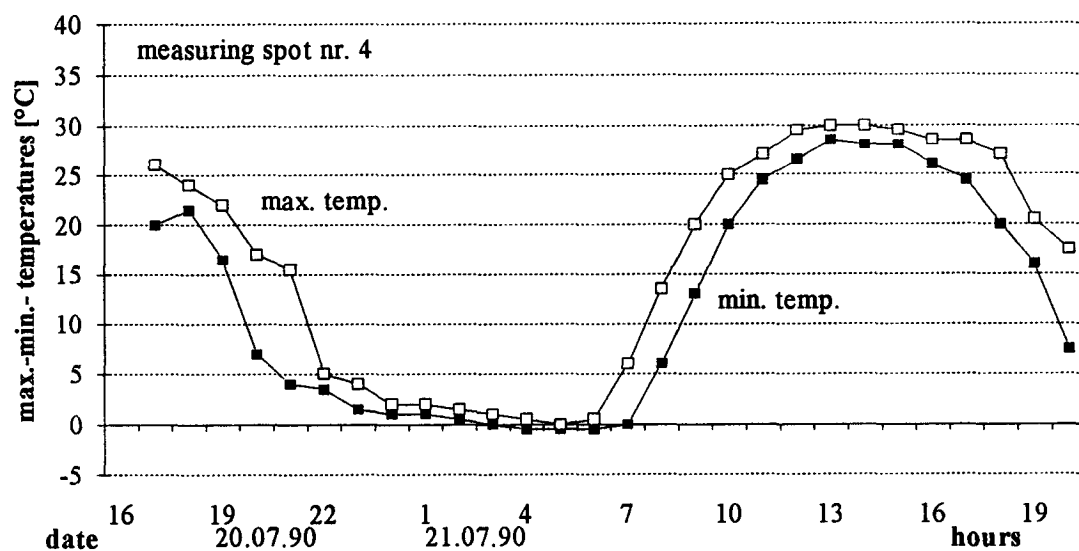
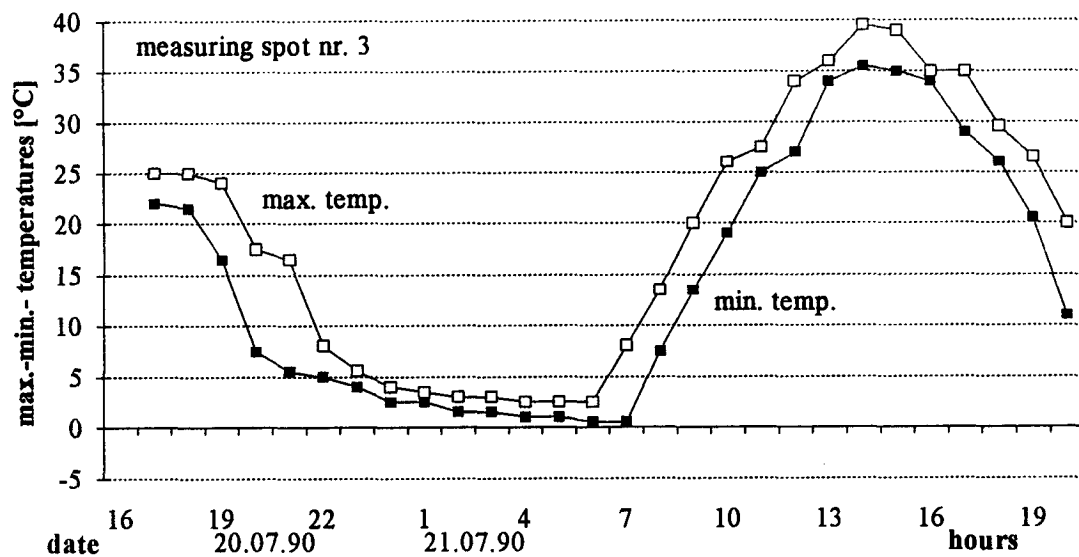
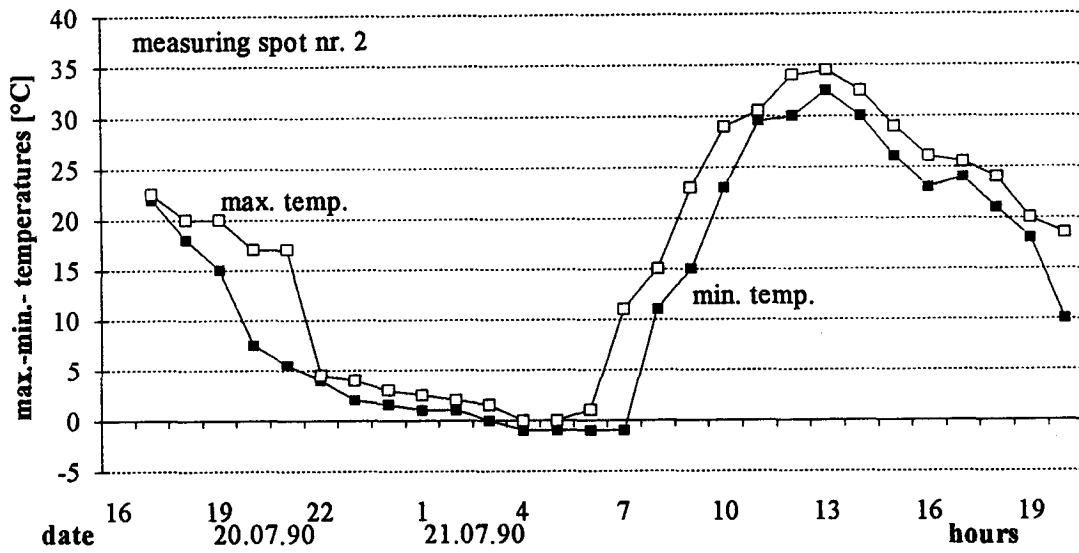


Fig. 9: continued.

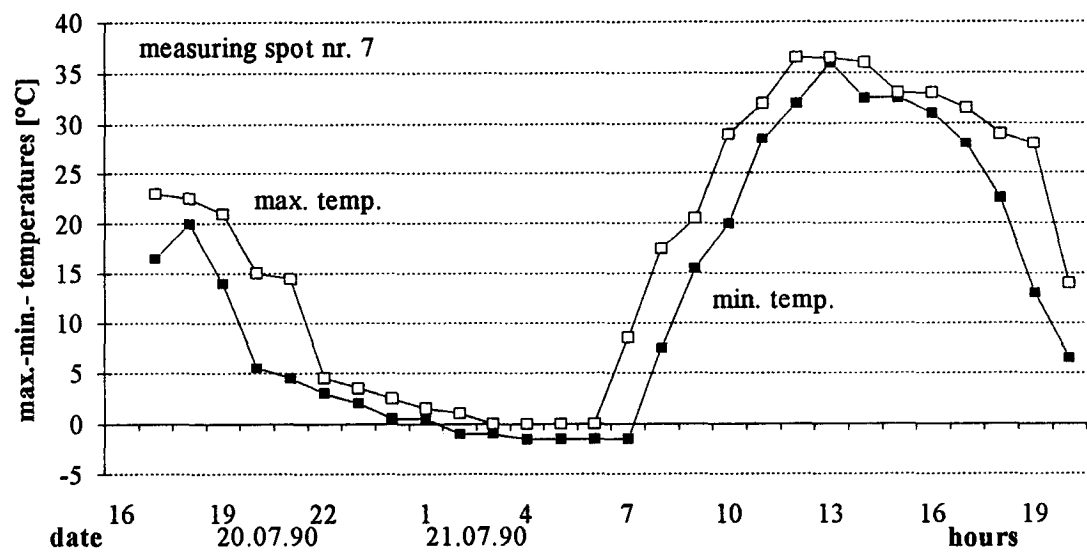
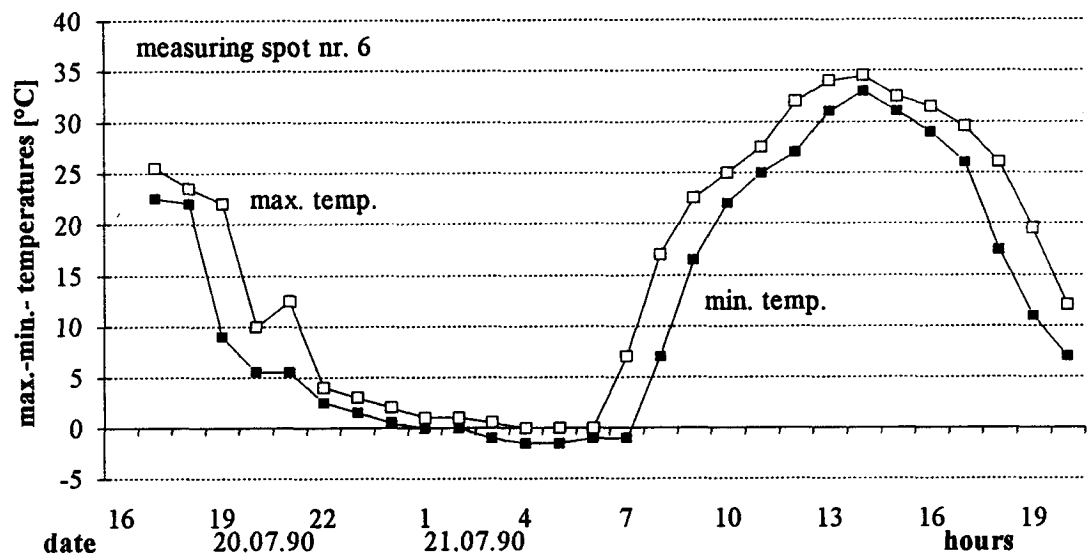
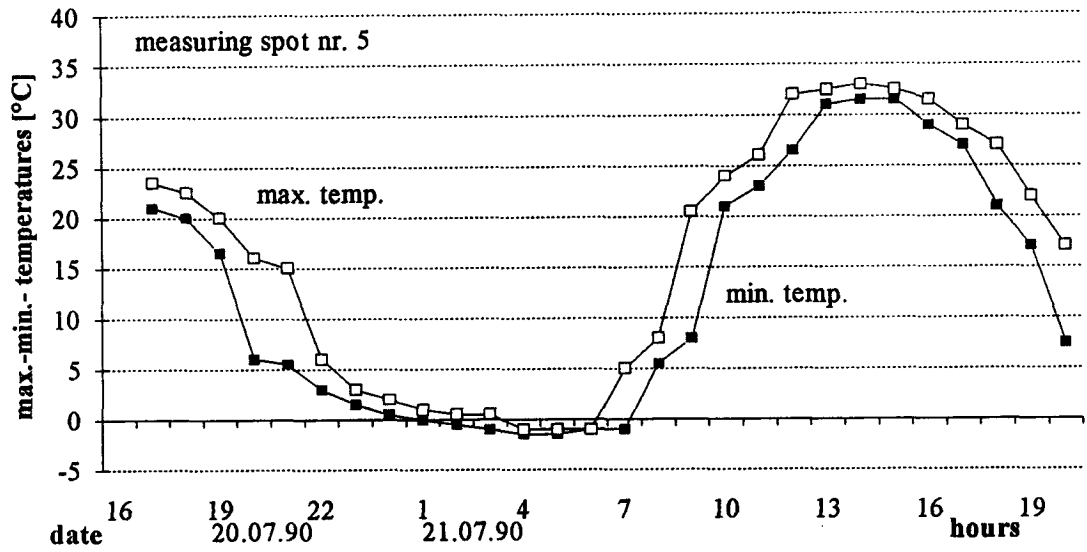


Fig. 9: continued.

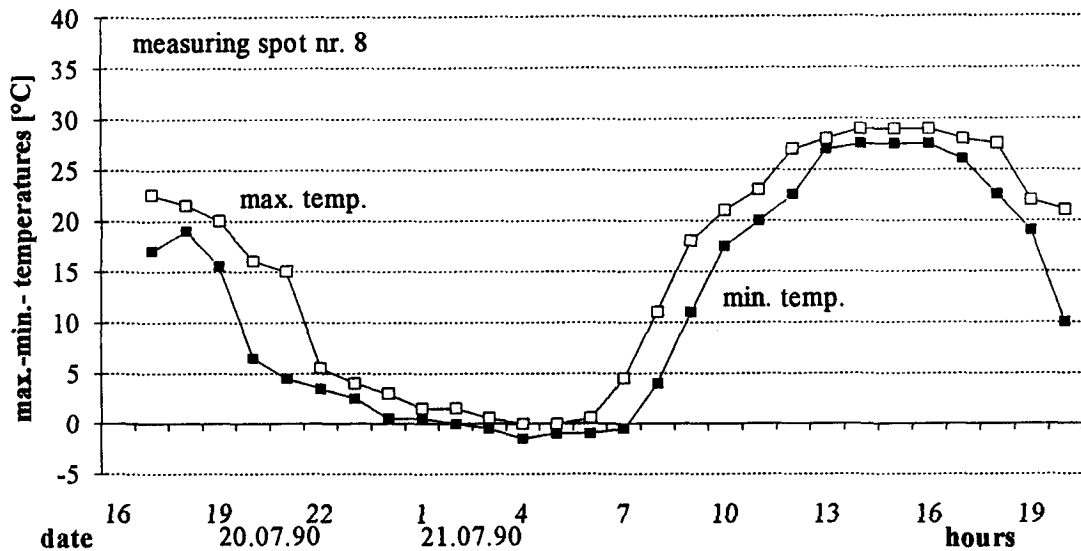


Fig. 9: continued.

3.1.3. Microclimatic comparison of the sites (I-V)

Remarkable climatic differences between the five Met.-stations are more or less restricted to the weekly measured temperatures. Precipitation, however, was very similar. In all five localities distinct deviations were more frequent for maximum than for minimum temperatures (cf. Figs. 6, 7). Fluctuations of this kind can be mainly explained by the fact that thermometers have been placed directly among the growing plants, at the soil surface. The particular development of the vegetation as well as the local topography next to the measuring place are able to cause different microclimatic situations, viz. cold air corridors, locally limited current air with temperature compensating effects or heating up by reflection.

Maximum temperatures (Fig. 10; cf Fig. 6, Tab. 13): In 1988 at site I and site II the highest maximum temperatures were measured in week 29 (18. to 24. July) with 37 and 35°C respectively. In the subsequent week 36° for site IV, and again two weeks later (15. to 21. August) 31°C for site III were reported. The Met.-station of site V was installed only on 28. August and, therefore, is not considered here. The lowest maxima were reached at all sites from 24. to 30. October, in the week before winter arrived. Then, thermometers indicated values between 11 and 14.5°C. At the five sites the average maximum temperatures, during the snow-free investigation period of this year (27. Jun. to 30. Oct.), ranged from 22.8 to 25.3°C.

Extreme maximum temperatures in 1989 are reported with 32 to 33°C in week 34 (21. to 27. Aug.) for site I, II, III and V and the week before for site IV. Partly due to an early start of winter (30. Sep.) the lowest maxima were

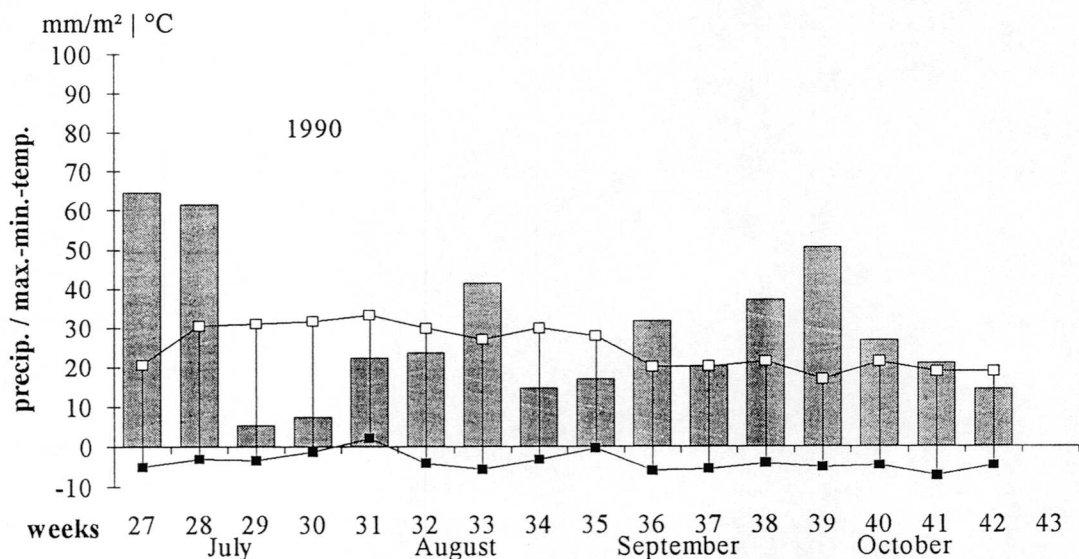
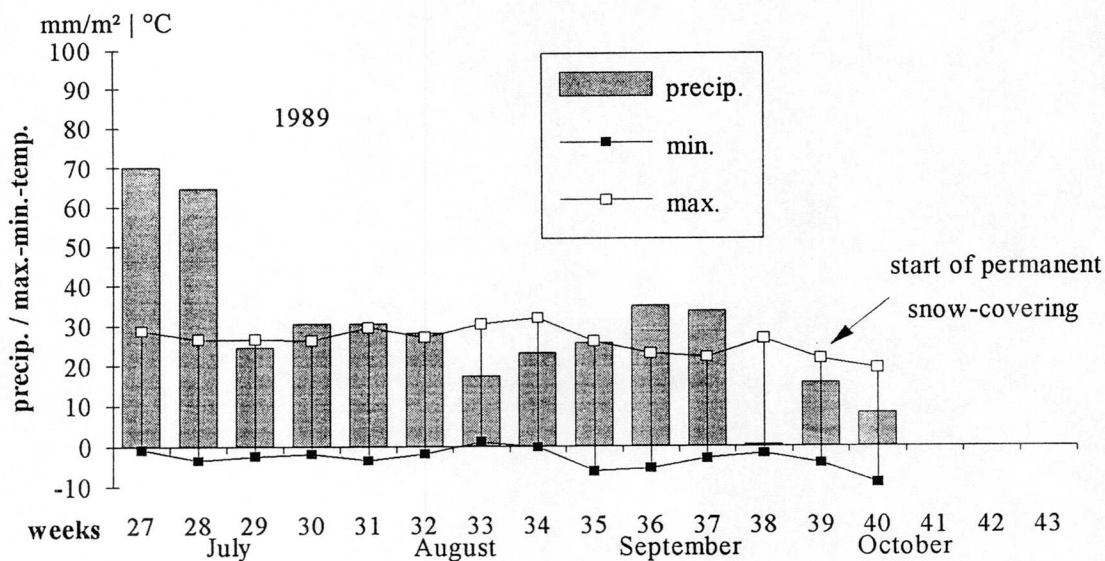
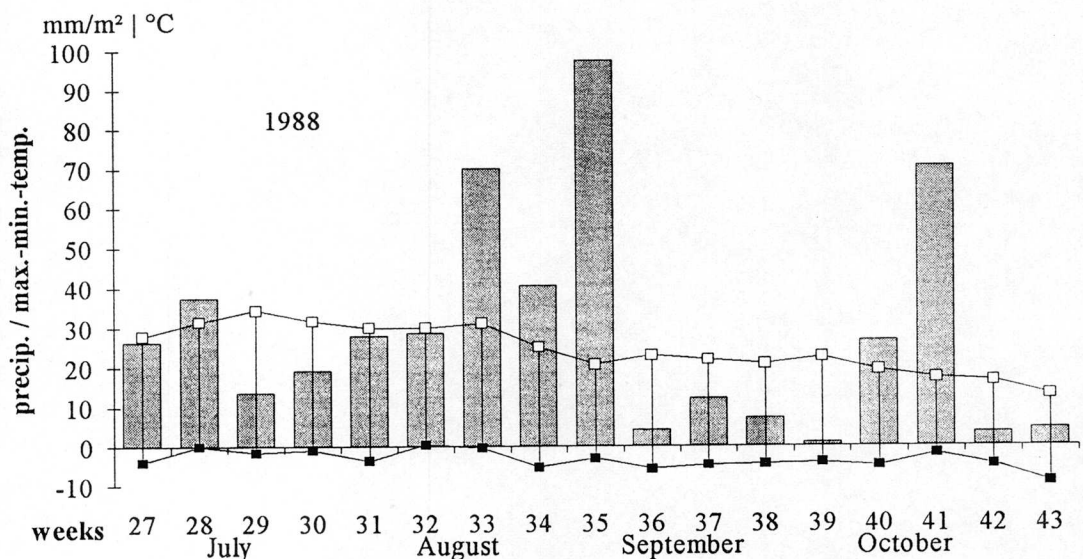


Fig. 10: Weekly mean values of precipitation and maximum and minimum temperatures (sites I-V) of the Radönt Valley from 1988 to 1990.

measured two weeks before the snow-in for site I (15°C) and site IV (17°C) and in the subsequent seven days, the study plots already snow-covered, for site II, III, and V, with values between 13°C and 19°C. In the same week the temperature of site I jumped to 26°C. During the period under review (26. Jun. to 30. Sep.) the mean maxima values of the five sites oscillated between 23.8 and 28.1°C.

In 1990 highest temperatures are reported uniformly from the measuring interval 29. July to 4. August. The recorded values ranged from 31.5°C to 35.5°C. The lowest maxima of the five Met.-stations, however, occurred during a period of seven weeks. Site II was the only one which had its minimum (19°C) in the week before the start of winter (14. to 20. Oct.). The significant temperature drop in week 36 (2. to 9. Sep.) already meant the lowest maximum (19°C) for site V, which on the other hand was reached in site I (15°C) between 23. and 29. of September. For site III and IV this parameter is reported from week 41 (7. to 13. Oct.) with 19°C and 18°C, respectively. From 25. June to 20. October the average values of all sites varied between 23.2°C and 25.8°C.

The average maximum temperatures over all investigation years were about 30°C, with slightly lower values in 1989, until the second half of August (week 34) when a drop of about 10°C announced the beginning of fall. During September of 1988 and 1990 maxima stayed more or less at about 20 °C until the end of the month or in 1990 even till the end of the vegetation period. In 1988 October was characterized by a slight and steady decrease towards the beginning of winter. In 1989, however, maximum temperatures were about 22°C in September with a short rise in mid month and a final value in the first week of October (19.1°C), although the area was already covered with the first winter snow.

Minimum temperatures (Fig. 10; cf. Fig. 7, Tab. 13): During the three investigation years the extreme minimum temperatures were measured equally in the last week before, or during the snow-in. In 1988 temperatures fell to -9°C at this period (24. to 30. Oct.). Minima between -8°C and -10°C were measured in 1989 one week after winter started (2. to 8. Oct.), with the study plots already snow-covered. In 1990 the absolute minima are reported from week 41 (7. to 13. Oct.), one week prior to the snow-in with temperatures ranging from -6°C to -9.5°C. Highest minima of the vegetation period of 1988 were recorded from week 32 (8. to 14. Aug.), two to three weeks after reporting the absolute maxima. The average minimum values during this year under review stayed between -3.1°C and -4.4°C. In 1989, it was exactly the other way round and the lowest minimum temperatures were recorded one week before measurement of the absolute maxima, i.e. in week 33 (14. to 20. Aug.) with values varying between -1°C and +4.5°C. The mean minimum of the five sites was with -2°C to -3.9°C slightly higher than in the previous year. Finally, in 1990

highest minima of all sites were measured in the week from 29. July to 4. August ranging between 0.5°C and 3.5°C. The average minimum temperatures over this vegetation period varied between -3°C and -5.3°C and, therefore, represent the lowest ones over all three years under review.

Mean minimum temperatures above freezing were reported only during one week each year with +0.4°C in 1988, +1.1°C in 1989 and +2.1°C in 1990.

Precipitation (Fig. 5, 10): In 1988 the vegetation period started with low to only moderate precipitation during the first 6 weeks of the season. Between week 33 and 35 (15. Aug. to 4. Jul.) a record amount of 208 mm water (rain and snow) was noted. The absolute weekly maximum (97 mm) occurred from 29. August to 4. September. The subsequent four weeks were dry, followed again by two weeks of high precipitation. The two weeks before the snow-in were again relatively dry.

In 1989 the period under review started with two weeks of heavy precipitation followed by moderate weekly amounts till mid September. The week from 18. to 24. September was the absolutely driest period (0.3 mm) during the three years of field work. Afterwards, two weeks of low to moderate precipitation followed, including the snowfall which finally turned out to be the start (30. Sep.) of winter.

The recording period of 1990 started with two weeks of heavy rainfall (126 mm) followed by fourteen dry days. During the subsequent three weeks moderate weekly precipitation was measured with a slight increase from week to week. From 19. to 25. August the amount dropped to 15 mm and increased again steadily during the next two weeks. This pattern was repeated from 9. to 29. September with a remarkable share of snow. For the last three weeks moderate precipitation was recorded before the permanent snow covered the research region.

The duration of the vegetation period and the seasonal sum of precipitation are positively correlated. In 1988 the longest snow-free period resulted in 490 mm water. On the contrary 406 mm were reported during the shortest snow-free period in 1989.

Differences in the seasonal precipitation sum between the Met.-stations are ± 8.1 ml in 1988 (without Met.-station V), ± 26.5 ml in 1989 and ± 12 ml in 1990. The higher deviations during the last two field seasons are mostly due to the additional Met.-station V, which was responsible for higher amounts throughout the measuring periods.

3.1.4. Mapping of snow covering and snow-melting zones

As mentioned in chapter 3.1.1.2. snow is a very important environmental parameter which is not to be neglected in research dealing with the ecology of alpine macromycetes. For this reason the snow depth of the winter snow pack (January to June) was registered and the snow-melting zones (June to July) were mapped during the winter half year (1988/89 and 1989/90). In addition snow fallen during the vegetation period of all three research years (1988-90) was registered.

3.1.4.1. Winter snow pack

In the Valley of Radönt the start of winter 1988/89 was on 25. Oct. (cf. Tab. 8). The mean snow depth of the 13 permanent plots raised to about 75 cm in the early winter period (snow-in until end of December) except in plot 12 (*Loiseleurio-Cetrarietum*) where only 30 cm were measured (Tab. 15 a). During the high winter period (1. January to mid March) snow depth increased to about 45 cm in plot 12 and to more than 1.5 m in all *Polytrichetum sexangulare* plots, in 4 of the 6 *Salicetum herbaceae* plots as well as in the *Eriophoretum scheuchzeri* (plot 2) and the *Oxyrietum digynae* (plot 1). The maximum of the snow depth was reached in the late winter period (mid March to thaw) during the interval from the end of April to mid May, when all snow measuring bars (1.5 m) were covered with snow except in plot 12. From the end of May snow depth decreased steadily to thaw except at the beginning of June, when a slight increase (5 to 20 cm) was registered in all plots. Winter ended (plot completely snow-free) earliest on 25. June (plot 12; *Loiseleurio-Cetrarietum*) and latest on 23. July (plot 8, *Polytrichetum sexangulare*).

The end of the vegetation period 1989 and therefore the start of winter (1989/90) in the Valley of Radönt was nearly one month earlier (30. Sept.) than in the previous year (cf. Tab. 8). At the end of the early winter period the mean snow depth was about 100 cm with the minimum (60 cm) in plot 12 and the maximum (> 1.5 m) in plot 8 (Tab. 15 b). During the high winter period snow depths increased to more than 1.5 m in all plots except in plot 3 (*Salicetum herbaceae*), plot 5 (*Polytrichetum sexangulare*) and plot 12 (*Loiseleurio-Cetrarietum*). The maxima of snow depths were reached in April (late winter period) with representative 285 cm in plot 13 (*Salicetum herbaceae*) on 18. April. Towards the end of this month the start of a steady decrease was noted until the beginning of the vegetation period (plot absolutely snow-free). The earliest (9. June) and latest (3. August) snow-free plots were again the *Loiseleurietum* (plot 12) and the *Polytrichetum* of the plot 8, respectively.

Table 15b: Snow depths during winter 1989/90 and dates of thaw of the 13 permanent plots in the Radónt Valley, compared with data of the Weissfluhjoch SLF station. Plot 11 (transect) with two measuring spots in depressions (a, c) and one on a ridge (b). * = partly snow-free; sf and dotted = completely snow-free; bold numbers = maximum snow depths, in brackets are corresponding water values [mm] of the snow pack; bold number and hatched = absolute maximum of snow depth.

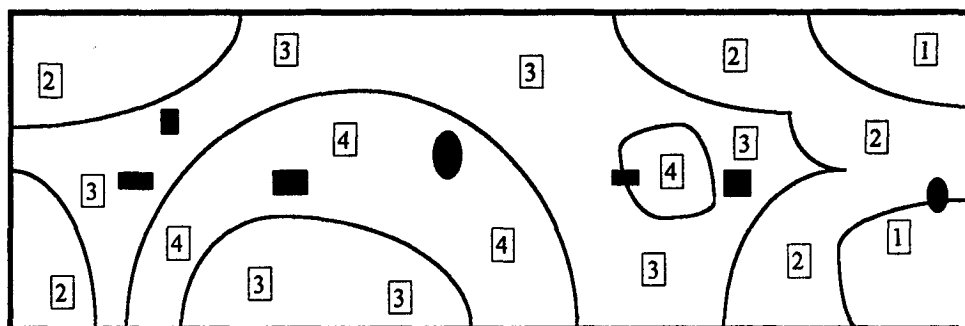
measuring areas	Weissfluhjoch 2540 m		VALLEY OF RADÓNT													Caricetum curvulae	Loiseleur-Cetrariet.
	plant associations	plot nr.	Salicetum herbaceae														
Date	Eriophor. scheuchz. 2	Oxyriet. digyna 1	3	6	7	9	13	11a	11b	11c	5	8	4	12			
13. Jan	90	85	70	75	100	95	105	110	130	115			4				
10. Feb	105	100	80	70	115	115	115	150	120	135			75				
17. Mär	>150	>150	130	>150	>150	>150	>150	>150	>150	>150			>150				
1. Apr	>150	>150	140	145	>150	>150	>150	>150	>150	>150			>150				
18. Apr	>150	>150	>150	>150	>150	>150	155 (895)	>150	>150	>150			>150				
5. Mai	>150	>150	>150	>150	>150	>150	235 (895)	>150	>150	>150			>150				
21. Mai	>150	120	100	90	>150	>150	170 (755)	>150	>150	>150			120				
30. Mai	>150	115	90	>150	>150	>150	*130	>150	>150	>150			105				
4. Jun	150	110	80	80	>150	>150	*120	>150	>150	>150			90				
9. Jun	145	95	75	70	>150	150	*100	>150	>150	>150			90				
16. Jun	140	90	65	60	140	140	*100	>150	140	>150			70				
24. Jun	100	50	*15	25	90	60	*100	>150	*60	90			35				
30. Jun	50	sf	sf	sf	90	*50	*10	110	sf	*40			sf				
7. Jul	15	sf	sf	sf	25	*10	sf	70	sf	*30			sf				
14. Jul	sf	sf	sf	sf	*10	sf	sf	*25	sf	sf			sf				
21. Jul	sf	sf	sf	sf	sf	sf	sf	sf	sf	sf			sf				
28. Jul	sf	sf	sf	sf	sf	sf	sf	sf	sf	sf			sf				
3. Aug	sf	sf	sf	sf	sf	sf	sf	sf	sf	sf			sf				

3.1.4.2. Snow-melting zones

Concerning the winter snow pack (Fig. 11), the mapping of the snow-melting zones of the 13 permanent plots of two subsequent years (1989 and 1990) showed a remarkable accordance in all plots (KIRNBAUER & BLÖSCHL 1993). In addition snow covering during the second half of the vegetation period, viz. September and October as well as longer covering (more than 3 days) during July and August followed more or less the same isochrones registered for winter snow. However, snow covering in the first half of the growth season (July and August), which lasted for one or two days at most, had a tendency to melt along different lines.

The duration of the melting process of the winter snow pack varied considerably among the plots as well as between the two subsequent investigation years. In 1989 the difference of the required time was 27 days with the shortest time (4 days) in plot 2 (*Eriophoretum scheuchzeri*) and plot 1 (*Oxyrietum digynae*) and the longest time (31 days) in plot 12 (*Loiseleurio-Cetrarietum*).

plot 3



plot 4

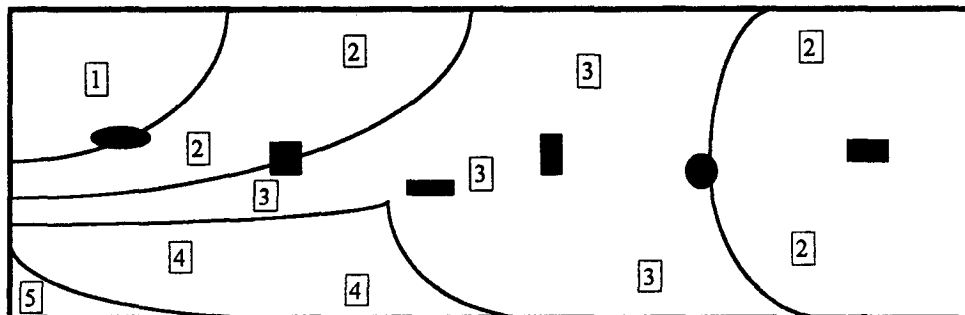
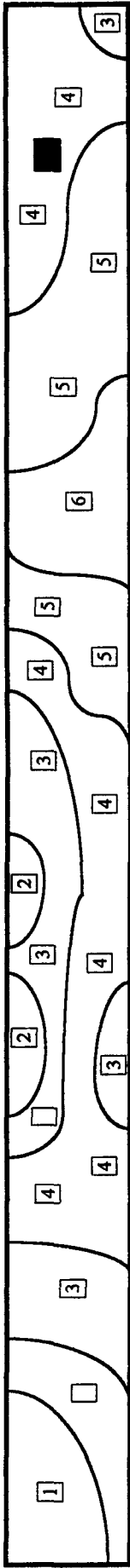


Fig. 11: Isochrones (snow-melting zones) of the winter snow pack and of snow covering during the vegetation period with the numbers (1-6) indicating the sequence of the snow melting process.

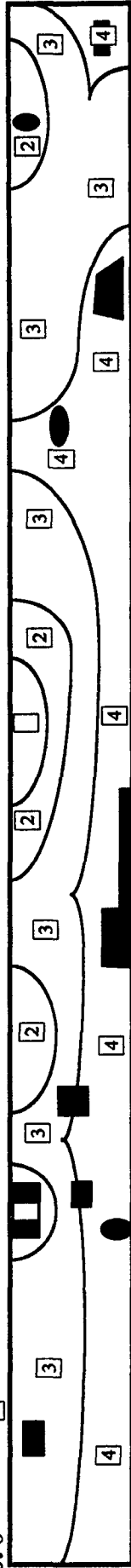
[1] - [6] : progress of the snow melting process from the first snow-free spot [1] until the last one [6].

● : bigger stones in the investigation plots

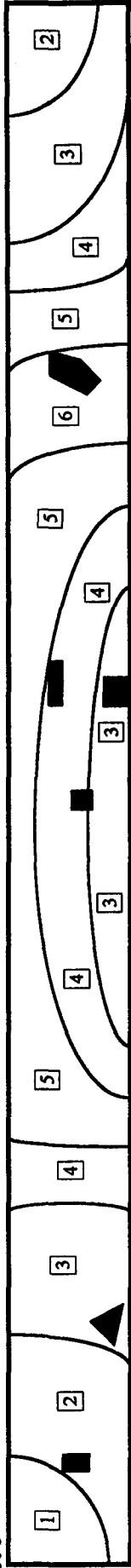
plot 5



plot 6



plot 9



plot 10



plot 11

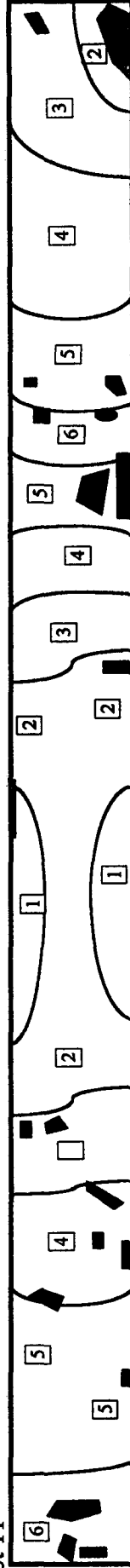
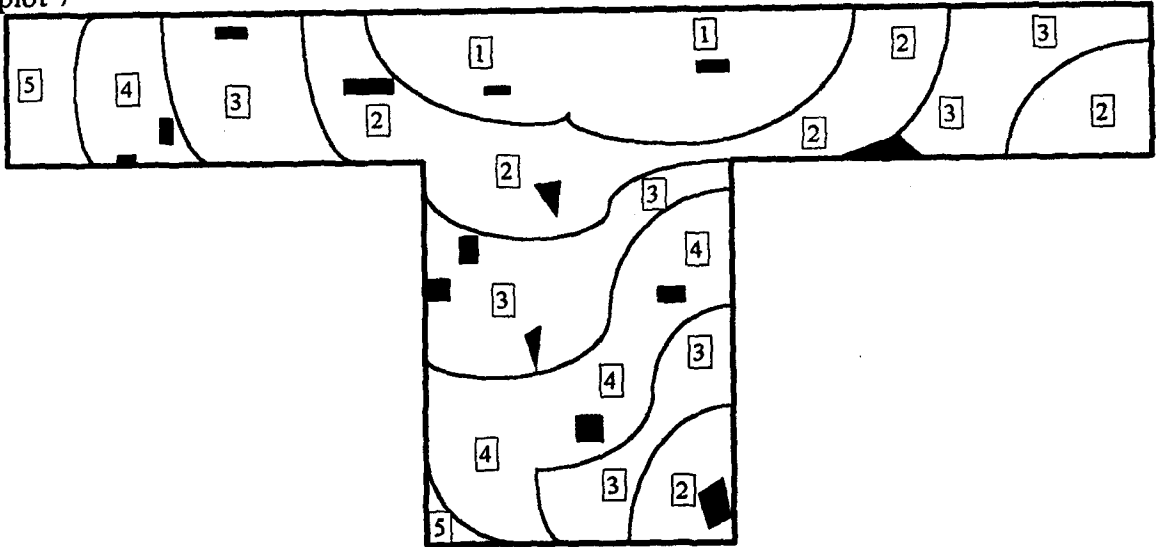
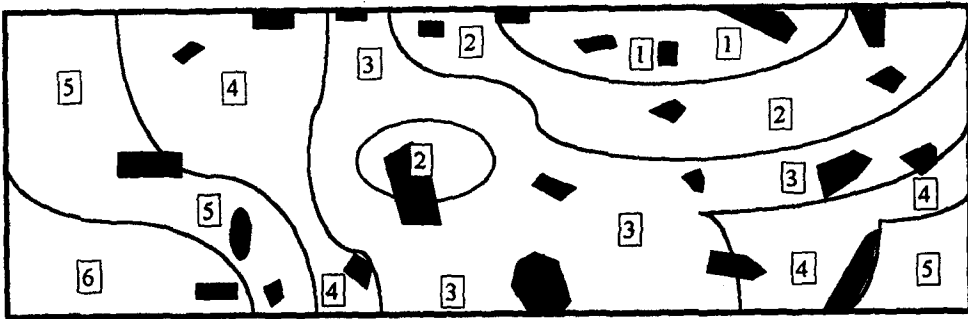


Fig. 11: continued.

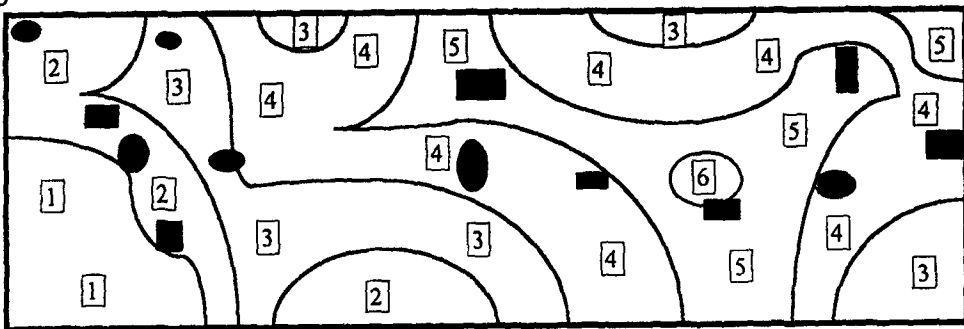
plot 7



plot 8



plot 13



plot 12

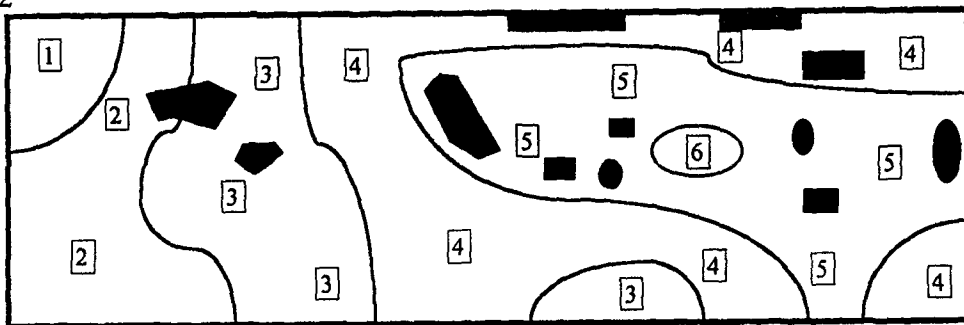


Fig. 11: continued.

In the following year the space of time increased to 31 days arising from the four days in plot 2 and 4 (*Caricetum curvulae*) and the 35 days in plot 13 (*Salicetum herbaceae*). The melting process of this year showed at the same time a tendency to last longer with the only remarkable exception in plot 4 and 12.

The variation among the six *Salicetum herbaceae* plots was 12 days in 1989 and 30 days in 1990. Whereas in plot 3 and 6 the melting process was of similar duration in both years and in plot 7 (2 days) and 11 (1 day) only slightly increased in 1990, a remarkable prolongation was observed in plot 9 (12 days) and plot 13 (26 days), respectively.

In all three *Polytrichetum sexangularis* plots thaw continued twice as long in 1990. Plot 5 and 8 showed similar values among themselves in both years, whereas the duration of the intermediate plot 10 (*Polytrichetum* and *Salicetum*) was significantly shorter during both observation periods.

3.1.4.3. Snowfall during the vegetation period

Whereas differences in precipitation measured at the five sites are negligible (Fig. 5), there are perceptible deviations concerning snow covering during the growth season on the plots investigated (Fig. 12; Tab. 16).

July, the month of thaw in the Valley of Radönt, shows similar results for all plots during all three research years (1988-90). Deviations of only one day were registered in August for every year. In September, however, differences increased to two days in 1988, three days in the following and four days in the last investigation year. In 1989 September was at the same time the last month of the vegetation period. Therefore, October was considered only for 1988, when the deviation among the plots was one day and for 1990 with differences of three years. Considering the whole vegetation period of each year the differences in duration of the snow covering was four days in 1988 and 1989 but 14 days in 1990. The extreme deviation during the last growth season is mostly due to the early thaw of plot 12 (4. June) which resulted in additional nine days of snow covering during June. If this plot is not taken into account the deviation decreases to eight days.

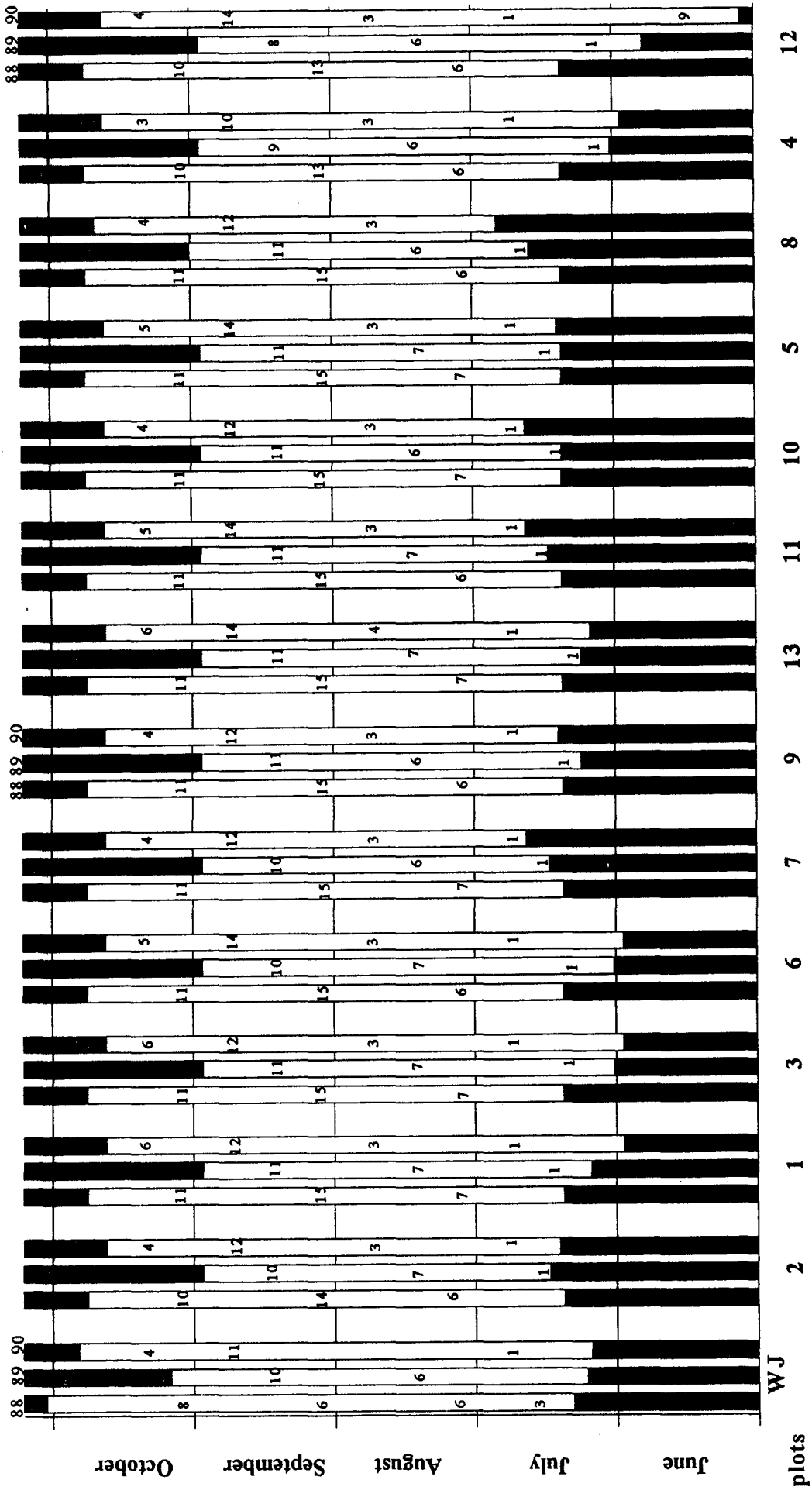


Fig. 12: Start and end of the vegetation period (blank) and the winter snow pack (black), respectively of the 13 permanent plots in the Radónt Valley and number of days with snow during the summer months from 1988 to 1990 compared with records of the SLF on Weissfluhjoch (WJ).

Table 16: Duration of the vegetation period, the number of days with permanent snow cover during the growth season and the effective snow-free vegetation period of the plots in the Radónt Valley during the three investigation years (1988-90), as well as the duration of the melting process in spring and the lasting of the winter snow pack. * = no snow melting data were available for 1988 and therefore the start of the vegetation period was set for 13. July. ** = no mapping of the snow melting zones (isochiones) in 1988.

measuring area		VALLEY OF RADÓNT																	
plant association		W.-Joch 2540 m																	
plot nr.	year	<i>Eriophorum scheuchzeri</i>			<i>Oxyrietum digyna</i>			<i>Salicetum herbaceae</i>						<i>Polytrichetum sexangulare</i>		<i>Caricetum curvulae</i>		<i>Loiseleurieton Cetrarietum</i>	
		2	1	3	6	7	9	13	11	10	5	8	4	12					
	1988	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	104 *	
vegetation period	1989	76	85	90	90	76	83	83	76	79	69	90	97						
[days]	1990	99	113	113	113	92	99	106	92	92	79	113	139						
	1988	30	33	29	32	33	32	33	32	33	32	29	29						
summer snow	1989	18	19	16	18	17	18	19	19	18	18	16	15						
[days]	1990	20	22	17	23	20	20	25	23	20	19	17	31						
	1988	74	71	73	72	71	72	71	72	71	71	75	75						
snow-free	1989	58	66	72	72	59	65	64	57	61	60	74	82						
vegetation-period	1990	71	91	89	90	72	79	81	69	72	76	96	108						
[days]	1988	**	**	**	**	**	**	**	**	**	**	**	**						
melting duration	1989	4	4	10	5	8	5	9	16	5	9	11	31						
[days]	1990	4	5	10	5	10	17	35	17	10	17	4	21						
	87/88	**	**	**	**	**	**	**	**	**	**	**	**						
winter snow pack	88/89	264	255	250	250	264	257	257	264	261	271	250	243						
[days]	89/90	287	273	273	273	294	287	280	294	294	307	273	247						

3.2. SOILS

In the Alps soil investigations in connection with plant associations are rather rare. Only in recent years was sporadic research carried out especially within the scope of the MaB (Man and Biosphere) project of the UNESCO (FRANZ 1980, MOSIMANN 1985, WILDI & EWALD 1986). As a rule most of the work was concentrated on alpine meadows and therefore snowbed communities viz. *Salicetum herbaceae* and *Polytrichetum sexangularis* were neglected. However, scattered results are available from a few thesis reports dealing with alpine problems (EYNARD 1977, MÜLLER 1983, SENN-IRLET 1987).

At first sight the results of the soil analyses (Tab. 17) in Radönt appear to vary significantly even within the same plant associations. However, comparison with data of the above-mentioned publications demonstrate that the evaluated results fit well within the limits of variations. In general the soil reaction, with values ($\text{pH}_{\text{CaCl}_2}$) between 3.4 and 4.0 in all plots, is comparatively low (EYNARD 1977, SENN-IRLET 1987) except for two pioneer plots viz. *Eriophoretum scheuchzeri* and *Oxyrietum digynae* (4.3 to 4.7).

MOSIMANN (1985) reports the same plant communities growing on different soil types within close neighbourhood. Therefore, differences in bulk density and skeleton within the same associations are not very surprising. In addition it is known that the main limiting factor for plant communities developing over the same bedrock is the length of the snow free period during summer time (ELLENBERG 1986, LANDOLT 1984) and not necessarily the soil type (MÜLLER 1983). According to differences in soil structures the same vegetation type is more or less distinctly developed. Deviations in the humus amount and correlated also in nutrients, however, are strongly linked to the particular association characteristics. Seasonal fluctuations in humus as well as nutrients are reported by DANNEBERG et al. (1980) who demonstrated two maxima of humus and organic carbon both at the beginning and at the end of the vegetation period separated by a reduction in mid summer. Contrary to lowland data (GRIESSER 1992), MOSIMANN (1985) reported a characteristic augmentation of nutrient concentration for various alpine plant associations at the beginning of August and rather low levels at thaw and the onset of winter time.

Snow covering, soil surface temperatures, soil humidity and retention capacity (not investigated in this study) are the most important parameters influencing the biological activity in soils. In addition the organic soil elements of the humus layer e.g. microorganisms, roots of plants and especially fungal mycelia are decisive in respect to nutrient reserves and nutrient availability. Phosphate as an example is positively correlated with the development of the fungal vege-

Table 17: Physical and chemical data of the two sections (A: 0/4 cm; B: -4/-8 cm) of soil analyses of the 13 permanent plots in the Radónt Valley. Samples were taken in August 1991. Hatched plot 10 and 11 with mosaic vegetation of different plant associations viz. *Salicetum herbaceae*, *Polytrichetum sexangularis* and *Caricetum curvulae*.

plant associations	Eriophor.	Oxyriet.	Salicetum herbaceae						Polytrichetum sexangularis			Caricetum	Loiseleu.				
			2	1	3	6	7	9	13	11	10			5	8		
soil parameters	plot nr.	section															
humus horizon	0	0.5	1	1	2	3	2	1	3	4	3	3	4	3			
root chamber	6	12	20	16	13	33	21	13	23	21	9	12	21	9			24
soil depth	13	21	34	29	24	46	34	21	42	47	23	22	47	23			36
skeleton	A	41.1	12.5	13.1	26.1	11.6	13.6	21.4	12.7	13.1	37.4	16.7	13.1	37.4			11.1
	B	65.1	62.3	48.2	37.1	32.2	25.0	30.1	56.0	14.8	50.7	44.5	14.8	50.7			50.4
bulk density	A	1.49	0.76	0.72	0.57	0.45	0.46	0.60	0.61	0.94	0.85	0.37	0.61	0.94			0.52
	B	0.02	0.61	0.74	0.93	0.84	0.82	0.87	0.65	1.19	0.91	0.53	0.65	1.19			0.64
humus	A	0.38	1.01	13.20	20.10	8.83	15.82	14.64	13.72	6.41	7.19	21.44	13.72	6.41			29.24
	B	0.29	0.96	7.32	10.19	5.18	14.44	7.91	7.71	4.46	2.31	11.88	7.71	4.46			15.67
pH [CaCl ₂]	A	4.25	4.45	3.70	3.36	3.37	3.71	3.41	3.30	3.39	3.57	3.50	3.30	3.39			3.48
	B	4.41	4.68	3.98	3.57	3.32	3.58	3.58	3.45	3.50	3.78	3.80	3.45	3.50			3.55
pH [H ₂ O _{dest.}]	A	4.91	5.18	3.79	3.89	3.55	3.96	3.60	3.54	3.62	3.85	3.76	3.54	3.62			3.78
	B	5.12	5.39	4.18	4.17	3.75	3.81	3.78	3.67	3.69	4.04	3.97	3.67	3.69			3.83
Carbonate	A	0.04	0.04	0.22	0.30	0.41	0.51	0.23	0.23	0.10	0.12	0.39	0.23	0.10			0.28
	B	0.01	0.04	0.34	0.27	0.17	0.23	0.18	0.17	0.12	0.09	0.34	0.17	0.12			0.19
Organic Carbon	A	0.22	0.58	7.33	7.62	11.61	9.11	8.45	7.93	3.70	4.15	12.38	7.93	3.70			16.92
	B	0.17	0.55	6.95	4.21	5.89	8.34	4.56	4.45	2.53	1.33	6.85	4.45	2.53			9.06
Total Nitrogen	A	0.06	0.06	0.44	0.54	0.81	0.95	0.57	0.50	0.22	0.31	1.02	0.50	0.22			0.98
	B	0.02	0.04	0.29	0.28	0.30	0.55	0.25	0.28	0.14	0.11	0.32	0.28	0.14			0.45
C/N ratio	A	3.9	9.4	16.6	14.0	14.3	9.6	14.8	15.9	16.9	13.6	12.1	15.9	16.9			17.3
	B	7.6	15.8	24.2	15.3	19.9	15.2	18.7	15.9	17.8	12.5	21.3	15.9	17.8			20.1
Phosphate (PO ₄)	A	0.71	0.84	0.42	0.65	3.30	2.02	0.66	0.98	0.28	2.28	3.58	0.98	0.28			9.36
	B	0.40	0.61	1.51	0.44	0.60	1.66	0.61	0.65	0.60	0.34	0.74	0.65	0.60			2.45

tative mycelia above all in ectomycorrhizae (SCHEFFER & SCHACHTSCHABEL 1984). Considering the following presentation of soil parameters one must be aware that the time available for the development of the vegetation since deglaciation differs from site to site. In addition, plot 11, treated as a *Salicetum herbaceae*, is actually a transect through different plant associations (*Polytrichetum*, *Salicetum* and *Caricetum*) with *Salix herbacea* as the dominating plant. Further, plot 10, classified as a *Polytrichetum sexangularis*, represents a gradual transition from a *Polytrichetum* to a *Salicetum*. Therefore, both plot 10 as well as 11 are influenced by the distinct non-homogeneity of the vegetation.

Abbreviations:

A	: first section (0/-4 cm)
B	: second section (-4/-8 cm)
C/N ratio < 20	: Indicating a good microbial soil activity
C/N ratio < 10	: Indicating a very good microbial soil activity

3.2.1. Physical and chemical characteristics

3.2.1.1. *Eriophoretum scheuchzeri* and *Oxyrietum digynae* (plot 2/1)

The *Eriophoretum scheuchzeri* plot as well as the *Oxyrietum digynae* plot are situated above raw silicated soils both lacking more or less a visible humus layer (0 and 0.5 cm respectively). In the former association the upper section (A) is remarkably fine-grained pointing to the alluvial origin of the site. By contrast, the profile of the latter plant community is dominated by a characteristic stony matrix (JENNY-LIPS 1930). The main root chamber is with 12 cm twice as deep in the *Oxyrietum*. The soil depth is 21 cm in this association, whereas only 13cm are reached in the *Eriophoretum*. In both soil profiles a distinct layer of rusty spots resulting from partially anaerobic conditions was registered at -3 cm in the *Eriophoretum* and between -9 and -11 cm in the *Oxyrietum*.

Physical characteristics

Skeleton: The recorded 1% of the *Eriophoretum* of A indicates the lowest value of all investigated plant associations. Reversely the 41.1% of the *Oxyrietum* stands for the highest. In both plant communities the values increase in B and again with 65.1% the *Oxyrietum* is responsible for the highest value of all 13 plots. The 23.4 % of the *Eriophoretum*, however represents the second lowest.

Bulk density: In A the *Eriophoretum* has the highest density (1.49 g/cm³), however, in B the value decreases for about 99% and thus marks the lowest of

all 13 plots (0.02 g/cm^3). The *Oxyrietum* on the other hand has a value in A (0.76 g/cm^3) comparable to that of the *Polytrichetum* plots (5 and 8), but unlike those, it decreases in B. Therefore, both the *Oxyrietum* as well as the *Eriophoretum* are the only two associations which show significantly less bulk density with increasing soil depth.

Chemical characteristics

Humus: Concerning humus, the *Eriophoretum* is the poorest association with 0.4% in A and 0.3% in B. With about 1% in both sections the values of the *Oxyrietum* are about three times higher than in the former association but still distinctly lower than in the remaining investigated plant communities.

Soil reaction ($\text{pH}_{[\text{CaCl}_2]} / \text{pH}_{[\text{H}_2\text{O}]}$): The *Eriophoretum* and the *Oxyrietum* are the least acidic plots with the highest pH measured in B of the latter association ($\text{pH}_{[\text{CaCl}_2]} = 4.8$). The difference between the two measuring methods is most significant in these two plots. The augmentation of corresponding data from $\text{pH}_{[\text{CaCl}_2]}$ to $\text{pH}_{[\text{H}_2\text{O}]}$ is around 0.7, whereas it does not exceed 0.3 in the other investigated plots.

Carbonate (CaCO_3): The 0.04% in both sections of the *Oxyrietum* and the 0.04% in A and 0.01% in B of the *Eriophoretum* are the absolute minima in all examined plant associations.

Organic Carbon (C_{org}): Both plots show only a slight decrease in B. Whereas the values are about 0.6% in the *Oxyrietum*, they are about 0.2% in the *Eriophoretum*, representing the lowest values of all 13 plots.

Total Nitrogen (N_{total}): Amounts between 0.02% and 0.06% point again to minima compared with data from the other plant communities.

C/N ratio ($\text{C}_{\text{org}}/\text{N}_{\text{total}}$): With 3.9 in A and 7.6 in B the ratios of the *Eriophoretum* are well below 10 which indicates a very good activity of soil microorganisms (SCHEFFER & SCHACHTSCHABEL 1984). The values of the *Oxyrietum* are 9.4 and 15.8, respectively, and accordingly still represent a good microbial activity.

Phosphate (PO_4): With 0.74 and 0.84 mg/100 g soil in A as well as 0.40 and 0.61 mg/100 g soil in B the *Eriophoretum* and *Oxyrietum*, respectively, show values between those evaluated for the *Polytrichetum* and the *Salicetum* plots.

3.2.1.2. *Salicetum herbaceae* (plot 3, 6, 7, 9, 11, 13)

The maximum soil depth of these six plots varies from 21 cm in plot 11 to 46 cm in plot 9. Differences in spaciousness of the root chamber are related to the previous parameter (13 cm in plot 11 vs. 33 cm in plot 9). The thickness of the humus horizon fluctuates between 1 and 3 cm. All investigated plots classified

as *Salicetum herbaceae* associations must be considered as tolerating more or less damming of water during the snow melting process in spring which causes at least temporary anaerobic conditions. Thus Planosols (Pseudogleys) are created especially in connection with the tendency to podzolisation (FRANZ 1980). In all plots except of plot 13 more or less distinct layers of rusty spots were registered at different soil depths (plot 3: -27cm; plot 6: -10 and -20 cm; plot 7: -15 cm; plot 9: -11 cm; plot 11: -14 cm). Within this soil type the six plots, however, are separated by differences in dynamics and development (BEGUIN & THEURILLAT 1982).

Physical characteristics

Skeleton: In A shares are between 11.6% and 26.1%. In B the degree of skeleton increases slightly to moderately in plot 7, 9, 11 and 13, whereas it is three and a half times higher in plot 6 and even 5 times higher in plot 3. Reasons for this striking difference can be found in the very thin soil cover of the latter two plots correlated to erosion parameters.

Bulk density: The values range between 0.45 and 0.72 g/cm³ in A and 0.43 and 0.93 g/cm³ in B respectively. In plot 3 and 6 evaluation did not emphasize any differences concerning the two distinguished levels. On the other hand, values of all other plots are generally increasing (145%-187%) in B.

Chemical characteristics

Humus: Plot 9 with 8.8% and plot 7 with 20.1% are responsible for the extreme values in A. The percentage of the other plots is varying between moderate 12.4% and 15.8%. In B lower results were evaluated for all plots decreasing substantially by 40% to 50% in plot 6, 7, 9 and 11 but only slightly (3% - 9%) in plot 3 and 13.

Soil reaction (pH_[CaCl₂] / pH_[H₂O]): In A the pH_[CaCl₂] varies between 3.4 - 3.7 vs. 3.6 - 4.0 (pH_[H₂O]), respectively. Whereas plot 9 and 13 show slightly lower values in B the other four have elevated values from 3.6 up to 4.0 (pH_[CaCl₂]) and from 3.8 up to 4.2 (pH_[H₂O]), respectively.

Carbonate (CaCO₃): In A the values are around 0.2% and 0.5%. The decrease in B varies from 10% to 70% except for plot 3 with a higher (about 155%) carbonate concentration.

Organic Carbon (C_{org}): For A values vary from 5.1% in plot 9 up to 11.6% in plot 7. All plots have lower values in B with the lowest in plot 9 (3%).

Total Nitrogen (N_{total}): Plot 3, 6, 9 and 11 have very similar amounts (0.44% - 0.57%) in A, whereas they are significantly higher (0.81% and 0.95%) in plot 7 and 13. In B values are all between 0.22% and 0.30 % except for plot 13 which still has a distinctly higher share (0.55%).

C/N ratio (C_{org}/N_{total}): In A the ratios (9.6 - 16.6) in all plots are well below 20 and therefore indicate good microbial soil activity. In B the values are all increased but do not exceed 20 except for plot 3 with 24.2. So even in the lower parts of the soil profile, a good decomposition and mineralisation of the plant debris is guaranteed.

Phosphate (PO_4): The variation in A is very high, i.e. from 0.42 (plot 3) up to 3.3 mg/100 g soil (plot 7). Except for plot 3, whose amount is more than 3 times higher in B, there is a marked decrease in all other plots with only half the variation of A (0.44 to 1.66 mg/100 g soil).

3.2.1.3. *Polytrichetum sexangulare* (plot 5, 8, 10)

Like the previously mentioned association, the soils of the *Polytrichetum sexangulare* plots belong to the Planosols. Underneath the dense moss carpet this alpine soil type is developed more distinctly due to longer periods of water damming conditions, a phenomenon which possibly occurs also during summer precipitation. In all three plots distinct layers of rusty spots were observed, however in different soil depths (plot 5: -33 to -37 cm; plot 10: -23 to -27 cm; plot 8: -7 to -11 cm). Whereas the maximum soil depth (47 and 42 cm) and the spaciousness (21 and 23 cm) of the root chamber are nearly equal in plot 5 and 10, both parameters are only about half in plot 8 (soil depth: 23 cm; root chamber: 9 cm).

Physical characteristics

Skeleton: In A the value of plot 8 (37.4%) is about three times higher as in the other two. This points among other factors to the comparatively shorter time available for soil development (disturbance by avalanches and small landslides). In B the percentage is raised slightly in plot 5 (113%) and 8 (136%) but extremely in plot 10 with 441%, possibly pointing to its transitional status towards the *Salicetum*.

Bulk density: The value (0.61 g/cm³) evaluated in A for plot 10 again refers to the *Salicetum* plots. In the other two plots the amount is considerably higher, i.e. 0.85 and 0.94 g/cm³ respectively. In B there is an increase in all three plots with the lowest in plot 10 and the highest in plot 8.

Chemical characteristics

Humus: Compared to the *Salicetum* plots the humus content of plot 5 and 8 is low in both sections. Plot 10, however, with its transitional status, has values comparable to this association.

Soil reaction ($\text{pH}_{[\text{CaCl}_2]} / \text{pH}_{[\text{H}_2\text{O}]}$): Both pH measuring methods yielded more or less the same value pattern in both sections, expressing a higher acidity in A (3.5 - 3.9), with the $\text{pH}_{[\text{H}_2\text{O}]}$ values constantly slightly higher.

Carbonate (CaCO_3): In A the amounts are about 0.1% for plot 5 and 8 and 0.23% for plot 10. In plot 8 and 10 values decline in B. But increase slightly in plot 5.

Organic Carbon (C_{org}): Values of plot 5 and 8 are very similar in A but in B the decrease in the latter is much more distinct (68% vs. 32%). Plot 10 on the other hand has in both sections values about twice as high, pointing to its close relationship to the *Salicetum*.

Total Nitrogen (N_{total}): Plot 10 again has in both sections values similar to those of the *Salicetum*. The percentage of plot 5 and 8 in A is 0.2% and 0.3% respectively and therefore only about half found in plot 10. More or less the same results were evaluated in B, where values are rather decreased in all plots.

C/N ratio ($\text{C}_{\text{org}}/\text{N}_{\text{total}}$): In both sections the values are well below 20 indicating a good microbial activity in the soil. Plot 8 is remarkable insofar as it is the only one with a lower ratio in B.

Phosphate (PO_4): In A values are widely ranging (0.28 to 2.28 mg/100g soil). Plot 8 and 10 have lower amounts in B with a very pronounced decrease in the former (85%). As far as plot 5 is concerned there is a double increase from A to B.

3.2.1.4. *Caricetum curvulae* and *Loiseleurio-Cetrarietum* (plot 4/12)

The *Caricetum curvulae* plot is characterized by a layer of dark brown humus (3 cm) storing considerable nutrient reserves. The shallow profile can be easily assigned to the alpine series of humic silicated soils (BRAUN-BLANQUET 1949). Following MÜLLER (1983) this soil type is a cryptopodzolic Ranker and belongs to the least developed and most shallow soils observed underneath alpine meadows on gneissic bedrock. The measured maximum soil depth is 22 cm and the corresponding root chamber reaches to about -12 cm.

The soil profile of the *Loiseleurio-Cetrarietum* ("*Loiseleurietum*") shows all features of a ferric humic Podzol. The rather low humus content (30%) of the black-brown and powdery layer (2 cm) is characteristic for the subassociation *alectorietosum* (BLASER 1980, PALLMANN et al. 1933). The profile showed a very stony matrix starting at -10 cm down to the maximum soil depth at -36 cm. Two third of this room are occupied by the roots (24 cm).

Physical characteristics

Skeleton: In A the *Caricetum* is characterized by 16.7% and in the *Loiseleurietum* by 11.1%. In both plots values increase in B reaching 44.5% in the former and 50.4% in the latter association.

Bulk density: With 0.52 g/cm³ for the *Loiseleurietum* and 0.37 g/cm³ for the *Caricetum* the difference is comparatively higher in A than in B with 0.65 and 0.53 g/cm³ respectively.

Chemical characteristics

Humus: The highest percentages in both associations in the 13 investigated plots are found in A, i.e. 29.2% in the *Loiseleurietum* and 21.4% in the *Caricetum* respectively. In B of both plots there is only about half.

Soil reaction (pH_[CaCl₂] / pH_[H₂O]): Acidity in A is similar in both plant associations (pH_[CaCl₂] = 3.5). In B the decrease is more distinctive in the *Caricetum*. The pH_[H₂O] values are constantly higher in all samples.

Carbonate (CaCO₃): The carbonate concentration of the *Caricetum* is more or less the same in both sections (0.3%, 0.4%). The value of the *Loiseleurietum*, however, is lower in B. All values are more or less comparable with corresponding data of the *Salicetum*.

Organic Carbon (C_{org}): The 16.92% in A of the *Loiseleurietum* means the absolute maxima of all 13 plots, followed by the one of the *Caricetum* (12.38%). In B values are in both plots slightly more than half of those in A.

Total Nitrogen (N_{total}): The highest nitrogen concentration of all 13 investigated plots is recorded with 0.98% for the *Loiseleurietum* and 1.02% for the *Caricetum*. In B, values are about three times lower in the latter and about twice lower in the former association.

C/N ratio (C_{org}/N_{total}): In A the *Caricetum* (12.1) as well as the *Loiseleurietum* (17.3) represent a good activity of the soil microorganisms. In B, however, ratios just exceed 20 in both plots.

Phosphate (PO₄): In A, the highest concentrations of phosphate of all investigated associations is found in these two plant communities. The absolute maximum was measured in the *Loiseleurietum* (9.36 mg/100 g soil). This value is more than two and a half times higher than any record for the *Caricetum*. For both plots, however, distinctly lower values were registered in B.

3.3. VEGETATION

3.3.1. History and actual situation of the timberline around the alpine Valley of Radönt

The actual timberline on the western side of the Flüela Pass, in the Flüela Valley, about 7.5 km westward of the Valley of Radönt is situated in the Tschuggen area between 1950 m (N-slopes) and 2100 m (S-slopes). The finding of a fossil *Pinus cembra* L. trunk on the Tschuggen Mountain (2279 m) proves a significant higher treeline in the sub Boreal period about 3000 years b.p. (BURGA 1990). At present, in the Flüela Valley the potential treeline - upper limit of the continuous line of *Rhododendron ferrugineum* L. (LANDOLT 1984) - is estimated at about 2200 m (VUAGNEUX 1983).

Today, scattered trees are found up to the Mälchasten area (2120 m) in about 5 km distance from the Valley of Radönt. Among *P. cembra* and *Larix decidua* Miller occasional representatives of *Alnus viridis* (Chaix) DC., *Sorbus aucuparia* L. and *Betula pendula* Roth are observed.

South of the Flüela Pass today's timberline is found in the Susasca Valley around the God Champatsch region, about 4 km from the Valley of Radönt, between 2000 m on the north side and 2250 m on the south side respectively. During the period of the Atlantikum (approx. 6500 years b.p.), however, the timberline reached at least 2375 m in the southerly exposed Tantermozza Chant Sura Valley (Vuagneux 1983).

At present, dense stands of *Pinus mugo* Turra. climb here and there on both sides of the Susasca river in the direction of the Flüela Pass up to the Chant Sura region (2 km distant from Radönt). Here, the remnants of a once larger tree stand are distributed up to 2150 m on the north side and to 2300 m on the south side respectively. Among dominating *P. mugo* shrubbery, there occur scattered *P. cembra*, *A. viridis*, *L. decidua*, *S. aucuparia* and *Salix appendiculata* L.

Taking into account the altitude (> 2400 m) and the northern exposition, it appears unlikely that the actual Valley of Radönt has ever been forested after the glacial retreat (BURGA 1990).

3.3.2. Flora and phytosociology

Totally 63 phanerogams, 23 mosses, 39 lichens and, in addition, one pteridophyte (Tab. 18) were found during the three year research period (1988-90) in the 13 permanent plots (50 m² each) and their closest border zone, totalling about 1200 m².

Table 18: continued.

DICOTYLEDONES	plant associations	Eriophoret. scheuchzeri	Oxyriet. dignaiae	Salicetum herbaceae										Polytrichetum sexangularis	Caricet. curvulae	Loiseleu.- Cetrariet.	
				3	6	7	9	13	10	5	8	4	12				
	plot nr.	2	1														
<i>Phyteuma globulariifolium</i> Stemb. et Hoppe																A,+	
<i>Phyteuma hemisphaericum</i> L.																ac,+	ac,1
<i>Polygonum viviparum</i> L.																	1
<i>Potentilla aurea</i> L.																O,+	+
<i>Primula latifolia</i> Lapeyr.																	
<i>Primula integrifolia</i> L.										+							
<i>Ranunculus glacialis</i> L.			O,2														
<i>Ranunculus grenierianus</i> Jord.			+														
<i>Rhododendron ferrugineum</i> L.			+														+
<i>Sagina linnaei</i> Presl.			+														
<i>Salix herbacea</i> L.			1	A,4	A,3	A,4	A,4	A,4	A,4	A,3	A,4	A,3	2	1	+	h,+	1
<i>Saxifraga bryoides</i> L.			V,+														
<i>Saxifraga exarata</i> Vill.			D,+														
<i>Saxifraga seguieri</i> Sprengel																	
<i>Saxifraga stellaris</i> L.	1		1							+	1	+		1	+		
<i>Sedum alpestre</i> Vill.	+		D,+	C,1	C,2	C,+				C,+	C,+	C,+				h,+	
<i>Senecio carniolicus</i> Willd.																A,+	
<i>Sibbaldia procumbens</i> L.			1	V,1	V,1				V,1							h,+	
<i>Soldanella pusilla</i> Baumg.			1,2	V,1	V,1	V,2	V,1	V,1	V,1	V,2	V,2	V,2	V,2	V,1	V,+	h,1	1
<i>Taraxacum alpinum</i> (Hoppe) Hegetschw.			1						1								
<i>Vaccinium gaultheroides</i> Bigelow									+								2
<i>Vaccinium myrtillus</i> L.																	A,1
<i>Vaccinium vitis-idaea</i> L.																	A,1
<i>Veronica alpina</i> L.			D,1	1	+	1	1	1	1	1	1	1				h,+	
TOTAL (49)		5	27	13	14	11	16	24	13	13	10	8	11	17	18		

Table 18: continued.

plant associations	Eriophoret. scheuchzeri	Oxyriet. digynae	Salicetum herbaceae											Polytrichetum sexangulare	Caricet. curvulae	Loiselei.- Cetrariet.			
			3	6	7	9	13	11	10	5	8	4	12						
MOSSSES	2	1																	
plot nr.																			
<i>Anthelia juratzkana</i> (Limpr.) Trev.	x	x	x	x	x	x	x	x	x	x	x	A,x	A,x	A,x					x
<i>Bartramia ityphylla</i> Brid.					x														
<i>Brachythecium rivulare</i> Br.																			
<i>Bryum</i> sp.																			
<i>Dicranoweisia crispula</i> (Hedw.) Milde		x	x	x															
<i>Dicranum fuscescens</i> Sm.			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
<i>Drepanocladus uncinatus</i> (Hedw.) Warnst.																			
<i>Grimmia alpestris</i> Limpr.	x	x																	
<i>Kiaeria starkei</i> (Web. & Mohr) Hagen		x	x	x	x	x	x	x	x	x	x	A,x	A,x	A,x					x
<i>Lophozia</i> sp.			x	x															
<i>Moerckia blytii</i> (Moerck) Brockm.																			
<i>Philonotis</i> cf. <i>arnellii</i> Husm.																			
<i>Philonotis tomentella</i> Lor.	2	4																	
<i>Pleuroclada albescens</i> (Hook) Spruce																			
<i>Pohlia nutans</i> (Hedw.) Lindb.	4	3																	
<i>Polytrichum commune</i> Hedw. var. <i>commune</i>																			
<i>Polytrichum juniperinum</i> Hedw.																			
<i>Polytrichum piliferum</i> Schreb. ex Hedw.																			
<i>Polytrichum sexangulare</i> (Flörke ex Hoppe) Brid.		+	1	1	3	3	3	3	3	3	3	A,4	A,5	A,5					+
<i>Porella platyphylla</i> (L.) Pfeiff.	x	x	x	x	x	x	x	x	x	x	x								
<i>Racomitrium canescens</i> (Hedw.) Brid.	x	x																	
<i>Racomitrium canescens</i> (Hedw.) Brid. f. <i>argentum</i>																			
<i>Racomitrium heterostichum</i> (Hedw.) Brid.		x	x	x	x	x	x	x	x	x	x								x
TOTAL (23)	6	10	9	11	10	10	10	12	10	10	10	6	10	9	7				6

Table 18: continued.

LICHENS	plant associations plot nr.	Eriophoret. scheuchzeri 2	Oxyriet. digyna 1	Salicetum herbaceae										Polytrichetum sexangulare	Caricet. curvulae 4	Loiseleu.- Cetrariet. 12
				3	6	7	9	13	11	10	5	8				
<i>Lecidea oligotropha</i> Laundon				x			x					x				
<i>Lecoidoma demissum</i> (Rustr.) G. Schneider & Hertel				x	x		x			x		x				
<i>Lepraria lobiflora</i> Nyl.				x	x			x								
<i>Peltigera krisstinsonii</i> Viték		x	x													
<i>Peltigera ponoyensis</i> Gyeln.		x	x													
<i>Porpidia macrocarpa</i> (DC.) Hertel & Schwab																
<i>Rhizocarpon geographicum</i> (L.) DC.			c,x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Solorina crocea</i> (L.) Ach.			c,x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Stereocaulon alpinum</i> Laurer			c,x													
<i>Thamnomelia vermicularis</i> (Swartz.) Ach.			x													
<i>Trapelia granulosa</i> (Hoffm.) V. Wirth				x				x		x						
<i>Umbilicaria cylindrica</i> (L.) Del. ex Duby										x						
<i>Umbilicaria</i> cf. <i>deusta</i> (L.) Baumg.			x				x		x			x	x	x	x	x
<i>Umbilicaria</i> sp.																
TOTAL (39)		3	9	8	12	8	12	23	15	9	4	2	14	15		

These plots represent six phytosociological associations. Floristically the richest association is the *Oxyrietum digynae* (1 plot) with 47 different species (phanerogams, mosses and lichens), closely followed by the *Loiseleurio-Cetrarietum* (1 plot) and the *Caricetum curvulae* (1 plot) with 46 species each and the *Salicetum herbaceae* (6 plots) with an average of 44 taxa, varying between 35 (plot 7) and 64 (plot 13). Significantly fewer phanerogams and cryptogams have been recorded both in the *Eriophoretum scheuchzeri* (1 plot) characterized by only 20 species, and in the *Polytrichetum sexangularis* (3 plots) with an average number of 26 taxa.

A survey of all found phanerogams, including their estimated cover (BRAUN-BLANQUET 1964), mosses and lichens as well as information about characteristic plants of the phytosociological associations are given in Table 18.

Eriophoretum scheuchzeri (Brockm.-Jerosch) Rübél (plot 2):

Caricion fuscae

Caricetalia fuscae

Scheuchzerio-Caricetea fuscae

BRAUN-BLANQUET (1948 b, 1971) mentioned that this association is characterized exclusively by *Eriophorum scheuchzeri*. It represents an initial stage of the *Caricetum fuscae* Br.-Bl. with numerous potential variations of development (OBERDORFER 1977).

Besides *E. scheuchzeri* the most important representatives in the investigated plot are the monocots *Carex lachenalii*, *C. fusca* and *Luzula spadicæ* and the dicots *Cardamine alpina*, *Cerastium trigynum* and *Saxifraga stellaris*. Among the mosses first and foremost *Pohlia nutans* and *Philonotis tomentella* have been the most frequent. Lichens, on the other hand, are very rare and represented by three scattered species only.

Oxyrietum digynae (Lüdi) Br.-Bl. (plot 1):

Androsacion alpinae

Androsacetalia alpinae

Thlaspietea rotundifolii

In the pertinent literature the *Oxyrietum* is described as a marked pioneer association on glacier moraines and on stable detritus (BRAUN-BLANQUET 1948 a, 1971, LÜDI 1958, OBERDORFER 1977). The soil reaction tends to be slightly acid, due to a poorly developed humus layer.

The most frequent dicots in the investigated plot are *Cerastium trigynum*, *Ranunculus glacialis* and *Soldanella pusilla*. The monocots, however, are rare and represented only by four scattered taxa. On the other hand mosses are rather frequent. Among the eight identified taxa, *Philonotis tomentella* and *Pohlia nutans* are the most important. In addition, nine lichen taxa have been

found including *Cetraria islandica*, *Solorina crocea* and *Stereocaulon alpinum*.

Differential taxa have been registered for both the sub-associations proposed by JENNY-LIPS (1930), viz. *Oxyrietum digynae cerastietosum* Jenny-Lips and *Oxyrietum digynae luzuletosum* Jenny-Lips (cf. Tab. 17).

Salicetum herbaceae Br.-Bl. (plot 3, 6, 7, 9, 10 and 13):

Salicion herbaceae

Salicetalia herbaceae

Salicetea herbaceae

The *Salicetum* is strictly limited to the alpine zone between 2200 and 2800 m on acid soils with a permanent snow pack lasting for about 8 to 9 months (OBERDORFER 1977, LANDOLT 1984).

Characteristic taxa of this snow-bed association (BRAUN-BLANQUET 1948 b, 1971) e.g. *Salix herbacea*, *Arenaria biflora*, *Gnaphalium supinum* and *Alchemilla pentaphyllea* are well represented in the investigated plots. In addition *Carex curvula*, *Luzula spadicea*, *Agrostis rupestris* and *Poa alpina* are the most frequent monocots. In this vegetation type mosses are important elements and their most common representatives are *Anthelia juratzkana*, *Dicranum fuscescens*, *Kiaeria starkei* and *Polytrichum sexangulare*. The lichen flora finally is well varied and best represented by *Cetraria islandica*, *Cladonia* spp., *Lepraria lobificans* and *Solorina crocea*.

Although some of the plots showed tendencies to fit the plant community *Salici herbaceae-Caricetum lachenalii* Béguin & Theurillat suggested by BEGUIN & THEURILLAT (1982) the propositions of the two authors were not considered during the present study.

Polytrichetum sexangularis (Rübel) Br.-Bl. (plot 5, 8 and 10):

Salicion herbaceae

Salicetalia herbaceae

Salicetea herbaceae

After BRAUN-BLANQUET (1948 b, 1971) the *Polytrichetum* is a pioneer association which comprises only few species restricted to acid, alpine depressions with a vegetation period of only two to three months (OBERDORFER 1977).

In the three investigated plots *Anthelia juratzkana*, *Kiaeria starkei*, *Pleuroclada albescens* and *Polytrichum sexangulare* are characteristic moss taxa of the association. In addition *Carex curvula* and *Luzula spadicea* are two of the sparsely intermixed monocots. The most frequent dicots are *Salix herbacea* and *Soldanella pusilla*. Lichens, however, are very rare and are mostly restricted to the acidophilic crustose lichens, viz. *Umbilicaria* cf. *deusta* and *Rhizocarpon geographicum*.

Caricetum curvulae (Kerner) Brockm.-Jerosch (plot 4):

Caricion curvulae

Caricetalia curvulae

Caricetea curvulae

Climate parameters are responsible that the *Caricetum* represents the final stage of soil development in the alpine zone of the Central Alps on very acid soils rich in humus (BRAUN-BLANQUET 1949 a, 1971; OBERDORFER 1978). As a rule this association is found in localities with 3½ to 5 snow-free months between altitudes of 2200 m (northern slopes) and 3000 m (southern slopes).

The investigated plot is characterized by *Carex curvula*, *Luzula spadicea*, *Helictotrichon versicolor*, *Nardus stricta* and *Poa alpina*, in addition to *Chrysanthemum alpinum*, *Gnaphalium supinum*, *Hieracium alpinum*, *Leontodon helveticus* and *Soldanella pusilla*. Whereas mosses are rather rare, the 14 taxa of lichens are dominated by *Cetraria islandica* and *C. nivalis* and *Cladonia* spp.

Loiseleurio-Cetrarietum Br.-Bl. ["*Loiseleurietum*"] (plot 12):

Loiseleurio-Vaccinion

Vaccinio-Piceetalia

Vaccinio-Piceetea

The typical *Cetrarietum* is found on wind-exposed and accordingly snow-poor ridges on very acid soils. The characteristic dicot is *Loiseleuria procumbens* accompanied by various wind-resistant fruticose lichens, e.g. *Cetraria* spp. (BRAUN-BLANQUET 1949 b, 1971).

Loiseleuria procumbens, *Chrysanthemum alpinum*, *Vaccinium* spp., *Gentiana punctata*, *Phyteuma hemisphaericum* and *Polygonum viviparum* are the most frequent dicots found in the investigated plot. Monocots are mainly represented by *Carex curvula*, *Helictotrichon versicolor*, *Sesleria disticha* and *Luzula lutea* and *L. spadicea*. Whereas mosses occur only sparsely, lichens dominate by covering about 50% of the plot. *Cladonia* spp., in particular *C. rangiferina* and *Cetraria* spp., above all *C. islandica* are the most important taxa.

3.3.3. Plant ecological indicator values

Indicator values around 3 for humidity (F), soil reaction (R), nutrient (N) and humus (H) indicate soils with ordinary site characteristics (LANDOLT 1977). Intermediate dispersion (D) is attested by a number of 4. In the moderate alpine zone characteristic temperature values (T) are between 1 and 2, whereas the continentality (K) number ranges from 2 to 3. It is important to know that

even minor deviations of these mean indicator values may point to particular features. In the subsequent Table 19 the weighted indicator values of the 13 investigated plots (six plant associations) are listed.

Table 18: Weighted averages of the ecological indicator values after Landolt (1977) of the vegetation at the 13 permanent plots. Hatched plot 10 and 11 with mosaic vegetation of different associations, viz. *Salicetum herbaceae*, *Polytrichetum sexangularis* and *Caricetum curvulae*.

plant associations	<i>Eriophoretum scheuchzeri</i>	<i>Oxyrietum digynae</i>	<i>Salicetum herbaceae</i>					
plot nr.	2	1	3	6	7	9	13	11
indicator values								
F (humidity)	4.2	3.6	3.3	3.3	3.6	3.5	3.4	3.5
R (reaction)	2.3	2.2	2.1	2	2	2.1	2.1	2.1
N (nutrient)	2.6	2.5	2.4	2.3	2.3	2.4	2.3	2.3
H (humus)	3.5	3	3.6	3.6	3.6	3.6	3.4	3.6
D (dispersion)	4	3.2	3.7	3.6	3.7	3.7	3.6	3.7
L (light)	4.2	4.5	4.5	4.5	4.5	4.4	4.4	4.4
T (temperature)	1.4	1.2	1.2	1.2	1.1	1.2	1.3	1.2
K (continentality)	2.4	2.2	2.5	2.4	2.2	2.2	2.4	2.2

plant associations	<i>Polytrichetum sexangularis</i>			<i>Caricetum curvulae</i>	<i>Loiseleurio- Cetrarietum</i>
plot nr.	10	5	8	4	12
indicator values					
F (humidity)	3.5	3.7	4	3.1	2.7
R (reaction)	2.1	2.1	2.1	2	1.9
N (nutrient)	2.3	2.5	2.5	2.3	1.9
H (humus)	3.6	3.6	3.5	3.5	3.5
D (dispersion)	3.8	3.8	3.6	3.6	3.7
L (light)	4.4	4.5	4.3	4.4	4.1
T (temperature)	1.2	1.1	1.1	1.3	1.5
K (continentality)	2.2	1.9	1.7	2.7	3.1

Eriophoretum scheuchzeri (plot 2): The high humidity (F = 4.2) of this plot is mainly due to several plants indicating wet situations (*Eriophorum scheuchzeri*, *Saxifraga stellaris*) and indicators of humidity (*Carex lachenalii*, *Epilobium alpinum*). The soil reaction is acid (R = 2.3) and the nutrient amount (N = 2.6) poor to medium. Different indicators of humus (H = 3.5) viz. *C. lachenalii*, *E. scheuchzeri*, *Cerastium trigynum*, and *S. stellaris* point to an average

or even rich soil, which is more or less well ventilated ($D = 4$). All plants occur chiefly or only in full light ($L = 4.2$) except *Deschampsia caespitosa*. The temperature value of 1.4 is characteristic for the alpine habitat. The continentality value is 2.4.

Oxyrietum digynae (plot 1): *Saxifraga stellaris* (indicator for wet situations) and various indicators of humidity (*Cerastium trigynum*, *Epilobium alpinum*, *Gnaphalium supinum*, *Salix herbacea* and *Soldanella pusilla*) refer to medium to wet soil ($F = 3.6$). The plot is further characterized by an acid soil reaction ($R = 2.2$), a low to medium nutrient level ($N = 2.5$), an average humus content ($H = 3.0$) and a well ventilated soil ($D = 3.2$). The high light value ($L = 4.5$) is expressed by all plants considered, except *Ranunculus grenierianus* which indicates half shaded habitats. The temperature ($T = 1.2$) value characterizes the alpine environment of the plot. The continentality (K) is indicated with 2.2.

Salicetum herbaceae (plot 3, 6, 7, 9, 10, 13): The humidity value ranges from 3.3 to 3.6. The lower numbers in plot 3, 6 and 13 are expressed by additional indicators of medium dryness, viz. *Helictotrichon versicolor*, *Sesleria disticha*, *Euphrasia alpina* and *Senecio carniolicus*. The soil reaction is acid in all plots ($R = 2.0-2.1$). The rather low nutrient content is represented by values from 2.3 to 2.4. Indicators for soils with little humus e.g. *Cardamine resedifolia*, *Oxyria digyna* and *Saxifraga bryoides*, exclusively found in plot 13, yield in a lower humus value ($H = 3.4$) than in the other *Salicetum* plots ($H = 3.6$). The same plants, and in addition *Saxifraga stellaris*, are responsible for the lower dispersion value ($D = 3.6$) in plot 13 which is 3.7 in the other plots. Except for *Homogyne alpina* (all plots) and *Vaccinium gaultheroides* (plot 7, 9) all recorded plants are indicators for light or full light situation ($L = 4.4-4.5$). The temperature value ($T = 1.1-1.3$) represents the conditions above timberline. The continentality value (K) ranges from 2.2 to 2.5 (cf. BEGUIN & THEURILLAT 1982).

Polytrichetum sexangularis (plot 5, 8, 10): The transitional stage of plot 10 (*Salicetum herbaceae* / *Polytrichetum sexangularis*) is mainly expressed by the deviation of the humidity value. Additional indicators of medium dryness, e.g. *Carex curvula* (plot 5, 10) and *Agrostis rupestris* (plot 10) and the lack of plants of wet and water soaked soils (*Eriophoron scheuchzeri*, and *Saxifraga stellaris* in plot 8) explain the lower humidity values in plot 5 ($F = 3.7$) and plot 10 ($F = 3.5$) compared with the well developed *Polytrichetum* of plot 8 ($F = 4.0$). The soil reaction is acid in all three plots ($R = 2.1$) and the nutrient value ($N = 2.3-2.5$) indicates mainly poor soils. The humus value ($H = 3.5-3.6$) represents soils being rather rich in humus. The well ventilated soils of plot 5 and 10 are expressed by a similar dispersion value viz. 3.8. However, in plot 8, *Epilobium alpinum* and *Veronica alpina* indicate the worse ventilation ($D =$

3.6). All plants are indicators for good to very good light conditions ($L = 4.3-4.5$), except *Homogyne alpina* (plot 8, 10). The alpine habitat is characterized by a temperature value between 1.1 and 1.2. The continentality value in plot 8 and 5 is between 1.7 and 1.9, respectively. The higher value in plot 10 ($K = 2.2$) is indicated by *C. curvula* and *A. rupestris*.

Caricetum curvulae (plot 4): The plants of this plot indicate a medium dry to damp soil ($F = 3.1$). The occurrence of *Phyteuma hemisphaericum* confirms the acid soil reaction ($R = 2.0$). Whereas the nutrient conditions ($N = 2.3$) are rather poor, the soil has an average to rich humus content ($H = 3.5$). The dispersion value ($D = 3.6$) implies a more or less well ventilated soil. The light value ($L = 4.4$) expresses very good light conditions which is specific for all registered plants, except for *Deschampsia caespitosa*. The alpine character of this plant association is represented by a temperature and continentality value of 1.3 and 2.7 respectively.

Loiseleurio-Cetrarietum (plot 12): Several indicators of medium dryness (*Cetraria islandica*, *Cladonia rangiferina*, *Carex curvula*, *Luzula lutea*, *Helictotrichon versicolor*, *Euphrasia alpina* and *Loiseleuria procumbens*) describe the rather dry conditions ($F = 2.7$). The acid soil reaction ($R = 1.9$) is confirmed by definite acid soil indicators, viz. *Gentiana punctata*, *Hieracium alpinum* and *Phyteuma hemisphaericum*. In addition to several indicators of poor soils, *Sesleria disticha* (definite indicator for poor soils) represents the low nutrient level ($N = 1.9$). The rather humus rich soil ($H = 3.5$) is indicated by *Rhododendron ferrugineum* and *Vaccinium myrtillus*. The dispersion value ($D = 3.7$) points to a more or less ventilated soil. Most of the plants are indicators for good light conditions ($L = 4.1$), except *Homogyne alpina*, *Rh. ferrugineum*, *Vaccinium gaultheroides*, *V. myrtillus* and *V. vitis-idea*. The temperature value ($T = 1.5$) points to a cool and sunny location with little competition in the alpine zone. The continentality value ($K = 3.1$) on the other hand expresses an alpine habitat on wind exposed ridges with a rather short snow covering.

3.3.4. Comparison of soil analysis with indicator values of the plants

Whereas the results of the soil analyses in the laboratory are just a candid shot of physical and chemical characteristics (cf. Tab. 17), which naturally change during the vegetation period, e.g. humus (DANNEBERG et al. 1980) and nutrients (MOSIMANN 1985), the weighted plant ecological indicator values (Tab. 19) allow an integral and comprehensive description of all investigated plots. However, indicator values were only available for the phanerogams but not for the mosses and lichens, except *Cetraria islandica* and *Cladonia rangiferina*.

Therefore, the following comparison of the laboratory results (numbers are mean values of the two sections A and B) on the one hand and the indicator values on the other hand has to be interpreted carefully.

Eriophoretum scheuchzeri (plot 2): The long snow covering and the fact that this plot is surrounded completely by little glacier brooklets cause the high humidity value ($F = 4.2$) indicating wet situations and a dispersion value of 4.0 which expresses rather insufficient ventilation. The humus ($H = 3.5$) and the nutrient values ($N = 2.6$) fake better conditions than the corresponding soil analyses results (humus: 0.34%; nitrogen: 0.04%; phosphate: 0.56 mg/100g soil). These differences may be mainly due to the high share of mosses, which are not considered for the evaluation of the indicator values. The same fact is responsible for the discrepancy of the soil reaction. With $R = 2.3$ a rather acid soil is indicated which more or less corresponds with the pH measured in the soil samples ($\text{pH}_{(\text{CaCl}_2)}$: 4.33).

Oxyrietum digynae (plot 1): The duration of the snow covering as well as the location on the shore of a glacier lake are responsible for a humidity value of 3.6, indicating a medium to wet soil. As already mentioned for the *Eriophoretum scheuchzeri* plot, the neglect of mosses for indicator values may result in differences to the soil analyses results concerning humus (0.99%; $H=3.6$), nutrients (nitrogen: 0.05% and phosphate: 0.73%; $N=2.5$), and pH ($\text{pH}_{(\text{CaCl}_2)}$: 4.57; $R=2.2$).

Salicetum herbaceae (plot 3, 6, 7, 9, 11, 13): Differences in humidity values between the plots ($F = 3.3-3.6$) are correlated with the duration of the winter snow pack and the effectively snow free vegetation period (cf. Tab. 16). Among the chemical soil characteristics the acid pH ($\text{pH}_{(\text{CaCl}_2)}$: 3.35-3.84) and the carbonate amount (CaCO_3 : 0.21-0.37%), the humus quantity (10.26-15.15%; excluding plot 9 [7.01%]), the low nitrogen content (0.31-0.4%; excluding plot 7 [0.56%] and plot 9 [0.75%]) and low phosphate amount (0.55-0.97 mg/100 g soil; excluding plot 7 and 9 [1.95 and 1.84 mg/100 g soil]) correspond rather well with the reaction value $R = 2-2.1$, the humus value $H = 3.4-3.6$ and the nutrient value $N = 2.3-2.4$. Differences between the plots, uncovered by the soil analyses, do not find their expression in the indicator values.

Polytrichetum sexangularis (plot 5, 8, 10): The lower humidity values of plot 5 (3.7) and 10 (3.5) compared with plot 8 (4.0) are well correlated with the length of the vegetation period (cf. Tab. 16). The soil reaction ($\text{pH}_{(\text{CaCl}_2)}$: 3.38-3.68) and the carbonate amount (CaCO_3 : 0.11-0.2%), the humus quantity (4.75-10.72%), the low nitrogen (0.18-0.39%) and phosphate amount (0.44-1.31 mg/100 g soil) stand more or less in accordance with the reaction value $R = 2.1$, the humus value $H = 3.5-3.6$ and the nutrient value $N = 2.3-2.5$. The de-

viations of the soil analyses results between the plots do not correspond with differences of the indicator values.

Caricetum curvulae (plot 4): The earlier melting of the winter snow pack, compared with snow-bed communities, and the slight inclination of the plot along a ridge result in a lower humidity value $F = 3.1$. The acid soil reaction ($\text{pH}_{(\text{CaCl}_2)}: 3.65$), the carbonate amount ($\text{CaCO}_3: 0.37\%$), the humus quantity (16.66%), the nitrogen (0.67%) and the phosphate share (2.16 mg/100 g soil) are well represented by the reaction value $R = 2$, the humus value $H = 3.5$ and the nutrient value $N = 2.3$.

Loiseleurio-Cetrarietum (plot 12): Partly snow free periods during winter time and the early melting of the winter snow, as well as the location on a wind swept ridge yield in a low humidity value $F = 2.7$. Whereas the low pH value ($\text{pH}_{(\text{CaCl}_2)}: 3.52$) and the carbonate amount ($\text{CaCO}_3: 0.24\%$) are more or less in accordance with the reaction value $R = 1.9$, the humus value $H = 3.5$ and the nutrient value $N = 1.9$ are too low compared with the soil analyses results, viz. humus (22.46%), nitrogen (0.72%) and phosphate (5.91 mg/100 g soil). One explanation for these differences may be the neglect of lichens for the evaluation of indicator values.

3.4 MYCOLOGY

3.4.1. List of macromycetes from the Valley of Radönt

The following list represents all macromycetes found during the three year (1988-90) investigation period in the Valley of Radönt. Taxa marked with an asterisk (*) were found outside the 13 permanent plots and are not considered in the subsequent evaluations.

Abbreviations:

E	Ectomycorrhizal symbiont	Lop	<i>Loiseleuria procumbens</i>
L	Lichenized	Phn	<i>Pohlia nutans</i>
S	Saprobe	Pit	<i>Philonotis tomentella</i>
P	Parasite	Pls	<i>Polytrichum sexangulare</i>
Brs	<i>Bryum</i> sp.	Pov	<i>Polygonum viviparum</i>
Cac	<i>Carex curvula</i>	Rag	<i>Ranunculus glacialis</i>
Cis	<i>Cirsium spinosissimum</i>	Sah	<i>Salix herbacea</i>
Dru	<i>Drepanocladus uncinatus</i>	Sar	<i>Salix retusa</i>

Basidiomycetes

Agaricales, Russulales

- | | | |
|------|---|-------------|
| * 1. | <i>Agrocybe praecox</i> (Pers.: Fr.) Fayod | S, soil |
| 2. | <i>Amanita nivalis</i> Grev. | E, Sah |
| * 3. | <i>A.</i> sp. | E, Sar |
| * 4. | <i>Anellaria semiovata</i> (Sowerby : Fr.) A. Pearson ex Dennis | S, cow dung |
| * 5. | <i>Arrhenia auriscalpium</i> Fr. | S, soil |
| 6. | <i>A. lobata</i> (Pers.: Fr.) Kühner & Lamoure ex Redhead | S, Dru, Brs |
| 7. | <i>Astrosporina asterospora</i> (Quél.) Rea | E, Sah, Pov |
| 8. | <i>A. aurea</i> (Huijsman) E. Horak | E, Sah, Pov |
| 9. | <i>A. boltonii</i> R. Heim | E, Sah |
| 10. | <i>A. egemula</i> (J. Favre) E. Horak | E, Sah |
| 11. | <i>A. giacomii</i> (J. Favre) E. Horak | E, Sah |
| 12. | <i>A. mundula</i> J. Favre & E. Horak | E, Sah |
| 13. | <i>A. ovatocystis</i> Kühner | E, Sah |
| 14. | <i>A. taxocystis</i> J. Favre & E. Horak | E, Sah |
| 15. | <i>A.</i> sp. 1 | E, Sah |
| 16. | <i>A.</i> sp. 2 | E, Sah |
| 17. | <i>Collybia loiseleurietorum</i> M.M. Moser, Gerhold & Tobies | S, Lop |
| 18. | <i>Cortinarius (Sericeocybe) cf. anomalus</i> (Fr.: Fr.) Fr. | E, Sah |
| 19. | <i>Cortinarius (Myxacium) cf. delibutus</i> Fr. | E, Sah, Pov |
| 20. | <i>C. favrei</i> M.M. Moser ex D.M. Hend. | E, Sah |
| 21. | <i>Cortinarius (Telamonia) caesionigrellus</i> Lamoure | E, Sah |
| 22. | <i>C. cavipes</i> J. Favre | E, Sah |
| 23. | <i>C. chrysomallus</i> Lamoure | E, Sah |
| 24. | <i>C. diasemospermus</i> Lamoure | E, Sah |
| 25. | <i>C. cf. gausapatius</i> J. Favre | E, Sah |
| 26. | <i>C. glandicolor</i> Fr. var. <i>exilis</i> J. Favre | E, Sah |

- | | | |
|-------|--|--------------|
| 27. | <i>C. hinnuleus</i> (Sowerby : Fr.) Fr. f. subtypique J. Favre | E, Sah |
| 28. | <i>C. lamourei</i> Bon | E, Sah |
| 29. | <i>C. cf. minutulus</i> J. Favre | E, Sah |
| 30. | <i>C. pauperculus</i> J. Favre | E, Sah |
| 31. | <i>C. pauperculus</i> J. Favre f. <i>luteovelata</i> ad int. | E, Sah |
| 32. | <i>C. percavus</i> J. Favre | E, Sah |
| 33. | <i>C. cf. pertristis</i> J. Favre | E, Sah |
| 34. | <i>C. phaeopygmaeus</i> J. Favre | E, Sah |
| 35. | <i>C. rufostriatus</i> J. Favre | E, Sah |
| 36. | <i>C. rusticellus</i> J. Favre | E, Sah |
| 37. | <i>C. cf. tenebricus</i> J. Favre | E, Sah |
| 38. | <i>C. sp. 1</i> | E, Sah |
| 39. | <i>C. sp. 2</i> | E, Sah |
| 40. | <i>C. sp. 3</i> | E, Sah |
| 41. | <i>C. sp. 4</i> | E, Sah |
| 42. | <i>Dermocybe cinnamomeolutea</i> P.D. Orton | E, Sah |
| 43. | <i>D. crocea</i> (Schaeff.: Fr.) Høil. | E, Sah |
| 44. | <i>Entoloma alpicola</i> (J. Favre) Noordel. | E, Sah |
| 45. | <i>E. atropellitum</i> (J. Favre) Bon & Courtec. | S, Sah, Pls |
| 46. | <i>E. conferendum</i> (Britzelmayr) Noordel. | E, Sah |
| 47. | <i>E. sericeum</i> (Bull.) Quél. | E, Sah |
| 48. | <i>Galerina atkinsoniana</i> f. <i>atkinsoniana</i> A.H. Smith | S, mosses |
| 49. | <i>G. chionophila</i> Senn-Irlet | S, Pls |
| 50. | <i>G. decipiens</i> var. <i>separans</i> A.H. Smith & Sing. | S, mosses |
| 51. | <i>G. hypnorum</i> (Schrank : Fr.) Kühner | S, mosses |
| 52. | <i>G. mniophila</i> (Lasch) Kühner | S, mosses |
| 53. | <i>G. pseudotundrae</i> Kühner | S, Pls |
| 54. | <i>G. vittaeformis</i> var. <i>vittaeformis</i> f. <i>tetraspora</i> A.H. Smith & Singer | S, Phn, Pit |
| 55. | <i>G. sp.</i> | S, mosses |
| 56. | <i>Hebeloma marginatum</i> (J. Favre) Bruchet | E, Sah |
| 57. | <i>H. repandum</i> Bruchet | E, Sah |
| 58. | <i>Hemimycena ochrogaleata</i> (J. Favre) M.M. Moser | S, Cis |
| * 59. | <i>Hygrocybe miniata</i> (Fr.) P. Kummer | S, Cac |
| * 60. | <i>nigrescens</i> (Quél.) Kühner | S, soil, Sar |
| 61. | <i>Hypholoma myosotis</i> (Fr.) M.M. Moser | S, Sah, Pls |
| 62. | <i>Inocybe calamistrata</i> (Fr.) Gillet | E, Sah |
| 63. | <i>I. fastigiata</i> (Schaeff.: Fr.) f. <i>alpestris</i> R. Heim | E, Sah |
| 64. | <i>I. lacera</i> (Fr.) P. Kummer | E, Sah |
| 65. | <i>I. lucifuga</i> (Fr.: Fr.) P. Kummer var. <i>lutescens</i> Velen. | E, Sah |
| 66. | <i>I. nitidiuscula</i> (Britzelm.) Sacc. | E, Sah |
| 67. | <i>I. peronatella</i> J. Favre | E, Sah |
| 68. | <i>I. piricystis</i> J. Favre | E, Sah |
| 69. | <i>I. pruinosa</i> R. Heim | E, Sah |
| 70. | <i>I. sp.</i> | E, Sah |
| 71. | <i>Laccaria bicolor</i> (Maire) P.D. Orton | E, Sah |
| 72. | <i>L. montana</i> Singer | E, Sah |
| 73. | <i>L. proxima</i> (Boud.) Pat. | E, Sah |

- * 74. *Lactarius dryadophilus* Kühner E, Sar
 75. *Marasmius androsaceus* (L.: Fr.) Fr. S, Lop
 * 76. *Mycena leptcephala* (Pers.) Gillet S, Sar
 77. *M. olivaceomarginata* (Masse) Masee f. *bispora* ad int. S, Lop
 78. *Naucoria bohémica* Velen. E, Sah
 79. *N. bohémica* f. *tetraspora* Velen. E, Sah
 * 80. *Omphalina alpina* (Britzelm.) Bresinsky & Stangl L, soil
 81. *O. chionophila* Lamoure S, Sah, mosses
 82. *O. grisella* (Weinm.) P. Karst. f. *tetraspora* ad int. L, Lop, mosses
 83. *O. kühneri* Lamoure S, soil, Phn, Pit
 84. *O. rivulicola* (J. Favre) Lamoure S, soil, Phn, Pit
 85. *O. velutipes* P.D. Orton S, soil, Phn, Pit
 86. *Panaeolus fimicola* (Fr.) Gillet S, sheep dung
 87. *Psilocybe apelliculosa* P.D. Orton S, Pls
 88. *P. chionophila* Lamoure S (P), Pls
 89. *P. luteonitens* (M. Vahl: Fr.) Park.-Rhodes S, soil, Pls
 90. *Russula chamiteae* Kühner E, Sah
 91. *R. norvegica* D.A. Reid E, Sah
 92. *R. pascua* (F.H. Møller & Jul. Schäff.) Kühner E, Sah

Aphylophorales

93. *Thelephora terrestris* Pers.: Fr. E, Sah, Pls
 94. *Tomentella coerulea* (Bres.) Höhn. & Litsch. S, soil, Sah, Pls

Gastromycetes

Lycoperdales

- * 95. *Bovista nigrescens* Pers.: Pers. S, soil, Sah
 * 96. *Lycoperdon* sp. S (E), soil, Sah

Hymenogastrales

97. *Hymenogaster saliciphilus* F. Graf & E. Horak E, Sah, Pls

Ascomycetes

Helotiales, Pezizales

98. *Cheilymenia fimicola* (DeNot. & Bag.) Dennis S, sheep dung
 99. *Mitrula gracilis* P. Karst. P (S), Pit, Phn
 100. *Neottiella aphanodyction* (Y. Kobayasi) H. Dissing, R.P. Korf & S. Sivertsen ap. Dissing & Sivertsen S, Pls
 101. *Sclerotinia glacialis* F. Graf & T. Schumach. P (S), Rag, soil
 102. *Scutellinia crinita* (Bull.: Fr.) Lambotte S, soil, mosses
 103. *S. cf. hyperborea* T. Schumach. S, soil, mosses
 104. *S. nigrohirtula* (Svrcek) Le Gal S, soil, mosses

Myxomycetes

Physarales

105. *Didymium squamulosum* (Alb. & Schwein.) Fr. S, Cis

During the three year investigation period (1988-90) a total of 105 macromycetes was found in the Valley of Radönt of which 94 were registered in the 13 permanent plots. Of these mapped species 90% (85 spp.) belong to the Basidiomycetes, followed by the Ascomycetes with 8% (7 spp.) and the Gastromycetes and the Myxomycetes with 1% (1 sp.) each.

Among the Basidiomycetes only a low number of Russulales (3 spp.) and Aphyllophorales (2 spp.) was found. With 80 species the Agaricales are the most frequent order. The families of the *Tricholomataceae* and *Cortinariaceae* are represented both by seven genera each and, with 24 taxa, the genus *Cortinarius* was the most abundant in the surveyed plots.

The taxa of the Ascomycetes, which were considered only occasionally, belong to the orders of the Helotiales (2 spp.) and the Pezizales (5 spp.), respectively.

During the 47 excursions between 1988 and 1990 several species were found only rarely. Among the 94 taxa 21 were registered once only. Furthermore, 5 additional species were reported in but one of the three investigation years. However, some macromycetes showed a remarkable productivity. More than 500 carpophores of *Cortinarius cavipes*, *C. chrysomallus*, *C. diasemospermus*, *C. favrei*, *C. glandicolor* var. *exilis*, *Galerina vittaeformis*, *Inocybe lacera*, *Laccaria montana*, *Psilocybe chionophila* and *Russula norvegica* were registered in one vegetation period. In all three years the most productive macromycete was *L. montana* with the highest number of 2548 carpophores in 1990.

It is obvious that of the above-mentioned most productive species, only two representatives do not belong to the ecological group of ectomycorrhizal symbionts. Therefore, it is not astonishing that 60 (64%) of the 94 taxa are associated with *Salix herbacea*. This is comparable with the results of EYNARD (1977) who registered 45 (61%) of totally 74 species as ectomycorrhizal macromycetes of *S. herbacea* during a two-year study in *Salicetum herbaceae* and closely related plant associations in the National Park of Vanoise (French Alps). Even more striking are the shares of the carpophore productivity. Of the 26413 registered macromycetes nearly three quarters, to be precise 19294 carpophores (73%), were ectomycorrhizal partners of this dwarf willow. On the other hand, not one single specific saprobe of this host plant was found.

Table 20: Saprobic and ectomycorrhizal macromycetes recorded in the 13 permanent plots (p) in the Valley of Radónt during the three investigation years (1988-90) in affiliation to the corresponding plant associations. Faintly hatched cells = reported only from the *Oxyrietum* (p1) of the *Caricetum* (p4), respectively; strongly hatched cells = reported only from the *Eriophoretum* (p2) or the *Loiseleurietum* (p12), respectively.

plant associations		Eriophoretum <i>scheuchzeri</i> p2 and <i>Oxyrietum dignyae</i> p1			Salicetum <i>herbaceae</i> p: 3, 6, 7, 9, 11, 13			Polytrichetum <i>sexangulare</i> p: 5, 8, 10			Loiseleurio- <i>Cetrarietum</i> p12 and <i>Caricetum curvulae</i> p4			TOTAL number of carpophores				
		88	89	90	88	89	90	88	89	90	88	89	90	88-90				
FUNGI																		
year																		
BASIDIOMYCETES																		
Agaricales, Russulales																		
1.	<i>Amanita nivalis</i>			1										1			1	2
2.	<i>Arrhenia lobata</i>			11													11	11
3.	<i>Astrosporina asterospora</i>																	1
4.	<i>A. aurea</i>																5	9
5.	<i>A. boltonii</i>			16	8	93	21	60						38	20	153	211	211
6.	<i>A. egenula</i>			1	5			1	1					3	6	1	10	10
7.	<i>A. giacomii</i>			83	11	7								83	11	7	101	101
8.	<i>A. mundula</i>			9	42	18		4						11	42	22	75	75
9.	<i>A. ovatocystis</i>			3										3			3	3
10.	<i>A. taxocystis</i>			11	6									11	6		17	17
11.	<i>A. sp. 1</i>					2										2	2	2
12.	<i>A. sp. 2</i>					4										4	4	4
13.	<i>Collybia loiseleurietorum</i>													2	2	1	5	5
14.	<i>Cortinarius cf. anomalus</i>					60										60	60	60
15.	<i>C. cf. delibutus</i>													1			1	1
16.	<i>C. favrei</i>			176	499	167	10							189	501	167	857	857
17.	<i>C. caesionigrellus</i>			55	28									55	28		83	83
18.	<i>C. cavipes</i>			91	144	323								91	144	323	558	558
19.	<i>C. chrysomallus</i>			33	97	1236								33	97	1236	1366	1366
20.	<i>C. diasemospermus</i>			1049	459	413	5							14	6	5	1951	1951
21.	<i>C. cf. gausapatius</i>					38										38	38	38
22.	<i>C. glandicolor</i> var. <i>exilis</i>			154	272	98								154	272	98	524	524
23.	<i>C. hinnuleus</i> f. <i>subtypique</i>			34	5									34	5		39	39
24.	<i>C. lamourei</i>			265	94	151								265	94	151	510	510

Table 20: continued.

plant associations		Eriophoretum scheuchzeri p2 and Oxyrietum digynae p1			Salicetum herbaceae p: 3, 6, 7, 9, 11, 13			Polytrichetum sexangularis p: 5, 8, 10			Loiseleurio- Cetrarietum p12 and Caricetum curvulae p4			TOTAL number of carpophores				
year		88	89	90	88	89	90	88	89	90	88	89	90	88	89	90	88-90	
FUNGI																		
BASIDIOMYCETES																		
Agaricales, Russulales																		
25.	<i>Cortinarius cf. minutulus</i>				17	6	1							17	6	1	24	
26.	<i>C. pauperculus</i>				326	20	3							326	20	3	349	
27.	<i>C. pauperculus f. luteovelata</i>				92	40	160							92	40	160	292	
28.	<i>C. percavus</i>			1	325		7							325		8	333	
29.	<i>C. cf. pertristis</i>				82	24	140							82	24	140	246	
30.	<i>C. phaeopygmaeus</i>					37	53								37	53	90	
31.	<i>C. rufostriatus</i>				92	20	289							92	20	289	401	
32.	<i>C. rusticellus</i>				82	72	336							82	72	336	490	
33.	<i>C. cf. tenebricus</i>				17		4							17		6	23	
34.	<i>C. sp. 1</i>				3	48	19							3	48	19	70	
35.	<i>C. sp. 2</i>				27	3								27		3	30	
36.	<i>C. sp. 3</i>				2	12	8							2	12	8	22	
37.	<i>C. sp. 4</i>						1									1	1	
38.	<i>Dermocybe cinnamomeolutea</i>				46	65	2							47	65	2	114	
39.	<i>D. crocea</i>				18	69	9							25	69	9	103	
40.	<i>Entoloma alpicola</i>				42	44	74							42	44	74	160	
41.	<i>E. atropellitum</i>				65	8	87							65	8	87	160	
42.	<i>E. confarendum</i>														9	25	34	
43.	<i>E. sericeum</i>				1									1			1	
44.	<i>Galerina atkinsoniana f. atkin.</i>					2	1								10	1	11	
45.	<i>G. chionophila</i>				23	1	6							257	119	62	438	
46.	<i>G. decipiens var. separans</i>														1	4	5	
47.	<i>G. hypnorum</i>				4	5	8							6	5	8	19	
48.	<i>G. mniophila</i>					2								1	2	2	5	
49.	<i>G. pseudotundrae</i>					3	12								5	17	22	
50.	<i>G. vittaeformis var. vittae f.</i>	344	1485	905			1							344	1485	906	2735	
51.	<i>G. sp.</i>															1	1	
52.	<i>Hebeloma marginatum</i>				96	59	159							96	59	159	314	

Table 20: continued.

FUNGI	Eriophoretum <i>scheuchzeri</i> p2 and <i>Oxyrietum digynae</i> p1		Salicetum <i>herbaceae</i> p: 3, 6, 7, 9, 11, 13		Polytrichetum <i>sexangulare</i> p: 5, 8, 10		Loiseleurio- <i>Cetrarietum</i> p12 and <i>Caricetum curvulae</i> p4		TOTAL number of carpophores				
	88	89	90	88	89	90	88	89	90	88	89	90	88-90
BASIDIOMYCETES													
Agaricales, Russulales													
53. <i>Hebeloma repandum</i>	8	3	27	116	87	245				124	90	272	486
54. <i>Hemimycena ochrogaleata</i>						8						8	8
55. <i>Hypholoma myosotis</i>					4	5					4	5	9
56. <i>Inocybe calamistrata</i>				5	18	9				5	18	9	32
57. <i>I. fastigiata</i> f. <i>alpestris</i>						2						2	2
58. <i>I. lacera</i>				398	215	212		2		398	217	215	830
59. <i>I. lucifuga</i> var. <i>lutescens</i>							1			1			1
60. <i>I. nitidiuscula</i>			27	3	6	3				3	6	30	39
61. <i>I. peronata</i>				14	34	51				14	34	53	101
62. <i>I. piricystis</i>						3						3	3
63. <i>I. pruinosa</i>				4						4			4
64. <i>I. sp.</i>						1						1	1
65. <i>Laccaria bicolor</i>				11	16	4				11	17	4	32
66. <i>L. montana</i>	2		10	1143	1351	1606				1823	1944	2548	6315
67. <i>L. proxima</i>				108	28	55				125	34	66	225
68. <i>Marasmius androsaceus</i>										4			4
69. <i>Mycena olivaceomarginata</i> f.										6	2	1	9
70. <i>Naucoria bohemica</i>					12	10					12	10	22
71. <i>N. bohemia</i> f. <i>tetraspora</i>					3						3		3
72. <i>Omphalina chionophila</i>					1						1		1
73. <i>O. grisella</i> f. <i>tetraspora</i>													24
74. <i>O. kuhneri</i>	10	49	76							12	12		135
75. <i>O. rivulicola</i>	5	87	209							10	49	76	301
76. <i>O. velutipes</i>	43	207	214							5	87	209	464
77. <i>Panaeolus fimicola</i>			1							43	207	214	464
78. <i>Psilocybe apelticulosa</i>				12	5							1	1
79. <i>P. chionophila</i>	7			25	121	108				12	5		17
80. <i>P. luteomitens</i>										185	892	523	1601
											1		1

Table 20: continued.

plant associations		TOTAL number of carpophores															
FUNGI	year	Eriophoretum scheuchzeri p2 and Oxyrietum digyna p1		Salicetum herbaceae p: 3, 6, 7, 9, 11, 13		Polytrichetum sexangulare p: 5, 8, 10		Loiseleurio- Cetrarietum p12 and Carricetum curvulae p4			88-90						
		88	89	90	88	89	90	88	89	90							
81.	<i>Russula chamiteae</i>			23	18	16					23	19	16	58			
82.	<i>R. norvegica</i>		1	324	241	522	122	44	139		458	289	662	1409			
83.	<i>R. pascua</i>			64	39	54					64	40	54	158			
Aphyllophorales																	
84.	<i>Thelephora terrestris</i>					3	2	26	56		2	26	59	87			
85.	<i>Tomentella coerulea</i>								1				1	1			
GASTROMYCETES																	
Hymenogastrales																	
86.	<i>Hymenogaster saliciphilus</i>								1				1	1			
ASCOMYCETES																	
Helotiales, Pezizales																	
87.	<i>Cheilymenia fimicola</i>		5	58								5	58	63			
88.	<i>Mitrella gracilis</i>	8									8			8			
89.	<i>Neottiella aphanodictyon</i>		10			1	3	68	216		3	78	217	298			
90.	<i>Sclerotinia glacialis</i>	204	79	14							204	79	14	297			
91.	<i>Scutellinia crinita</i>	157									157			157			
92.	<i>Scutellinia hyperborea</i>	38		2							38		2	40			
93.	<i>Scutellinia nigrohirtula</i>	181		48							181		48	229			
MYXOMYCETES																	
Physarales																	
94.	<i>Didymium squamulosum</i>		5											5			
Total of carpophores		1007	1930	1593	5590	4381	6948	1231	1640	1898	84	61	50	7912	8012	10489	26413

3.4.2. Macromycetes of the *Eriophoretum* and *Oxyrietum* (plot 2/1)

With only six different macromycetes and a total of 648 carpophores during the three year investigation period, the *Eriophoretum* plot belongs to one of the poorest habitats examined (Tab. 21). All species observed are saprobic except *Mitrula gracilis* which is considered to be a parasite (SENN-IRLET 1987) on living mosses (*Philonotis tomentella*, *Pohlia nutans*). The most frequent of the three Basidiomycetes were *Galerina vittaeformis* var. *vittaeformis* f. *tetraspora*, which was found in all three vegetation periods and *Omphalina rivulicola*, which only occurred in 1989 and 1990. The three Ascomycetes, viz. *M. gracilis*, *Scutellinia* cf. *hyperborea*, and *S. nigrohirtula* have been reported exclusively in the context of this pioneer vegetation.

Table 21: Macromycetes in the *Eriophoretum scheuchzeri* (p2) and the *Oxyrietum digynae* plot (p1) and their productivity (number of carpophores) during the three year investigation period (1988-90).

plant association	<i>Eriophoretum</i> (p 2)				<i>Oxyrietum</i> (p 1)				
	year	88	89	90	88-90	88	89	90	88-90
Basidiomycetes									
1. <i>Cortinarius percausus</i>							1		1
2. <i>Galerina vittaeformis</i> var.	39	27	54	120	305	1458	851		2614
3. <i>Hebeloma repandum</i>					8	3	27		38
4. <i>Inocybe nitidiuscula</i>							27		27
5. <i>Laccaria montana</i>					2		10		12
6. <i>Omphalina kühneri</i>					10	49	76		135
7. <i>O. rivulicola</i>		58	120	178	5	29	89		123
8. <i>O. velutipes</i>		28	45	73	43	179	169		391
9. <i>Panaeolus fimicola</i>							1		1
10. <i>Psilocybe chionophila</i>					7				7
11. <i>Russula norvegica</i>							1		1
Ascomycetes									
12. <i>Cheilymenia fimicola</i>						5	58		63
13. <i>Mitrula gracilis</i>	8			8					
14. <i>Neottiella aphanodictyon</i>						10			10
15. <i>Sclerotinia glacialis</i>					204	79	14		297
16. <i>Scutellinia crinita</i>					157				157
17. - <i>S.</i> cf. <i>hyperborea</i>	38		2	40					
18. - <i>S. nigrohirtula</i>	181		48	229					
Myxomycetes									
19. <i>Didymium squamulosum</i>						5			5
carpophores									
	266	113	269	648	741	1817	1324		3882
Total taxa / plot									
	6				16				

SENN-IRLET (1987) found eight different taxa in a *Drepanoclada exannulati-Eriophoretum scheuchzeri* association but only *Galerina vittaeformis* is in common with the results of this study.

By comparison a completely different situation is observed in the *Oxyrietum* plot (Tab. 21) situated close to the *Eriophoretum* plot mentioned before. At least 16 taxa were distinguished and with 3882 carpophores counted during the research period, this plot is the second most productive in the Radönt Valley. *G. vittaeformis* var. *vittaeformis* f. *tetraspora* and *Omphalina velutipes* are the most characteristic Agarics, whereas *O. kühneri* and *Panaeolus fimicola* were exclusively found there at the edge of an glacier lake. As in the *Eriophoretum* the saprobes dominated. However, five taxa (31%) producing 79 carpophores (2%), are ectomycorrhizal partners of the few scattered *Salix herbacea* plants. The most interesting Ascomycete is *Sclerotinia glacialis* (GRAF & SCHUMACHER 1994), a cup fungus, whose fruit-bodies emerge from sclerotia associated with *Ranunculus glacialis* shortly after the melting of the winter snow pack. This parasite as its host are restricted to this plot. In addition, *Didymium squamulosum*, found on dead leaves of *Cirsium spinosissimum*, was the one and only representative of Myxomycetes registered during the period under review. BON & GÉHU (1973) indicate *Clitocybe senilis* Fr. ss. Joss., *Inocybe dulcamara* (Alb. & Schwein.: Pers.) Kummer, *Laccaria montana*, *Omphalina alpina*, and *O. grisella* as the characteristic macromycetes of the *Androsacion alpinae* Br.-Bl. alliance. This is only partly in accordance to the above-mentioned results of whom only *Laccaria montana* fits. *Omphalina alpina*, however, was found outside the actual plot on the crest of a nearby side-moraine.

3.4.3. Macromycetes of the *Salicetum* (plot 3, 6, 7, 9, 11, 13)

During the three year (1988-90) investigation period, totally 68 Basidiomycetes and one Ascomycete were distinguished in the six *Salicetum* plots represented by 16920 mapped carpophores (Tab. 22). There are, however, considerable differences in species diversity as well as in carpophore productivity among these plots. Three of them, plot 3, 7 and 11, are very similar regarding both parameters. Plot 9 differs with a remarkably higher carpophore productivity (5317 carpophores, equals highest productivity in all 13 investigated plots) and plot 13 with a significantly higher species diversity (43 taxa; equals highest species number in all 13 investigated plots). The yields of plot 6 on the other side were poorest in diversity (19 taxa) as well as in productivity (858 carpophores). Concerning the number of taxa, 55 (80%) are suspected to form ectomycorrhiza with *Salix herbacea*. Considering the carpophore productivity the impressive share increases to 97% (16391 carpophores).

Therefore, among the characteristic and most productive taxa (more than 500 carpophores during the three year investigation period) only symbionts occur, viz. *Cortinarius cavipes*, *C. chrysomallus*, *C. diasemospermus*, *C. favrei*, *C. glandicolor* var. *exilis*, *C. lamourei*, *C. pauperculus*, *Inocybe lacera*, *Laccaria montana* and *Russula norvegica*. Furthermore, there are additional representatives, with certainly lower productivity, but nevertheless are distinctive, viz. *Astrosporina giacomii*, *Cortinarius percavus*, *C. pertristis*, *C. rufostriatus*, *C. rusticellus*, *Dermocybe cinnamomeolutea*, *Entoloma alpicola*, *E. atropellitum*, *Hebeloma repandum*, *H. marginatulum*, *Inocybe peronatella*, *Laccaria proxima*, *Psilocybe chionophila*, *Russula chamiteae* and *R. pascua* (cf. Tab. 25). Rare but interesting taxa, because they have not yet been reported from alpine habitats, are *Naucoria bohémica* f. *tetraspora* and *Psilocybe apelluculosa*.

3.4.4. Macromycetes of the *Polytrichetum* (plot 5, 8, 10)

Among the three *Polytrichetum* plots significant differences were observed both, concerning species diversity and carpophore productivity (Tab. 23). Whereas plot 5 and 8 are very similar with nine and seven different species respectively, 18 taxa were registered in plot 10, which is, in a plant sociological point of view, in a transitional stage between a *Polytrichetum* and a *Salicetum* (cf. Tab. 18). Of the 23 macromycetes recorded, 21 belong to the Basidiomycetes and one to the Gastromycetes and Ascomycetes, each. Considering all three plots, 12 taxa (52%) are ectomycorrhizal partners of *Salix herbacea*, responsible for 2707 carpophores (57%) of the total carpophore production.

The most characteristic representatives of this vegetation type are *Laccaria montana*, *Psilocybe chionophila*, *Russula norvegica* and *Neottiella aphano-dyction*, which were found in all three plots. Furthermore, *Galerina chionophila* (plot 5 and 8) and *Thelephora terrestris* (plot 5 and 10) were also registered rather frequently. The record of *Tomentella coerulea* (plot 10) is the first of this taxon from the alpine zone. However, the most interesting macromycete undoubtedly is *Hymenogaster saliciphilus* (plot 10), which represents the first published record of a hypogeous Basidiomycete from an alpine habitat (GRAF & HORAK 1993).

Among the seven species found in a similar plant association by EYNARD (1977) and the two by SENN-IRLET (1987) are *Galerina chionophila*, *Laccaria laccata*, *Psilocybe chionophila* and *Russula norvegica*, which stand in perfect accordance with the results of plot 5 and 8 in the Radönt Valley.

Table: 23: Macromycetes in the three *Polytrichetum sexangularis* plots (p: 5, 8, 10) and their productivity (number of carpophores) during the three year investigation period (1988-90).

plot		p10			p5			p8			SUM
		88	89	90	88	89	90	88	89	90	88-90
Basidiomycetes											
1.	<i>Astrosporina boltonii</i>	21		60							81
2.	<i>A. egenula</i>		1	1							2
3.	<i>A. mundula</i>			4							4
4.	<i>Cortinarius favrei</i>							10			10
5.	<i>C. diasemospermus</i>				5						5
6.	<i>Dermocybe crocea</i>		7								7
7.	<i>Galerina atkinsoniana</i>		8								8
8.	<i>G. chionophila</i>					3	1	234	115	55	408
9.	<i>G. decipiens</i> var. <i>sep.</i>		1	4							5
10.	<i>G. hypnorum</i>				2						2
11.	<i>G. mniophila</i>			2	1						3
12.	<i>G. pseudotundrae</i>		2	5							7
13.	<i>G. sp.</i>			1							1
14.	<i>Inocybe lacera</i>									3	3
15.	<i>I. peronatella</i>			2							2
16.	<i>Laccaria montana</i>	287	260	537	382	286	352	9	47	43	2203
17.	<i>Psilocybe chionophila</i>	7	173	22	21	149	30	125	449	363	1339
18.	<i>P. luteonitens</i>		1								1
19.	<i>Russula norvegica</i>	90	28	109	12	3	21	20	13	9	305
20.	<i>Thelephora terrestris</i>			5	2	26	51				84
21.	<i>Tomentella coerulea</i>			1							1
Gastromycetes											
22.	<i>Hymenogaster salici.</i>			1							1
Ascomycetes											
23.	<i>Neottiella aphanody.</i>	2	59	210		9	4	1		2	287
carpophores / year		407	540	964	425	476	459	399	624	475	
carpophores / plot		1911			1360			1498			4769
Total taxa / plot		18			9			7			23

3.4.5. Macromycetes of the *Caricetum* and *Loiseleurietum* (plot 4/12)

The four Basidiomycetes reported from the *Caricetum* plot (Tab. 24) did produce humble 31 carpophores during the three year research period, meaning the poorest species diversity and absolute lowest productivity of all 13 investigated plots. The most common representative was *Laccaria proxima*, one of

three ectomycorrhizal partners associated with the few scattered *Salix herbacea* plants. The only non-mycorrhizal carpophore, was *Psilocybe chionophila* parasitizing one of the rare moss individuals of *Polytrichum sexangulare*.

Table: 24: Macromycetes in the *Caricetum curvulae* (p 4) and the *Loiseleurio-Cetrarietum* plot (p 12) and their productivity (number of carpophores) during the three year investigation period (1988-90).

plant association	<i>Caricetum</i> (p 4)				<i>Loiseleurietum</i> (p 12)			
	88	89	90	88-90	88	89	90	88-90
Basidiomycetes								
1. <i>Amanita nivalis</i>					1			1
2. <i>Astrosporina asterospora</i>					1			1
3. <i>A. aurea</i>					4		5	9
4. <i>A. boltonii</i>					1	12		13
5. <i>A. egenula</i>	2			2				
6. <i>A. mundula</i>					2			2
7. <i>Collybia loiseleurietorum</i>					2	2	1	5
8. <i>Cortinarius delibutus</i>					1			1
9. <i>C. favrei</i>					3	2		5
10. <i>C. diasemospermus</i>		3		3	14	3	5	22
11. <i>C. cf. tenebricus</i>							2	2
12. <i>Dermocybe cinnamomeol.</i>					1			1
13. <i>Entoloma conferendum</i>						9	25	34
14. <i>Inocybe lacera</i>						2		2
15. <i>I. lucifuga</i>					1			1
16. <i>Laccaria bicolor</i>						1		1
17. <i>L. proxima</i>	11	6	8	25	6		3	9
18. <i>Marasmius androsaceus</i>					4			4
19. <i>Mycena olivaceomargin.</i>					6	2	1	9
20. <i>Omphalina grisella</i> f. <i>tet.</i>					12	12		24
21. <i>Psilocybe chionophila</i>		1		1				
22. <i>Russula chamiteae</i>						1		1
23. <i>R. norvegica</i>					12	4		16
24. <i>R. pascua</i>						1		1
carpophores	13	10	8	31	71	51	42	164
Total taxa / plot	4				22			

The present results confirm the observations of FAVRE (1955) and SENN-IRLET (1987). However, they are not in accordance with the data published by BON & GÉHU (1976) who indicate *Hygrocybe flavescens* (Kauffmann) Sing. and *H. aurantiosplendens* R. Haller as characteristic taxa of the *Caricion curvulae* alliance.

Although 22 different taxa were distinguished in the *Loiseleurietum* plot (Tab. 24), a number similar to the *Oxyrietum* and the *Polytrichetum* associations, the carpophore productivity is with 164 individuals comparatively low. With only some scattered *Salix herbacea* and *Polygonum viviparum* plants as potential ectomycorrhizal hosts, it is rather surprising that 19 species (86%) of the registered taxa belong to ectomycorrhiza-forming genera of which *Astrosporina asterospora*, *Cortinarius* cf. *delibutus* and *Inocybe lucifuga* are exclusively reported from this plot. Furthermore the lichenized *Omphalina grisella* f. *tetraspora*, the terricol-saprobe *Entoloma conferendum* and the three saprobes on *Loiseleuria procumbens*, viz. *Mycena olivaceomarginata* f. *bispora*, *Marasmius androsaceus* and *Collybia loiseleurietorum* (MOSER & RAMESEDER 1993) were only mapped also in this plot.

An interesting fact is the absence of *Laccaria montana* in both associations. Otherwise, this macromycete would have been registered in all plots where *Salix herbacea* was present. It seems, that in the *Caricetum* as well as in the *Loiseleurietum*, where the lowest humidity values (cf. Tab. 19) were measured, *L. proxima* occurs as a substitute. Similar observations were made in the two *Salicetum* plots 6 and 11, where both taxa were found with *L. proxima* always restricted to the driest spots in these plots.

3.4.6. Basidiomycetes of the *Salicetum herbaceae* in the Alps

In Table 25 all Basidiomycetes found in typical *Salicetum herbaceae* associations are listed. Only taxa published in ecological studies are considered, viz. FAVRE (1955; Eastern Swiss Alps), BON & GÉHU (1973), EYNARD (1977; French Alps), SENN-IRLET (1987; Central Swiss Alps) and GRAF (present study; Eastern Swiss Alps).

This comparison results in 95 Agaricales reported from *Salicetum herbaceae* associations in the Alps, of which one fifth was noticed by at least three of the above-mentioned authors. Therefore, it seems not too hazardous to declare these 19 taxa as indicator species of the *Salicetum herbaceae*; or in terms of plant sociology: characteristic species of the association. It is not a great surprise that 16 (84%) of these indicator taxa are ectomycorrhiza-forming partners of the dwarf willow. Except for *Russula norvegica*, FAVRE (1955) already observed more than 40 years ago all other indicative macromycetes (characteristic species) in association with *Salix herbacea*.

A comparison of common taxa between the authors shows interesting facts (Tab. 26). It was to be expected that the two studies realized in the eastern part of the Swiss Alps are most congruent (29 common species).

Table 25: Basidiomycetes reported from typical *Salicetum herbaceae* associations in the Alps based upon data of FAVRE (1955) BON & GÉHU (1973), EYNARD (1977; facies 3 et 4), SENN-IRLET (1987; Fläche 11 und 22) and GRAF (present study; plot 3,6,7,9,11, and 13). (x) = species related to *Salix herbacea* found in plant associations other than *Salicetum herbaceae*. **Bold** indicates taxa found by at least three authors.

	BASIDIOMYCETES	Authors	FAVRE	BON& GÉHU	EYNARD	SENN- IRLET	GRAF
		year	1955	1973	1977	1987	1994
1.	<i>Amanita nivalis</i>		x	x	x		x
2.	<i>Anellaria semiovata</i>					x	
3.	<i>Arrhenia lobata</i>					(x)	x
4.	<i>Astrosporina boltonii</i>						x
5.	<i>Astrosporina egenula</i>		x				x
6.	<i>Astrosporina giacomii</i>		x	x		x	x
7.	<i>Astrosporina mundula</i>				x		x
8.	<i>Astrosporina ovatocystis</i>						x
9.	<i>Astrosporina taxocystis</i>		x				x
10.	<i>Camarophyllus pratensis</i>				x		
11.	<i>Clitocybe festivoides</i>				x		
12.	<i>Clitocybe lateritia</i>				(x)	x	
13.	<i>Clitocybe subcylindrospora</i>				x		
14.	<i>Cortinarius albonigrellus</i>		x	x			
15.	<i>Cortinarius anomalus</i>		x				x
16.	<i>Cortinarius caesionigrellus</i>						x
17.	<i>Cortinarius cavipes</i>		x				x
18.	<i>Cortinarius chrysomallus</i>					(x)	x
19.	<i>Cortinarius diasemospermus</i>						x
20.	<i>Cortinarius favrei</i>		x	x	x	x	x
21.	<i>Cortinarius gausapatius</i>				x		x
22.	<i>Cortinarius glandicolor</i> var. <i>exilis</i>		x		x		x
23.	<i>Cortinarius hinnuleus</i> f. <i>subtypique</i>		x				x
24.	<i>Cortinarius hinnuleus</i> var. <i>gracilis</i>		x		x	x	
25.	<i>Cortinarius lamourei</i>						x
26.	<i>Cortinarius levipileus</i>				x		
27.	<i>Cortinarius minutalis</i>				x		
28.	<i>Cortinarius minutulus</i>		x				x
29.	<i>Cortinarius oreobius</i>		x	x			
30.	<i>Cortinarius pauperculus</i>		x			(x)	x
31.	<i>Cortinarius percavus</i>					(x)	x
32.	<i>Cortinarius pertristis</i>		x	x			x
33.	<i>Cortinarius phaeopygmaeus</i>		x				x
34.	<i>Cortinarius rufostriatus</i>		x			(x)	x
35.	<i>Cortinarius rusticellus</i>		x				x
36.	<i>Cortinarius subtilior</i>		x	x			
37.	<i>Cortinarius tenebricus</i>		x		x		x
38.	<i>Dermocybe cinnamomeolutea</i>		x		x	x	x
39.	<i>Dermocybe crocea</i>						x
40.	<i>Entoloma alpicola</i>		x		x		x

Table 25: continued.

	BASIDIOMYCETES	Authors	FAVRE	BON& GÉHU	EYNARD	SENN- IRLET	GRAF
		year	1955	1973	1977	1987	1994
41.	<i>Entoloma anthracinum</i>		x		x		
42.	<i>Entoloma atropellitum</i>		x				x
43.	<i>Entoloma conferendum</i>		x			x	(x)
44.	<i>Entoloma cucullatum</i>		x	x			
45.	<i>Entoloma favrei</i>					x	
46.	<i>Entoloma mammosum</i>				x		
47.	<i>Entoloma sericeum</i>		x		(x)	x	x
48.	<i>Galerina atkinsoniana</i>					(x)	x
49.	<i>Galerina chionophila</i>					x	x
50.	<i>Galerina hypnorum</i>						x
51.	<i>Galerina mniophila</i>						x
52.	<i>Galerina pseudotundrae</i>					(x)	x
53.	<i>Galerina vittaeformis</i>		x		x	x	x
54.	<i>Hebeloma alpinum</i>		x		x		
55.	<i>Hebeloma marginatulum</i>		x		x	(x)	x
56.	<i>Hebeloma minus</i>				x	x	
57.	<i>Hebeloma repandum</i>						x
58.	<i>Hemimycena ochrogaleata</i>						x
59.	<i>Hygrocybe conica</i>				x		
60.	<i>Hypholoma myosotis</i>					(x)	x
61.	<i>Inocybe calamistrata</i>		x		x	x	x
62.	<i>Inocybe canescens</i>				x		
63.	<i>Inocybe dulcamara</i>		x	x	x		
64.	<i>Inocybe fastigiata</i>		x		x		x
65.	<i>Inocybe geraniodora</i>		x	x			
66.	<i>Inocybe lacera</i>		x			(x)	x
67.	<i>Inocybe nitidiuscula</i>						x
68.	<i>Inocybe peronatella</i>						x
69.	<i>Inocybe piricystis</i>						x
70.	<i>Inocybe pruinosa</i>						x
71.	<i>Inocybe rhacodes</i>		x			x	
72.	<i>Inocybe subbrunnea</i>				x		
73.	<i>Laccaria bicolor</i>						x
74.	<i>Laccaria laccata</i>				x		
75.	<i>Laccaria montana</i>		x			(x)	x
76.	<i>Laccaria proxima</i>		x				x
77.	<i>Laccaria tetraspora</i>					x	
78.	<i>Lactarius nanus</i>		x	x	(x)	(x)	
79.	<i>Lactarius salicis-herbaceae</i>				x		
80.	<i>Lactarius uvidus</i>				x	x	
81.	<i>Naucoria bohemica</i>						x
82.	<i>Naucoria bohemica</i> f. <i>tetrasp.</i>						x
83.	<i>Naucoria tantilla</i>		x	x			
84.	<i>Omphalina chionophila</i>				x		x

Table 25: continued.

	BASIDIOMYCETES	Authors	FAVRE	BON& GÉHU	EYNARD	SENN- IRLET	GRAF
		year	1955	1973	1977	1987	1994
85.	<i>Omphalina obatra</i>		x	x	x		
86.	<i>Omphalina velutipes</i>				x	x	
87.	<i>Phaeotellus griseopallidus</i>				x		
88.	<i>Phaeotellus griseopallidus</i> var. <i>gris.</i>				x		
89.	<i>Psilocybe apeliculosa</i>						x
90.	<i>Psilocybe chionophila</i>		x		x	x	x
91.	<i>Russula chamiteae</i>				x		x
92.	<i>Russula nana</i>		x		x	(x)	
93.	<i>Russula norvegica</i>				x	x	x
94.	<i>Russula pascua</i>		x		x		x
95.	<i>Thelephora terrestris</i>						x
Species of <i>Salicetum herbaceae</i> associations			44	13	39	19	60
Species related with <i>Salix herbacea</i> found in other associations (x)			-	-	(3)	(13)	(1)

However, it is somehow astonishing that the affinity is higher between the French Alps and the Eastern Swiss Alps (16 and 18 common species), than between the French and Central Swiss Alps (ten common species) or the Eastern and Central Swiss Alps (nine and ten common species).

The situation does not change except in one case when considering the species (related to *Salix herbacea*) found outside typical *Salicetum herbaceae* associations. The affinity between the studies of SENN-IRLET (1987; Central Swiss Alps) and GRAF (present study; Eastern Swiss Alps) exceeds the one between the latter author and EYNARD (1977; French Alps).

Table 26: Comparison of common species in typical *Salicetum herbaceae* associations.

Bold numbers = common species restricted to the *Salicetum*.

italic numbers = with additional species from other plant associations.

	French Alps	Central Swiss Alps	Eastern Swiss Alps	
	EYNARD	SENN-IRLET	GRAF	FAVRE
EYNARD		10	16	18
SENN-IRLET	<i>15</i>		9	10
GRAF	<i>17</i>	<i>21</i>		29
FAVRE	<i>20</i>	<i>17</i>	<i>30</i>	

3.4.7. Basidiomycetes reported with *Salix herbacea* from arctic and alpine habitats

The number of arctic-alpine Basidiomycetes (296) in Europe registered in association with *Salix herbacea* (Fig. 13, Tab. 27) is about three times higher than the one (95) found in typical *Salicetum herbaceae* associations situated in the Alps (cf. chapter 3.4.6.). However, it must be considered that the number from the Alps resulted from four mycosociological studies (four authors), whereas for the arctic-alpine result other than sociological works were evaluated too, resulting in 82 publications (34 authors). In this connection it should not be neglected that, although every taxon was reported in association with *Salix herbacea* there is not necessarily a natural relationship between the plant and the fungus. Furthermore, the names of the taxa were accepted as they were cited in the particular publication without any attempt undertaken to prove eventual accordance to later noticed synonyms.

The total of 296 species are distributed among 38 genera. Of them, only 64 taxa were found in the Alps (Fig. 13 A - D) as well as in arctic regions (Fig. 13 G - O). Whereas 70 species were reported exclusively from arctic collecting sites, there were remarkable 161 restricted representatives noticed from the Alps. One single taxon, *Inocybe rickenii* Heim, was registered in the alpine zone of the Rhodope mountains (Bulgaria, F). The collecting sites in the French Alps (A) distinctly dominated with 67 exclusive taxa followed by the sites in Greenland (O) with 28 taxa, the Grisons (C) with 27, Scotland (G) with 16, the Central Alps (B) with 13 and North Sweden (J) with 9 taxa.

The genera *Inocybe* (66 species) and *Cortinarius* (55 species) are by far the best represented, followed by *Russula* (20), *Entoloma* and *Galerina* with 18 taxa each, *Omphalina* (16) and *Lactarius* (13). Therefore it is not surprising that 68% of the listed Basidiomycetes are putative ectomycorrhizal partners of the dwarf willow *Salix herbacea*.

Comparing the Alps with the arctic area, the specific taxa constitute 68% of ectomycorrhizal symbionts in the former and 60% in the latter. Considering the common species of both areas 77% are ectomycorrhizal representatives associated with *S. herbacea*.

Whereas the species diversity (only species found exclusively in the particular region are considered) of the ectomycorrhizal genera *Cortinarius* (Alps: 32; arctic area: 9), *Inocybe* (52 / 5) and *Hebeloma* (8 / 1) is distinctly higher in the Alps, *Russula* (6 / 7), *Lactarius* (4 / 5) and *Laccaria* (3 / 3) are well balanced. *Dermocybe* (0 / 5) on the other hand is the only ectomycorrhizal genus with a higher diversity in the arctic areas. Concerning the saprobes, *Entoloma* (12 / 3), *Omphalina* (8 / 4) and *Galerina* (7 / 3) are better represented in the Alps, whereas *Mycena* (1 / 5) is more frequent in the arctic areas.

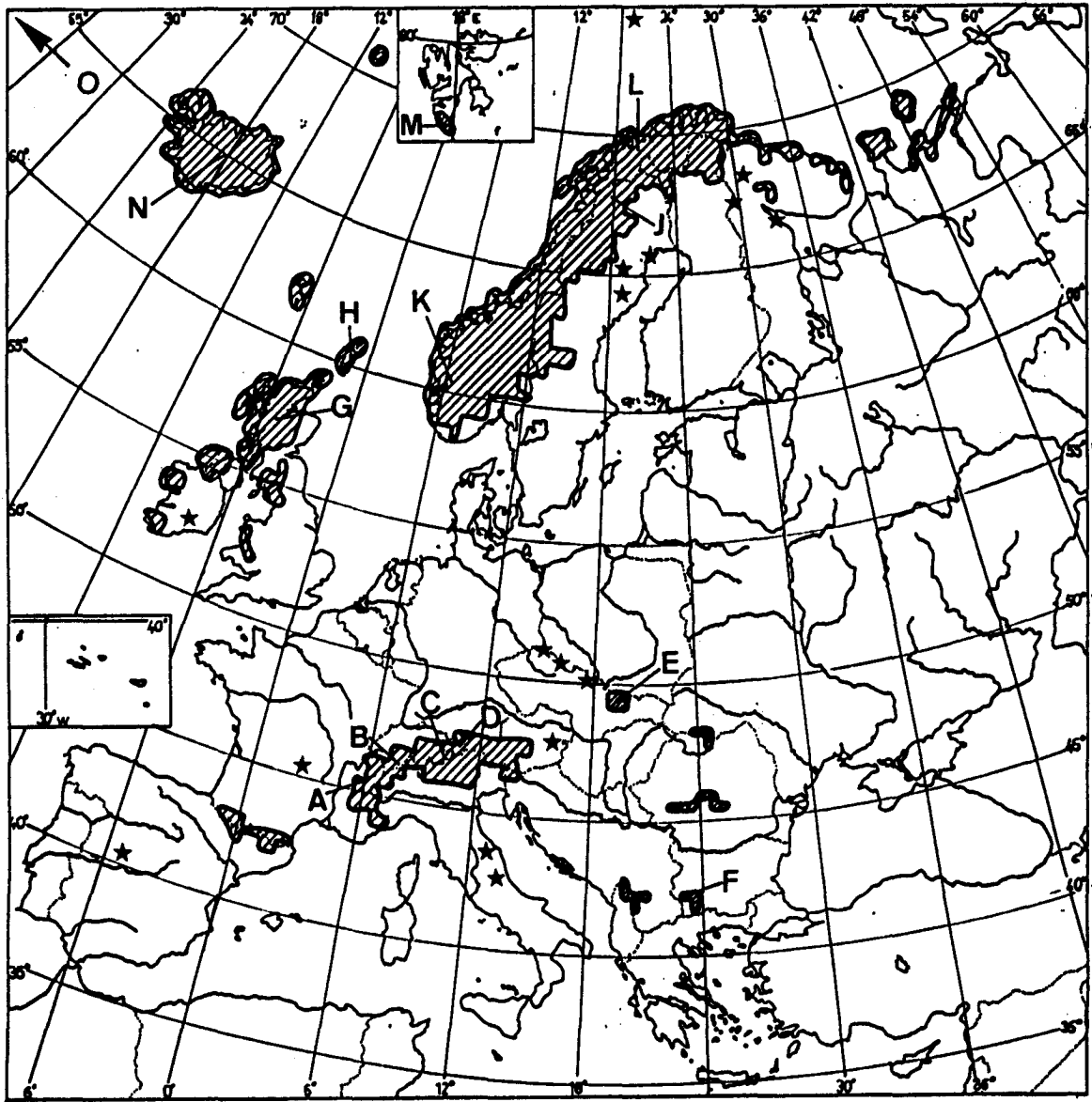


Fig. 13: Distribution of *Salix herbacea* in Europe (hatched = large connected areas; ★ = small isolated spots) with main collecting areas (A - O) of associated Basidiomycetes (after JALAS & SUOMINEN 1976, changed).

- | | |
|----------------------------------|---|
| A = West Alps (France, Italy) | H = Shetland (part of Scotland) |
| B = Central Alps (Swiss, Italy) | J = North Sweden (Abisko) |
| C = Eastern Swiss Alps (Grisons) | K = South Norway (Jotunheimen, Hardangar) |
| D = East Alps (Austria, Italy) | L = North Norway (Tromsø, Finnmark) |
| E = Tatra | M = Svalbard |
| F = Rhodope mountains (Rila) | N = Island |
| G = Scotland (mainland) | O = Greenland (☞ = not on the map) |

Table 27: Basidiomycetes reported in association with *Salix herbacea* from arctic and alpine habitats of 82 selected publications. Bold letters (A - O) indicate main collecting sites of carpophores in Europe (cf. Fig. 13). Italic and underlined numbers (1 - 82) refer to the selected publications. Bold taxa were registered with *Salix herbacea* during this research project (situated in region C). ¹ = taxa strictly reported from arctic collecting sites; ² = taxa strictly reported from collecting sites in the Alps.

1: BAS, 1982; 2: BON, 1985a; 3: BON, 1985b; 4: BON, 1988a; 5: BON, 1989; 6: BON, 1990; 7: BON, 1991; 8: BON, 1992b; 9: BON, 1993; 10: BREITENBACH & KRÄNZLIN, 1991; 11: BRUCHET, 1970; 12: BRUCHET, 1974; 13: DEMOULIN, 1972; 14: EYNARD, 1977; 15: FAVRE 1955; 16: GERHOLD, 1986; 17: GULDEN, 1980; 18: GULDEN & LANGE, 1971; 19: GULDEN et al., 1985; 20: GULDEN et al., 1988; 21: HALLGRIMSON, 1972; 22: HALLGRIMSON, 1980; 23: HENDERSON, 1958; 24: HØILAND, 1983; 25: HORAK, 1960; 26: HORAK, 1987a; 27: HORAK, 1987b; 28: JAMONI, 1991a; 29: JAMONI, 1991b; 30: JAMONI, 1991c; 31: JAMONI & BON, 1991; 32: JAMONI & BON, 1992; 33: KNUDSEN & BORGEN, 1982; 34: KNUDSEN & BORGEN, 1987; 35: KNUDSEN & BORGEN, 1992; 36: KOBAYASI et al., 1971; 37: KREISEL, 1959; 38: KÜHNER, 1972a; 39: KÜHNER, 1972b; 40: KÜHNER, 1975a; 41: KÜHNER, 1975b; 42: KÜHNER, 1977a; 43: KÜHNER, 1977b; 44: KÜHNER, 1977c; 45: KÜHNER, 1981; 46: KÜHNER, 1988; 47: KÜHNER & LAMOURE, 1972; 48: KÜHNER & LAMOURE, 1986; 49: LAMOURE, 1974; 50: LAMOURE, 1975; 51: LAMOURE, 1977a; 52: LAMOURE, 1977b; 53: LAMOURE, 1978; 54: LAMOURE, 1982a; 55: LAMOURE, 1982b; 56: LAMOURE, 1984; 57: LAMOURE, 1986; 58: LAMOURE, 1987; 59: LANGE, 1946; 60: LANGE, 1948-57; 61: LANGE & SKIFTE, 1967; 62: MOSER, 1983b; 63: NESPIAK, 1953; 64: NOORDELOOS & GULDEN, 1989; 65: PETERSEN, 1977; 66: PEYRONEL, 1930; 67: REID, 1972; 68: RÖMER, 1993; 69: ROSTRUP, 1891; 70: SCHÄRER-BIDER, 1951; 71: SENN-IRLET, 1986; 72: SENN-IRLET, 1987; 73: SENN-IRLET, 1988; 74: SENN-IRLET, 1992; 75: SKIFTE, 1979; 76: SKIFTE, 1989; 77: TRIMBACH, 1978; 78: VESTERHOLT, 1989; 79: WATLING, 1977; 80: WATLING, 1981; 81: WATLING, 1985; 82: WATLING, 1987.

1.	¹ <i>Agaricus campestris</i>	G82
2.	¹ <i>Amanita arctica</i>	O34
3.	¹ <i>Amanita groenlandica</i>	O34
4.	<i>Amanita nivalis</i>	A14, 48; B72; D16; G80, 81, 82; K19; L19; N21; O34, 79
5.	<i>Amanita vaginata</i>	A48; C1; E36; O60, 65
6.	² <i>Amanita vaginata</i> f. <i>oreina</i>	C1, 15
7.	<i>Arrhenia auriscalpium</i>	A47; J47; O65
8.	² <i>Arrhenia lobata</i>	B72
9.	¹ <i>Boletus spadiceus</i>	G80
10.	¹ <i>Bovista nigrescens</i>	O79
11.	¹ <i>Calvatia tatrensis</i>	O79
12.	² <i>Camarophyllus niveus</i>	A48
13.	² <i>Camarophyllus pratensis</i>	A14, 48
14.	¹ <i>Clitocybe diatreta</i>	O65
15.	² <i>Clitocybe festivoidea</i>	A14, 48
16.	² <i>Clitocybe incilis</i>	A48
17.	² <i>Clitocybe lateritia</i>	A14, 48; B72, 73
18.	² <i>Clitocybe subcylindrospora</i>	A14
19.	² <i>Conocybe kühneriana</i>	A48
20.	² <i>Conocybe siennophylla</i>	A7, 48
21.	² <i>Conocybe tetraspora</i>	B73

Table 27: continued.

22.	² <i>Cortinarius albonigrellus</i>	A48, 51; C15, 27
23.	¹ <i>Cortinarius acutus</i>	O60
24.	¹ <i>Cortinarius alpinus</i>	K18; O36, 60, 65
25.	<i>Cortinarius anomalus</i>	A48; C15; G82; L61
26.	² <i>Cortinarius bresadolae</i>	A48, 53
27.	<i>Cortinarius caesionigrellus</i>	A48, 53; C53; J53
28.	² <i>Cortinarius cavipes</i>	C15, 30, 51
29.	¹ <i>Cortinarius cedriolens</i>	J51
30.	² <i>Cortinarius cf. delibutus</i>	
31.	² <i>Cortinarius chamaesalicis</i>	A48
32.	<i>Cortinarius chrysomallus</i>	A48, 51, 55; B31, 72; J51; K51
33.	² <i>Cortinarius comatus</i>	C53; D25
34.	² <i>Cortinarius cucumisporus</i>	D62
35.	² <i>Cortinarius cyanites</i>	A48
36.	² <i>Cortinarius decipiens</i>	D25
37.	<i>Cortinarius diasemospermus</i>	A48, 53; B72; D53; J53
38.	<i>Cortinarius favrei</i>	A14, 48, 55, 77; B72, 73; C15, 74; G19, 80, 82; K19; M19; O19, 79
39.	² <i>Cortinarius fulvescens</i>	A55; C51
40.	² <i>Cortinarius galerinoides</i>	A48, 51
41.	<i>Cortinarius gausapatus</i>	A14, 48, 53; C27; G82
42.	<i>Cortinarius glandicolor</i> var. <i>exilis</i>	A14; C15, 27; O60
43.	² <i>Cortinarius hemitrichus</i> f. <i>improcerus</i>	A48, 51; B27; C27, 51
44.	² <i>Cortinarius hinnuleus</i>	A48, 51; B73
45.	² <i>Cortinarius hinnuleus</i> f. <i>subtypique</i>	C15, 27
46.	² <i>Cortinarius hinnuleus</i> var. <i>favreanus</i> f. <i>graveolens</i>	A32
47.	² <i>Cortinarius hinnuleus</i> var. <i>gracilis</i>	A48, 51; B72; C15, 51
48.	² <i>Cortinarius hinnuleus</i> var. <i>minutalis</i>	A77
49.	² <i>Cortinarius inconspicuus</i>	C15, 27
50.	<i>Cortinarius inops</i>	A2, 6, 48, 53; B31, 72; C53; J53
51.	² <i>Cortinarius lamourei</i>	A48, 53; C53
52.	² <i>Cortinarius levipileus</i>	A14
53.	² <i>Cortinarius minutalis</i>	A48; C51
54.	² <i>Cortinarius minutulus</i>	A2, 14; C15
55.	¹ <i>Cortinarius obtusus</i>	G80
56.	² <i>Cortinarius oreobius</i>	B72; C15, 27
57.	<i>Cortinarius paleiferus</i>	A48, 57, 58; J57, 58; K58
58.	¹ <i>Cortinarius paleiferus</i> var. <i>brachyspermus</i>	J58
59.	<i>Cortinarius pauperculus</i>	A48, 53; B72; C15, 27; L61; M20
60.	² <i>Cortinarius pauperculus</i> f. <i>luteovelata</i>	
61.	² <i>Cortinarius percavus</i>	B72
62.	<i>Cortinarius pertristis</i>	C15, 27; G23
63.	<i>Cortinarius phaeopygmaeus</i>	A48, 51; C15, 27, 51; D62; M20; O60
64.	² <i>Cortinarius proteus</i>	B66
65.	¹ <i>Cortinarius pseudosalor</i>	G80
66.	¹ <i>Cortinarius pulchellus</i>	O60
67.	² <i>Cortinarius pulchripes</i>	A48, 51; C51

Table 27: continued.

68.	<i>Cortinarius purpureoluteus</i>	A48, 51; J51
69.	<i>Cortinarius rufostriatus</i>	C15, 27, 51; G82
70.	² <i>Cortinarius rusticellus</i>	A48, 53; C15, 27
71.	² <i>Cortinarius saniosus</i>	A2
72.	<i>Cortinarius scotoides</i>	C15, 27; G82; K18
73.	¹ <i>Cortinarius striatuloides</i>	H82
74.	² <i>Cortinarius subtilior</i>	A48, 53; C15, 27, 53
75.	¹ <i>Cortinarius subtorvus</i>	J51; M19; O19, 65
76.	² <i>Cortinarius tenebricus</i>	A14, 48, 53; C15, 27
77.	² <i>Cupophyllus pratensis</i> f. <i>pallidus</i>	B28
78.	<i>Dermocybe cinnamomea</i>	B66; L61
79.	¹ <i>Dermocybe cinnamomea</i> var. <i>ignivelata</i>	J56
80.	¹ <i>Dermocybe cinnamomea</i> - <i>parvulus</i>	J56
81.	<i>Dermocybe cinnamomeolutea</i>	A2, 14, 48, 55, 56; B72, 73; C15; J24, 56; K24; L24
82.	<i>Dermocybe crocea</i>	G82
83.	¹ <i>Dermocybe croceocona</i>	J24; K24; L24; N24
84.	¹ <i>Dermocybe norvegica</i>	G82; J24; K24; L24
85.	<i>Dermocybe polaris</i>	B5; G82; K19, 24; L24; M19; N19, 24
86.	¹ <i>Dermocybe sphagneti</i>	O79
87.	<i>Entoloma alpicola</i>	A2, 14, 48; B32; C15; K18; L19
88.	<i>Entoloma anthracinum</i>	A14, 44, 48; C15; J44
89.	² <i>Entoloma atropellitum</i>	C15
90.	² <i>Entoloma atrosericeum</i>	A4, 44, 48; B31
91.	¹ <i>Entoloma cetratum</i>	G82
92.	² <i>Entoloma clandestinum</i> f. <i>acutissimum</i>	C15
93.	² <i>Entoloma conferendum</i>	A48; B31, 72, 73; C15
94.	² <i>Entoloma cucullatum</i>	C15
95.	¹ <i>Entoloma dispernum</i>	J44
96.	² <i>Entoloma favrei</i>	B72, 73
97.	² <i>Entoloma mammosum</i>	A14
98.	² <i>Entoloma occultopigmentatum</i>	B73
99.	² <i>Entoloma olivaceoumbrina</i>	A48
100.	² <i>Entoloma sericellum</i>	C15
101.	<i>Entoloma sericeum</i>	A14; B72, 73; C15; O36, 65
102.	² <i>Entoloma subcollariatum</i>	A44, 48
103.	² <i>Entoloma subflexipes</i>	A48
104.	¹ <i>Entoloma subsepiaceum</i>	J44
105.	² <i>Galerina annulata</i>	A68
106.	<i>Galerina antheliae</i>	C68; G68; K17, 19, 68; M19, 68
107.	² <i>Galerina atkinsoniana</i>	B72
108.	² <i>Galerina chionophila</i>	B72, 73
109.	<i>Galerina clavata</i>	A68; C15, 68; G68; H68; J68; M68; N68; O68
110.	<i>Galerina heterocystis</i>	A55; O65
111.	<i>Galerina hypnorum</i>	A38; J38; O60
112.	² <i>Galerina mniophila</i>	
113.	<i>Galerina mölleri</i>	A38; K17; O65

Table 27: continued.

114.	¹ <i>Galerina mycenopsis</i>	<u>K18</u>
115.	² <i>Galerina obscurata</i>	<u>A68</u>
116.	<i>Galerina pseudomniophila</i>	<u>C38, 39; J38; K38</u>
117.	<i>Galerina pseudotundrae</i>	<u>A38, 39, 68; B38, 72; C38, 68; D68; K17, 68</u>
118.	¹ <i>Galerina pumila</i>	<u>O60</u>
119.	¹ <i>Galerina tundrae</i>	<u>J38, 68; K38, 68</u>
120.	² <i>Galerina vittaeformis</i> 2 sp.	<u>A7, 38; C38</u>
121.	<i>Galerina vittaeformis</i> 4 sp.	<u>A7, 14, 55; B72, 73; C15; O60</u>
122.	² <i>Galerina vittaeformis</i> 4 sp. var. <i>megaspora</i>	<u>A14, 38</u>
123.	² <i>Gerronema melleum</i>	<u>A55</u>
124.	² <i>Hebeloma alpinum</i>	<u>A14, 48; C15; D25</u>
125.	² <i>Hebeloma bruchetii</i>	<u>C78</u>
126.	¹ <i>Hebeloma crustuliniforme</i>	<u>O65</u>
127.	² <i>Hebeloma gracilipes</i> var. <i>gracilipes</i>	<u>A48</u>
128.	² <i>Hebeloma kühneri</i>	<u>A11, 48; B72; C11</u>
129.	<i>Hebeloma marginatulum</i>	<u>A11, 14, 48; B72; C11, 15; D11; G82</u>
130.	<i>Hebeloma mesophaeum</i>	<u>D25; O60, 65</u>
131.	² <i>Hebeloma minus</i>	<u>A2, 11, 12, 14, 48; B72, 73</u>
132.	² <i>Hebeloma nigellum</i>	<u>A11, 12, 48, 78</u>
133.	² <i>Hebeloma repandum</i>	<u>A2, 11, 12, 48; B72; C11</u>
134.	² <i>Hebeloma subconcolor</i>	<u>A11, 12, 48, 55</u>
135.	² <i>Hemipholiota myosotis</i> var. <i>evelata</i>	<u>B31</u>
136.	<i>Hygrocybe conica</i>	<u>A14, 42; C42; G82</u>
137.	² <i>Hygrocybe flavescens</i>	<u>C15; G82</u>
138.	¹ <i>Hygrocybe langei</i>	<u>G82</u>
139.	¹ <i>Hygrocybe nitrata</i>	<u>G82</u>
140.	² <i>Hygrocybe pseudoconica</i>	<u>B28</u>
141.	¹ <i>Hygrocybe quieta</i>	<u>G82</u>
142.	² <i>Hygrocybe salicis-herbaceae</i>	<u>A48</u>
143.	² <i>Hygrocybe vitellina</i>	<u>A48</u>
144.	² <i>Hymenogaster saliciphilus</i>	
145.	² <i>Hypholoma myosotis</i>	<u>B72</u>
146.	² <i>Inocybe aghardi</i>	<u>B72</u>
147.	² <i>Inocybe alpigenes</i>	<u>C26</u>
148.	² <i>Inocybe ampullacea</i>	<u>A48</u>
149.	² <i>Inocybe arthrocytis</i>	<u>A46, 48</u>
150.	² <i>Inocybe asterospora</i>	<u>C15, 26</u>
151.	² <i>Inocybe aurea</i>	<u>C15, 26</u>
152.	² <i>Inocybe auricomella</i>	<u>A46, 48</u>
153.	² <i>Inocybe boltonii</i>	<u>F37</u>
154.	² <i>Inocybe bulbosissima</i>	<u>A8</u>
155.	² <i>Inocybe calamistrata</i>	<u>A14, 48; B72, 73; C15</u>
156.	² <i>Inocybe canescens</i>	<u>A2, 14, 48; B72</u>
157.	² <i>Inocybe cavipes</i>	<u>C15</u>
158.	² <i>Inocybe concinnula</i>	<u>A46; B72; C15, 26; D26</u>
159.	² <i>Inocybe cucullata</i>	<u>A2</u>

Table 27: continued.

160.	<i>²Inocybe curreyi</i>	<u>A8</u>
161.	<i>Inocybe decipiens</i>	<u>A2, O65</u>
162.	<i>¹Inocybe decipientoides</i>	<u>G82</u>
163.	<i>¹Inocybe descissa</i>	<u>K18</u>
164.	<i>Inocybe dulcamara</i>	<u>A14, 55, C15, 74, G80, 82</u>
165.	<i>²Inocybe dulcamaroides</i>	<u>A8</u>
166.	<i>²Inocybe egenula</i>	<u>A14, B26, 72, C15, 26</u>
167.	<i>Inocybe fastigiata</i>	<u>A2, 14, 48, 55, C15, G82</u>
168.	<i>²Inocybe favrei</i>	<u>A2</u>
169.	<i>²Inocybe friesii</i>	<u>A48</u>
170.	<i>²Inocybe fuscomarginata</i>	<u>A48, C15</u>
171.	<i>²Inocybe geophylla</i>	<u>A48</u>
172.	<i>²Inocybe geraniodora</i>	<u>A46, 48, C15</u>
173.	<i>Inocybe giacomii</i>	<u>A48, 77, B32, 72, 73, C15, 26, F37, G82</u>
174.	<i>²Inocybe hebelomoides</i>	<u>A46, B8</u>
175.	<i>²Inocybe humilis</i>	<u>C26</u>
176.	<i>Inocybe lacera</i>	<u>A48, 55, B72, C15, G82</u>
177.	<i>Inocybe lacera</i> f. <i>heterospora</i>	<u>A2, 4, G82</u>
178.	<i>²Inocybe lacera</i> f. <i>megaspora</i>	<u>A46</u>
179.	<i>¹Inocybe lanuginella</i>	<u>O60</u>
180.	<i>²Inocybe lucifuga</i> var. <i>lutescens</i>	
181.	<i>²Inocybe microfastigiata</i>	<u>A8</u>
182.	<i>Inocybe mixtilis</i>	<u>B72, G82</u>
183.	<i>²Inocybe mundula</i>	<u>A14, 48, C26</u>
184.	<i>²Inocybe nitidiuscula</i>	
185.	<i>²Inocybe obtusiuscula</i>	<u>A46</u>
186.	<i>²Inocybe oreina</i>	<u>A48</u>
187.	<i>²Inocybe ovatocystis</i>	
188.	<i>²Inocybe peronatella</i>	
189.	<i>²Inocybe piricystis</i>	<u>A55, C15</u>
190.	<i>²Inocybe polytrichi-norvegici</i>	<u>A46</u>
191.	<i>Inocybe praetervisa</i>	<u>A26, B31, C15, 26, G80</u>
192.	<i>²Inocybe pruinosa</i>	
193.	<i>²Inocybe pseudohiulca</i>	<u>C26</u>
194.	<i>²Inocybe rhacodes</i>	<u>B72, 73, C15</u>
195.	<i>Inocybe rickenii</i>	<u>F37</u>
196.	<i>²Inocybe rimosa</i> var. <i>bulbosissima</i>	<u>A46</u>
197.	<i>²Inocybe salicis-herbaceae</i>	<u>A46, 48</u>
198.	<i>¹Inocybe scabella</i> var. <i>fulvella</i>	<u>G82</u>
199.	<i>²Inocybe sericeipes</i>	<u>A48</u>
200.	<i>²Inocybe squarrosoannulata</i>	<u>A5, 48, C15</u>
201.	<i>²Inocybe striaepes</i>	<u>A48</u>
202.	<i>²Inocybe subannulata</i>	<u>A8, 46</u>
203.	<i>²Inocybe subbrunnea</i>	<u>A14, 48, C15</u>
204.	<i>²Inocybe subconcinula</i>	<u>A48</u>
205.	<i>²Inocybe substellata</i>	<u>A46</u>

Table 27: continued.

206.	² <i>Inocybe substraminipes</i>	A5; C5
207.	² <i>Inocybe taxocystis</i>	A26; C15, 26
208.	² <i>Inocybe tetragonospora</i>	A46
209.	² <i>Inocybe tricolor</i>	A48
210.	¹ <i>Inocybe umbrina</i>	G82
211.	² <i>Inocybe umbrinofusca</i>	A48
212.	² <i>Laccaria altaica</i>	A48, 77
213.	<i>Laccaria bicolor</i>	G82
214.	¹ <i>Laccaria farinacea</i>	G82
215.	<i>Laccaria laccata</i>	A2, 14, 48, 55; G80, 82; O60
216.	² <i>Laccaria montana</i>	B29, 72; C15
217.	<i>Laccaria proxima</i>	C15; M20
218.	¹ <i>Laccaria proximella</i>	G82
219.	¹ <i>Laccaria pumila</i>	M20
220.	² <i>Laccaria tetraspora</i>	B72, 73
221.	¹ <i>Lactarius aurantiacus</i>	J40
222.	² <i>Lactarius dryadophilus</i> var. <i>saliceticola</i>	B32
223.	¹ <i>Lactarius glyciosmus</i>	J40; K40; O36
224.	¹ <i>Lactarius mitissimus</i>	O60
225.	<i>Lactarius namus</i>	A14, 40, 48, 55; B72; C15, 40; D25; J19, 40; K19; L19; M19; O19, 33
226.	<i>Lactarius pseudouvidus</i>	A40, 48; C40; K19, 40; O19
227.	² <i>Lactarius robertianus</i>	A2; B2, 73
228.	<i>Lactarius salicis-herbaceae</i>	A14, 40, 48; K19; N19
229.	² <i>Lactarius salicis-herbaceae</i> var. <i>immutabilis</i>	A40, 48; B5
230.	¹ <i>Lactarius trivialis</i>	L61
231.	¹ <i>Lactarius tabidus</i>	J40
232.	<i>Lactarius uvidus</i>	A2, 14, 40, 48, 55; B72; C40; D25; K19, 40; O60
233.	² <i>Lactarius uvidus</i> f. <i>alpigenus</i>	B31
234.	¹ <i>Leccinum scabrum</i>	O79
235.	¹ <i>Lepiota cristata</i>	G82
236.	¹ <i>Lepista nuda</i>	L61
237.	¹ <i>Lycoperdon frigidon</i>	N13
238.	¹ <i>Lyophyllum erosum</i>	O60
239.	¹ <i>Marasmius epiphyllum</i>	O69
240.	² <i>Mycena chlorinella</i>	A48
241.	¹ <i>Mycena citrinomarginata</i>	O79; 60
242.	¹ <i>Mycena filopes</i>	O60
243.	¹ <i>Myceneae griseogilva</i>	O65
244.	¹ <i>Mycena psammicola</i>	N21
245.	¹ <i>Mycena vitilis</i>	O79
246.	<i>Naucoria bohémica</i>	C45; G82
247.	² <i>Naucoria bohémica</i> f. <i>tetraspora</i>	
248.	² <i>Naucoria chamiteae</i>	A45, 48
249.	¹ <i>Naucoria macrospora</i>	O36
250.	¹ <i>Naucoria solecina</i>	O60
251.	¹ <i>Naucoria scorpioides</i>	O60

Table 27: continued.

252.	<i>Naucoria tantilla</i>	<u>C15; M20</u>
253.	² <i>Omphaliaster borealis</i>	<u>A4</u>
254.	<i>Omphalina chionophila</i>	<u>A14, 48, 49, 54; J54; O54</u>
255.	¹ <i>Omphalina ericetorum</i>	<u>O60</u>
256.	² <i>Omphalina griseopallida</i>	<u>A55</u>
257.	² <i>Omphalina hepatica</i>	<u>C10</u>
258.	¹ <i>Omphalina luteovitellina</i>	<u>G23</u>
259.	² <i>Omphalina obatra</i>	<u>A14, 48, 50, 55; B29, 31; C15, 50</u>
260.	<i>Omphalina obscurata</i>	<u>A50; C50; J50; K50</u>
261.	² <i>Omphalina pseudomuralis</i>	<u>B29</u>
262.	² <i>Omphalina pyxidata</i>	<u>A48</u>
263.	¹ <i>Omphalina rickenii</i>	<u>O79</u>
264.	² <i>Omphalina rigidipes</i>	<u>A48, 55</u>
265.	² <i>Omphalina rivulicola</i>	<u>A48, 55</u>
266.	² <i>Omphalina sphaerospora</i>	<u>A48, 50; B50</u>
267.	<i>Omphalina trigonospora</i>	<u>A50; J50; O50</u>
268.	¹ <i>Omphalina umbellifera</i>	<u>J59</u>
269.	<i>Omphalina velutipes</i>	<u>A14, 48, 50, 55; B72, 73; C50; D50; J50; K50</u>
270.	² <i>Phaeotellus griseopallidus</i>	<u>A14</u>
271.	² <i>Pholiotina dentatmarginata</i>	<u>A48</u>
272.	² <i>Psilocybe apelliculosa</i>	
273.	² <i>Psilocybe chionophila</i>	<u>A14, 48, 52; B72, 73</u>
274.	¹ <i>Psilocybe montana</i>	<u>O65</u>
275.	² <i>Rickenella setipes</i>	<u>A48</u>
276.	¹ <i>Russula aeruginea</i>	<u>O65</u>
277.	² <i>Russula alpigenes</i>	<u>A9</u>
278.	<i>Russula alpina</i>	<u>B70; G23, 80; O65</u>
279.	¹ <i>Russula altaica</i>	<u>O33</u>
280.	<i>Russula brunneoviolacea</i>	<u>C15; O33</u>
281.	<i>Russula chamiteae</i>	<u>A14, 41, 48, 55; B30, 72; C41; K19; M76; O19</u>
282.	¹ <i>Russula citrinochlora</i>	<u>O35</u>
283.	² <i>Russula cupreola</i>	<u>A9; B9</u>
284.	¹ <i>Russula delica</i>	<u>M76</u>
285.	² <i>Russula emetica</i>	<u>D25</u>
286.	² <i>Russula fragilis</i> var. <i>alpigenes</i>	<u>A6</u>
287.	¹ <i>Russula medullata</i>	<u>K41; O33</u>
288.	<i>Russula nana</i>	<u>A14, 41, 48, 55; B30, 72; C15, 41; G82; K19, 41; M19, 76</u>
289.	² <i>Russula nauseosa</i>	<u>A41, 48</u>
290.	<i>Russula norvegica</i>	<u>A14, 41, 48, 55; B30, 72, 73; C41; G82; J19, 41; K19, 66; L66; M76; O19</u>
291.	¹ <i>Russula obscura</i>	<u>O65</u>
292.	² <i>Russula ochracea</i> f. <i>felicolor</i>	<u>B9</u>
293.	<i>Russula pascua</i>	<u>A14, 41, 48, 55; B30, 72; C15, 41; G80, 82; J41</u>
294.	¹ <i>Russula persicina</i>	<u>G82</u>
295.	<i>Russula saliceticola</i>	<u>B30; J41; K41</u>
296.	² <i>Thelephora terrestris</i>	

3.5. ECOLOGY

3.5.1. Seasonal course of productivity

In the investigated plots of the Radönt Valley the start of the mycological season (Fig. 14) was heralded by the appearance of *Sclerotinia glacialis* (*Oxyrietum* plot) one week after the melting of the winter snow pack (beginning of July; around week 27). Subsequently a slow but steady increase of carpophore productivity was noticed until mid August (week 33 and 34). During this period small saprobic Discomycetes, viz. *Cheilymenia fimicola*, *Scutellinia crinita*, and *S. nigrohirtula* as well as ectomycorrhizal and saprobic Agaricales, viz. *Cortinarius favrei*, *Entoloma alpicola*, *Galerina vittaeformis*, *Inocybe lacera*, *Laccaria montana*, *Omphalina velutipes* and *Psilocybe chionophila* dominated the mycoflora.

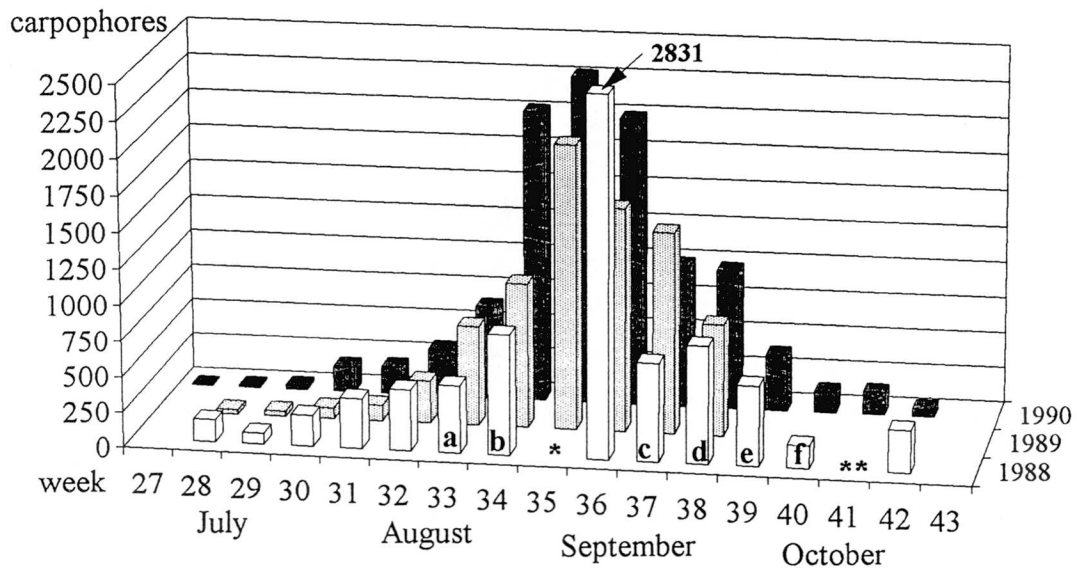


Fig. 14: Carpophore productivity of all macromycetes found during the three investigation years (1988-90) in the 13 plots in the Valley of Radönt.

- * = no collecting due to snowfall or snow covering.
- ** = no excursion due to military manoeuvres in the region.
- a = investigation of plot 9-12 only, due to snowfall.
- b = investigation of plot 1-5 and 13 only, due to snowfall.
- c = investigation of plot 3-6 and 13 only, due to lack of time.
- d = investigation of plot 1, 2 and 7-12 only, due to lack of time.
- e = investigation of plot 1-6, 8, 10 and 13 only, due to snowfall.
- f = investigation of plot 7, 9, 11 and 12 only, due to lack of time.

As a rule, around the last week of August, two to four weeks after the minimum temperatures had stayed for the first time above freezing during a whole

week, accompanied by summer snowfall, the carpophore productivity shot up explosively and reached its maximum in the following three to four weeks (week 34-37). The succeeding one to two weeks (last week of September, first week of October) were characterized by a moderate fructification rate. The number of carpophores, then, decreased more or less constantly in October depending on the beginning of winter. The 26413 macromycetes found during the three investigation years are distributed among the individual vegetation periods as following: In 1988, 7912 carpophores were registered, of which 6905 were mapped in 2567 individual records (a record is a group of carpophores of the same taxa within a basal area of 5 cm in diam.). In the following year, characterized by its early set in of winter, the carpophore productivity resulted in 8012 individuals and 3328 records consisting of 6082 mapped macromycetes. With 10489 carpophores the last year was the most productive. Furthermore, a maximum of 4602 mapped records with 8896 considered individuals was reported.

***Eriophoretum scheuchzeri* and *Oxyrietum digynae* (plot 2/1)**

In the *Eriophoretum* plot the season of macromycetes (Fig. 15a) started only in the last week of August except in 1990, when a previous fructification period of *Omphalina rivulicola* and *O. velutipes* was observed from the last week of July until the second week of August. The absolute maximum of 108 carpophores per excursion was noticed in 1988 in the second week of September.

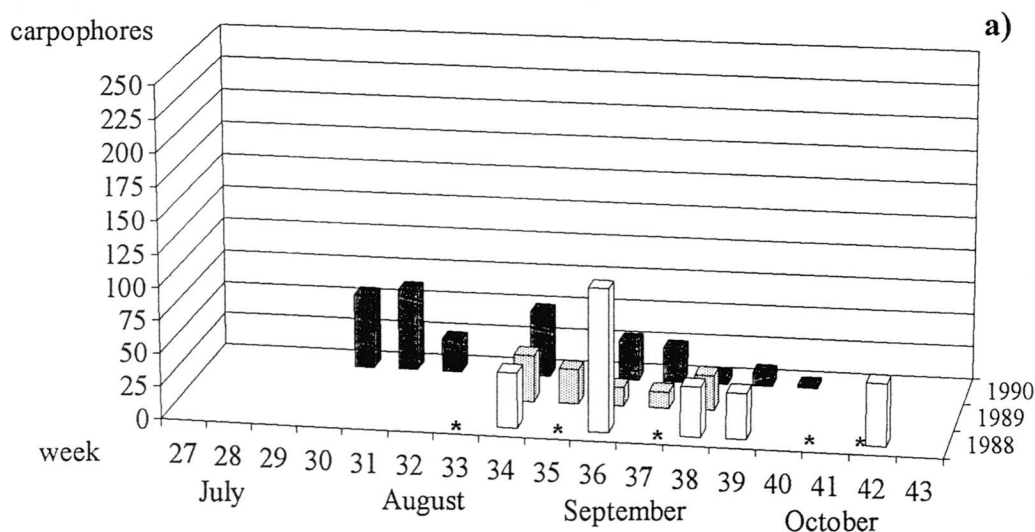


Fig. 15a: Carpophore productivity: Seasonal courses of the macromycetes per excursion in the *Eriophoretum scheuchzeri* plot 2 during the three year investigation period (1988-90). * = no carpophore collecting.

The yield of the three year research amounted to 648 carpophores of which 266 were noticed in 1988, 113 in 1989 and 269 in 1990. In the *Oxyrietum* plot (Fig. 15b) a vernal aspect was registered during the last three weeks of July in 1988 and 1989 with *Sclerotinia glacialis* and *Scutellinia crinita*, whereas in 1990 *Cheilymenia fimicola*, *Galerina vittaeformis* and *Omphalina* spp. were responsible for this period, which was observed however, with two weeks delay (last week of July until the second in August). The main fructification period lasted from about mid-August until the end of September. The absolute maximum (697 carpophores per excursion) was noticed in 1989 during the first week of September. Totally 3882 macromycetes were registered in this plot during this research project. Whereas in 1988 only 741 carpophores were noticed, the 1817 individuals of 1989 stand for the highest number per plot in this year. In 1990, however, the amount decreased again to 1324 carpophores.

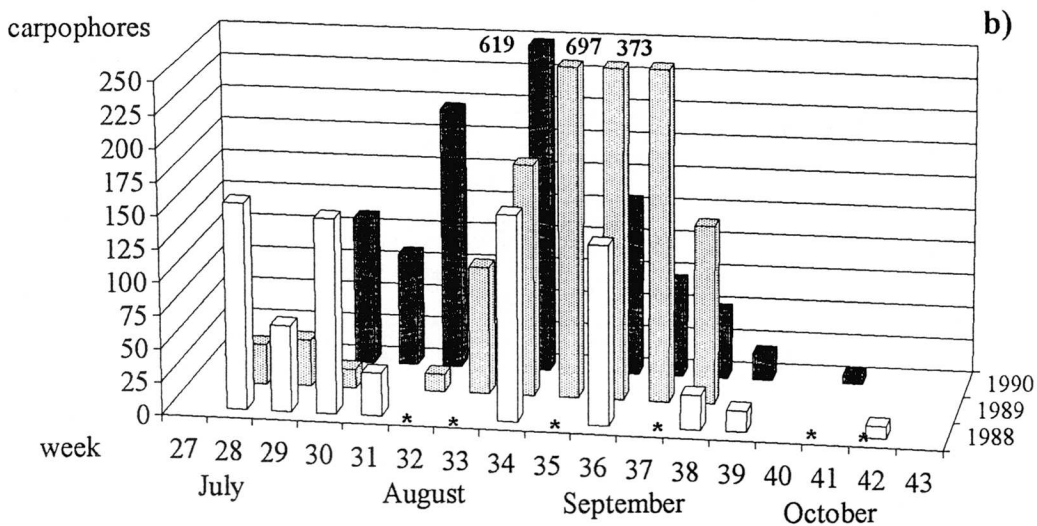


Fig. 15b: Carpophore productivity: Seasonal courses of the macromycetes per excursion in the *Oxyrietum digyanae* plot 1 during the three year investigation period (1988-90). * = no carpophore collecting.

Salicetum herbaceae (plot 3, 6, 7, 9, 11, 13)

In the *Salicetum* plots the first macromycetes occurred in 1988 in the third, in 1989 in the second and in 1990 in the last week of July (Fig. 16a). *Cortinari* *favrei* (1989, 1990), *Hebeloma repandum* (1988) and *Inocybe calamistrata* (1990), all ectomycorrhizal symbionts, were responsible for the first carpophores produced in the seasons. In all three years the course of the growing season was nearly identical with a steady increase until the maximum of productivity, which was noticed in 1988 in the second week of September and

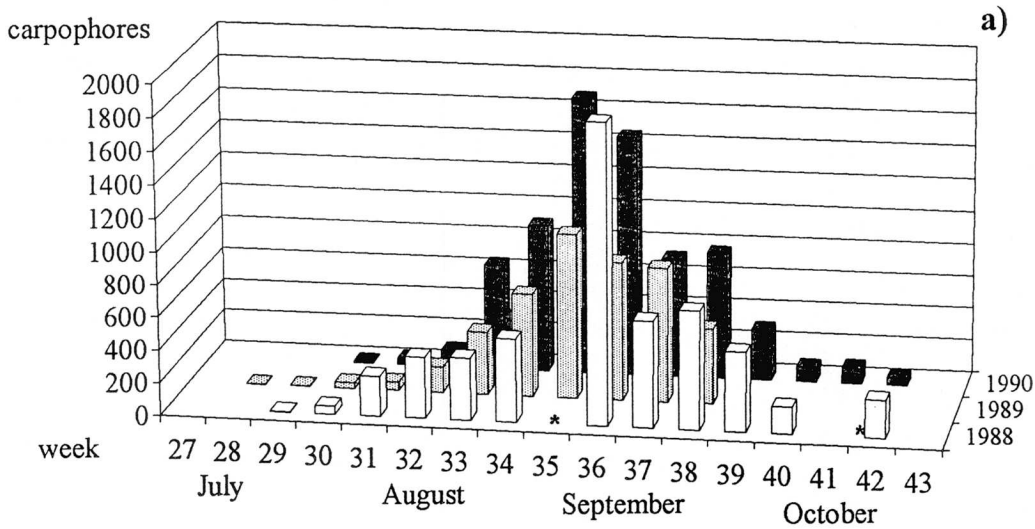


Fig. 16a: Carpophore productivity: Seasonal courses of the macromycetes per excursion in the *Salicetum herbaceae* associations (plot 3, 6, 7, 9, 11, 13) during the three year investigation period (1988-90). * = no carpophore collecting.

seven days earlier in 1989 and 1990. Subsequently the number of macromycetes per excursion decreased constantly until the beginning of winter. During the three year investigation period 16919 macromycetes were registered and mapped in 7773 records. The 5590 carpophores noticed in 1988 resulted from 1891 records.

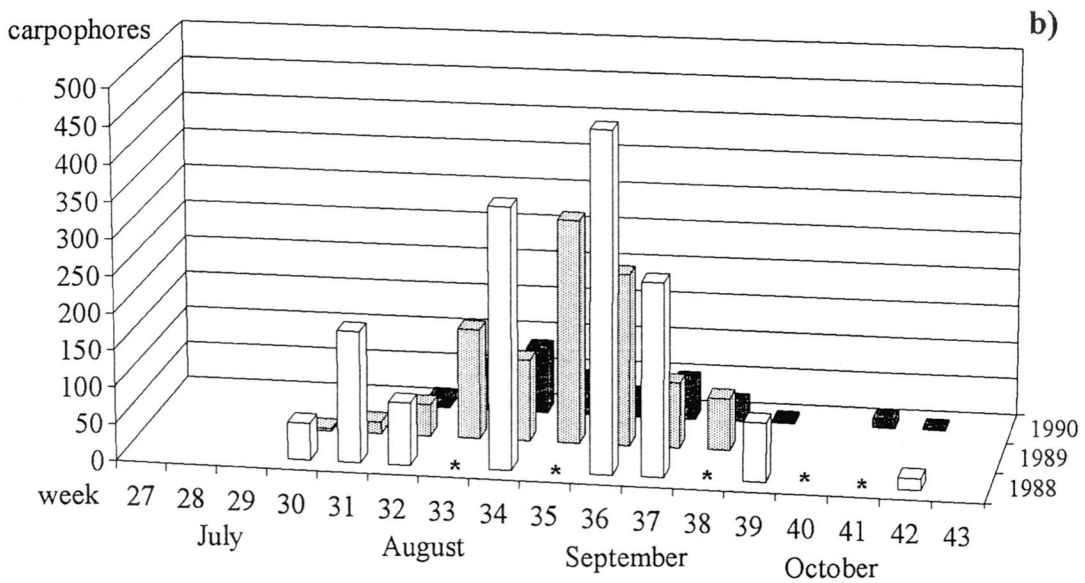


Fig. 16b: Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 3 (b) of the *Salicetum herbaceae* associations during the three year investigation period (1988-90). * = no carpophore collecting.

Although the record number increased to 2384 in 1989, the macromycete productivity was reported with only 4381 individuals. However, in 1990, the records (3498) as well as the carpophore number (6948) were noticed with maximum values. Nevertheless, there were some more or less obvious deviations from this scheme among the individual plots (Figs. 16 b-g). In plot 3 and 6 a distinct decline in carpophore productivity was registered in the last investigation year (1990).

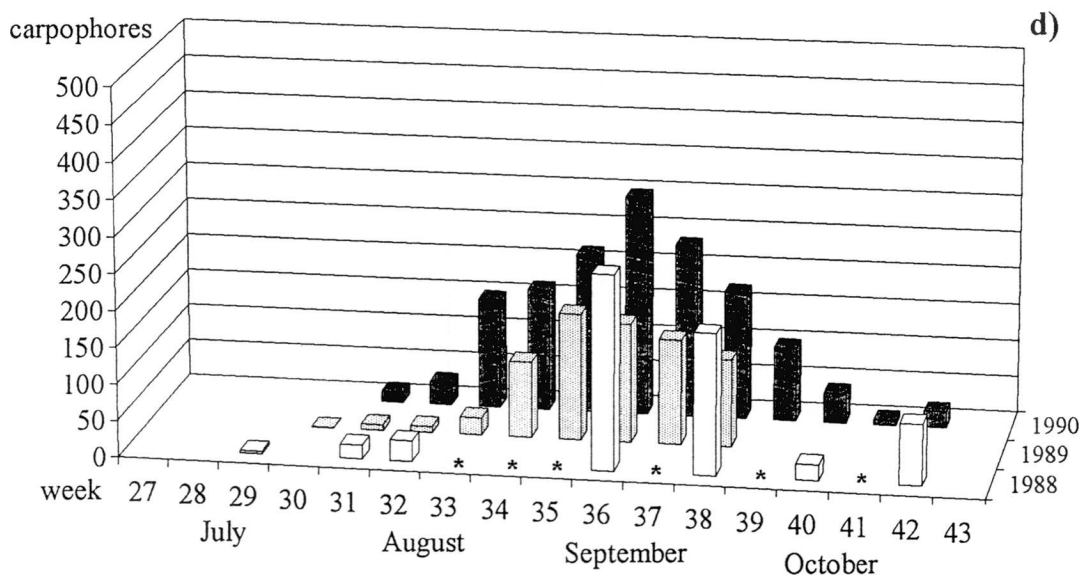
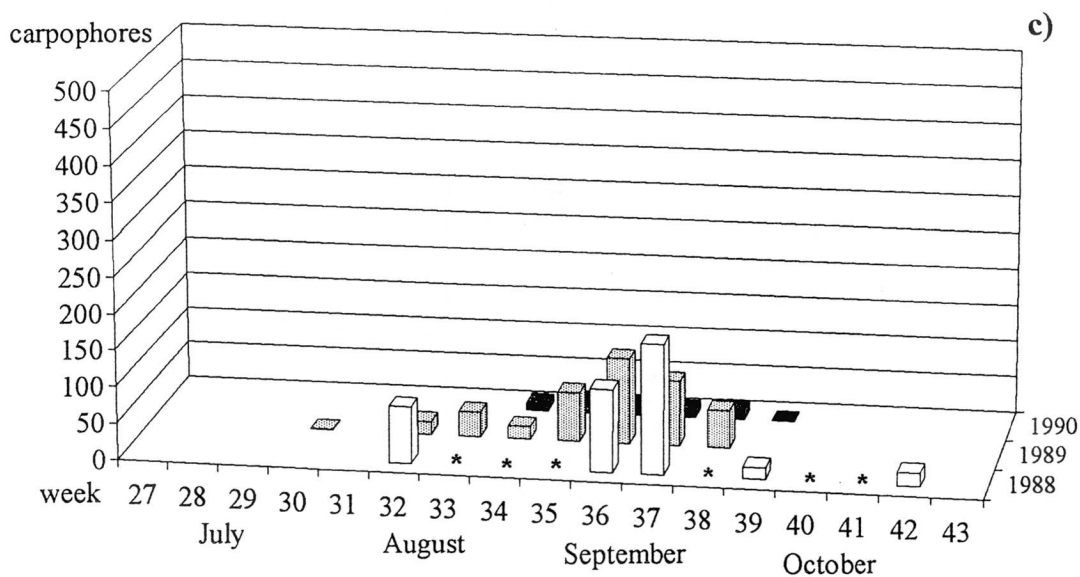


Fig. 16c, d: Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 6 (c) and plot 7 (d) of the *Salicetum herbaceae* associations during the three year investigation period (1988-90). * = no carpophore collecting.

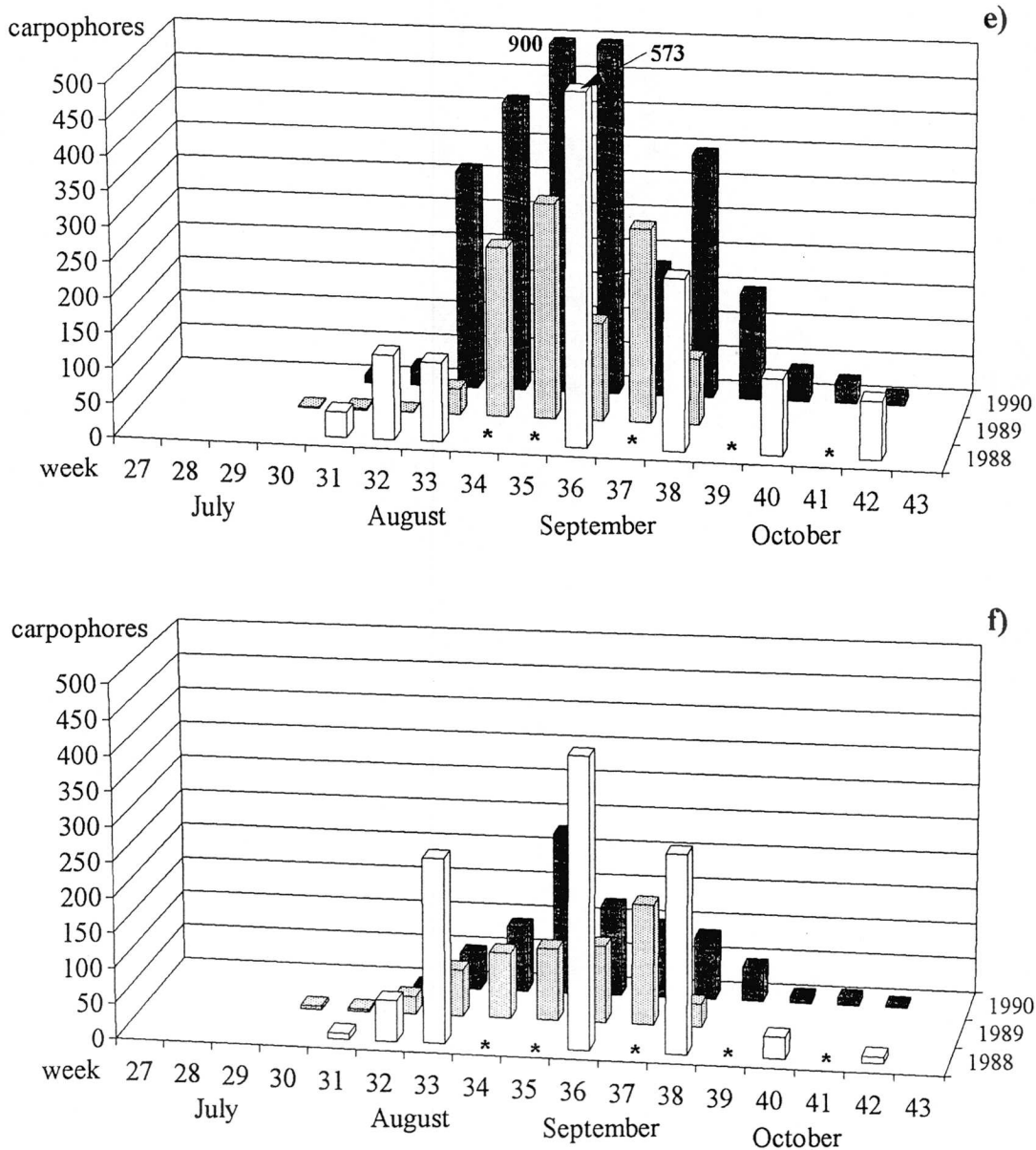


Fig. 16e, f: Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 9 (e) and plot 11 (f) of the *Salicetum herbaceae* associations during the three year investigation period (1988-90). * = no carpophore collecting.

Furthermore, in plot 11 the maximum of productivity was observed in 1988. However, the maxima of plot 7, 9 and 13 in 1990 were much more pronounced and therefore dominated the total productivity course of the *Salicetum herbaceae* association over the three investigation years. In addition, the maximum of productivity in plot 13 (Fig. 16g) was reached only in the first week of October, and in plot 3 (Fig. 16b) a second, previous peak in the first week of August was noticed. In 1989 a second productivity rise was reported from plot 9 (Fig. 16e), two weeks after the maximum in the first week of September. In the same plot there was an abrupt increase in productivity in the third week of

August in 1990 and three weeks after the maximum (first week of September) a second aspect was registered.

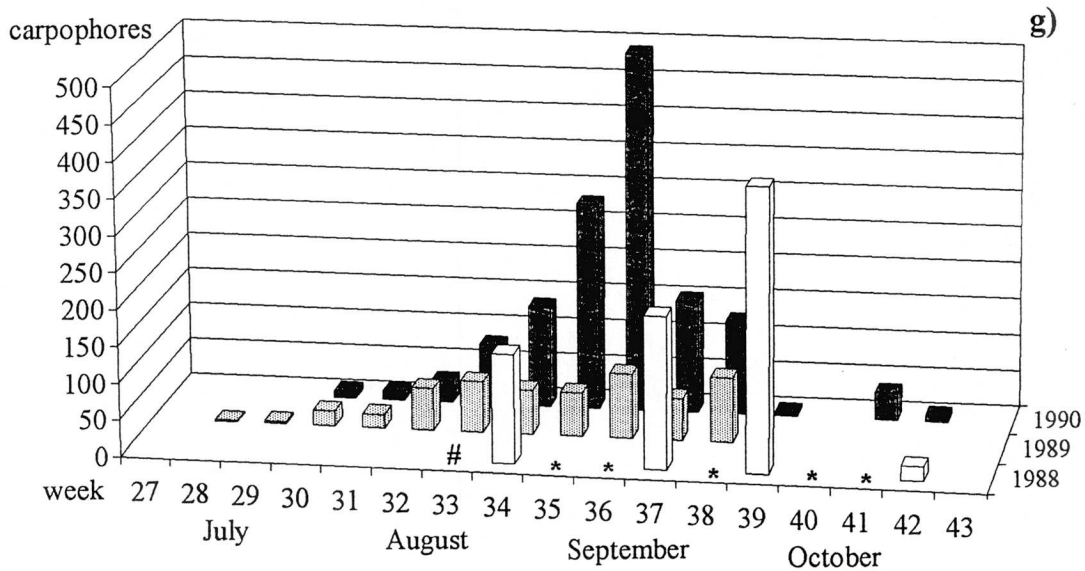


Fig. 16 g): Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 13 (g) of the *Salicetum herbaceae* associations during the three year investigation period (1988-90). * = no carpophore collecting; # = plot 13 was installed on 28. August in 1988 (week 34).

Polytrichetum sexangularis (plot 5, 8, 10)

In the *Polytrichetum* association the macromycete season (Fig. 17a) opened in the last week of July (1988 and 1989). In 1990, however, the first carpophores were already registered two weeks earlier. In 1988 and 1989 a more or less steady increase of productivity was observed until the absolute maximum was reached in the second week of September. In 1990 productivity stayed on an unusually low level during the first six weeks of the growing season, but then shot up in the last week of August to reach the maximum during the subsequent excursion. Afterwards the course of productivity collapsed abruptly in 1988, but decreased more or less constantly in 1989 and 1990 depending on the beginning of winter. The 4769 carpophores registered during the three year investigation period were mapped with 2602 records. From 1988 to 1990 a steady increase in both records and carpophore productivity was noticed. In the first year the 1231 macromycetes were mapped in 620 records. In the following vegetation period 907 records resulted in 1640 carpophores. In 1990 the record number was 1075 with 1898 corresponding individuals. Considering the individual plots (Figs. 17 b-d) there are, however, some deviations from the above-explained pattern. In plot 5 the carpophore productivity was nearly similar in all three investigation years, whereas in plot 8 a distinctive maximum

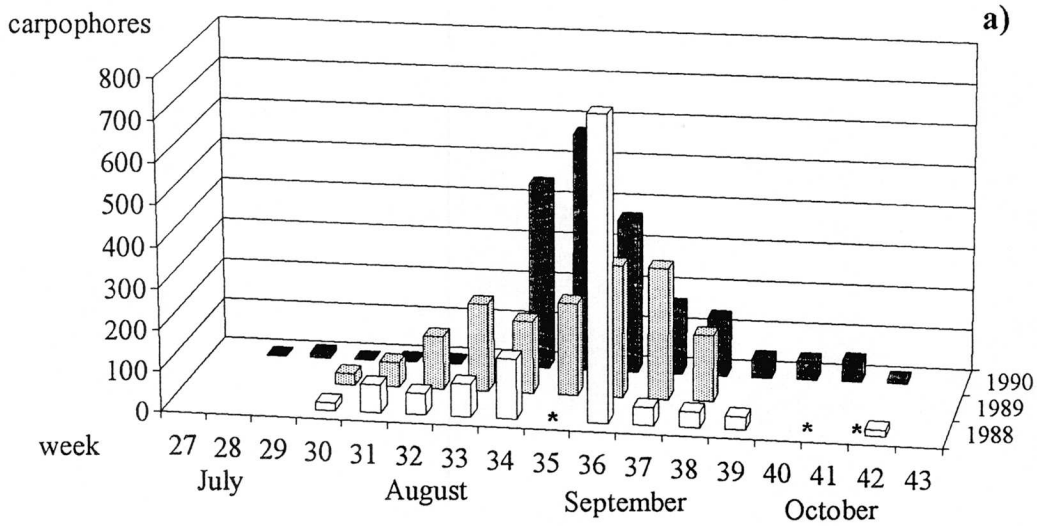


Fig. 17a: Carpophore productivity: Seasonal courses of the macromycetes per excursion in the *Polytrichetum sexangularis* associations (plot 5, 8, 10) during the three year investigation period (1988-90) * = no carpophore collecting.

was registered in the second vegetation period. However, the increase in carpophore productivity in plot 10 from 1988 to 1990 was much more dominant and therefore decisive for the seasonal course of the *Polytrichetum sexangularis* association over the three year investigation period. In 1989 two separate aspects were registered in plot 10 (Fig. 17d).

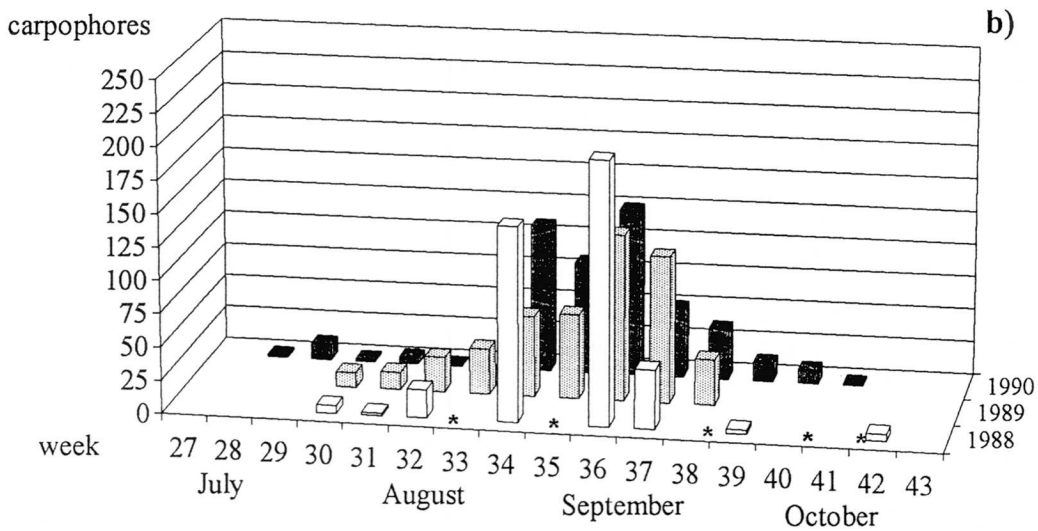


Fig. 17b: Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 5 of the *Polytrichetum sexangularis* associations during the three year investigation period (1988-90). * = no carpophore collecting.

In plot 8 (Fig. 17c) the maximum was noticed in the third week of August but was observed in plot 5 (Fig. 17b) only in the second and in plot 10 (Fig. 17d) in the third week of September, respectively.

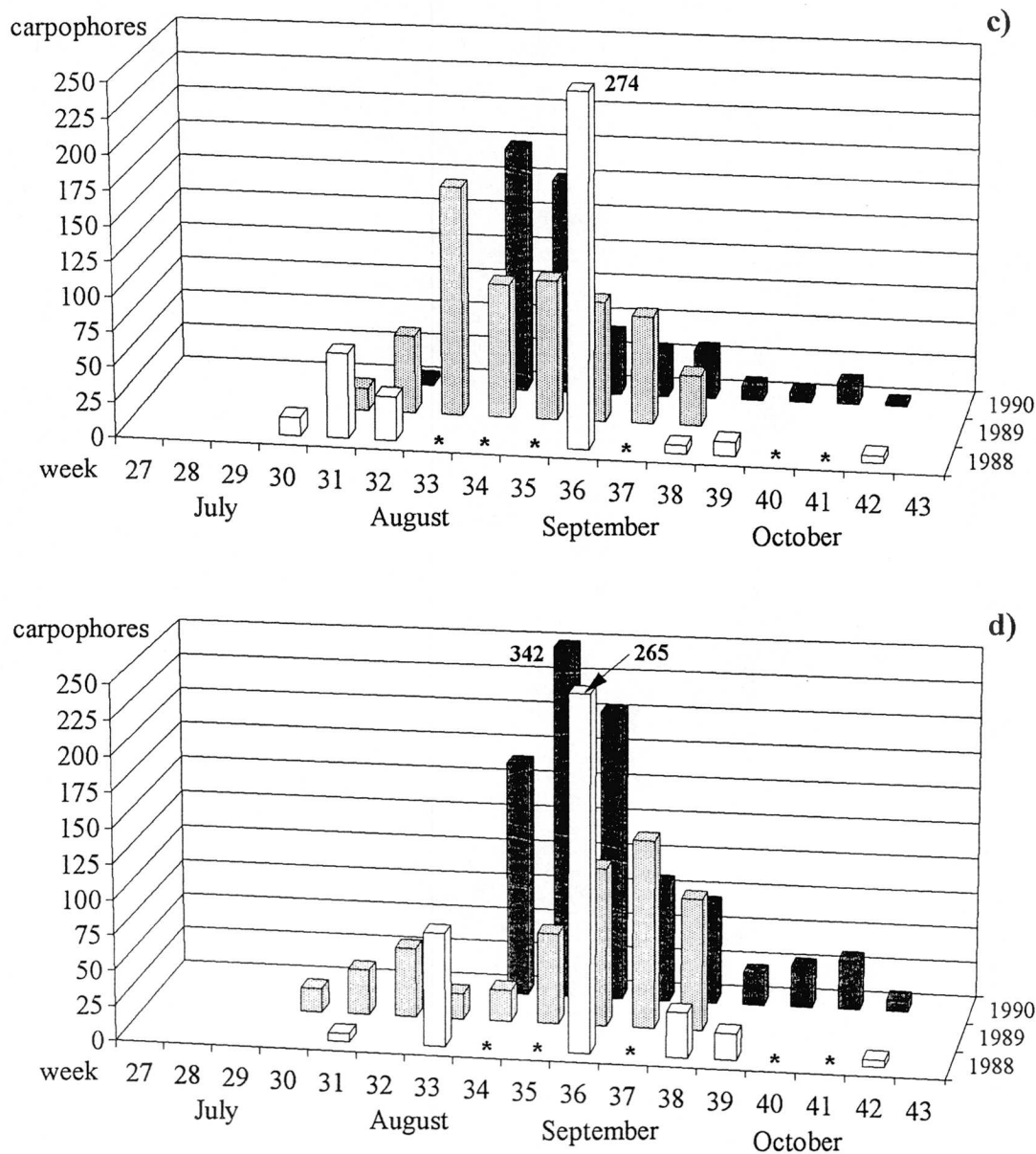


Fig. 17c, d: Carpophore productivity: Seasonal courses of the macromycetes per excursion in plot 8 (c) and plot 10 (d) of the *Polytrichetum sexangularis* associations during the three year investigation period (1988-90). * = no carpophore collecting.

***Caricetum curvulae* and *Loiseleurio-Cetrarietum* (plot 4/12)**

In the *Caricetum* plot (Fig. 18a) macromycetes were found only occasionally and the fructification period was restricted to September during the three years of investigation, except in 1990 when the last five carpophores were registered in the first week of October. The maximum of productivity with 11 individuals

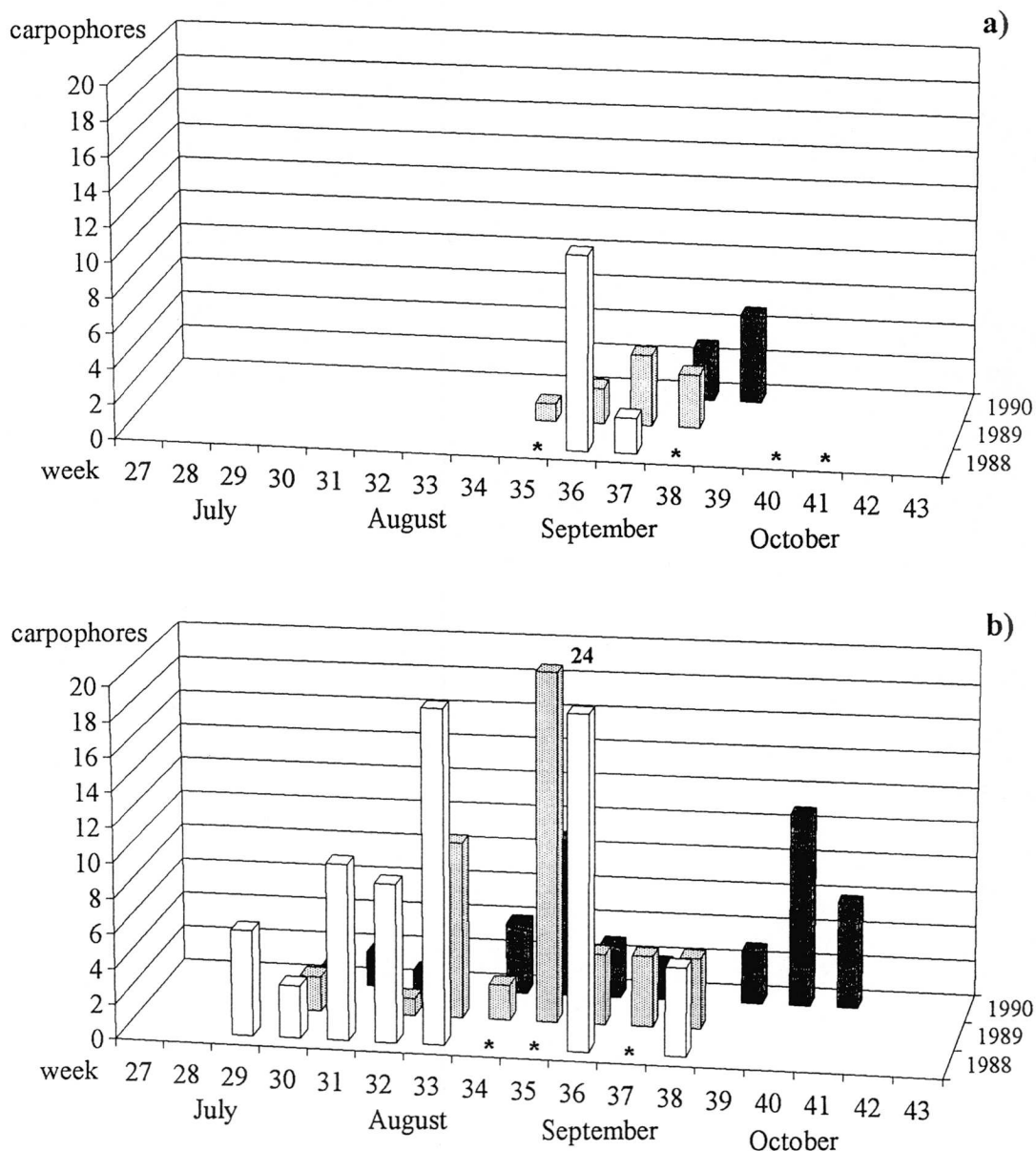


Fig. 18a, b: Carpophore productivity: Seasonal courses of the macromycetes per excursion in the *Caricetum curvulae* plot 4 (a) and in the *Loiseleurio-Cetrarietum* plot 10 (b) during the three year investigation period (1988-90). * = no carpophore collecting.

was noted in 1988 in the second week of September. From 1988 to 1990 not more than 31 carpophores were mapped in 18 records. In 1988, 13 individuals were distributed among 4 records, in 1989, 10 carpophores among 9 records. In 1990, 5 records were mapped constituting alike 8 carpophores. Although the *Loiseleurietum* plot is the first to become snow-free (cf. Tab. 16 a & b), macromycetes do not occur earlier than in the other associations examined (Fig. 18b). *Collybia loiseleurietorum* was always the first macromycete, registered at the end of July. The seasonal course of productivity normally stopped at the end of September. However, in 1990 the fructification period was pro-

longed due to *Entoloma conferendum*, which was observed only in the first week of October and the two subsequent weeks. With 24 carpophores the maximum productivity was reported in 1989 in the first week of September. In this plot 104 records with a total of 164 carpophores were reported from 1988 to 1990. A steady decrease in both, the number of records and the carpophore productivity was observed from year to year. In 1988, 71 carpophores were mapped in 53 records. During the following vegetation period 28 records resulted in 51 macromycetes and in the last investigation year 42 carpophores were distributed among 24 records.

3.5.2. Dynamics and diversity of macromycetes

Because the three investigation years differed in their climatic courses, viz. precipitation (rain, snow) and max.-min. temperatures (cf. chap. 3.1.), different patterns of species dynamics and species diversity (Fig. 19a) of the investigated area in the Valley of Radönt were observed during the individual vegetation periods. In 1988 and 1990 the seasonal courses of the taxon-finds (a taxon-find is the proof of a taxon found in one of the 13 permanent plots during an excursion) were identical with the ones of the corresponding productivity

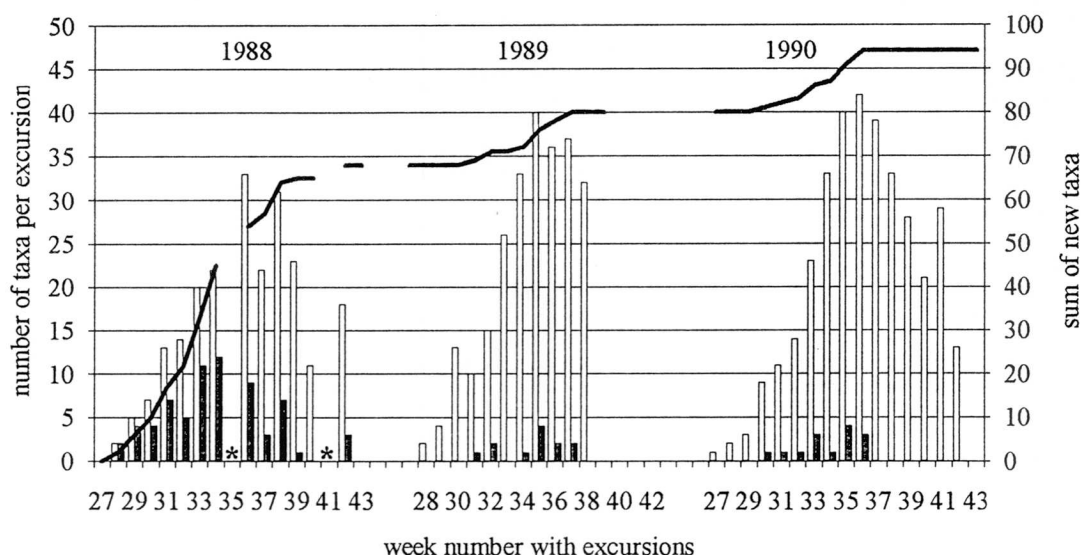


Fig. 19a: Number of macromycete species and newly recorded taxa in the 13 permanent plots in the Valley of Radönt found during the excursions from 1988 to 1990 with summation graph of the newly recorded taxa. Blank bars = total of taxa found per excursion; hatched bars = newly recorded taxa per excursion; * = no carpophore collecting.

(cf. Fig. 14). Therefore an increase in the carpophore productivity was always linked with an enrichment in macromycete diversity, though the connection is

not based upon a simple linear function. However, in 1989 there were two exceptions, when the numbers of taxon-finds were lower in the first week of August and higher in the third week of September, respectively, than was registered during each, of the previous excursions.

In 1988, 221 taxon-finds were registered, revealing the lowest number of the three seasons. The comparatively low number was not necessarily a fact of climatic influences but might be mainly explained by the lower frequency of excursions concerning the individual plots (cf. Fig. 14). The maximum of 33 taxon-finds per excursion was registered in the second week of September. A second peak was reported two weeks later with 31 taxon-finds.

Although in 1989 the vegetation period was about four weeks shorter (12 weeks) than in 1988 and 1990, the considerable number of 248 taxon-finds was registered. Without the abrupt end of the fructification season in the last week of September, the total would certainly have been increased to more than 300. The maximum of species diversity per excursion was noticed in the first week of September with 40 different species. In the last week of the vegetation period this diversity parameter was still registered with 32 different species.

In 1990 a maximum of 341 taxon-finds was reported. The steady increase with each excursion reached its maximum in the second week of September with 42 distinctive macromycetes. In the second last week of the fructification season the number of taxon-finds again increased to 29, from 21 registered in the previous week. During the following excursion, the last before the beginning of winter, a distinct drop to 13 taxon-finds was noticed.

The summation graph of the newly recorded taxa per excursion in the Valley of Radönt (Fig. 19a) during the three vegetation periods (1988-90) has its steepest incline in the first year, when 68 different taxa (72 %) were found. Concerning the second fructification season the graph is strongly levelled out with a minimum growing rate of 12 new species (13 %). In 1990, the last vegetation period under review, 14 new taxa were found, and therefore, the summation curve continued in a similar way as in the previous year. The last three new macromycetes were already found in the second week of September, six weeks before the beginning of winter.

Salicetum herbaceae (plot 3, 6, 7, 9, 11, 13)

Compared with the carpophore productivity (cf. Fig. 16a), the taxon-finds (a taxon-find is the proof of a taxon found in one of the six *Salicetum* plots during an excursion) of the *Salicetum herbaceae* association were in perfect accordance only in 1988 (Fig. 19b). However, deviations in 1989 and 1990 were registered but during one excursion each. In 1989, referring to data of the pre-

vious week, there was an increase of the taxon-finds in the third week of September, whereas the carpophore productivity slightly decreased. Conversely, in the last week of September of 1990, a decrease of taxon-finds was registered in connection with a higher carpophore productivity than during the proceeding excursion.

In 1988 totally 165 taxon-finds were reported from the six *Salicetum* plots. This number is comparatively low, presumably due again to the lower frequency of excursions concerning the individual plots, than in 1989 and 1990. The maximum of 26 taxon-finds per excursion was registered in the second week of September, with a second peak (24 taxon-finds) two weeks later.

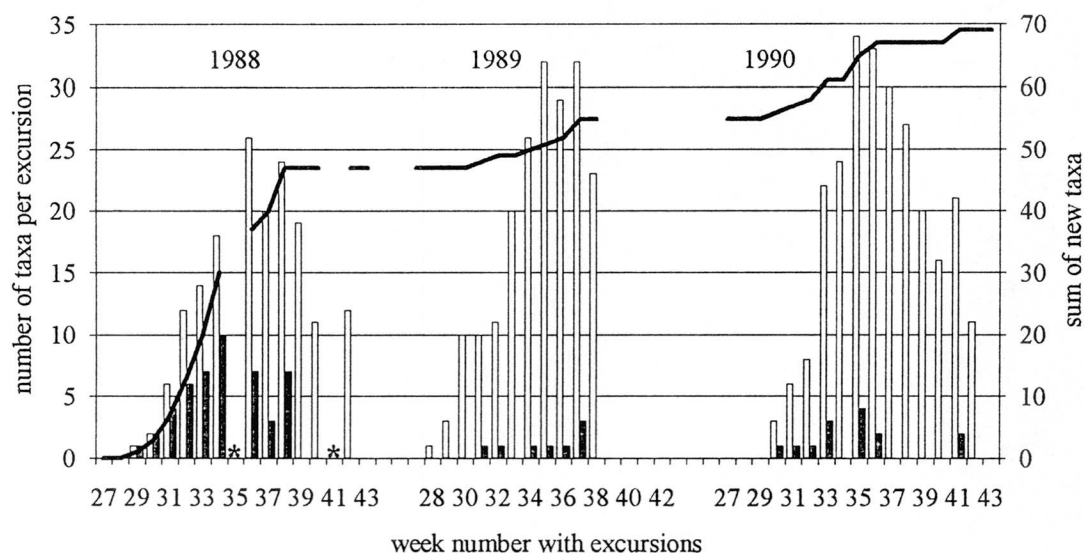


Fig. 19b: Number of macromycete species and newly recorded taxa in the *Salicetum herbaceae* association (plot 3, 6, 7, 9, 11, 13) found during the excursions from 1988 to 1990 with summation graph of the newly recorded taxa. Blank bars = total of taxa found per excursion; hatched bars = newly recorded taxa per excursion; * = no carpophore collecting.

In the second vegetation period, 197 taxon-finds were noticed, although this fructification season was 4 weeks shorter than in 1988 and 1990. The maximum number of 32 different taxa per excursion resulted in the first week of September, and again, with a similar result, two weeks later.

Regarding the three fructification seasons, the maximum of 255 taxon-finds was reported from 1990. The highest numbers per excursion resulted in the first week of September with 34 taxon-finds and one week later with 33, respectively.

The summation graph of the newly recorded taxa per excursion of the *Salicetum herbaceae* plots (Fig. 19b) during the three investigation years proceeds nearly identically with the curve for all plots (cf. Fig. 19a). In 1988 the steep incline of the graph resulted from the 47 different species found during this

vegetation period. In the two succeeding years the summation curve is levelled out, due to a very distinct decrease of new taxa. In 1989 only eight species (12 %) were reported as new, whereas in 1990 the number was noted with 14 (20 %).

Polytrichetum sexangulare (plot 5, 8, 10)

For the *Polytrichetum* association there seems to be no characteristic, positive relation between the carpophore productivity (cf. Fig. 17a) and the taxon-finds (Fig. 19c). At least, the connection is not as evident as demonstrated for the *Salicetum* plots and the whole investigation area, respectively. However, the maxima of the taxon-finds per excursion were correlated in all three years with the highest carpophore productivity.

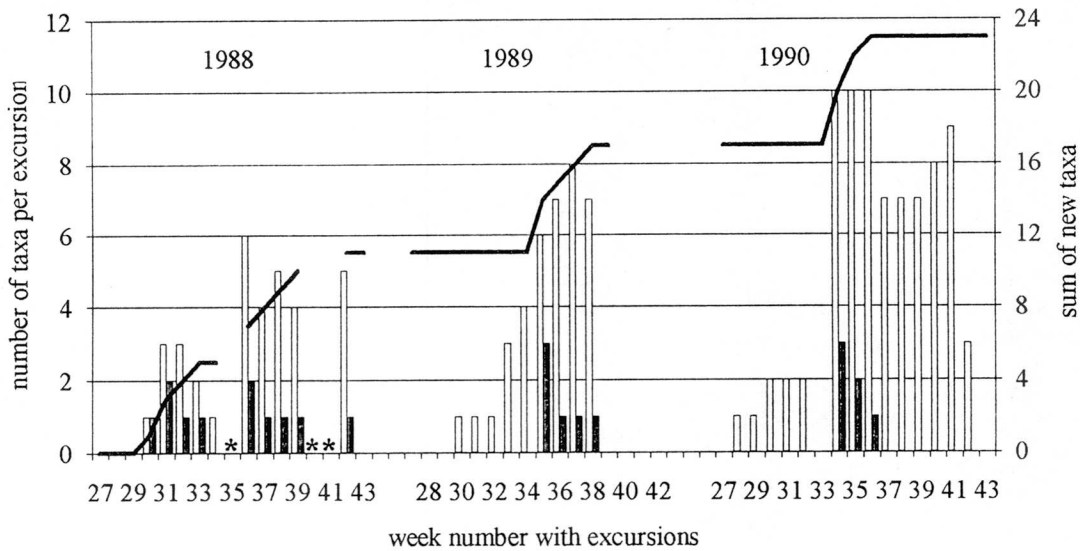


Fig. 19c: Number of macromycete species and newly recorded taxa in the *Polytrichetum sexangulare* association (plot 5, 8, 10) found during the excursions from 1988 to 1990 with summation graph of the newly recorded taxa. Blank bars = total of taxa found per excursion; hatched bars = newly recorded taxa per excursion; * = no carpophore collecting.

In 1988, a total of 36 taxon-finds was reported during the vegetation period. The highest number per excursion, six different macromycetes, was registered in the second week of September.

During the investigation period of 1989 the maximum of the fructification season amounted to 38 taxon-finds with the maximum per excursion, eight taxa, in the third week of September.

In 1990, the third investigation year, more than the double of the taxon-finds during the vegetation period (79 taxon-finds) was noticed. The maximum num-

ber per excursion, ten different species, was reported during three subsequent weeks, viz. last week of August, first and second week of September.

The summation curve of the newly recorded taxa per excursion from the *Polytrichetum sexangulare* plots (Fig. 19c) during the three vegetation periods differs obviously from the two presented before (cf. Figs. 19a, b). Although 48% (21 taxa) of the total of found species was reported from the first investigation year, the difference of the gradient of the summation graph, comparing the three fructification seasons, is not exceedingly distinct. In 1989 and 1990, six new taxa (26 %) were registered in each year.

3.5.3. Phenology of selected characteristic macromycetes in snow-bed communities

Based upon the evaluated, most characteristic taxa registered in the snow-bed plots (6 plots in *Salicetum herbaceae* [$\approx 600 \text{ m}^2$] and 3 plots in *Polytrichetum sexangulare* [$\approx 300 \text{ m}^2$]) represented in the Figures 20 a & b the following three phenological patterns are recognizable:

1.) A minority of species started their fructification season soon after the snow melting period (end of July) and continued to be present during the whole vegetation period until the beginning of winter. This pattern, correlated with a high productivity, was typical for the ectomycorrhizal species *Laccaria montana*, *Cortinarius (Myxadium) favrei* and the moss parasite *Psilocybe chionophila*. However, most of the taxa followed this pattern with the start of the carpophore productivity delayed until about the end of the flowering season of *Salix herbacea* (from mid to end of August). Characteristic representatives of this fructification behaviour were *Astrosporina boltonii*, *Hebeloma marginatulum*, *H. repandum*, and nearly all species of the genus *Cortinarius* (subgenus *Telamonia*).

2.) On the other hand, there were a few taxa with an obviously limited fructification period. *Astrosporina giacomii*, *Inocybe calamistrata* and *Psilocybe apeliculosa* for example occurred only early in the vegetation period, whereas *Cortinarius pauperculus* and *C. pertristis* were observed towards the end of the season. Furthermore, the phenology of *Inocybe peronatella* is interesting in so far as this species is the only taxon with the fructification season restricted to a rather short time during the main vegetation period (mid August to mid September).

3.) Furthermore there were species with an increasing number of carpophore regarding productivity from 1988 to 1990, such as *Laccaria montana*, *Entoloma alpicola*, *Cortinarius cavipes* and *Inocybe peronatella*. But *Astrosporina giacomii*, *Cortinarius diasemospermus*, *C. pauperculus* and *C. cf. minutulus*,

taxa from corresponding genera showed inverse fructification patterns, with the highest yield in 1988 and the lowest one in 1990. Nevertheless, the majority of the taxa had their lowest carpophore productivity in the second season (1989) under review. However, there were a few remarkable exceptions, such as *Inocybe calamistrata*, *Dermocybe cinnamomeolutea*, *D. crocea*, *Cortinarius favrei* and *Psilocybe chionophila* which increased their productivity rate to the absolute maximum in 1989.

Furthermore, several species occurred only in one, e.g. *Entoloma sericeum*, *Cortinarius cf. anomalus*, *Inocybe fastigiata* var. *alpestris*, or two of the three examined vegetation periods, e.g. *Cortinarius pertristis*, *Amanita nivalis*, *Hypholoma myosotis*, *Naucoria bohémica*, *Psilocybe apelliculosa*.

Ectomycorrhizal macromycetes: The annual carpophore productivity periods of the symbionts of *Salix herbacea* showed more or less two different patterns (Fig. 20a). The absolute majority of the ectomycorrhizal species started their fructification period towards the end of the flowering season of *S. herbacea*, the only host plant occurring in the investigated snow-bed community plots (cf. Tab. 18). However, there were a few species, which produced their first carpophores already with the start (*Inocybe lacera*, *Laccaria proxima*), or even prior to (*Cortinarius favrei*, *Entoloma alpicola*, *I. calamistrata*, and *L. montana*) the beginning of the dwarf willow's blossom. Furthermore, some interesting phenology patterns were observed between closely related taxa within the same genera. *Astrosporina giacomii* for example occurred early in the vegetation period and was never again registered after the last week of August. Conversely, *A. boltonii* started its fructification season only with the disappearance of the previously mentioned taxon, and was constantly registered until the beginning of winter. *Cortinarius caesionigrellus* and *C. percausus* were both reported only from the first (1988) and the third (1990) vegetation period. The absence of the two species in 1989 is even more remarkable, because they were reported together in four plots and in one different plot each in 1988 and 1990 (cf. Tab. 22). An additional, remarkable fructification behaviour was registered for *C. pauperculus* and its f. *luteovelata* ad int. The former was found rather frequent in 1988, but obviously decreased its productivity in 1989 and finally was registered only during one excursion in 1990. Reversely, the f. *luteovelata* reached its maximum in 1990 and was observed at a distinctly lower frequency in the two previous years.

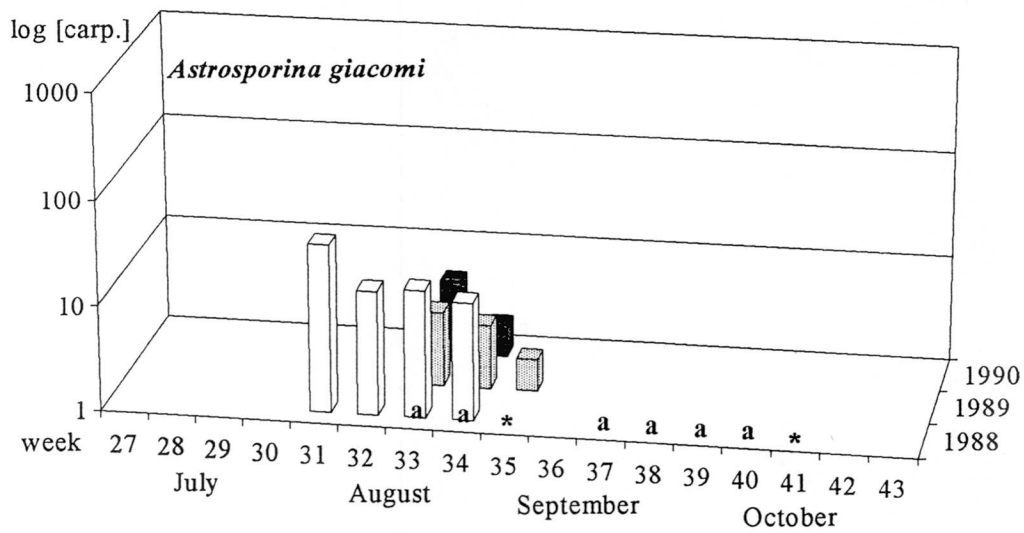
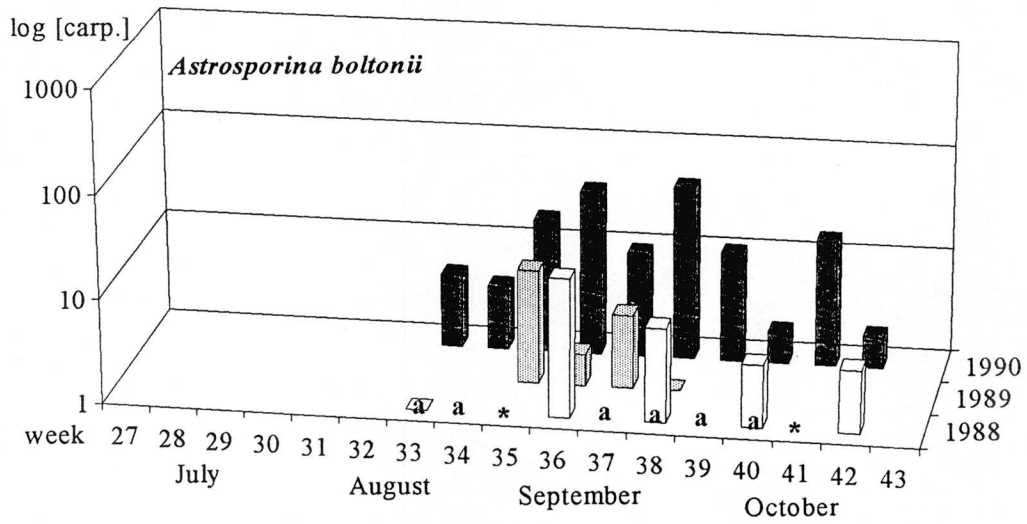


Fig. 20a: Phenology and productivity of characteristic ectomycorrhizal Basidiomycetes in the investigated snow-bed community plots, viz. *Salicetum herbaceae* and *Polytrichetum sexangularis*. X-axis with logarithmic scale of the number of carpophores (log [carp.]).
 ★ = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres.
 a = not all plots considered due to snow-covered plots or lack of time (cf. Fig. 14).

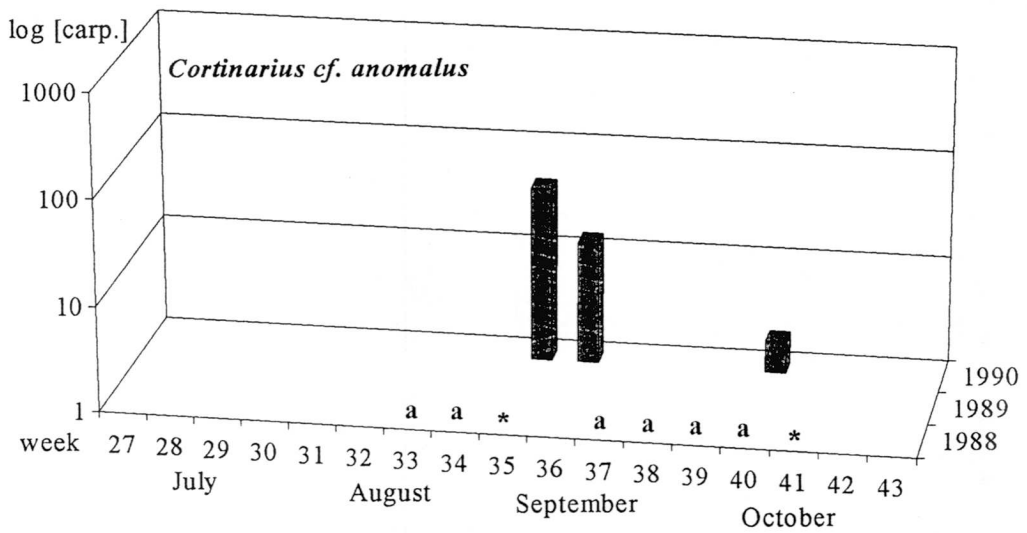
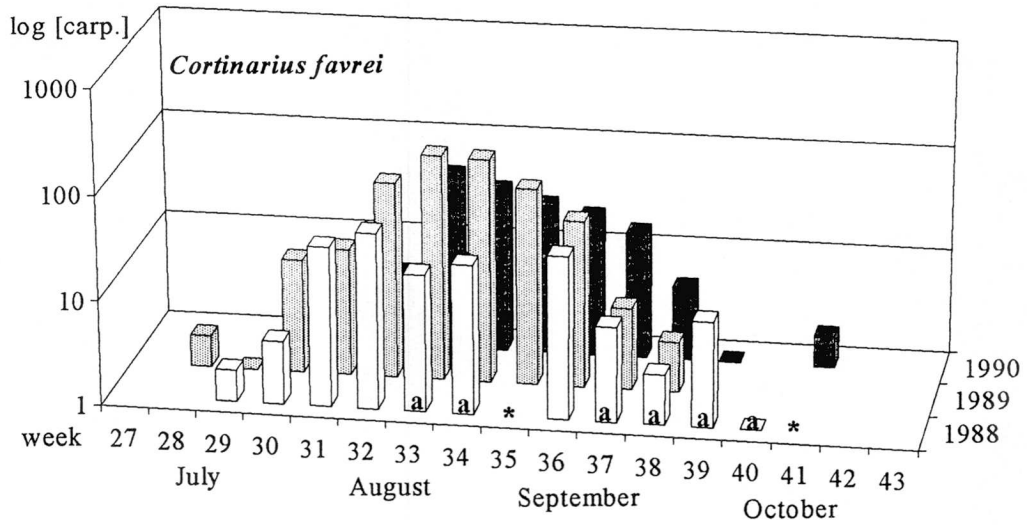
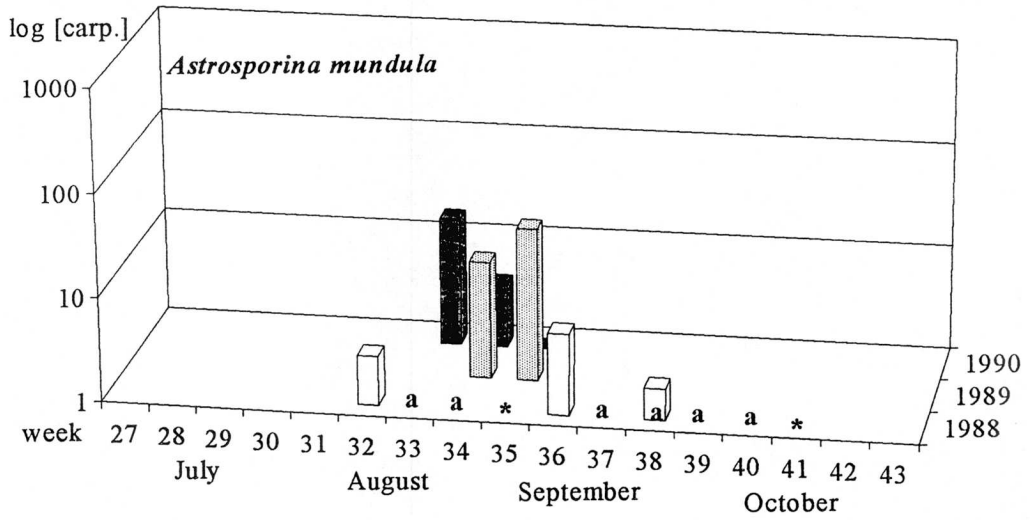


Fig. 20a: continued.

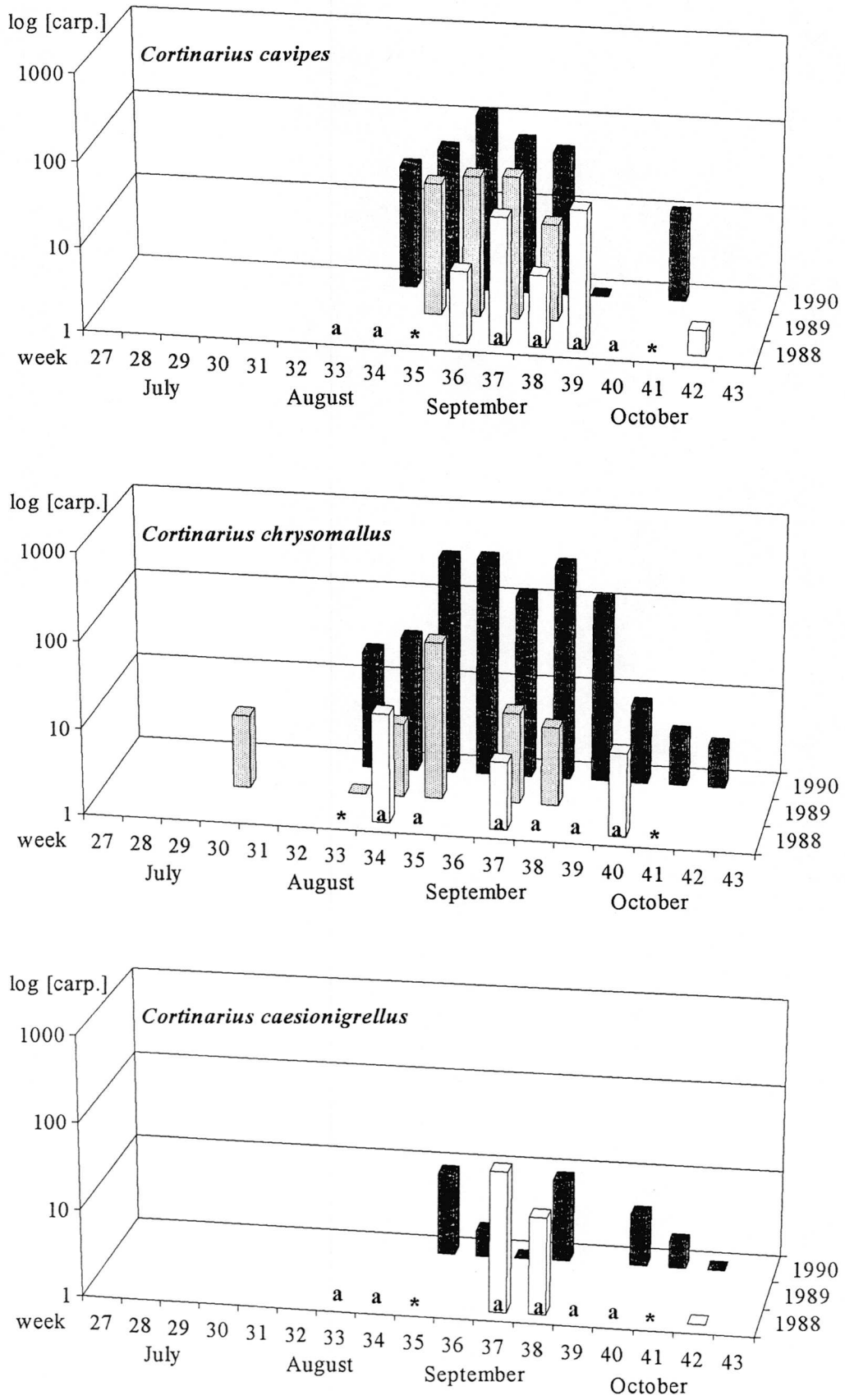


Fig. 20a: continued.

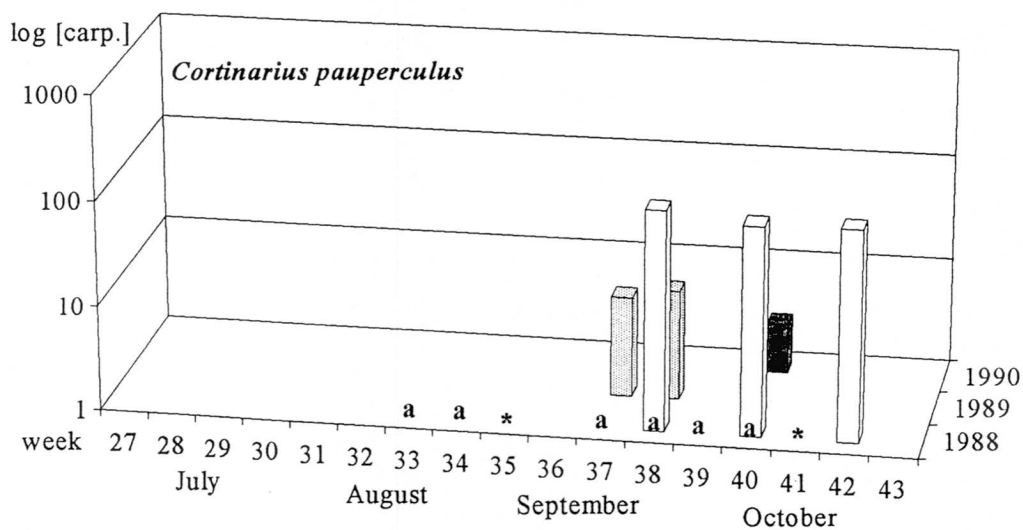
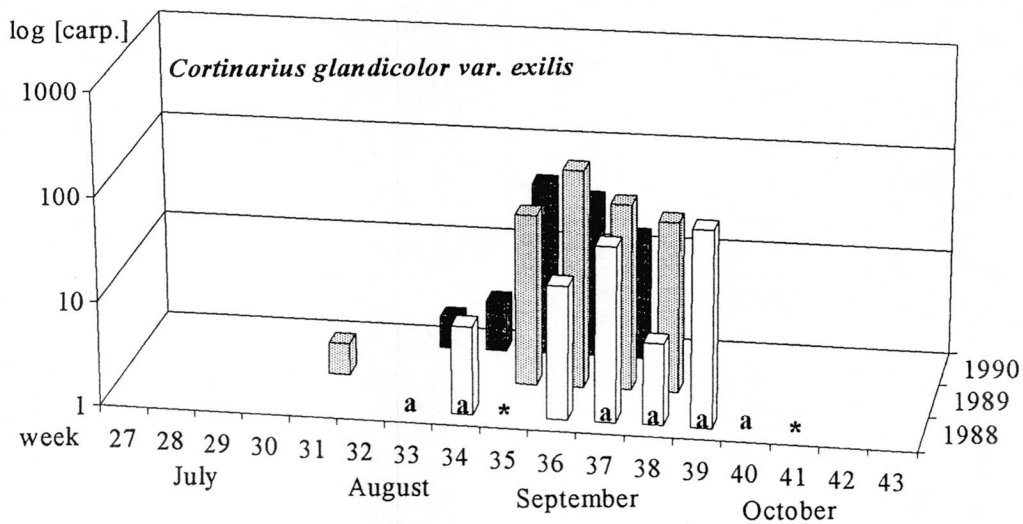
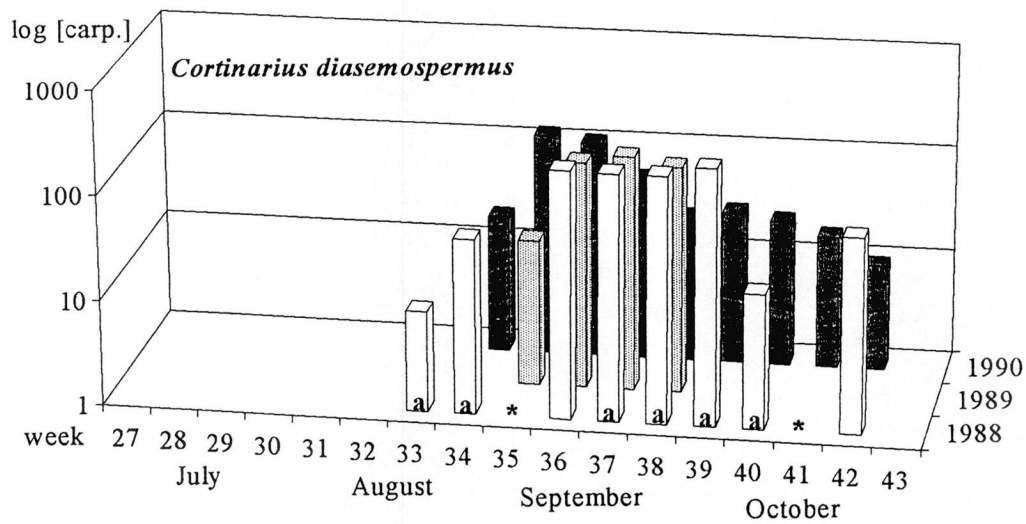


Fig. 20a: continued.

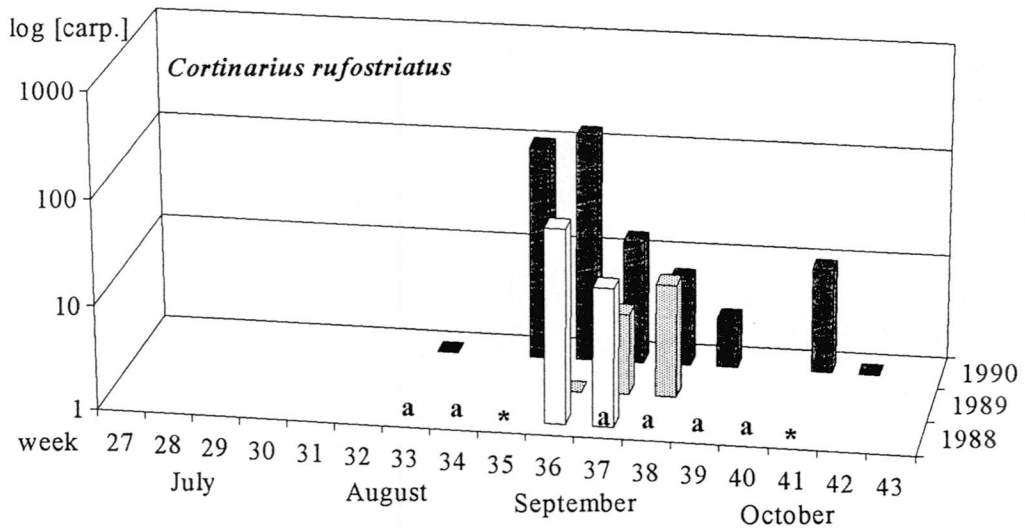
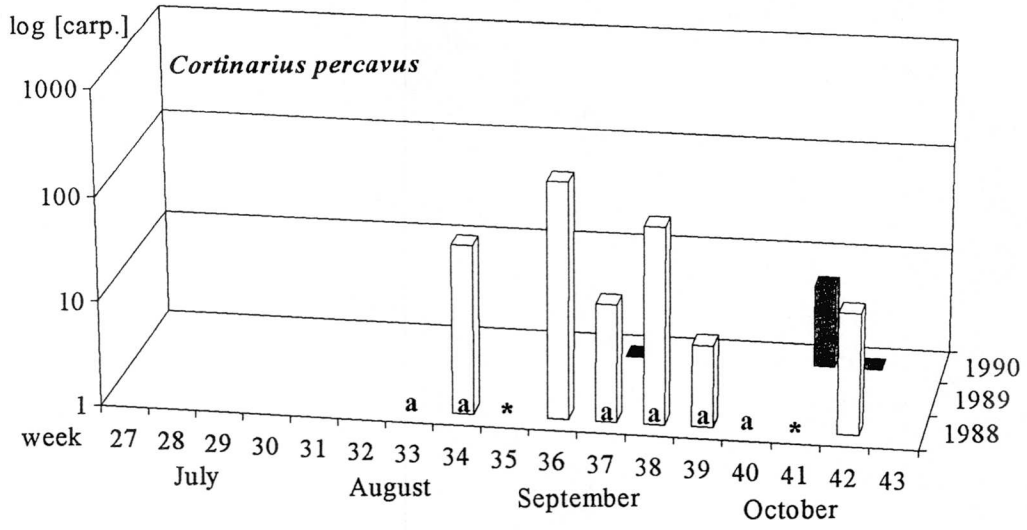
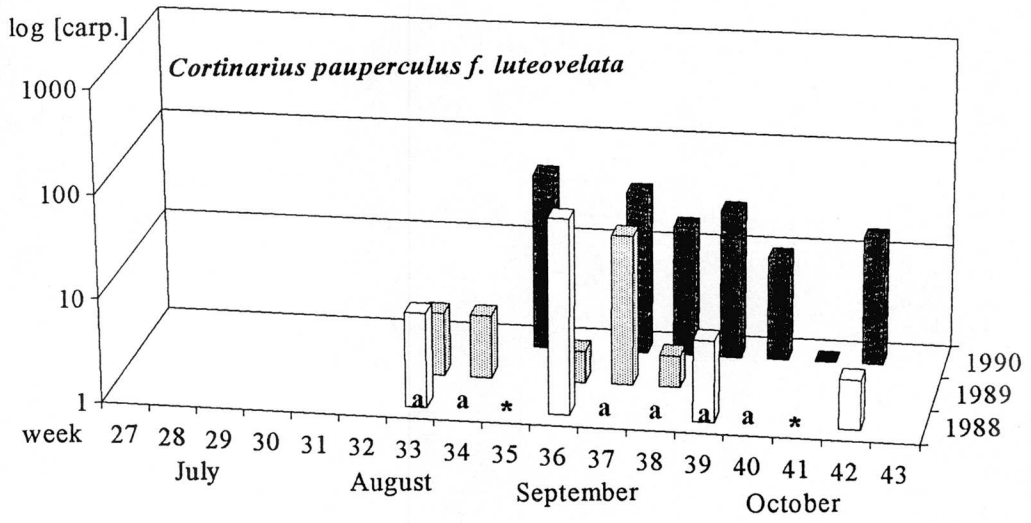


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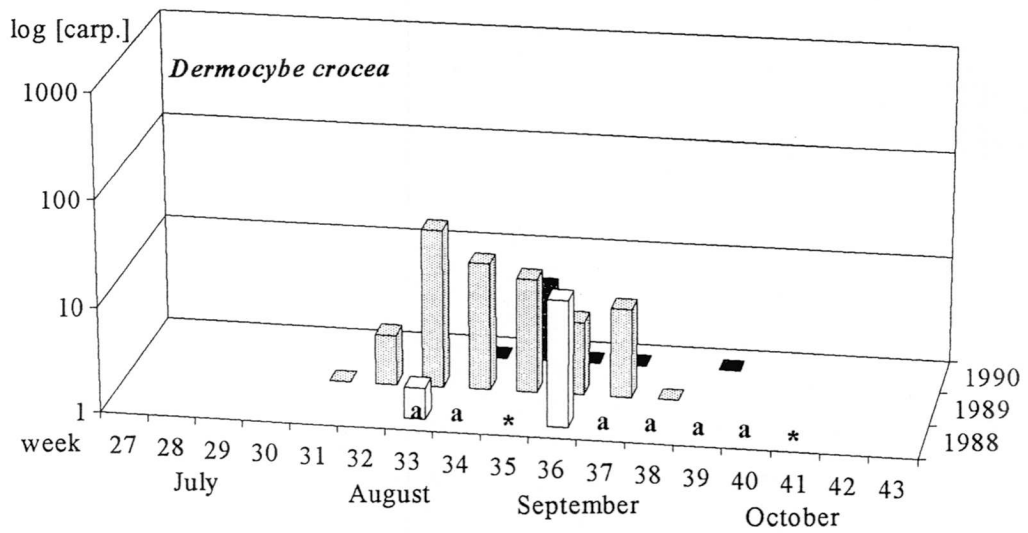
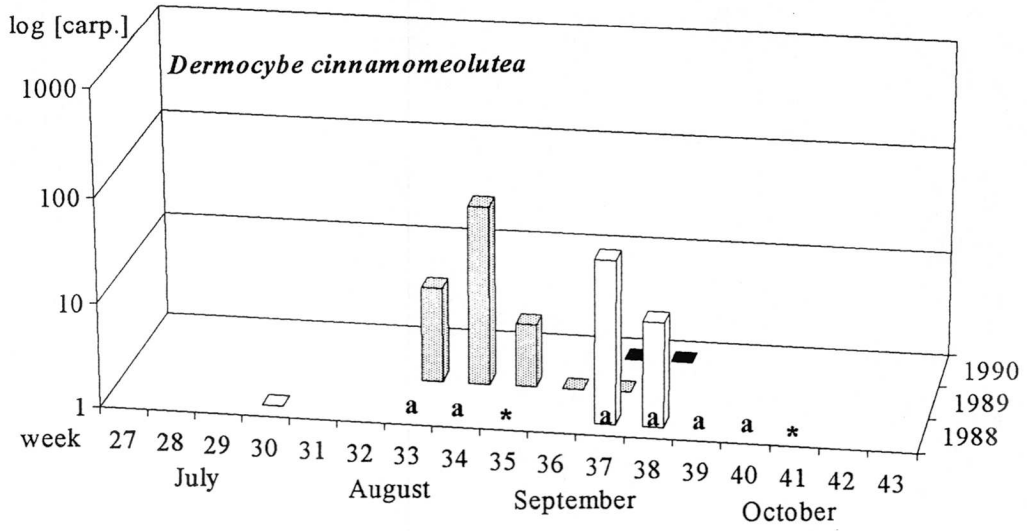
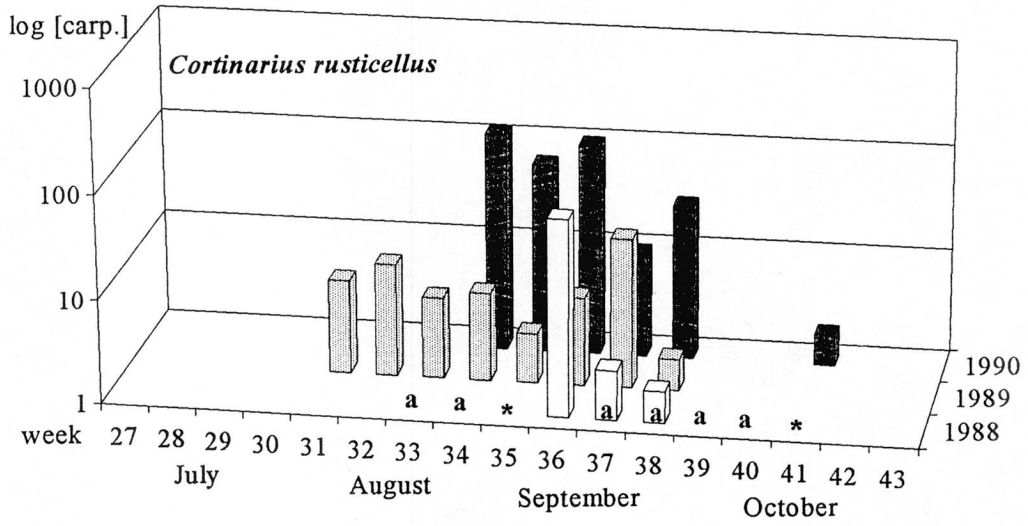


Fig. 20a: continued.

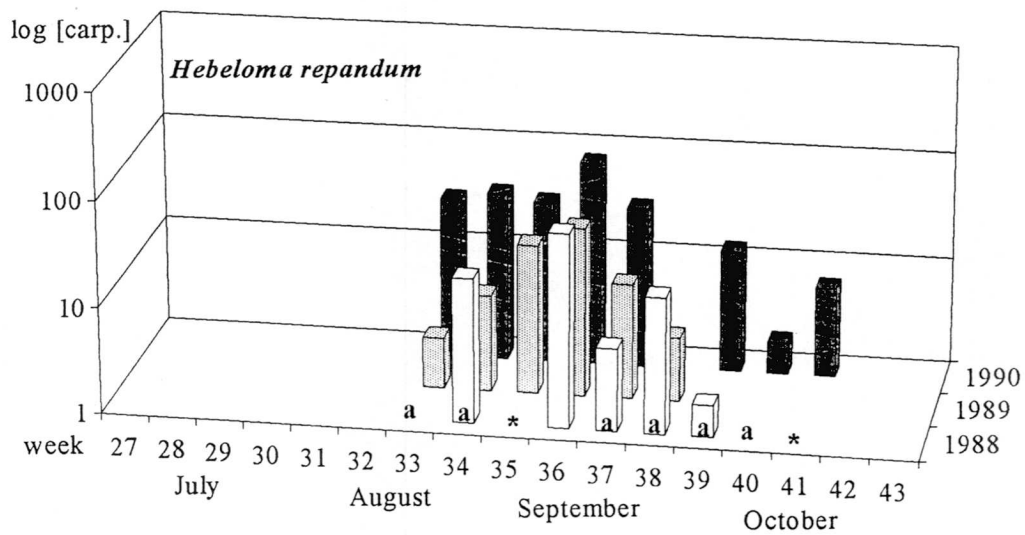
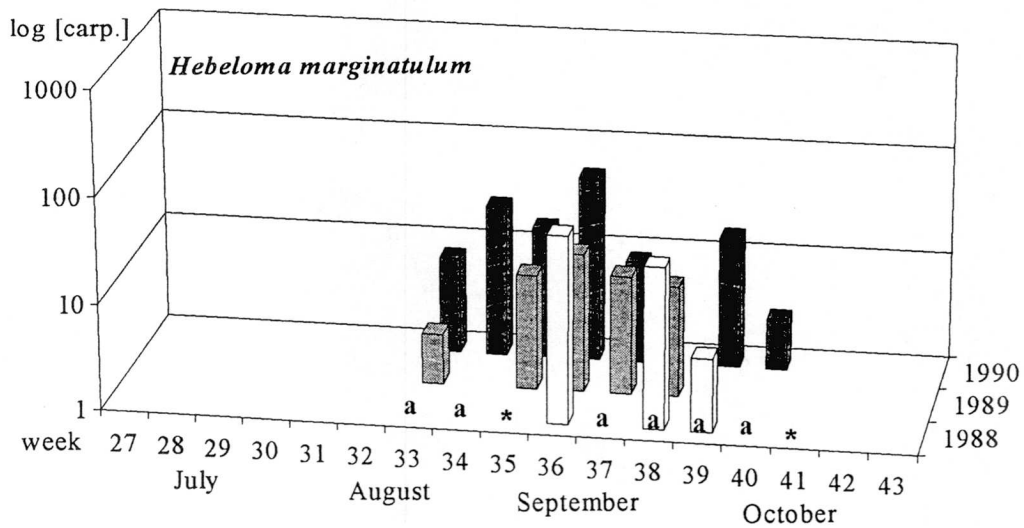
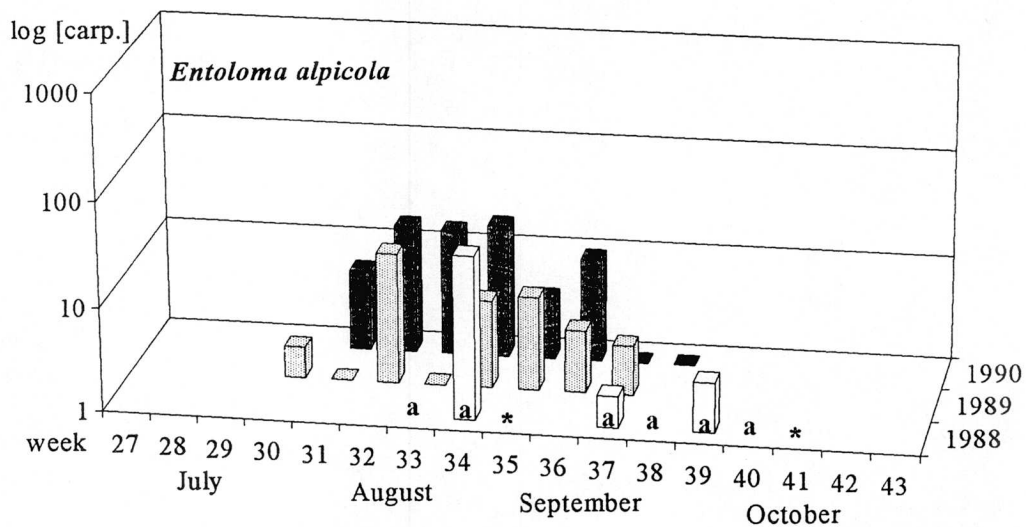


Fig. 20a: continued.

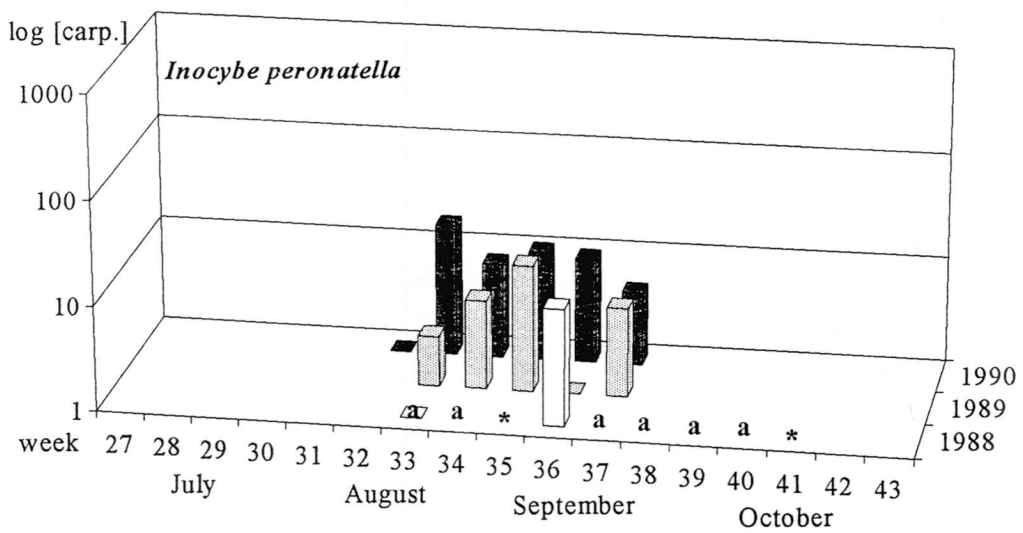
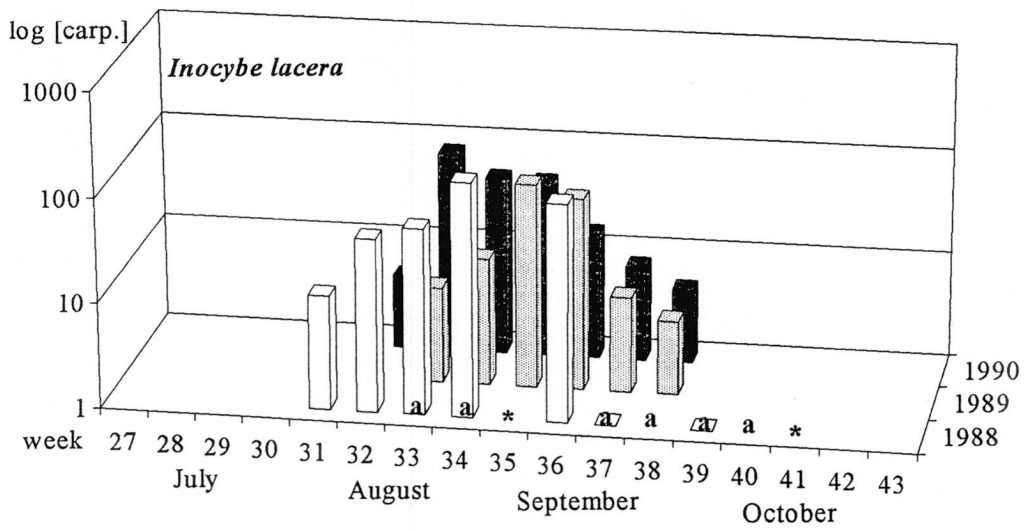
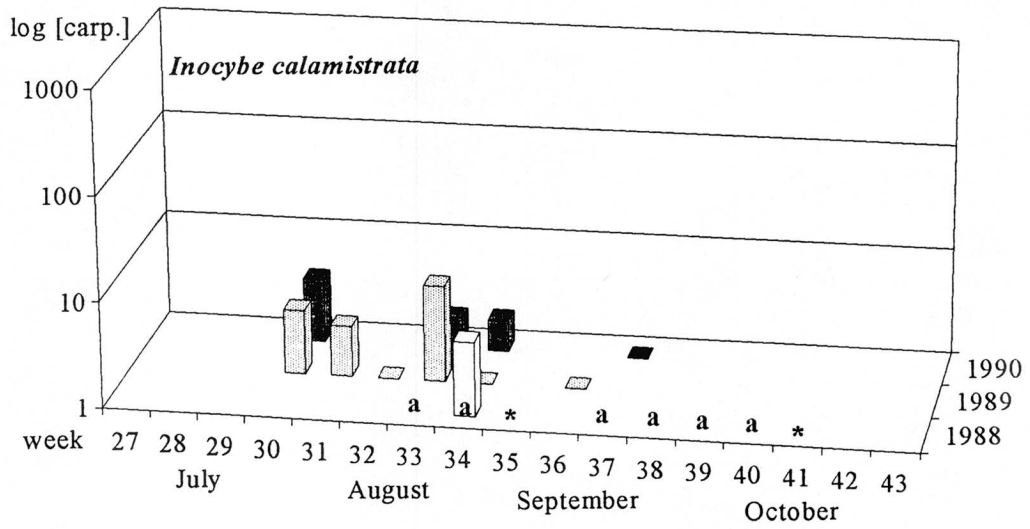


Fig. 20a: continued.

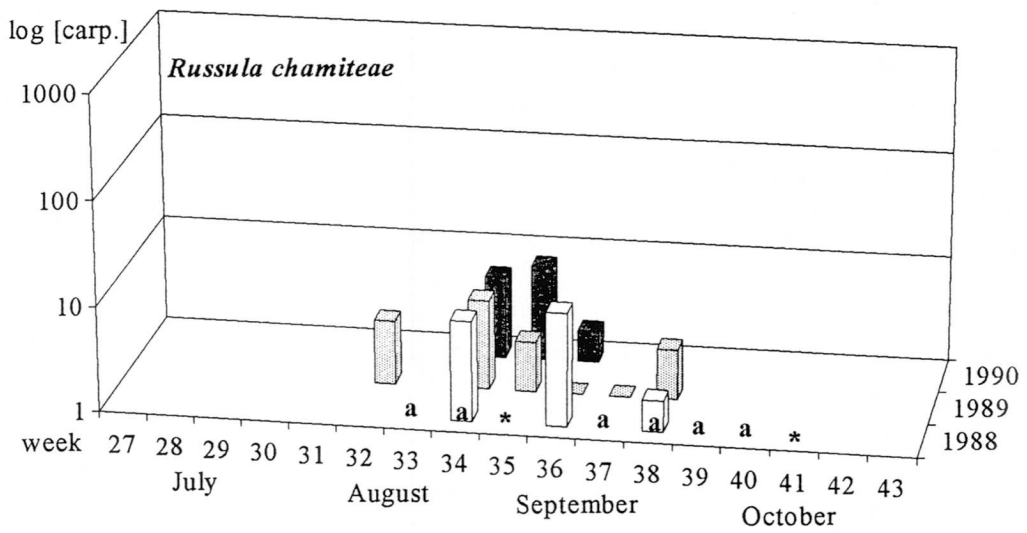
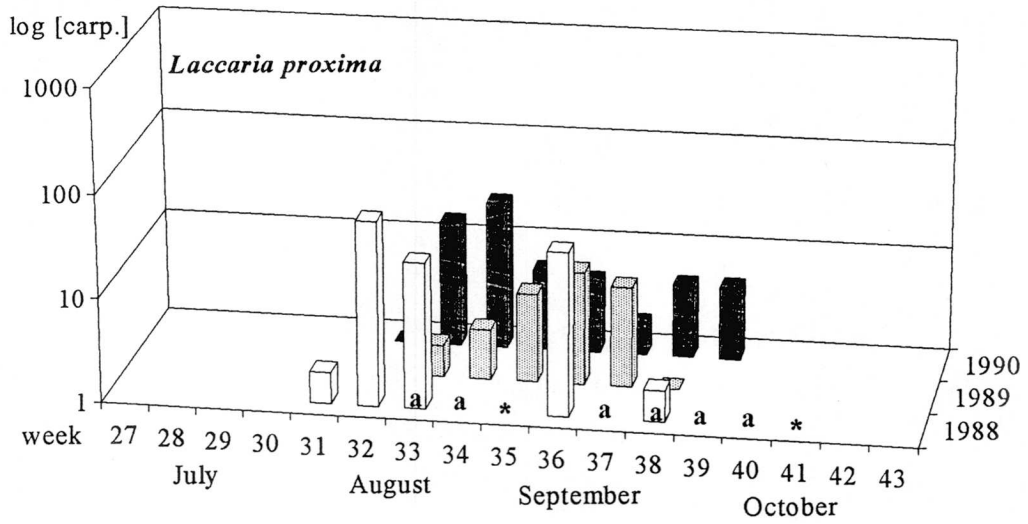
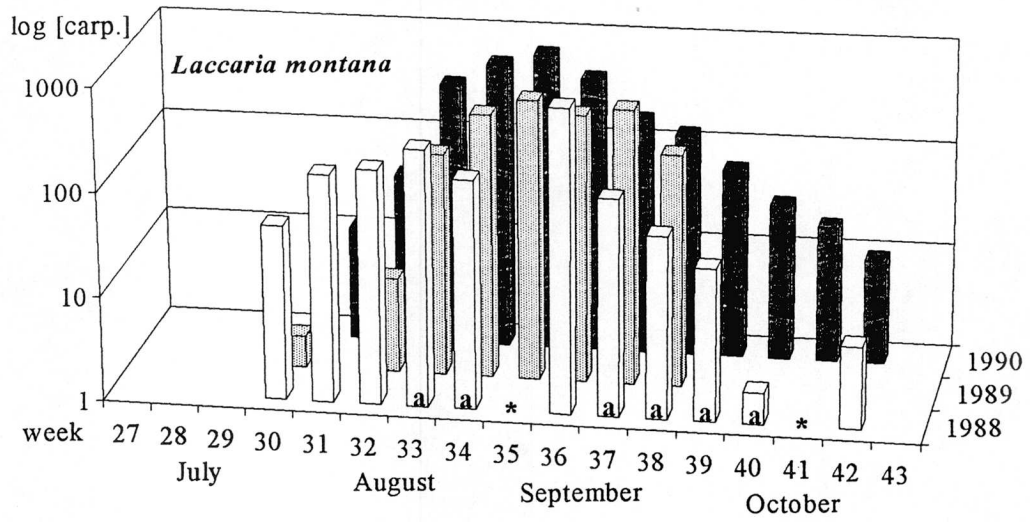


Fig. 20a: continued.

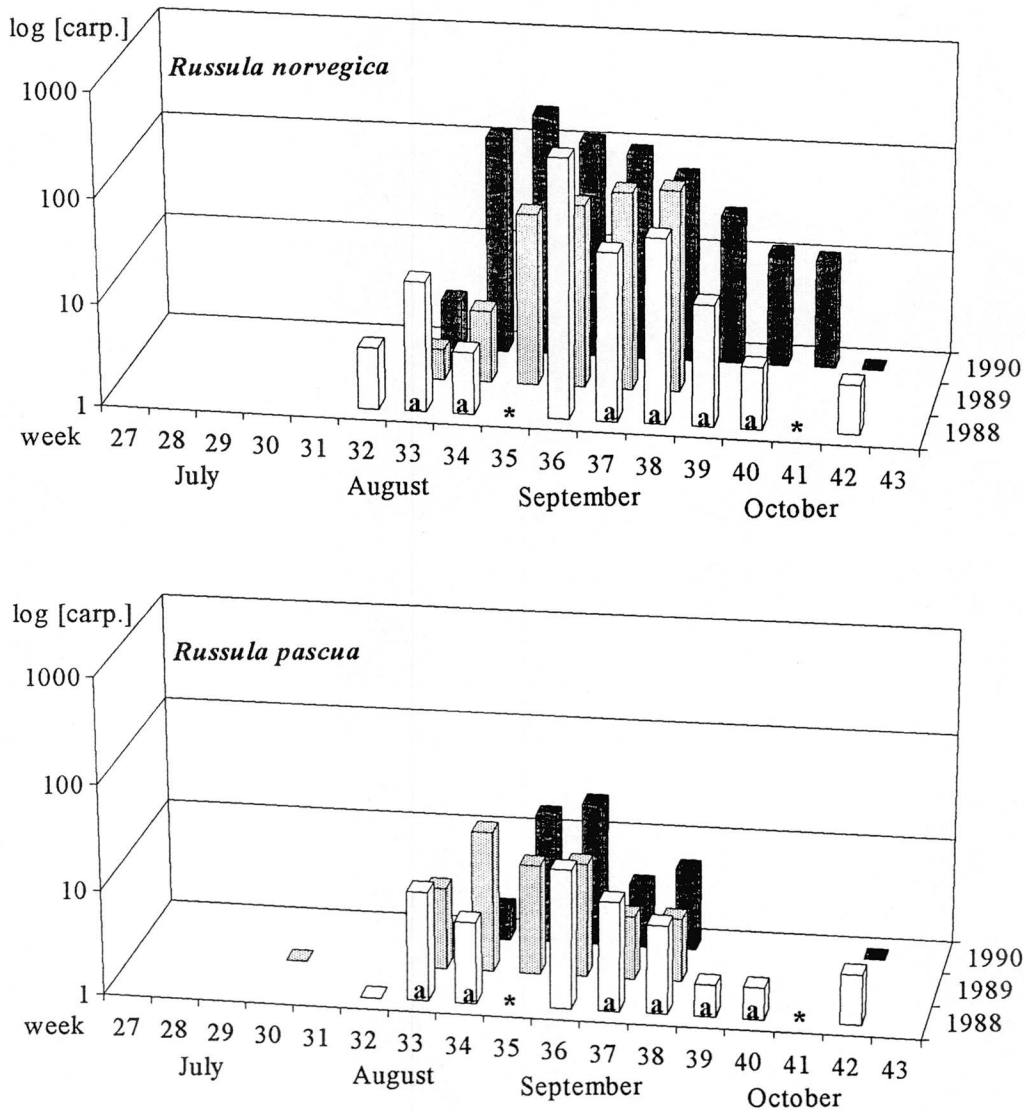


Fig. 20a: continued.

Saprobic macromycetes: Before discussing any results it is important to keep in mind that the saprobes (parasites) were conspicuously under represented in the investigated snow-bed plots. The comparison of the phenology between the ectomycorrhizal species (Fig. 20 a) with the few saprobic (parasitic) taxa (Fig. 20 b) registered in the snow-bed community does not confirm an evident difference among the two ecological groups. The most abundant species, *Psilocybe chionophila*, a weak parasite of the moss *Polytrichum sexangulare*, exactly showed the same seasonal distribution pattern of carpophore productivity as *Laccaria montana* and, to a lesser extent, as *Cortinarius favrei*. *Galerina chionophila*, apart from a few exceptional reports in the *Polytrichetum* plots, had a very similar phenology as *Inocybe lacera*. Furthermore, the pattern of

Neottiella aphanodyction can be easily assigned to the one followed by most *Cortinari* taxa. Although lesser inescapable, this is true also for *Entoloma atropellitum*. The only exception was *Psilocybe apeliculosa*, which was found only during the first two investigation years (1988-89) with a phenology pattern completely different to the other species presented (Fig. 20 b).

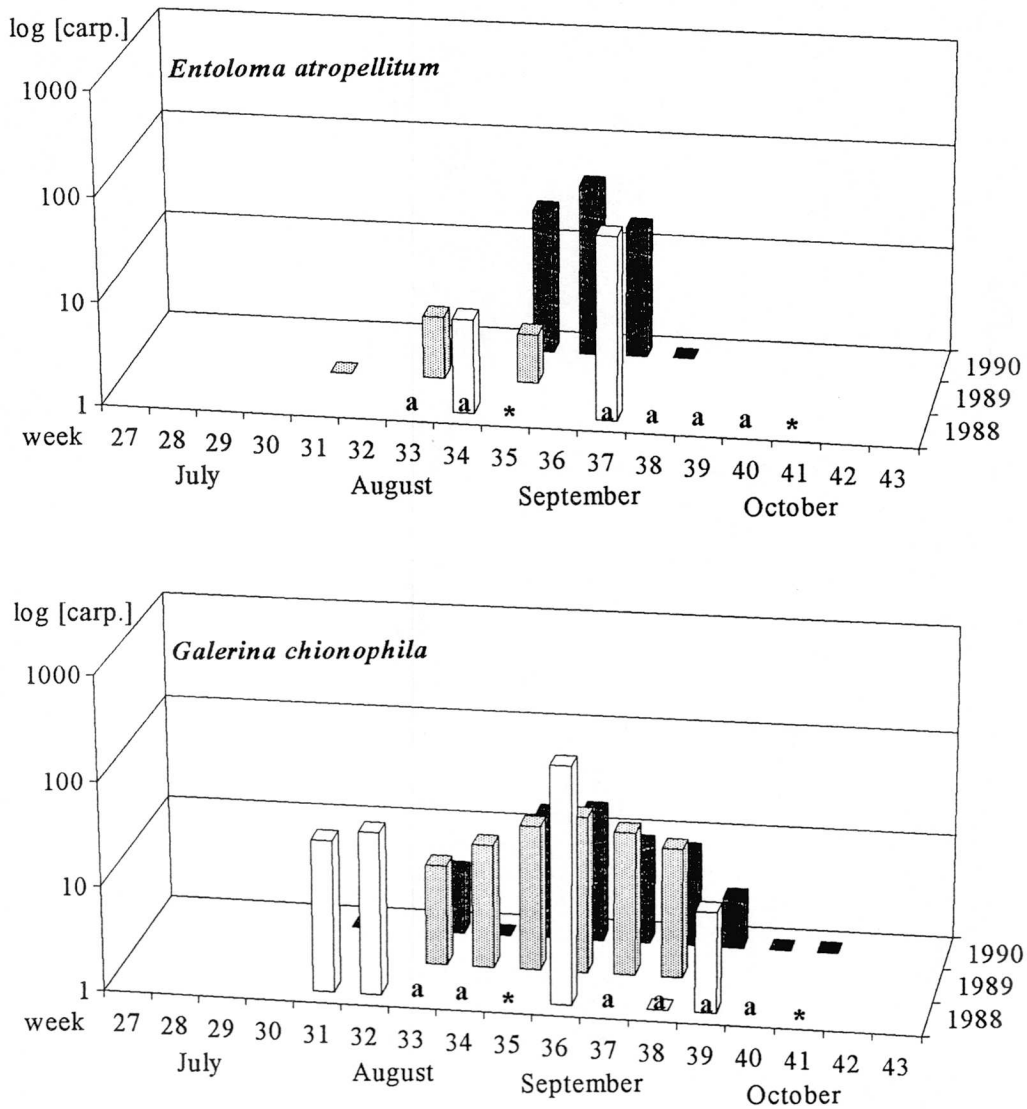


Fig. 20b: Phenology and productivity of characteristic non-ectomycorrhizal macromycetes in the investigated snow-bed community plots, viz. *Salicetum herbaceae* and *Polytrichetum sexangularis*. X-axis with logarithmic scale of the number of carpophores (log [carp.]); * = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres; a = not all plots considered due to snow-covered plots or lack of time (cf. Fig. 14).

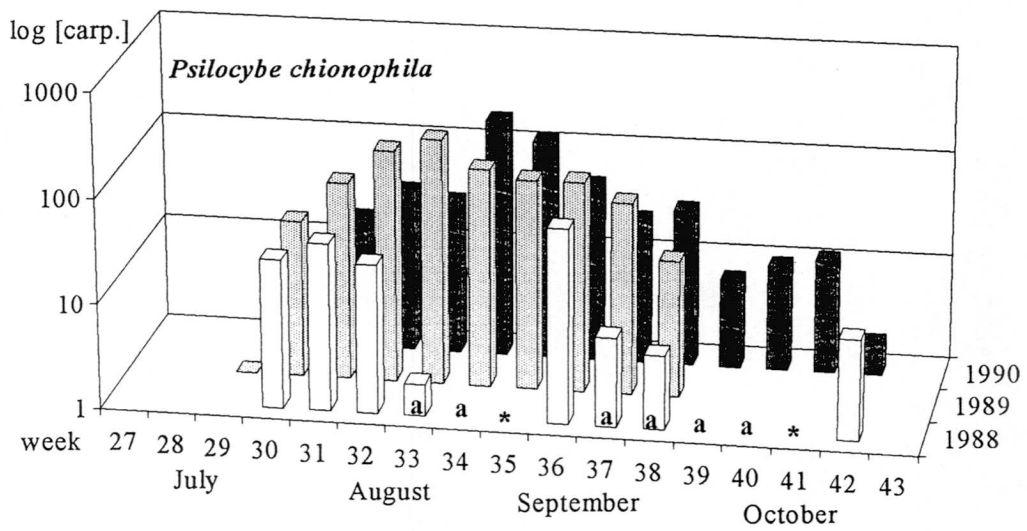
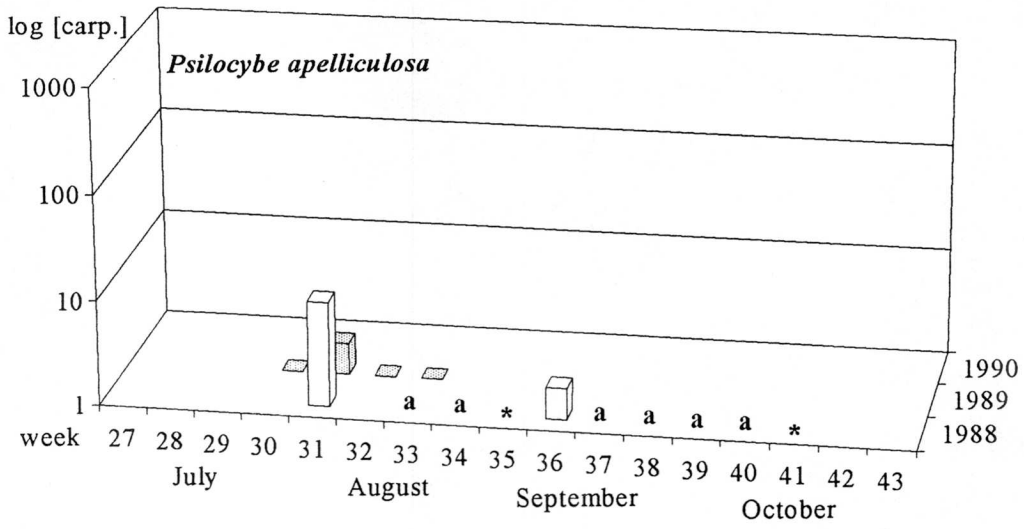
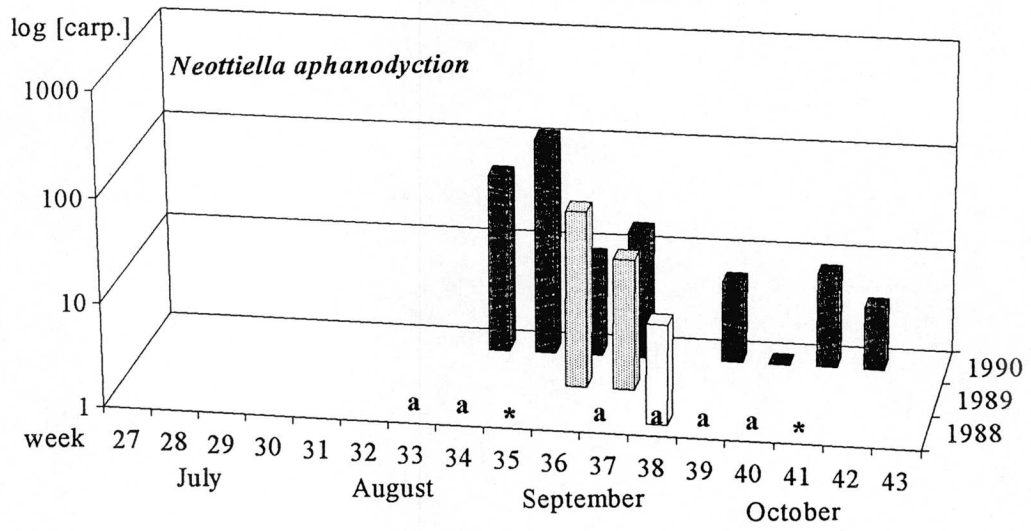


Fig. 20b: continued.

3.5.4. Relationships between local climate and fructification of macromycetes in snow-bed communities

There is no doubt about the influence of the seasonal course of the various climatic parameters on carpophore productivity and phenology of alpine macromycetes. However, the actual impact and the importance of any of the parameters and their combination, especially precipitation (rain, snow) and temperature, still remain to be seen. This lack of information in alpine regions is mainly based upon the high complexity of the subject on the one hand, but also upon the absence of relevant studies on the other hand. Apart from EYNARD (1975, 1977), who mentioned that the time of the snow melting period may influence the occurrence of several macromycetes, DEBAUD (1983) only thoroughly investigated the possible interactions of precipitation and temperature regarding the fructification behaviour of some *Clitocybe* species associated with *Dryas octopetala* in the French Alps. More information and data are, however, available from studies in arctic regions (PETERSEN 1977, HANSEN 1973, VASSILIKOV 1967). In addition numerous investigations about this subject were performed in lowland habitats (GRIESSER 1992, BRUNNER 1987, THOEN 1976, LANGE 1948).

Before comparing the following results, it must be emphasized that there are important differences between the three investigation years. Whereas in 1988 it was impossible to check the 13 plots in continuous weekly intervals, this was achieved in 1989 and 1990. Therefore, results of the carpophore productivity and phenology of the registered macromycetes in 1988 are far from demanding completeness. In contrast, these parameters are reported indeed in an unbroken, weekly succession in 1989 and 1990. Consequently, it is not permissible to support any conclusions resulting from differences between the first and the two succeeding fructification seasons concerning climatic influences on carpophore productivity and phenology. In the following, the main conclusions are based upon the investigation years of 1989 and 1990.

In the evaluation, it has to be taken into consideration that snow registered during the vegetation period was considered in combination with rain (cf. chapter 3.5.4.1.) as well as an independent parameter itself (cf. chapter 3.5.4.2.).

Subsequently these parameters (rain, snow, max.-min. temperatures) are analyzed independently, each in relation to the carpophore productivity. However, it is obvious that only the complex interactions of all parameters may explain the still obscure phenomenon of the fructification of macromycetes, in particular in the alpine environment.

3.5.4.1. Precipitation

Concerning phenology of macromycetes the seasonal course of precipitation is regarded as more important than the total sum per year (GRIESSER 1992). In the alpine zone, however, one must be aware, that the total of precipitation (rain, snow) during the vegetation period (July to October) may be of particular importance for the carpophore productivity as well as for the formation of primordia. Precipitation in the first half of the vegetation period (July, August) must be considered as most substantial to trigger subsequently the fructification of macromycetes (PETERSEN 1977).

Ectomycorrhizal macromycetes: In 1988 and 1990 precipitation dropped to an aestival minimum in the last week of July preceded by two weeks of higher precipitation (Fig. 21). From this point of relative dryness, the weekly measured amounts steadily increased until the third week of August. With a two to three weeks delay the carpophore productivity followed the same scheme until reaching its maximum. In the second half of the fructification season this positive correlation continued, however, with a less distinct response of the carpophore productivity to the fluctuations of precipitation. Although in 1989 the course of precipitation started as in 1990, the drop at the end of July was not as distinct. Furthermore, during the following three weeks the measured amounts stayed more or less at the same level to drop to a relative minimum in the third week of August. Regardless of these differences, the carpophore productivity steadily increased more or less the same way as in 1988 and 1990 until mid-August. However, from this date, the increase was only about half or even less than that in 1990. Furthermore, instead of culminating in a distinct productivity maximum, the fructification rate was noticed on a slightly increased level during the first three weeks of September. During the second period of the fructification season there was no correlation anymore. Regardless continuing increase of precipitation until mid-September, the carpophore productivity constantly decreased until the early beginning of winter in the last week of September.

Saprobic (parasitic) macromycetes: Whereas all symbionts found during this three year investigation have been reported in association with the phanerogame *Salix herbacea*, the most important saprobes (parasites), viz. *Psilocybe chionophila* and *Galerina chionophila*, were linked to cryptogams, namely the moss *Polytrichum sexangulare*. In this group of macromycetes a significantly different response pattern to precipitation was noticed compared with ectomycorrhizal species (Fig. 21).

In all three fructification seasons (1988-90) there was a weak positive correlation recognizable during the first two to three weeks between precipitation and carpophore productivity with the latter having a response delay of a few days

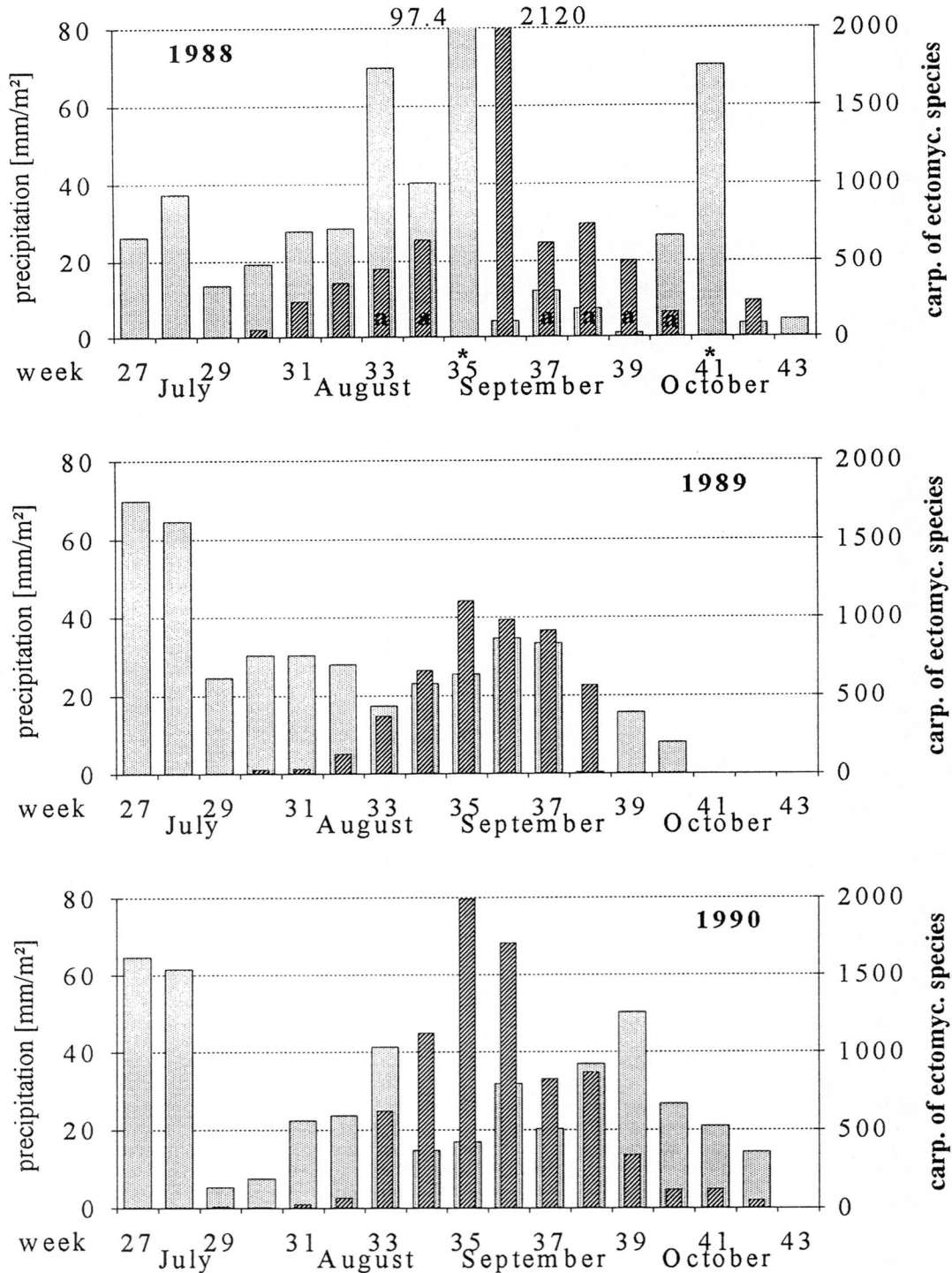


Fig. 21: Relationships between the seasonal course of precipitation (rain, snow) and the carpophore productivity and phenology of ectomycorrhizal and saprobic (parasitic) macro-mycetes in the investigated snow-bed communities (6 plots of *Salicetum herbaceae* and 3 plots of *Polytrichetum sexangularis* association) from 1988-90.

hatched bars = number of carpophores (carp.) per excursion

dotted bars = precipitation [mm/m²]

* = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres

a = not all plots considered, due to snow-covered plots or lack of time (cf. Fig. 14)

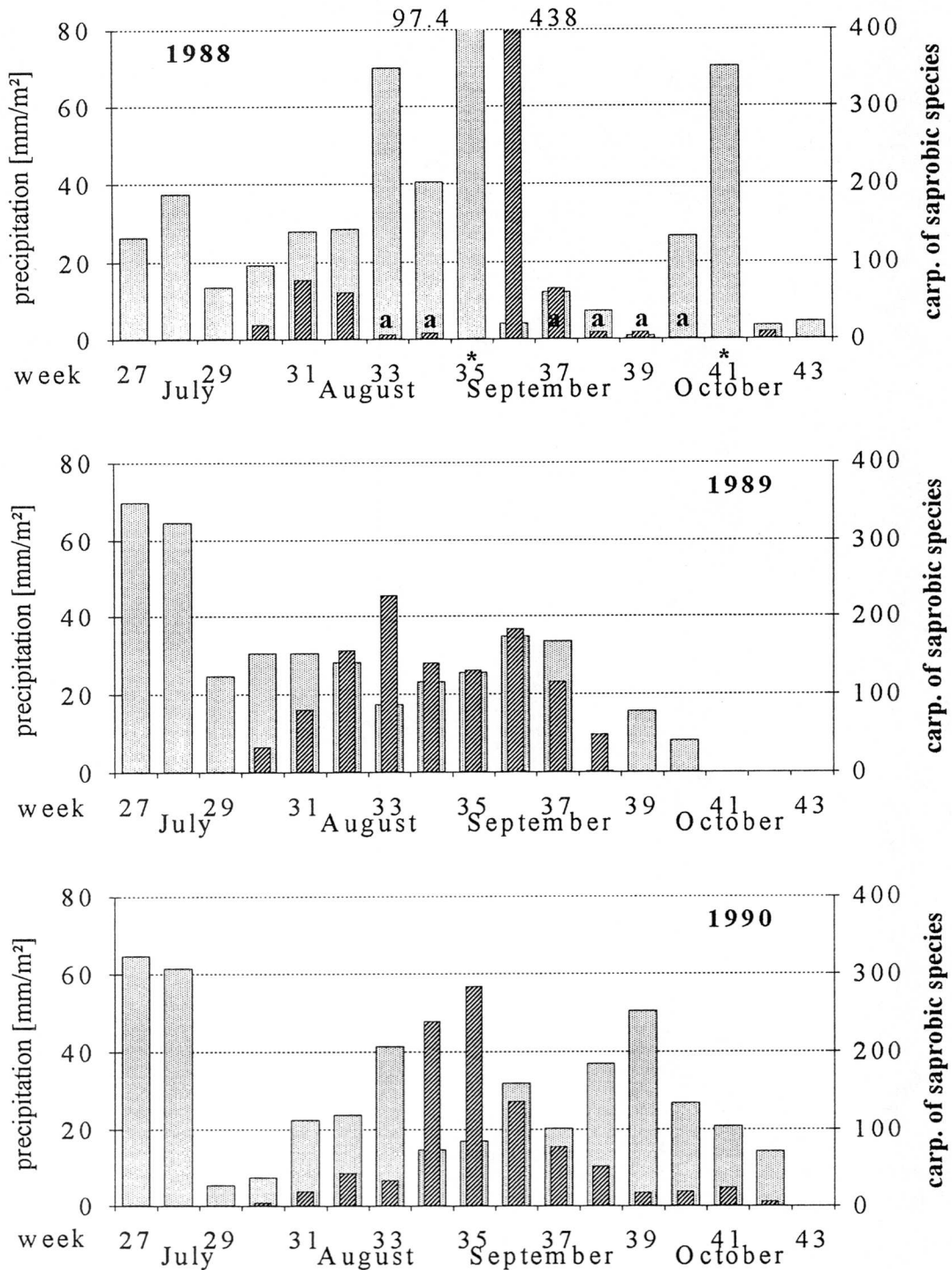


Fig. 21: continued (saprobic macromycetes).

to about one week. In 1988 and 1990 the distinct maximum of the carpophore productivity occurred with a one-week (1988) and a one to two-week (1990) delay, respectively to an early autumnal (first week of September 1988) and a late aestival (third week of August 1990) precipitation maximum. From this culmination until the beginning of winter no further correlation, neither positive

nor negative was clearly recognizable in 1988 as well as in 1990 when the productivity rate continuously declined in both years regardless of the different patterns of precipitation.

In 1989 no marked fluctuations were apparent in the course of precipitation. Therefore, no definite correlation with the carpophore productivity was observed. In contradiction to the two other years, a lack of a distinct productivity maximum was registered. Instead, a period of a higher fructification rate resulted from mid-August to mid-September.

3.5.4.2. Snowfall and snow-cover during the vegetation period

Only few hard facts are known about the influence of snow on the fructification behaviour of macromycetes. Some data are, however, available from correlations between the time of the snow melting of the winter snow pack and the occurrence of the first carpophores of selected taxa (DEBAUD 1983, EYNARD 1977, PETERSEN 1977). Nevertheless, no information was found about snowfall and snow-cover during the fructification season and their influence on the carpophore productivity after thoroughly checking the present literature. Subsequently, these two parameters are presented combined with the fructification numbers, based upon half-weekly to weekly mappings of the snow-cover and the corresponding melting process (cf. chapters 3.1.4.2. and 3.1.4.3.).

Ectomycorrhizal macromycetes: Regarding the vegetation period as an entirety, there was no obvious correlation between the snow-cover and the carpophore productivity in all three investigation years (Fig. 22). The situation looks quite different after dividing the vegetation period into an aestival (July, August) and autumnal (September, October) period. In 1988 and 1990 the first snowfall, resulting in a considerable snow-covered research area, was noticed not earlier than in the last week of August (1988) and the first week of September (1990), respectively. Accordingly, phenology and carpophore productivity were very similar in both years .

Different preconditions were registered in 1989, when the research area was under snow during the first week of July and for five days in the first week of August. This deprivation of time for the developing of the host plant *Salix herbacea* as well as for the linked ectomycorrhizal mycelia resulted in a lower carpophore productivity and a different phenology of the macromycetes. Namely the absence of a distinct productivity maximum as reported for 1988 and 1990 at the beginning of September is most conspicuous.

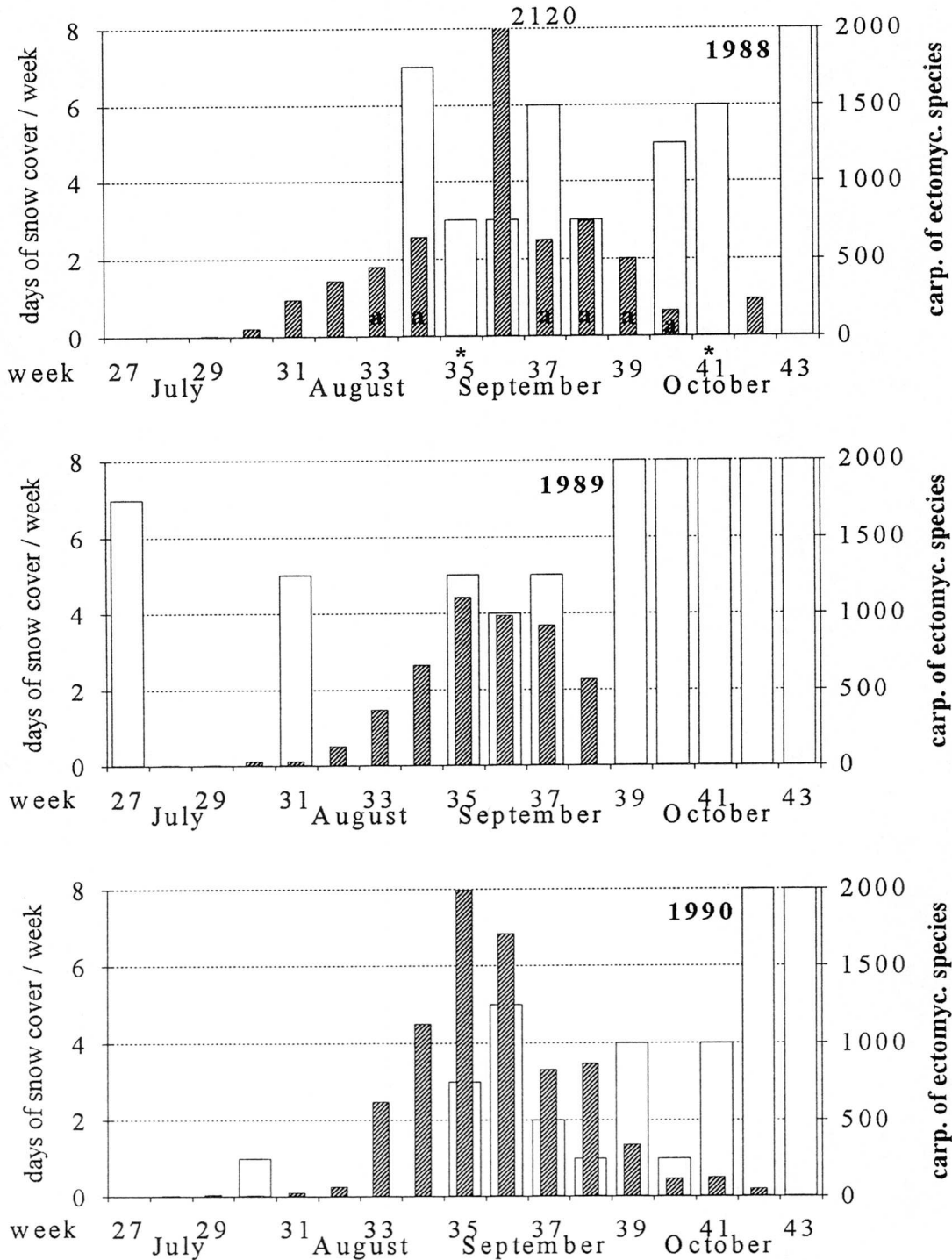


Fig. 22: Relationships between the days of snow-cover and the carpophore productivity and phenology of ectomycorrhizal and saprobic (parasitic) macromycetes in the investigated snow-bed communities (6 plots of *Salicetum herbaceae* and 3 plots of *Polytrichetum sexangularis* association) from 1988-90.

hatched bars = number of carpophores (carp.) per excursion

blank bars = days of snow-cover per week

* = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres

a = not all plots considered, due to snow-covered plots or lack of time (cf. Fig. 14)

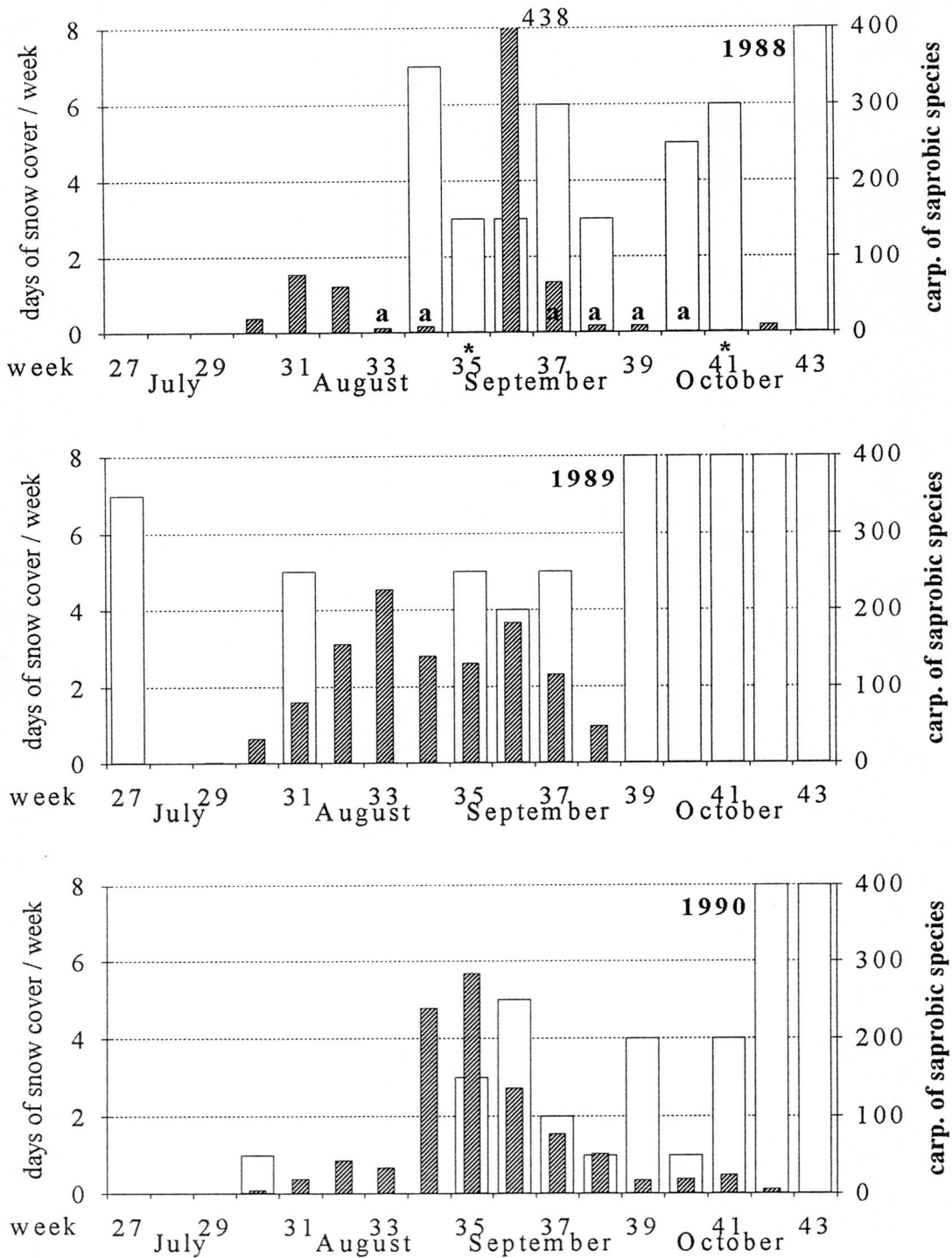


Fig. 22: continued (saprobic macromycetes).

During the second half of the vegetation period there was no apparent relationship observed between the time and length of snow-cover and the number of fructifications. However, there seems to be a tendency that longer periods of snow-cover alternately interrupted by snow free-days result in a higher productivity rate.

Saprobic (parasitic) macromycetes: Whereas aestival (July, August) snow-cover was correlated negatively with the carpophore productivity of ectomycorrhizal macromycetes, a distinct positive influence of summer snowfall on saprobic (parasitic) species in 1989 was noticed (Fig. 22). In the same year even the first autumnal snow-cover (first week of September) resulted, once more, in an increase of the number of fructifications. Snowfall later in the year, on the other hand was not positively correlated anymore.

Conversely, in 1988 and 1990, when no or only little summer snow was registered, snowfall during the second half of the vegetation period (September, October) was not correlated with the productivity rate. Furthermore, the absence of snow during the first half of the season resulted in a lower number of carpophores combined with a belated maximum of productivity. As already described for ectomycorrhizal taxa in 1988 and 1990, there were noticed significant maxima of the productivity, whereas in 1989 a period of a higher fructification rate was registered from mid-August to mid-September.

3.5.4.3. Maximum and minimum temperatures

From a biological point of view, maximum and minimum temperatures are not very appropriate parameters (PETERSEN 1977) except when they get close to the tolerance limits of an organism (FADERL & MOSER 1988). Accordingly, weekly maximum and minimum temperatures were the only temperature parameters measured unbroken during the three year investigation period, and, besides it must be expected that other temperature parameters are to a higher or lesser degree correlated. DEBAUD (1983) demonstrated a highly significant relationship between remarkable drops of maximum temperatures and the occurrence of saprobic *Clitocybe* spp. in alpine habitats. Unfortunately, the behaviour of ectomycorrhizal species has not been examined in this investigation.

Ectomycorrhizal macromycetes: In this study it has been discovered that the main fructification batch of the symbionts associated with *Salix herbacea* started about three weeks after the minimum temperature stayed above zero for the first and only time during the vegetation period for a weekly intervall (Fig. 23). In 1988 this ignition point was noticed during the second week of August, in 1989 one week later and one week earlier in 1990, respectively. For a better understanding of a putative correlation between maximum and minimum temperatures and the carpophore productivity, the vegetation period should be divided into an aestival and autumnal period as already proposed above in the analysis of the influence of precipitation (rain) and snow. The difference between the productivity pattern in 1988 and 1990 on the one hand and in 1989

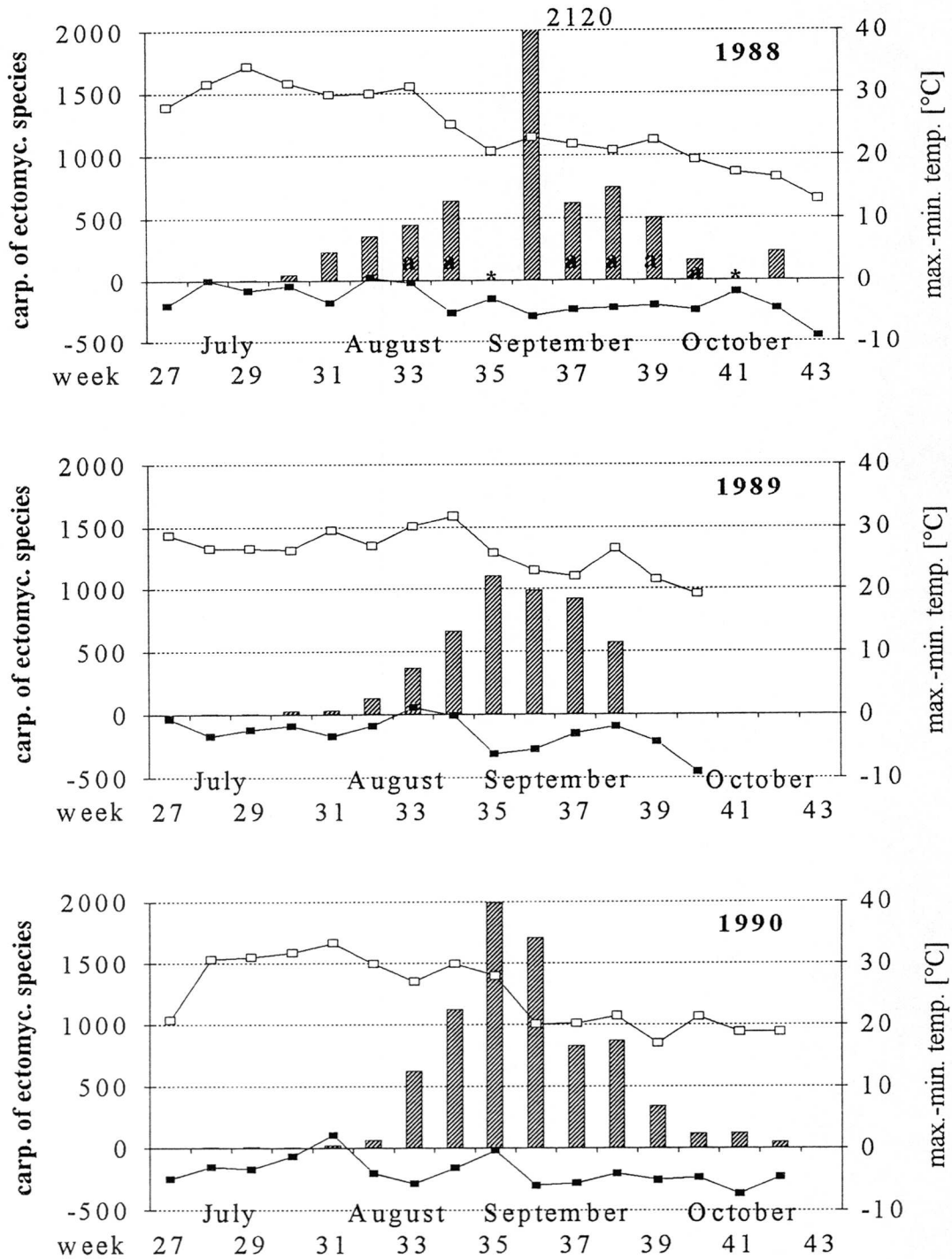


Fig. 23: Relationships between the seasonal course of the maximum and minimum temperatures and the carpophore productivity and phenology of ectomycorrhizal and saprobic (parasitic) macromycetes in the investigated snow-bed communities (6 plots of *Salicetum herbaceae* and 3 plots of *Polytrichetum sexangulare*) from 1988-90.

bars = number of carpophores (carp.) per excursion

curves = course of maximum and minimum temperatures [°C] on the soil surface

* = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres

a = not all plots considered, due to snow-covered plots or lack of time (cf. Fig. 14)

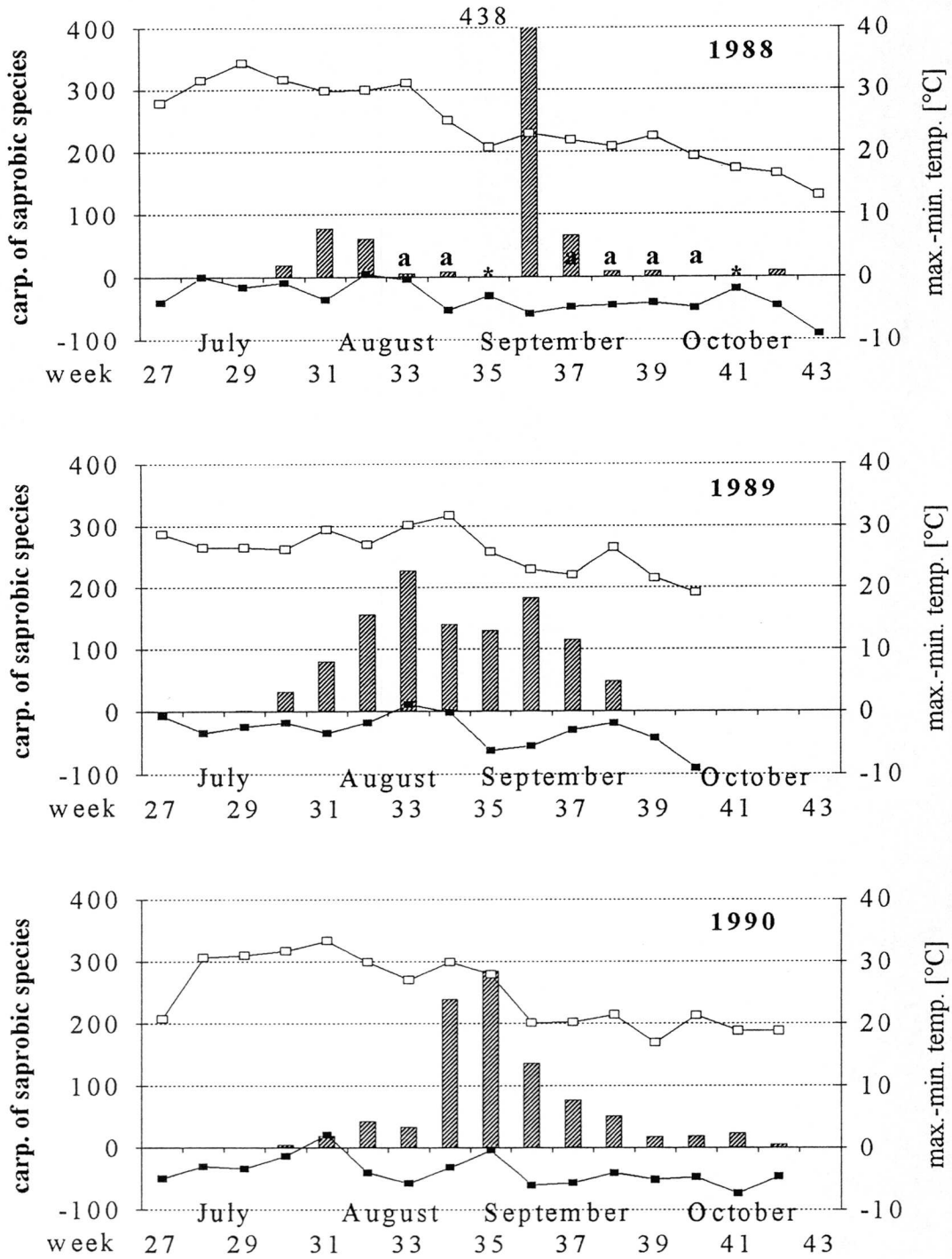


Fig. 23: continued (saprobic macromycetes).

on the other hand seems to be well correlated with the aestival course of maximum as well as minimum temperatures. Significant differences were registered comparing the four weeks before the minimum temperatures exceeding for the first and only time the zero degree (°C) isotherm.

In 1988 the mean extreme temperatures during this period (second week of July to second week of August) were noticed with 31.4°C for the maximum and -1.4°C for the minimum, respectively. The corresponding values for this aestival interval in 1990 (first week of July to first week of August) were determined with 31.7°C and -1.4°C, respectively. This accordance stands in good coincidence with the high affinity of the carpophore productivity in both years. Nevertheless, in 1989 the comparable period was postponed to the third week of July until the third week of August. Furthermore, the mean maximum temperature was with 28.3°C about 3°C lower. The corresponding mean minimum (-1.5°C) on the other hand deviated only about -0.1°C. The significant lower maximum temperature during the pre-fructification season, as well as the late ignition point (minimum temperature above zero) may be an explanation, among others, for the lower productivity rate in 1989.

Saprobic (parasitic) macromycetes: In contrast to the symbiotic species, the saprobes (parasites) were less obvious dependent on the extreme temperatures as analyzed above. At least the observation of DEBAUD (1983) was confirmed, that after a remarkable drop of the maximum temperatures, and to a less conspicuous part also of minimum temperatures, saprobic (parasitic) macromycetes responded, within a few days up to one week, with a distinct increase of their productivity. In 1988 and 1990, however, this was only true for the aestival part (July and August) of the vegetation period.

3.5.5. Characteristic macromycetes in snow-bed communities and their response to environmental parameters

Although a more or less indicative phenology was registered for ectomycorrhizal taxa as well as for saprobic (parasitic) species as an entirety each (cf. chapter 3.5.3.), deviating patterns were observed among the corresponding, individual Basidiomycetes.

Concerning the plants, it has to be kept in mind that *Salix herbacea* was the only host partner for ectomycorrhiza forming macromycetes. In addition, the considered saprobic (parasitic) taxa were associated without exception with *Polytrichum sexangulare*. Therefore, on the part of the plant material, there seems to be no distinct difference affecting the phenology patterns of the investigated macromycetes. However, it has to be added that the age of the dwarf willow, which was not taken into account, is certainly of decisive importance concerning the spectrum of associated taxa and eventually has its influence on their phenology.

3.5.5.1. Ectomycorrhizal taxa

All representatives of macromycetes which are obligate ectomycorrhiza formers are strictly linked to their host. Therefore the 55 (cf. table 22) determined fungal partners in the six *Salicetum* plots compete all for a connection with the root tips of the dwarf willow, *Salix herbacea*. In plot 13 for example, 35 ectomycorrhizal taxa were registered within an area of 50 m². Early stage macromycetes, i.e. *Hebeloma* spp. and *Laccaria montana* were observed, as well as late stage species as *Cortinarius* spp. and *Russula* spp. The quite impressive diversity may be explained on the one hand with the succession of the ectomycorrhizal macromycetes with the ageing of the host plant. On the other hand, different fungal symbionts may be responsible for specific requirements of the host and therefore, only a certain fungal entirety is crucial for the survival of the plant. Furthermore, microclimatic parameters, as well as differences in the soil properties may be of selective character for the ectomycorrhizal macromycetes, according to their efficiency to satisfy the demands of the host under certain environmental conditions.

- *Astrosporina boltonii*: In 1990 the carpophore productivity of *A. boltonii* was positively correlated with precipitation, with a lag phase of two weeks. In the two previous investigation years no distinct correlation was observed. In 1989 the occurrence of *A. boltonii* was noticed about two weeks later than in 1990 which may be due to the remarkable snowfalls during the first half of the vegetation period. However, in both years the first carpophores were reported two weeks after the minimum temperature was noticed for the first time above zero during a weekly measuring interval.

A. boltonii was registered only sporadically in the plots 7 and 11, but rather frequently in plot 9. These three plots are characterized by a comparatively lower pH value (cf. Tab. 17) and, in plot 9 the humus and nitrogen contents were actually the lowest of all *Salicetum* plots. Furthermore, the melting process of the winter snow pack ended later in the season in these three plots than elsewhere in the *Salicetum* communities (cf. Tabs. 15a, b and 16).

- *Cortinarius favrei*: A tendency of a positive correlation was registered between the carpophore productivity and precipitation during the first half of the vegetation period. The delay of the fructifications was about one to two weeks. In all three investigation years *C. favrei*, in contrast to most other ectomycorrhizal macromycetes, occurred already early in the season. The snowfall in 1989 in the first half of the vegetation period did not suppress the carpophore productivity but, in contradictory fashion rather stimulated the fructification process. The belated occurrence of the carpophores in 1990 may have been caused by the higher minimum temperatures and the lower precipitation

amount in July. *Cortinarius favrei* was the only ectomycorrhizal representative with the absolute productivity maximum in 1989 which was characterized by the shortest vegetation period, the lowest maximum temperatures, the highest precipitation amount and remarkable snowfalls at the beginning of July and August.

Cortinarius favrei was found in all six *Salicetum* plots. Records were reported occasionally from the plots 6 and 9, with remarkable numbers from the plots 3, 11 and 13 and with the absolutely highest frequency from plot 7 (cf. Tab. 22). This occurrence pattern is positively correlated with the amount of humus and its organic carbon content (cf. Tab. 17). In addition, in plot 7 the highest phosphate amount was registered. Concerning the duration of the snow-melting process no correlation was recognizable.

- *Cortinarius diasemospermus*: With a delay of one to three weeks the carpophore productivity of *C. diasemospermus* was positively correlated with the precipitation in the first half of the vegetation periods in 1989 and 1990. The high productivity rate in September 1988 was well correlated with the intense precipitation at the end of August and the beginning of September. Furthermore, the frequent snowfalls during September may have been of stimulating influence too. In all three investigation years the first occurrence of the carpophores was well linked with the end of the flowering season of *Salix herbacea*. In 1989 the start of the fructification season was one to two weeks later than in 1988 and 1990, respectively, presumably due to the severe snowfalls in the first half of the vegetation period.

C. diasemospermus was registered in all six *Salicetum* plots with a distinct lower frequency in plot 9 and a comparatively higher productivity rate in the plots 11 and 13 (cf. Tab. 22). Plot 9 is characterized by the lowest skeleton amount, the lowest pH, organic carbon and nitrogen value (cf. Tab. 17). Furthermore, in this plot the humus horizon as well as the root chamber were most developed. The duration of the snow-melting process was not correlated with the different fungal frequencies in the six plots.

- *Entoloma alpicola*: No clear correlation was recognized between the measured microclimatic parameters and the carpophore productivity of *E. alpicola*. In 1990 there was a slightly positive correlation with precipitation. In 1988 the fructification season lasted two to three weeks longer than in 1989 and 1990, which was probably linked to the frequent snowfalls in September. *E. alpicola* was restricted to plot 13 (cf. Tab. 22), which is characterized by the highest amount of carbonate and nitrogen and the lowest C/N ratio (cf. Tab. 17) of the six *Salicetum* plots. In addition, in plot 13 the highest number of snow-covered days during the vegetation period was registered (cf. Tab. 16).

- ***Hebeloma repandum***: There was a low positive correlation between the carpophore productivity of *H. repandum* and precipitation in 1989 and 1990 with a two to three weeks response delay of the carpophores. Despite the snowfall during the first half of the vegetation period in 1989 the occurrence of the first individuals was registered at the same time as in 1990, when snowfall during this period was ignorable. However, the number of carpophores was more than twice as high in 1990 than in 1989.

Hebeloma repandum was found sporadically in the plots 3, 9 and 13 but had an impressive frequency maximum in plot 7 (cf. Tab. 22) characterized by the highest amount of organic carbon and phosphate of all six *Salicetum* plots (cf. Tab. 17). Furthermore, the nitrogen amount was the second highest after the one measured in plot 13 which, in its turn was reported with the second highest number of *H. repandum* carpophores. In addition plot 7 was the one with the longest cover of the winter snow pack (cf. Tabs. 15a, b) and therefore with the shortest vegetation period (cf. Tab. 16).

- ***Inocybe lacera***: In the first half of the vegetation period precipitation was positively correlated with the productivity of carpophores which, in its turn had a response delay of one to two weeks. Concerning the first occurrence of *I. lacera* and its productivity maximum, the snowfalls at the beginning of July and August in 1989 may have been responsible for the delay of two to three weeks, compared with the other two investigation years.

Inocybe lacera was registered in all six *Salicetum* plots. However, only few records were reported from plot 6 and 13, whereas in the plots 7, 9 and 11 the number of mapped carpophores was rather considerable (cf. Tab. 22). Finally in plot 3, *I. lacera* was the most abundant macromycete, with a number of carpophores three to four times higher than in the above-mentioned plots. The characteristic soil parameters of plot 3 in comparison with the others are the lowest bulk density and phosphate amount and the highest C/N ratio (cf. Tab. 17). Furthermore, plot 3 was the one with the longest vegetation period (cf. Tab. 16) or, in other terms, the first one being snow-free (cf. Tabs. 15a, b). However, it was obvious that in this plot *I. lacera* was strictly limited to the spots where the winter snow pack disappeared at the end of the melting event.

- ***Laccaria montana***: A positive correlation was noticed between precipitation in the first half of the vegetation period and the carpophore productivity of *L. montana* with a delay of about one to two weeks. The occurrence of the first carpophores was early in the fructification season, namely around the end of July and the beginning of August. The heavy snowfall during the first half of the vegetation period in 1989 interrupted the carpophore productivity and postponed the productivity maximum, eventually supported by further snowfalls in September.

Laccaria montana was reported from all six *Salicetum* plots. As an exception only few records were noticed in plot 13. However, the number of carpophores in the plots 3, 6 and 7 were already considerable and even about three times higher in plot 11 (cf. Tab. 22). Finally, in plot 9 the number was, once more about twice higher resulting in 2282 carpophores, meaning the absolute highest number of individuals per plot. The lowest humus and nitrogen contents are the distinctive soil parameters of plot 9. Furthermore, the melting process of the winter snow pack ended later in the season in the plots 7 and 9 than in the four other *Salicetum* communities (cf. Tabs. 15a, b and 16).

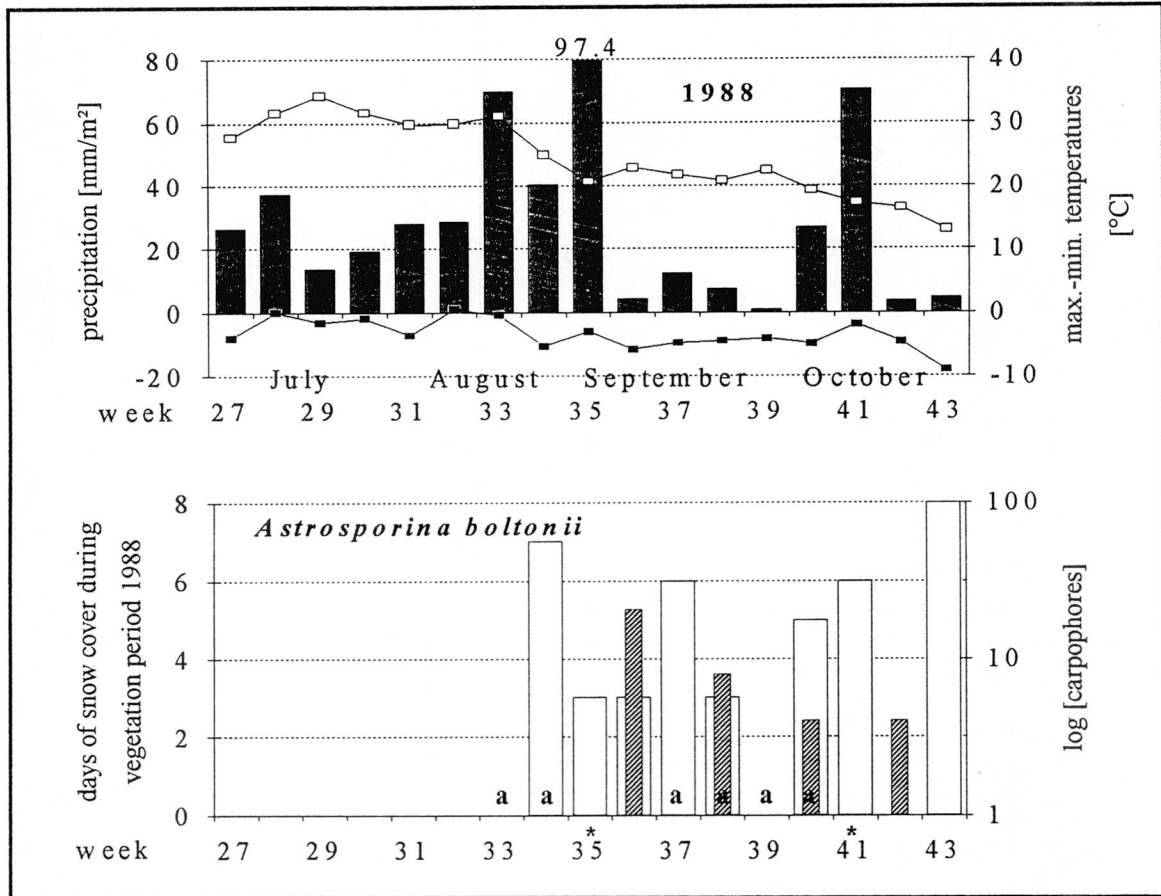


Fig. 24: Relationships between the seasonal course of precipitation (rain, snow), snowfall and maximum and minimum temperatures and the carpophore productivity and phenology of ectomycorrhizal macromycetes in the six *Salicetum* plots from 1988-90.

hatched bars = number of carpophores (carp.) per excursion

dotted bars = precipitation [mm/m²]

blank bars = days of snow-cover per week

curve with white squares = maximum temperatures [°C]

curve with black squares = minimum temperatures [°C]

* = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres

a = not all plots considered for sampling, due to snow-cover or lack of time (cf. Fig. 14)

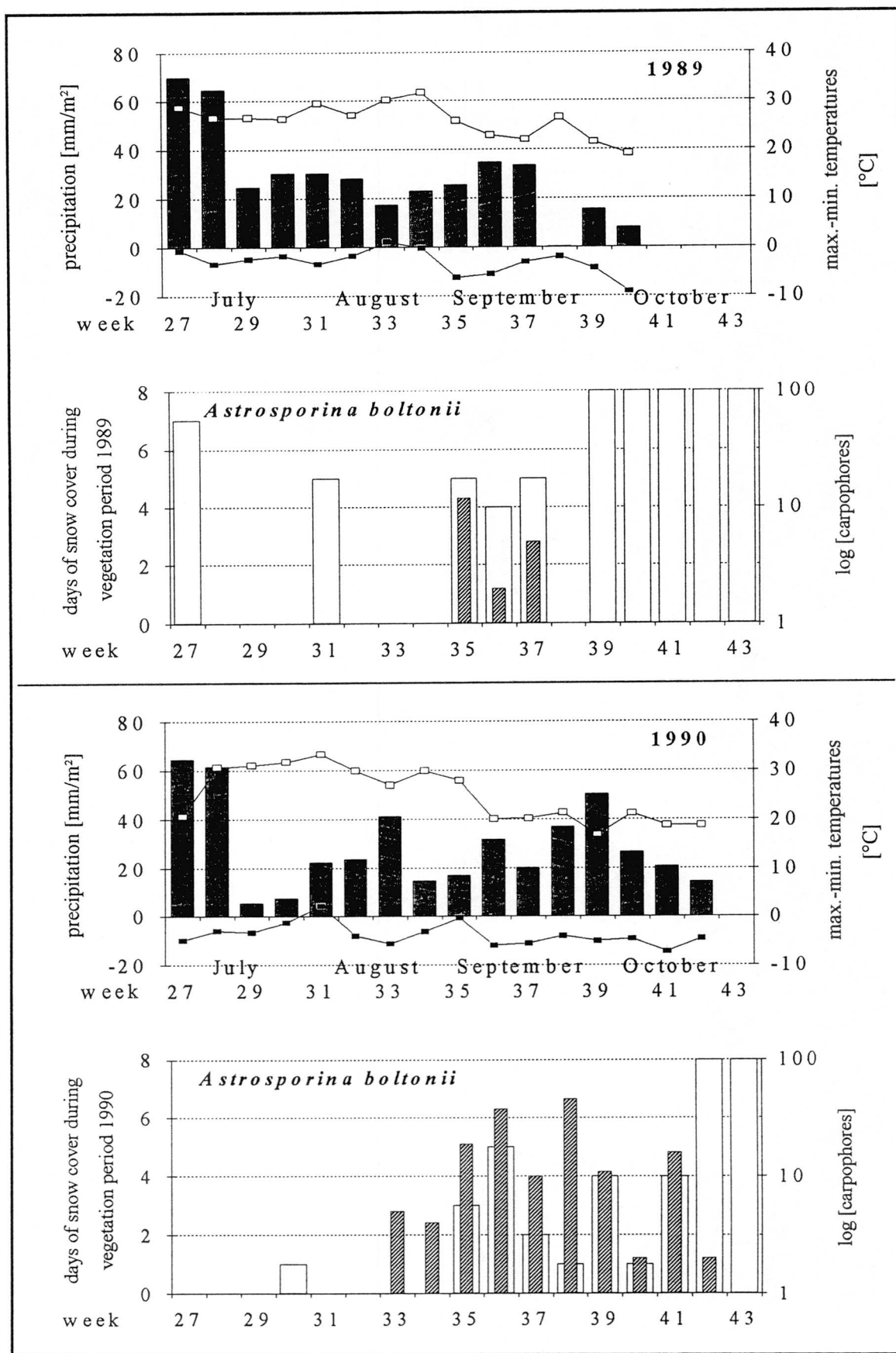


Fig. 24: continued.

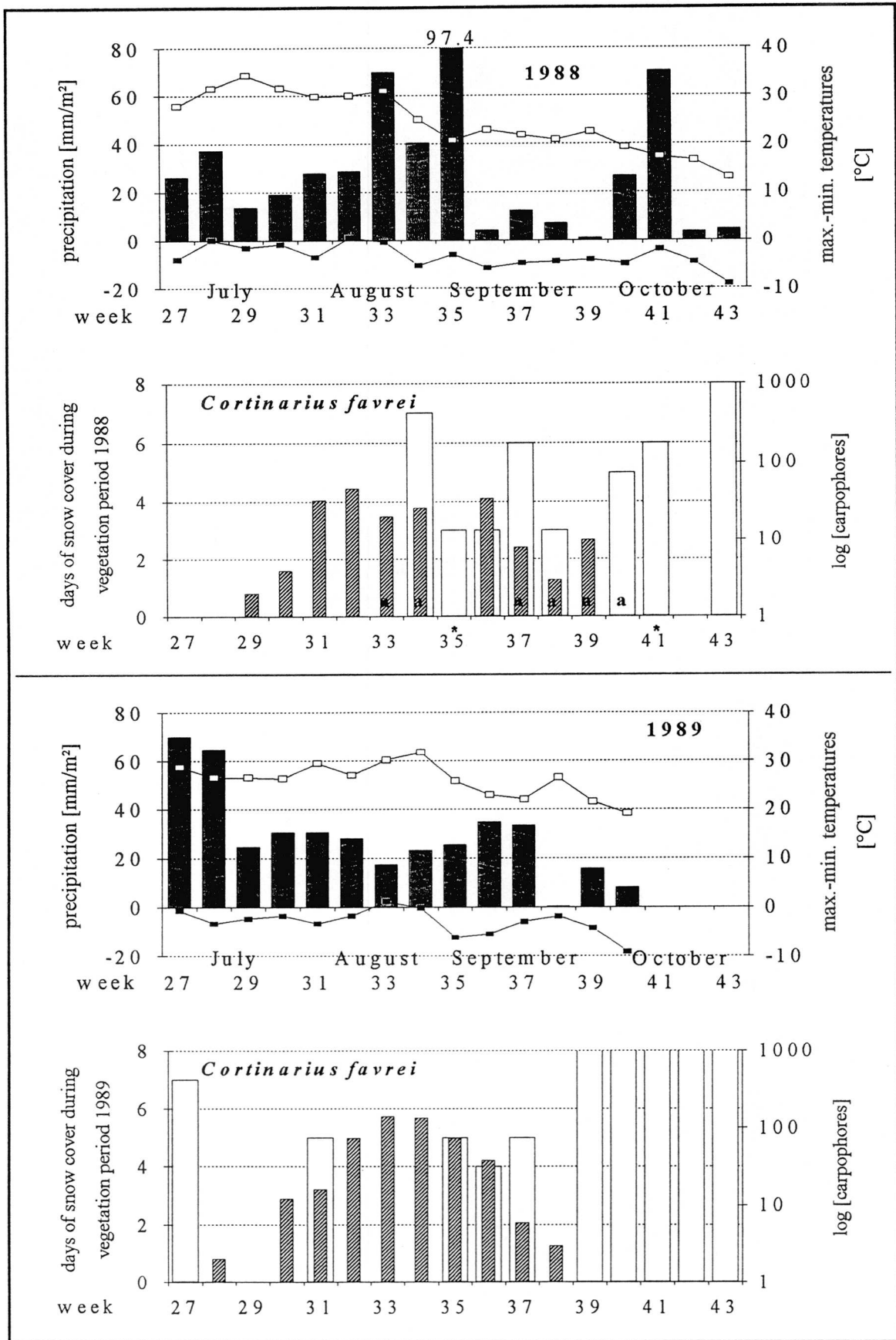


Fig. 24: continued.

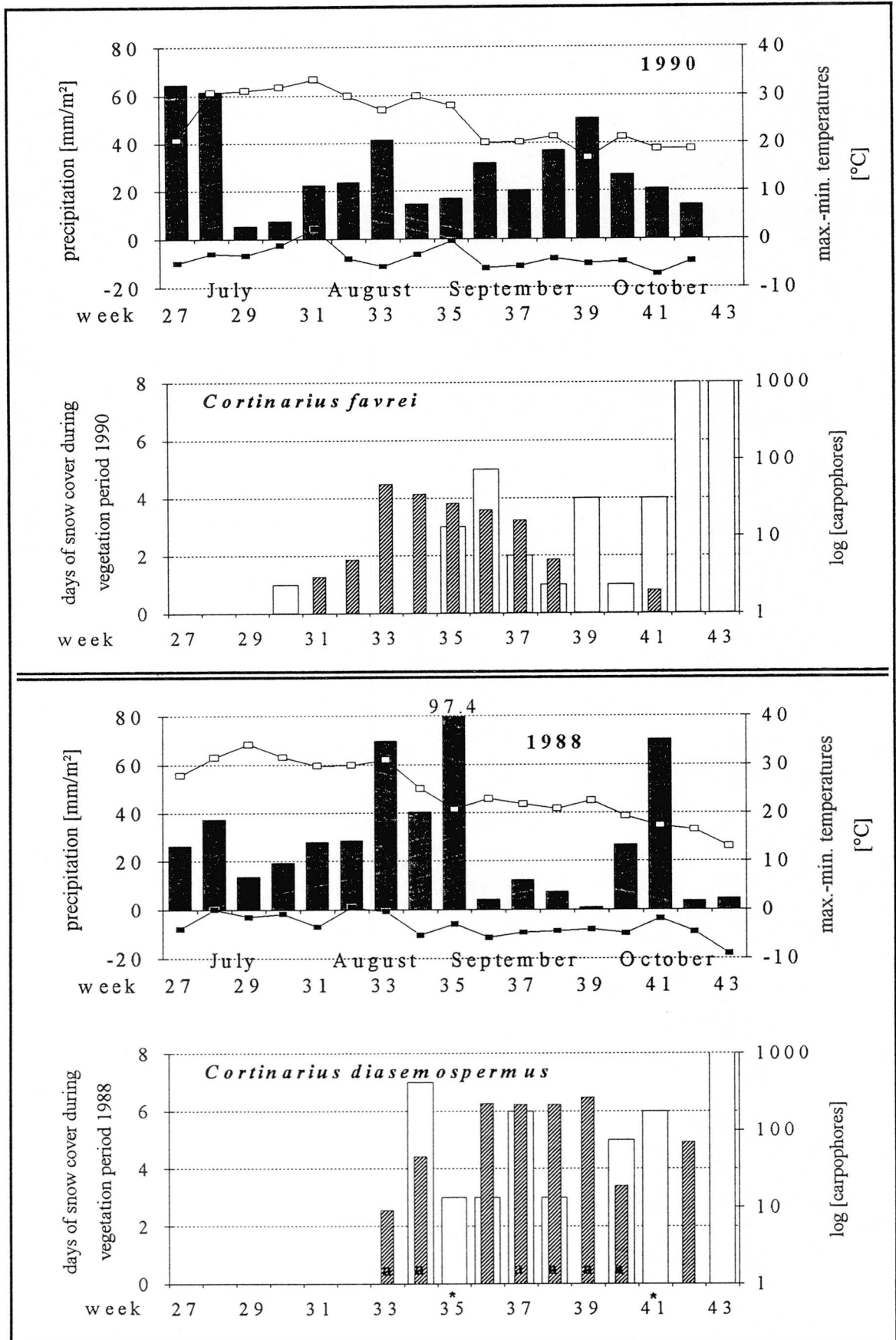


Fig. 24: continued.

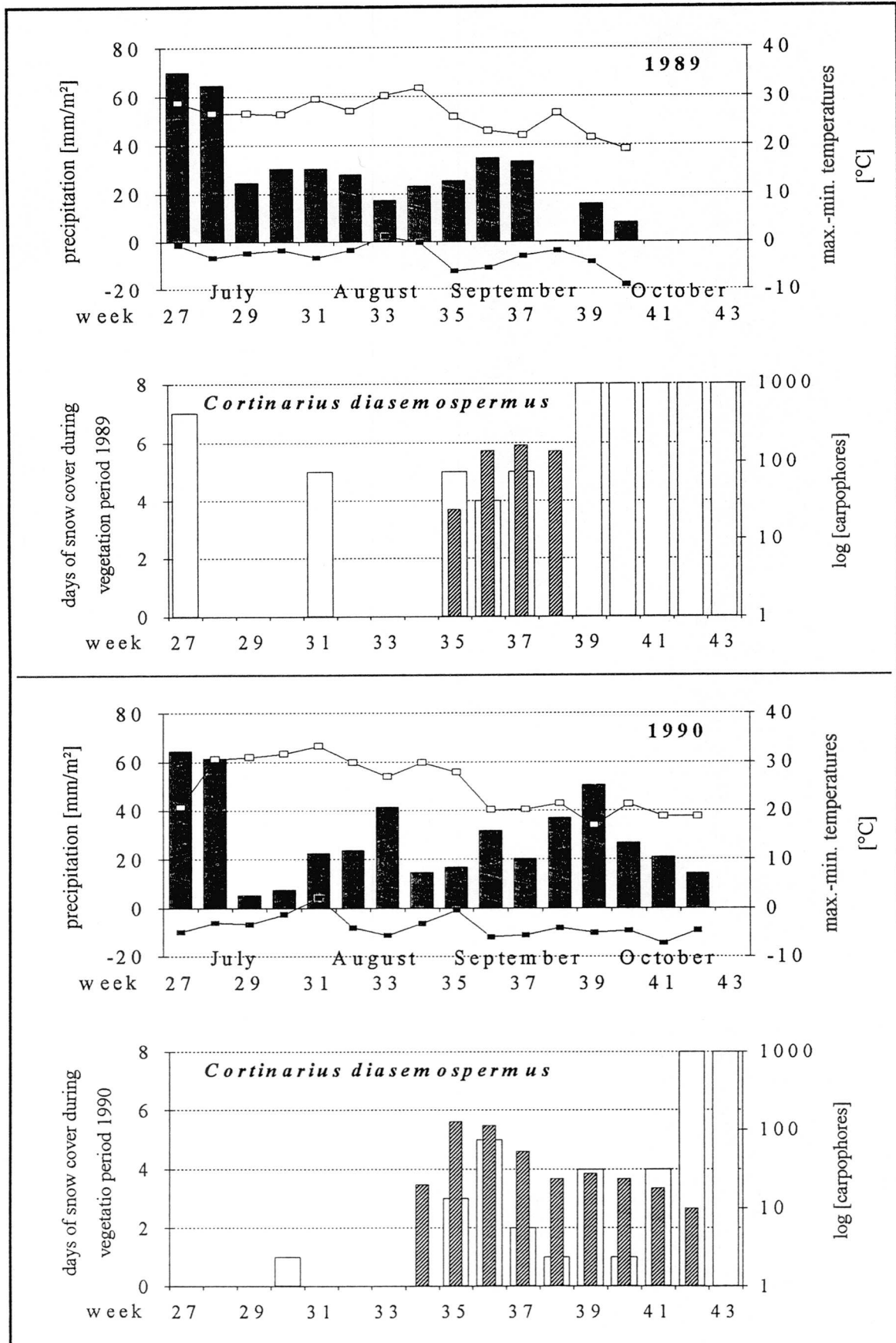


Fig. 24: continued.

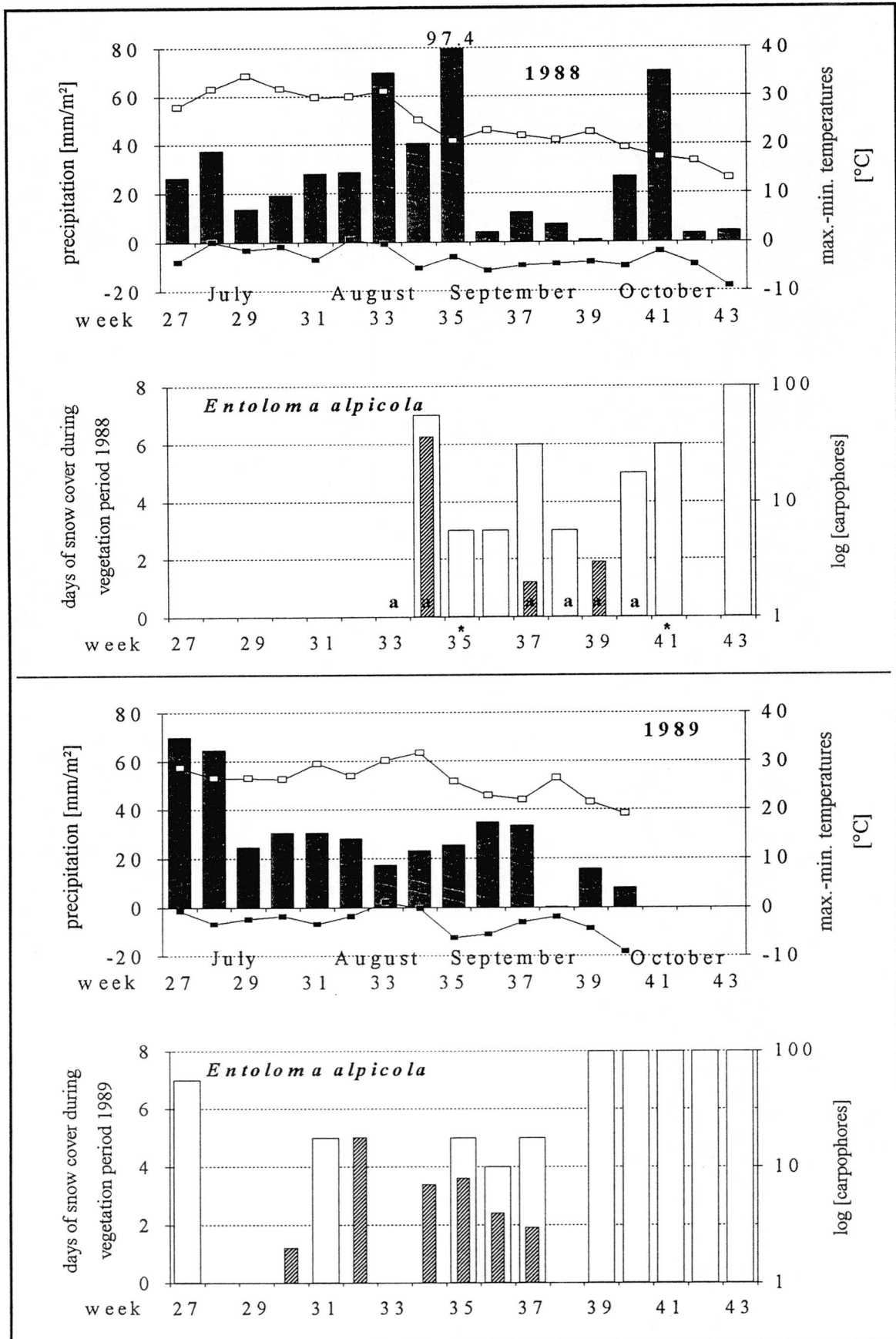


Fig. 24: continued.

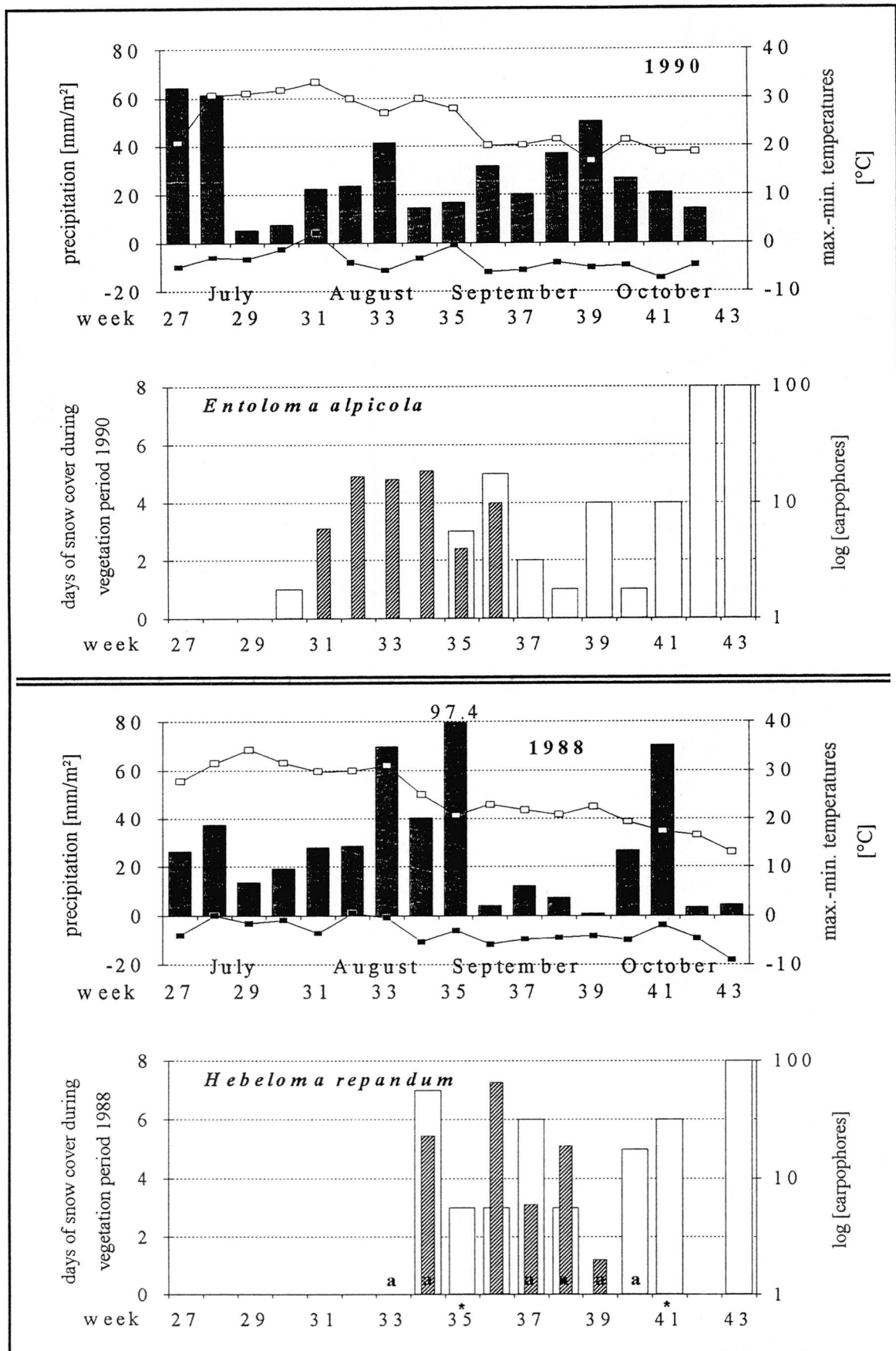


Fig. 24: continued.

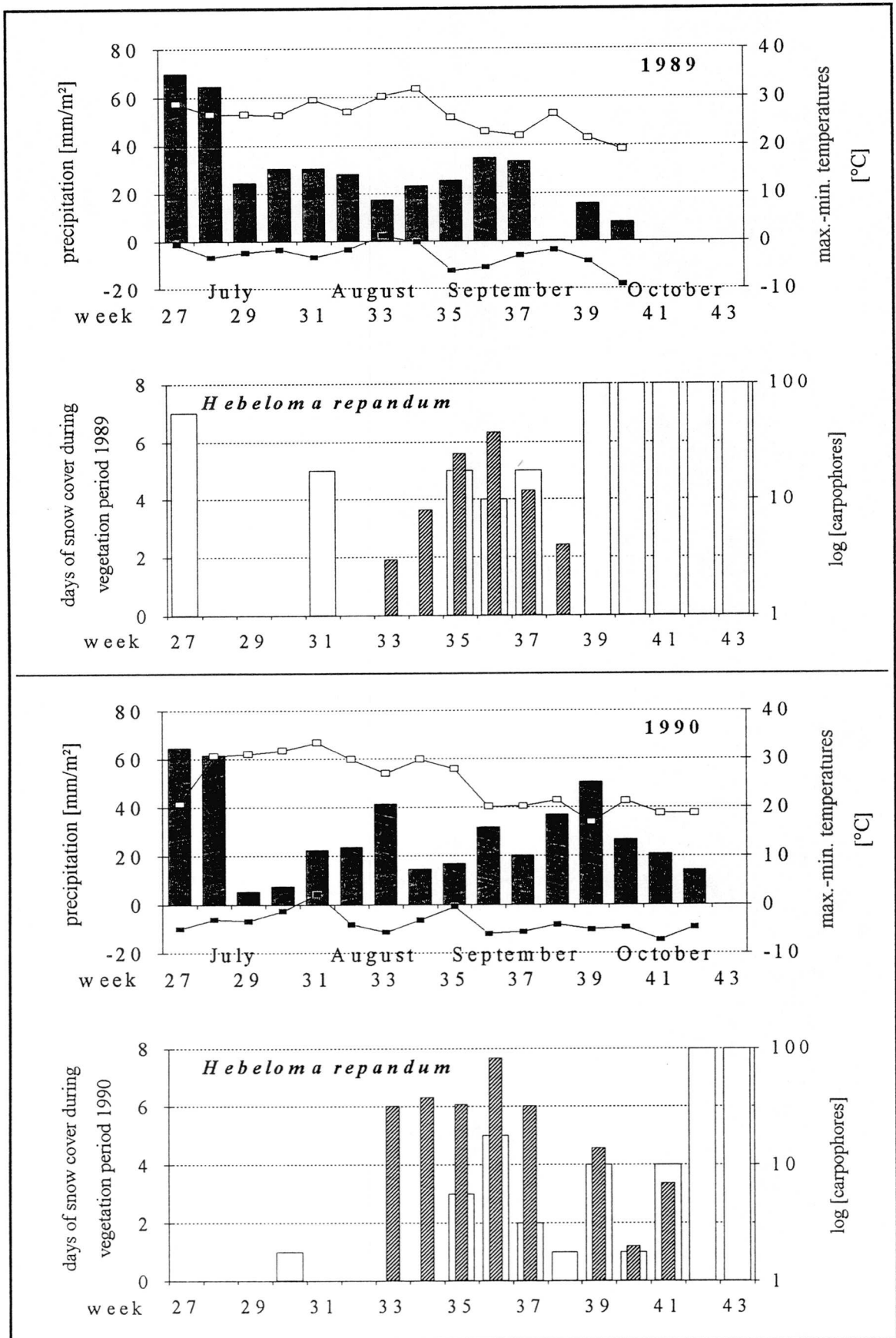


Fig. 24: continued.

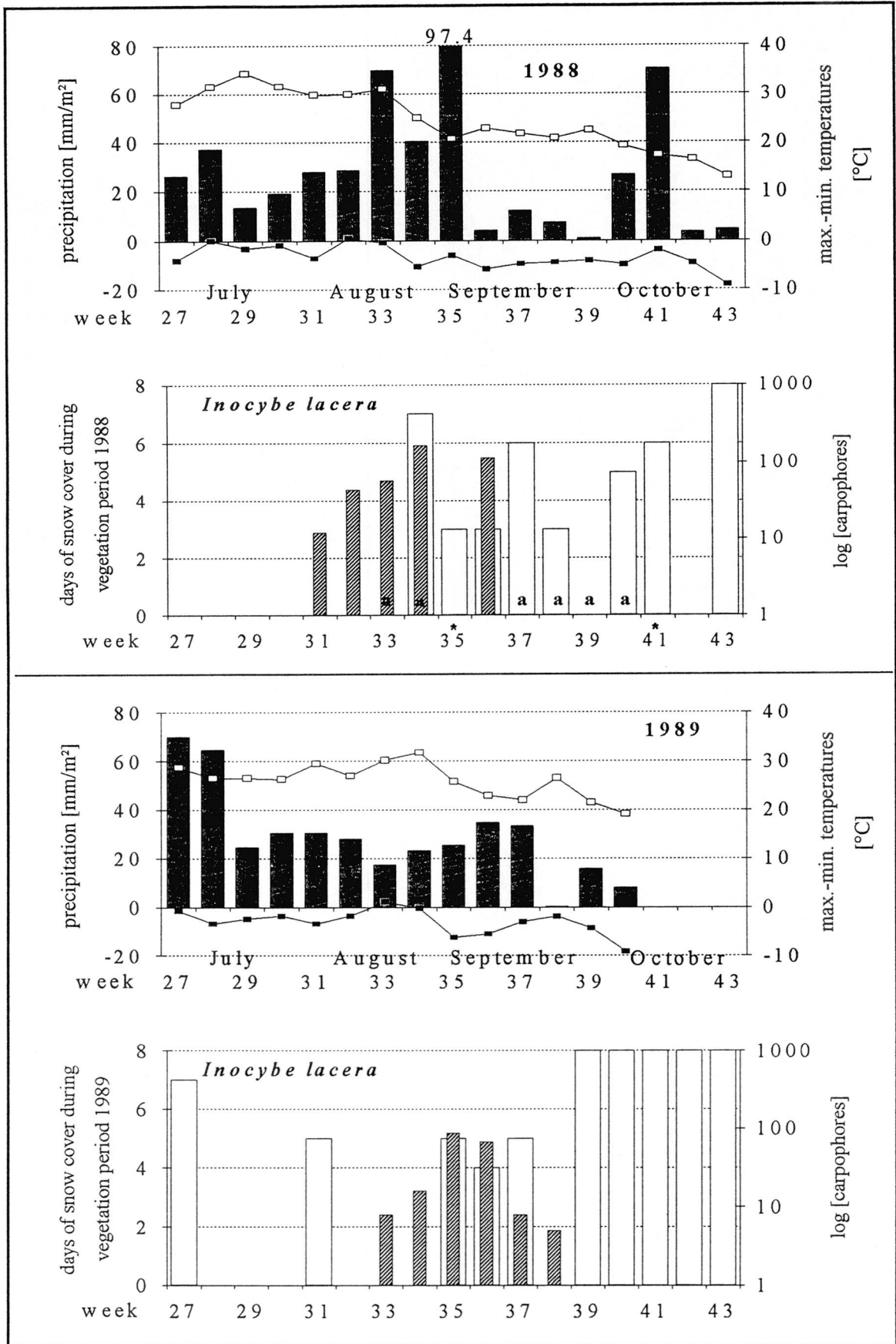


Fig. 24: continued.

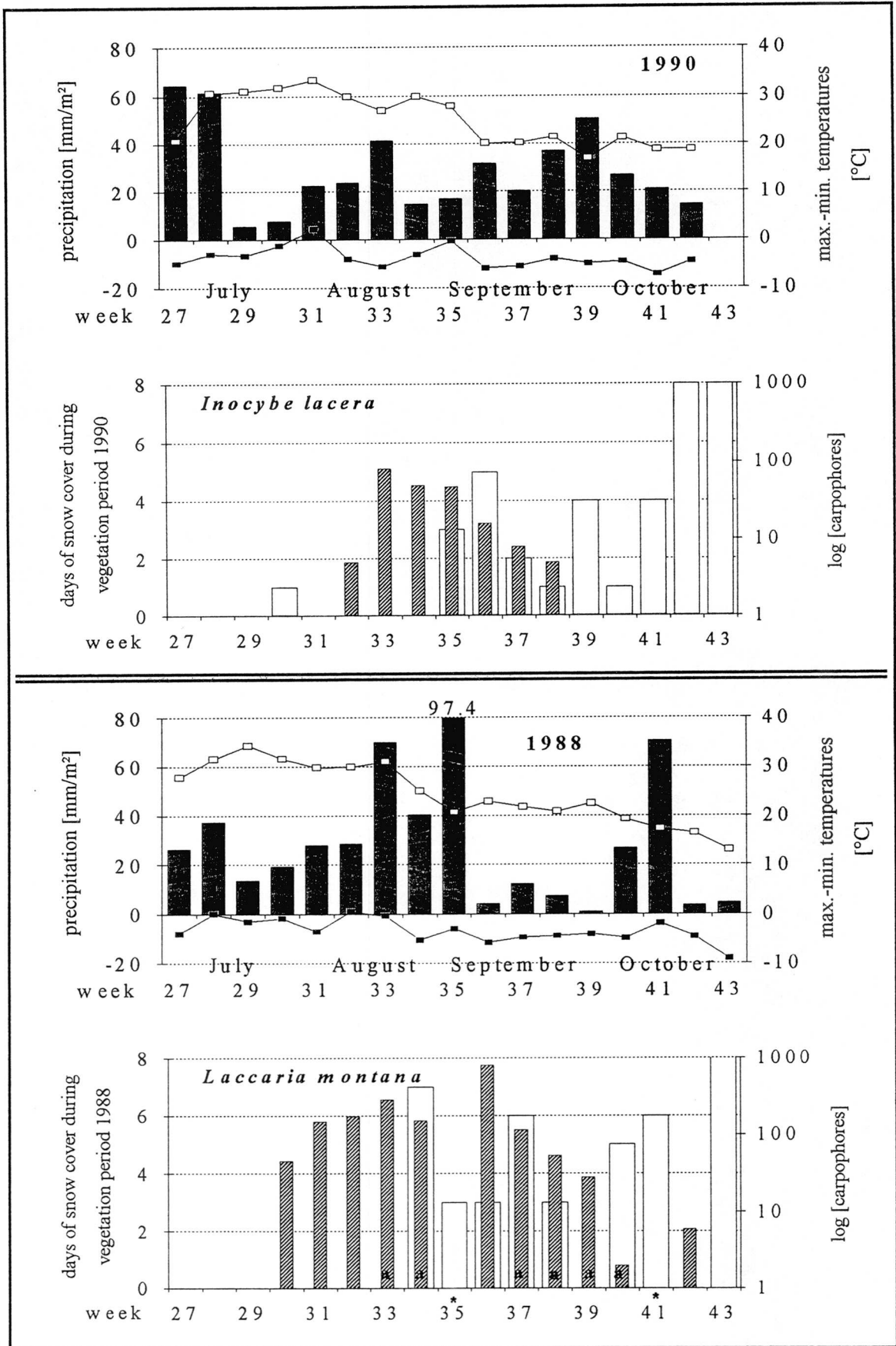


Fig. 24: continued.

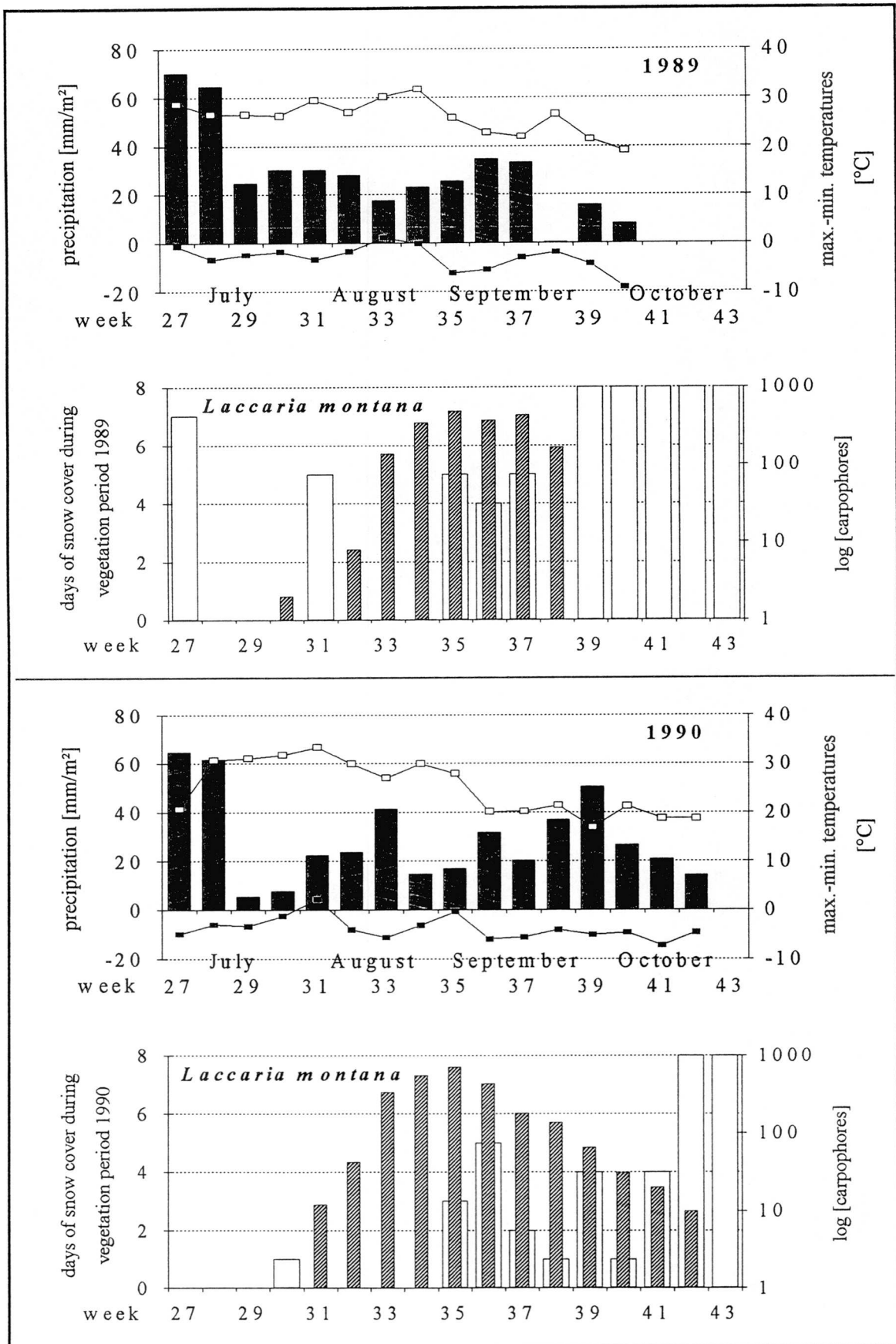


Fig. 24: continued.

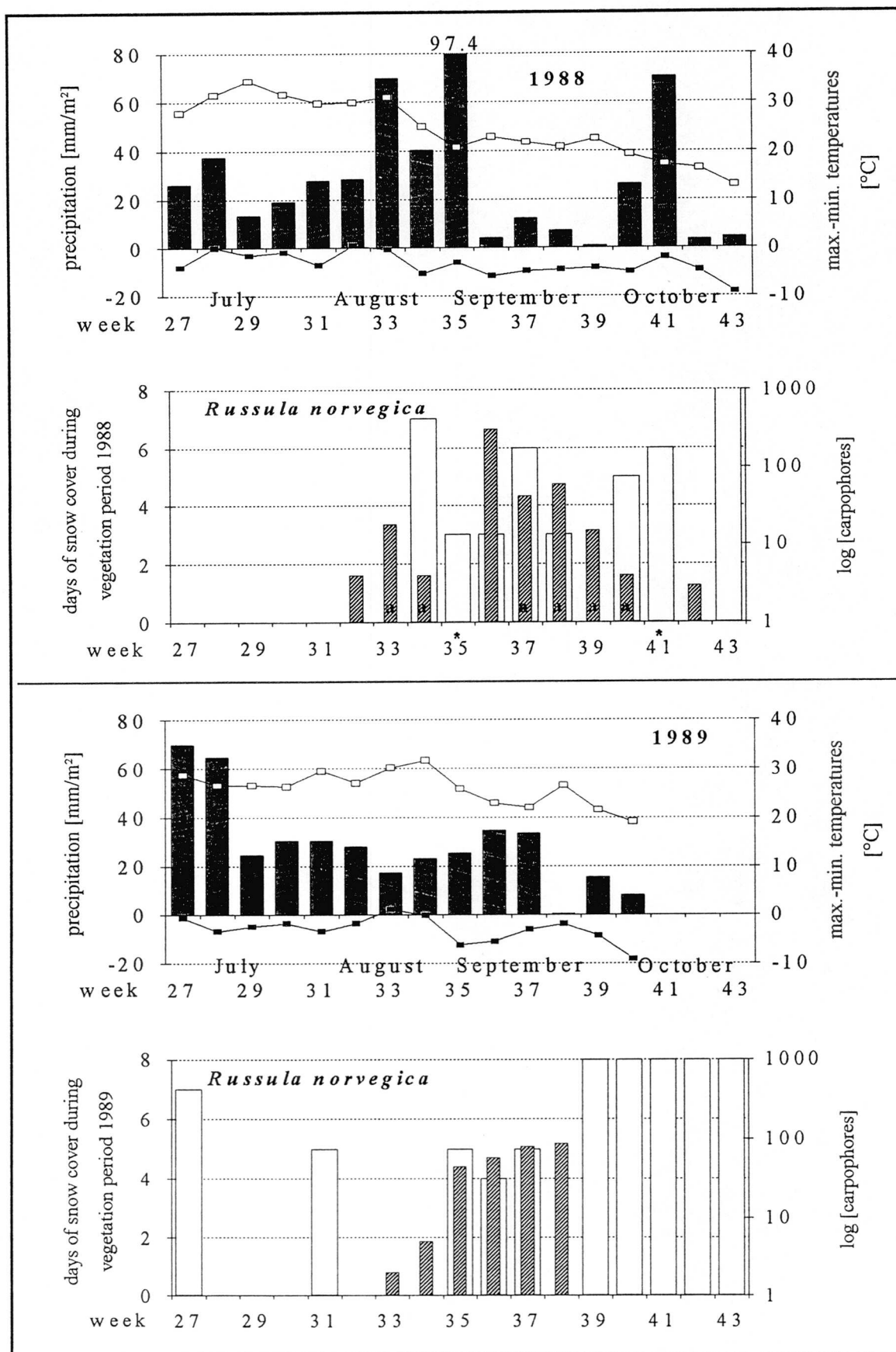


Fig. 24: continued.

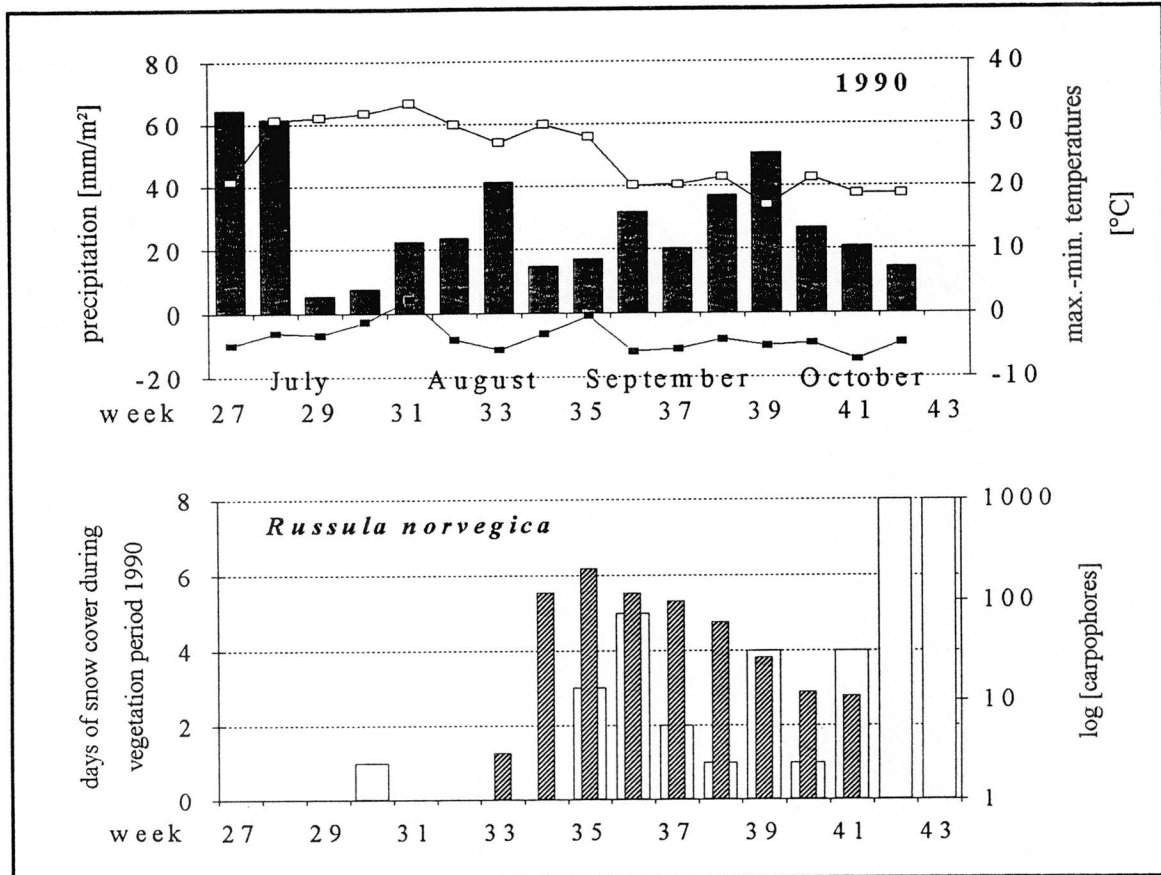


Fig. 24: continued.

- *Russula norvegica*: With about a two-week response delay *R. norvegica* was positively correlated with precipitation in the first half of the vegetation period. The first occurrence of carpophores was more or less linked with the end of the flowering season of *Salix herbacea*. Although this was about one to two weeks later in 1989, due to snowfall at the end of July and the beginning of August, the first records of *R. norvegica* were registered at the same time as in 1990. However, in 1989 the carpophore productivity steadily increased until heavy snowfall at the end of September abruptly stopped the vegetation period.

Except for plot 6, *R. norvegica* was found in all *Salicetum* plots. High numbers of carpophores were registered in the plots 3, 7, 11, and 13 (cf. Tab. 22). The highest abundance, however, was noticed in plot 9 with an individual number about five to six time higher than in the other plots. The characteristic edaphic and climatic parameters are as mentioned above under *Laccaria montana* the lowest humus and nitrogen contents and a late ending snow-melting process of the winter snow pack.

3.5.5.2. Saprobic (parasitic) taxa

In the three investigated *Polytrichetum* plots only two saprobic (parasitic) Basidiomycetes were registered quite frequently (cf. Tab. 23). Both species, *Galerina chionophila* and *Psilocybe chionophila*, are strictly linked to the moss *Polytrichum sexangulare*. Whereas the latter is well known from arctic and alpine habitats (LAMOURE 1977 b, LAMOURE et al. 1982, GULDEN et al. 1985) as a weak parasite of its host, the former has rarely been reported so far and exclusively from the Alps. In addition, only little is known about its ecology and its host relationships (SENN-IRLET 1986). In the *Polytrichetum* plot 8 both taxa were very abundant. *Psilocybe chionophila* was registered gregariously along the periphery of brown-coloured, circular patches of *Polytrichum sexangulare*, whereas *G. chionophila* occurred singly or in small groups of two to five individuals, without any significant links to the necrosis of the moss.

- *Galerina chionophila*: Precipitation was positively correlated with the carpophore productivity of *G. chionophila*, with a maximum lag phase of about one week. In 1988 the first occurrence of the carpophores was two weeks earlier than in the two succeeding years. In 1989 this postponement may have had its explanation in the remarkable snowfalls in July and August. However, this does not hold true for the situation in 1990, when snowfall was registered only on one day during this particular period. A possible reason may have been the early beginning of winter in the previous year leaving not enough time for the primordia production. Nevertheless, snowfall during the second half of the vegetation period seemed to stimulate the carpophore production.

G. chionophila was absent in plot 10, very rarely found in plot 5, but was registered with an impressive number of records in plot 8 (cf. Tab. 23). Plot 8 has the least depth concerning root chamber and soil profile. In addition, compared with the two other *Polytrichetum* plots, distinctive soil characteristics are the highest percentage of skeleton, the highest bulk density, pH and phosphate value, as well as the lowest C/N ratio (cf. Tab. 17). Furthermore, the vegetation period was the shortest (cf. Tab. 16), with the winter snow pack lasting one to two weeks longer (cf. Tabs. 15a,b) than in any other plot.

- *Psilocybe chionophila*: During the first half of the vegetation period precipitation and carpophore productivity were well correlated with a response delay of the fructification process from a few days to one week. In the second half, longer periods of snow-cover were actually stimulating the carpophore productivity. Furthermore, the snowfalls in 1989 at the beginning of July and August have certainly had an essential positive influence on carpophore productivity. In 1990 the occurrence of the first basidiomata of *P. chionophila* was one

week later than in the other two investigation years. A possible explanation may be again the early set in of winter in 1989 as already mentioned above under *Galerina chionophila*.

In the plots 5 and 10 *P. chionophila* was noticed rather frequently and, with a more than four times higher carpophore number registered in plot 8 (cf. Tab. 23). The characteristic edaphic parameters are the same as mentioned above under *Galerina chionophila*.

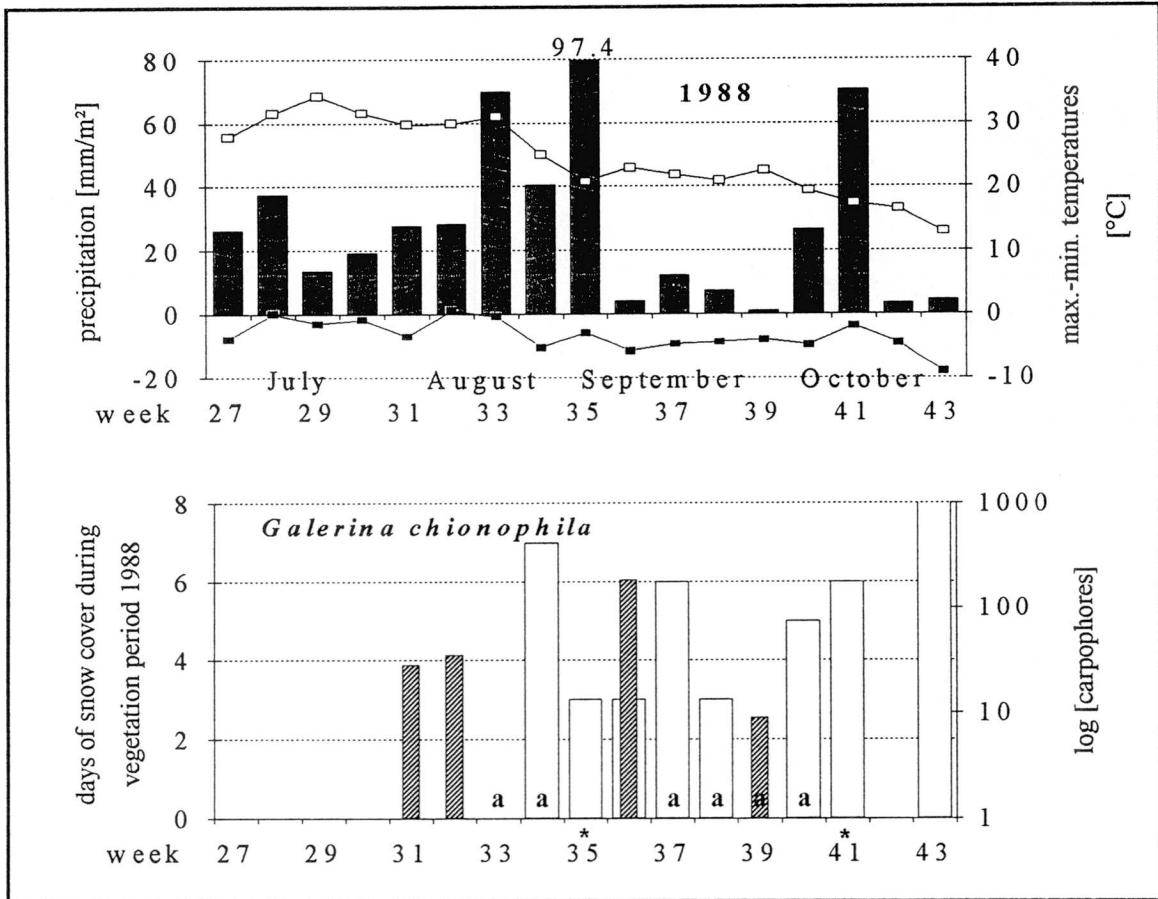


Fig. 25: Relationships between the seasonal course of precipitation (rain, snow), snowfall and maximum and minimum temperatures and the carpophore productivity and phenology of saprobic (parasitic) macromycetes in the three *Polytrichetum* plots from 1988-90.

hatched bars = number of carpophores (carp.) per excursion

dotted bars = precipitation [mm/m²]

blank bars = days of snow-cover per week

curve with white squares = maximum temperatures [°C]

curve with black squares = minimum temperatures [°C]

* = no carpophore collecting during this excursion due to snow-covered research area or military manoeuvres

a = not all plots considered for sampling due to snow-cover or lack of time (cf. Fig. 14)

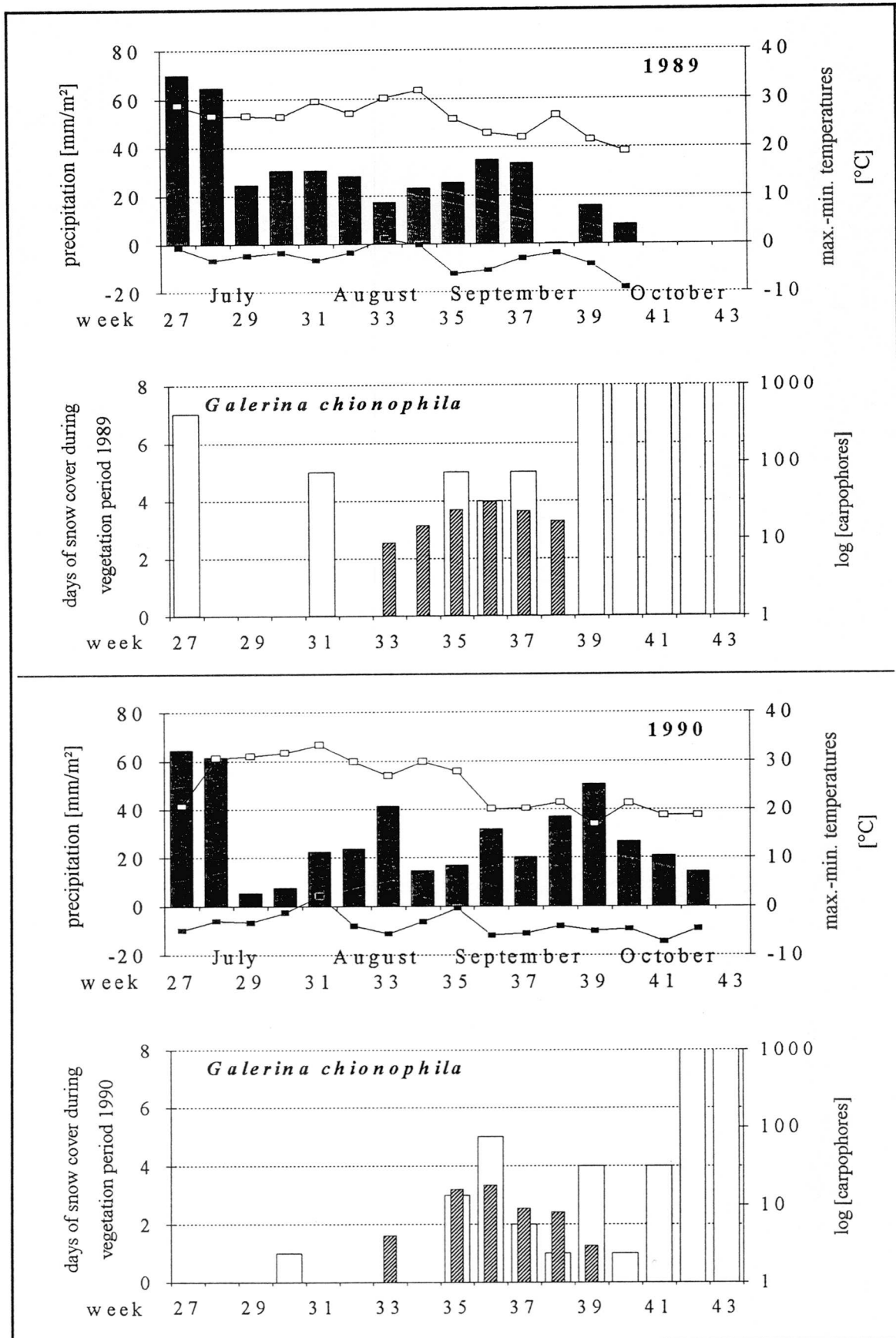


Fig. 25: continued.

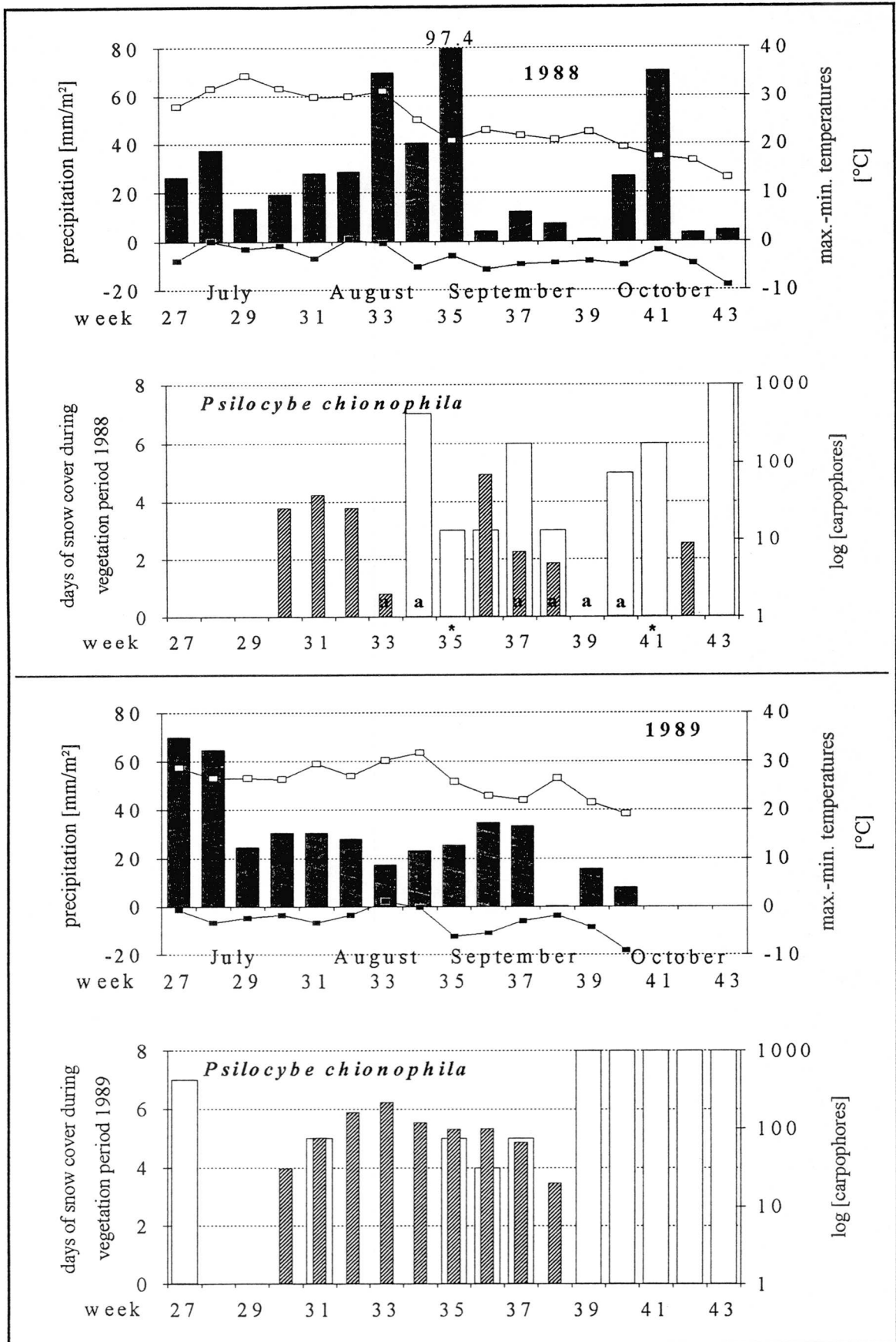


Fig. 25: continued.

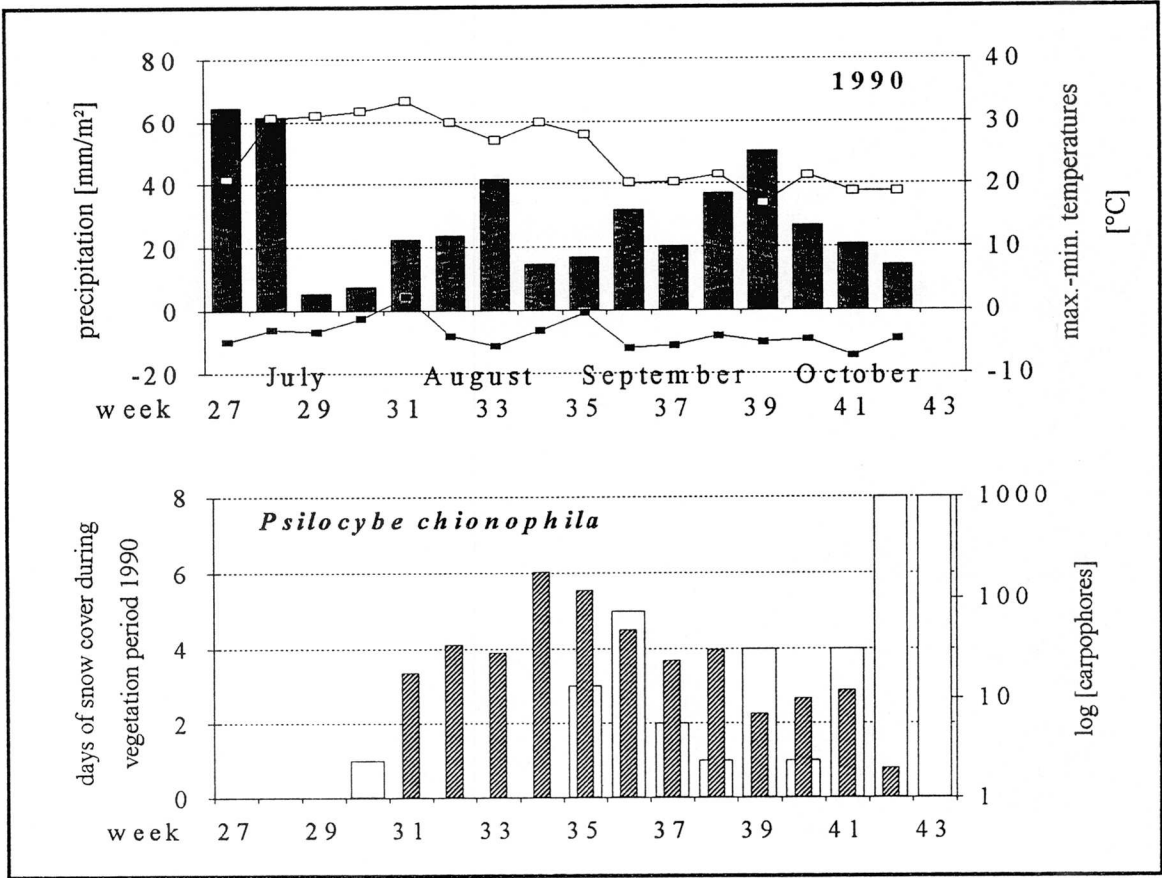


Fig. 25: continued.

3.6. STATISTICAL ANALYSES OF MAPPING DATA

Analyzing mapping data and comparing mapping cards (cf. chapter 3.7.) of different species in various plots, it is obvious that some macromycetes seem to occur associated, whereas others show tendencies to exclude each other. To test for possible interspecific associations or antagonisms, the statistical significance for all co-occurrences for major species, i.e. taxa with a frequency higher than 20 records (Tab. 27), the X^2 values using Yate's correction for continuity was calculated for the 2 x 2 contingency table (PIELOU 1977). In addition, the Ochiai index (OCHIAI 1957) for interspecific association was computed based on the same set of data (Tab 28).

The Shannon index (SHANNON & WIENER 1949) in combination with the evenness index (Tab. 29, 30) proposed by PIELOU (1977) were calculated for all taxa in the 13 investigation plots indicating their relative species diversity (cf. also chapter 3.5.2.).

Furthermore, the Jaccard index (JACCARD 1908) was taken into account for comparing the species composition during the three individual investigation years (Tabs. 29, 30).

3.6.1. Interspecific association of selected macromycetes

The data, the following analyses are based upon, resulted from observations and mapping data from carpophores of the considered taxa but neglected the corresponding vegetative mycelia in the soil. Therefore, results and conclusions about association and exclusion of the compared species are strictly based on the presence and absence of carpophores. Hence, concerning the entire organism, it is not possible to verify any exclusion resulting from statistical analysis alone. However, the tested data may be understood as a basis of comparison for further mycoecological and mycosociological studies.

Before presenting the results of the X^2 -test and the Ochiai indices of the pairs of macromycetes compared, it may be useful to point to some basic features of these two methods. Whereas the values computed with the X^2 -test are based on the hypothesis of independence (neither associated nor excluded occurrence of the taxa), the Ochiai index (OI) is only a measure of the degree or strength of the association. In this study, based upon observations in the field and mapping data, OI-indices below 0.05 are regarded as indices for distinct exclusion, whereas values greater than 0.4 are declared as characteristic associations. Furthermore, the X^2 -test involves the number of joint absences, which is completely neglected by the Ochiai index (LUDWIG & REYNOLDS 1988).

Table 27: Ectomycorrhizal taxa found within the borders of the six *Salicetum* plots considered for statistical analysis. For the individual plots only species with a frequency of at least 10%, that is 20 records (shaded cells) registered from 1988-90 were examined. The first number indicates the records, the second number stands for the carpophores.

	Ectomycorrhizal Taxa	plot 3	plot 6	plot 7	plot 9	plot 11	plot 13
1.	<i>Astrosporina boltonii</i>	---	---	1/1	78/98	5/5	---
2.	<i>A. mundula</i>	1/1	---	1/2	23/44	---	---
3.	<i>Cortinarius (Myxac.) favrei</i>	100/165	13/18	140/230	5/6	66/119	116/154
4.	<i>Cortinarius (Telam.) cavipes</i>	38/125	---	7/14	18/46	23/69	107/276
5.	<i>C. chrysomallus</i>	7/22	2/2	85/146	224/1031	---	15/43
6.	<i>C. diasemospermus</i>	56/230	94/187	79/198	19/53	140/413	201/505
7.	<i>C. glandicolor</i> var. <i>exilis</i>	74/191	23/50	25/53	4/25	9/15	29/62
8.	<i>C. lamourei</i>	19/102	2/4	20/48	15/93	25/67	7/15
9.	<i>C. pauperculus</i>	---	6/14	3/21	30/178	14/47	11/17
10.	<i>C. pauperculus</i> v. <i>luteovel.</i>	1/5	---	17/76	---	35/166	13/26
11.	<i>C. percavus</i>	20/51	2/4	4/7	23/72	---	5/7
12.	<i>C. cf. pertristis</i>	---	---	92/220	---	1/1	---
13.	<i>C. phaeopygmaeus</i>	3/8	---	28/45	2/6	1/1	3/6
14.	<i>C. rufostriatus</i>	14/31	6/6	---	9/63	3/5	136/277
15.	<i>C. rusticellus</i>	30/116	1/1	---	---	8/20	105/214
16.	<i>Dermocybe cinnamomeolutea</i>	24/61	5/5	5/10	1/1	---	---
17.	<i>D. crocea</i>	48/66	---	---	5/5	2/3	---
18.	<i>Entoloma alpicola</i>	---	---	---	---	---	93/146
19.	<i>Hebeloma marginatulum</i>	---	---	157/228	---	3/6	5/6
20.	<i>H. repandum</i>	---	---	206/319	22/28	---	28/39
21.	<i>Inocybe lacera</i>	172/377	5/5	68/114	52/80	88/102	21/26
22.	<i>I. peronatella</i>	---	---	32/49	---	21/25	7/9
23.	<i>L. montana</i>	32/70	91/231	152/271	800/1845	299/506	44/63
24.	<i>L. proxima</i>	---	---	---	---	68/118	---
25.	<i>R. norvegica</i>	56/68	---	80/92	471/563	66/77	93/119
26.	<i>R. pascua</i>	8/12	1/1	33/35	16/17	4/4	22/28

There has been much debate as to whether the joint absence of species has any ecological meaning (CLIFFORD & STEPHENSON 1975, GOODALL 1978, SNEATH & SOKAL 1973). In this study, the opinion of HUBALEK (1982), that indices considering the joint absences are limited in ecology, is supported by the evaluation of the carpophore mapping cards (cf. chapter 3.7.). In other words, the observed and mapped patterns of carpophore distribution are in better accordance with the Ochiai indices than with the results of the X²-test. However, one has to be aware that first, the present study was limited to a period of three investigation years and consequently, does not represent a complete survey of the macromycetes in the snow-bed plots. Secondly, the above-mentioned statistics depend also upon the size of the sampling units (cf. chapter 2.7.8.). It is possible to influence the outcome of the strength of association by varying size and shape of the sampling units. In this study quadrats of 50 x 50 cm were

chosen, based on the mapped macromycetes and the distribution of *Salix herbacea*, the host plant of all included ectomycorrhizal species.

Finally, in connection with the sampling units, the X^2 -test demands a more or less even distribution of the individuals in the plots. Hence, results may vary strongly whether taxa occur evenly spread or predominantly clustered. In other words the number of sample units without any registered individual causes bias beyond control.

Plot 3: Of the total 30 taxa registered in this plot, 11 were examined for association relationships (Tab. 27). Concerning the X^2 -test, 11 of the 55 pairs of taxa considered turned out to be significantly associated (seven on the 1%-level), mostly within the genus *Cortinarius* (Tab. 28). Of the three associations registered not within *Cortinarius* spp. the co-occurrence of *Dermocybe cinnamomeolutea* and *Laccaria montana* was the only on the 1%-significance level. There was no distinctive exclusion located with the X^2 -test.

The values of the Ochiai index turned out quite differently (Tab. 28). Absolute exclusion (OI = 0.0) resulted for the pair *C. diasemospermus* and *D. crocea*. Furthermore, additional eight pairs of taxa significantly excluded each other. In three pairs the partner was *D. crocea* and in the other five it was *Russula norvegica*. Interesting fact: *D. crocea* and *R. norvegica* did not exclude each other. Only two pairs were considered as distinctively associated, viz. *C. glandicolor* var. *exilis* with *C. favrei* and *C. rusticellus*, which were also significantly associated (1%-level) according to the X^2 -test.

Plot 6: In this plot only three of the total 19 registered species were tested (Tab. 27). Whereas the X^2 -test statistic designated *Laccaria montana* and *C. diasemospermus* as significant (1%-level) antagonists, the Ochiai index pointed at antagonism between *C. diasemospermus* and *C. glandicolor* var. *exilis*. No further significant results were obtained, neither with the X^2 -test nor with the Ochiai index (Tab. 28).

Plot 7: In this plot 14 of the totally 33 reported taxa were statistically analyzed (Tab. 27), resulting in 91 species pairs. Concerning the X^2 -test, 20 dyads were found as associated (13 on 1%-level) and five to be antagonistic (one on 1%-level). Of the positively associated pairs of taxa 12 were consisted exclusively of *Cortinarius* spp. (Tab. 28). Furthermore, one partner in each of the remaining eight dyads also belonged to the genus *Cortinarius*. Only five pairs were considered to be antagonistic with only the co-occurrence of *Laccaria montana* and *Russula pascua* on the 1%-level. In three of these pairs *Cortinarius* spp. was not involved.

Table 28: Matrices of X²-values (lower left) indicating association (**s1**, **s5**) and exclusion (**x1**, **x5**) and Ochiai index (upper right) of selected macromycetes, found in the *Salicetum* plots (3, 6, 7, 9, 11, 13) and the *Polytrichetum* plot 8. Only records within the actual plot borders were considered with a frequency of at least 10% (20 records). Significance levels of the X²-test are 1% (**s1**, **x1**) and 5% (**s5**, **x5**). An Ochiai Index of **0.0** (bold) indicates total (absolute) exclusion, indices greater than 0.40 (underlined and italic) point to relative association (1.0 = species pairs occur strictly associated).

- | | |
|---|---------------------------------------|
| a1 : <i>Astrosporina boltonii</i> | t11 : <i>C. cf. pertristis</i> |
| a2 : <i>A. mundula</i> | d1 : <i>Dermocybe cinnamomeolutea</i> |
| m : <i>Cortinarius (Myxaciun) favrei</i> | d2 : <i>D. crocea</i> |
| t0 : <i>Cortinarius (Telamonia) cavipes</i> | e : <i>Entoloma alpicola</i> |
| t1 : <i>C. chrysomallus</i> | g : <i>Galerina chionophila</i> |
| t2 : <i>C. diasemospermus</i> | h1 : <i>Hebeloma marginatulum</i> |
| t3 : <i>C. glandicolor</i> var. <i>exilis</i> | h2 : <i>H. repandum</i> |
| t4 : <i>C. lamourei</i> | i1 : <i>Inocybe lacera</i> |
| t5 : <i>C. pauperculus</i> | i2 : <i>I. peronatella</i> |
| t6 : <i>C. pauperculus</i> v. <i>luteovelatum</i> | l1 : <i>Laccaria montana</i> |
| t7 : <i>C. percavus</i> | l2 : <i>L. proxima</i> |
| t8 : <i>C. phaeopygmaeus</i> | r1 : <i>Russula norvegica</i> |
| t9 : <i>C. rufostriatus</i> | r2 : <i>R. pascua</i> |
| t10 : <i>C. rusticellus</i> | p : <i>Psilocybe chionophila</i> |

plot 3

	m	t0	t2	t3	t7	t10	d1	d2	i1	l1	r1
m		.14	.26	<u>.41</u>	.25	.25	.19	.04	.19	.18	.12
t0	-		.24	.30	.35	.13	.21	.12	.20	.15	.04
t2	-	-		.37	.14	.38	.09	0.0	.22	.24	.03
t3	s1	s5	s1		.27	<u>.50</u>	.08	.05	.30	.19	.06
t7	-	s1	-	s5		.35	.19	.07	.10	.17	.05
t10	-	-	s1	s1	s1		.09	.05	.26	.17	.03
d1	-	-	-	-	-	-		.26	.13	.33	.04
d2	-	-	-	-	-	-	s5		.07	.12	.10
i1	-	-	-	-	-	-	-	-		.06	.34
l1	-	-	-	-	-	-	s1	-	-		.12
r1			-	-	-	-	-	-	s5	-	

plot 7

	m	t1	t2	t3	t4	t8	t11	h1	h2	i1	i2	l1	r1	r2
m		.39	.11	.11	.07	<u>.46</u>	.33	.10	.20	0.0	0.0	.09	.29	.28
t1	s1		.35	.32	.16	<u>.57</u>	<u>.50</u>	.28	.11	0.0	.06	.22	.30	.23
t2	-	s1		.28	.11	.33	<u>.47</u>	.23	.11	0.0	.13	.22	.30	.13
t3	-	s1	s5		.34	.07	.16	<u>.53</u>	.04	0.0	0.0	.11	.09	.10
t4	-	-	-	s1		0.0	.06	.26	.15	0.0	0.0	.03	.22	.06
t8	s1	s1	s1	-	-		<u>.49</u>	0.0	.09	0.0	0.0	.15	.19	.11
t11	s1	s1	s1	-	-	s1		.18	.18	0.0	0.0	.30	.29	.27
h1	-	-	-	s1	s5	-	-		.31	0.0	0.0	.16	.14	.22
h2	-	-	-	-	-	-	-	-		.04	0.0	.30	.26	.25
i1	-	-	-	-	-	-	-	-	-		0.0	.29	.08	0.0
i2	-	-	-	-	-	-	-	-	-	-		.12	.13	0.0
l1	x5	-	-	-	x5	-	s5	x5	-	-	-		.30	.04
r1	s5	s5	s5	-	-	-	s1	-	-	-	-	-		.17
r2	s5	-	-	-	-	-	s5	-	-	x5	-	x1	-	

Table 28: continued.

plot 9

	a1	a2	t1	t2	t5	t7	h2	i1	l1	r1
a1		.31	.02	.05	.05	0.0	.14	.45	.48	.38
a2	s1		0.0	0.0	0.0	0.0	.08	.49	.25	.19
t1	x1	x5		.49	.40	.39	.21	.03	.38	.38
t2	-	-	s1		.12	.20	.20	.06	.16	.24
t5	-	-	s1	-		0.0	0.0	0.0	.17	.18
t7	-	-	s1	-	-		.38	.05	.15	.19
h2	-	-	-	-	-	s1		.17	.18	.16
i1	s1	s1	x5	-	-	-	-		.43	.27
l1	s5	-	-	-	-	-	-	s5		.60
r1	-	-	-	-	-	-	-	-	-	

plot 11

	m	t0	t2	t4	t6	i1	i2	l1	l2	r1
m		.13	.31	.15	.32	0.0	0.0	.03	.07	0.0
t0	-		.34	.32	.14	0.0	0.0	.25	.18	.13
t2	s1	s1		.33	.24	.04	0.0	.16	.18	.18
t4	-	s1	s1		0.0	0.0	0.0	0.0	.35	.10
t6	s1	-	-	-		.28	0.0	.15	.23	.13
i1	-	-	-	-	s1		.20	.33	.15	.34
i2	-	-	-	-	-	-		.22	0.0	.25
l1	x1	-	x5	x5	-	s1	-		0.0	.53
l2	-	-	-	s1	-	-	-	x5		.05
r1	-	-	-	-	-	s1	s5	s1	-	

plot13

	m	t0	t2	t3	t9	t10	e	h2	i1	l1	r1	r2
m		.25	.34	.25	.46	.24	.30	.06	.04	.25	.19	.04
t0	-		.63	.15	.34	.34	.11	.22	.09	.24	.32	.04
t2	-	s1		.24	.44	.44	.18	.27	.14	.30	.40	.06
t3	-	-	-		.27	.37	.05	0.0	0.0	.10	.18	0.0
t9	s1	-	s5	-		.38	.19	.14	.04	.19	.34	.04
t10	-	-	s1	s1	s5		.18	.24	0.0	.20	.31	.12
e	-	-	-	-	-	-		0.0	0.0	.07	.02	.10
h2	-	-	-	-	-	-	x5		.19	.04	.29	.18
i1	-	-	-	-	-	-	-	-		.12	.08	0.0
l1	-	-	-	-	-	-	-	-	-		.22	.11
r1	-	-	-	-	-	-	x1	-	-	-		.15
r2	-	-	-	-	-	-	-	-	-	-	-	

plot 6

	t2	t3	l1
t2		.04	.11
t3	-		.13
l1	x1	-	

plot 8

	g	p
g		.62
p	s1	

The evaluation of the Ochiai indices showed better correlation with the chi-square test than in the two previous mentioned plots (Tab 28). However, the X²-test proved association only in six cases on the 1%-level. Concerning exclusions only three of the total five resulting from the X²-test were in accordance. In addition, for the two species *Inocybe lacera* and *I. peronatella*, nine and eight absolute exclusions respectively were registered, including the one between themselves. A high degree of exclusion was further calculated in four cases.

Plot 9: For the statistical analysis ten species were taken into account. This is less than a third of the actual 35 registered taxa (Tab. 27). The computing of the 45 species dyads with the chi-square test resulted in nine associated and three excluding pairs of taxa (Tab 28). Of the former seven were significant on the 1%-level, whereas from the latter only one belonged to this class. In this plot the dominance of *Cortinarius* spp. as positively correlated taxa was not as characteristic as in the plots dealt with above. On the contrary, the three exclusions were noticed with the one partner always as *C. chrysomallus* and the others *Astrosporina boltonii*, *A. mundula* and *Inocybe lacera*.

Concerning association, the Ochiai indices were well correlated with the results of the X²-test (Tab 28). However, some important differences have been noted. The associations obtained from the chi-square test between *A. boltonii* vs. *A. mundula* and *C. percavus* vs. *H. repandum*, both on the 1%-level were not confirmed by the Ochiai indices. Conversely, the second highest index (OI = 0.60) in all investigated *Salicetum* plots indicating association between *Laccaria montana* and *Russula norvegica* was not proved by the X²-test. Furthermore, seven additional absolute exclusions were located with the Ochiai index of which four in combination with *A. mundula* and *C. pauperculus*, three with *C. percavus* and one with *A. boltonii*.

Plot 11: Ten out of a total of 35 reported taxa were analyzed resulting in 45 compared pairs of species (Tab 27). The X²-test computed 11 positive (ten on 1%-level) and four negative (one on the 1%-level) associations (Tab. 28). Five positive associations were calculated within *Cortinarius* spp., and two additional with one partner belonging to this genus. Three pairs were associated in combination with *Russula norvegica* and one was noticed between *Inocybe lacera* and *Laccaria montana* each. Concerning exclusions, *L. montana* was the one partner in all four pairs, of which in one the other partner was *L. proxima*.

Only low correlation was noticed by comparing the results of the X²-test and the Ochiai indices. There was but one positive co-occurrence indicated with an index of 0.53 between *L. montana* and *R. norvegica*, which is supported also

by the X^2 -test. For the remaining dyades, 16 exclusions, of which 13 absolute, were calculated. *Cortinarius favrei* and *I. lacera* with three, *C. lamourei* with four and *I. peronatella* with six negative correlations were the most antagonistic taxa. Exclusion between *L. montana* and *L. proxima*, already noted with help of the chi-square test, was confirmed with the Ochiai index as well.

Plot 13: Applying the chi-square test, the analysis of 66 pairs of taxa resulting from 12 examined species, of totally 43 recorded, yielded six positive (four on 1%-level) and two negative (one on 1%-level) associations (Tabs. 27, 28). In this plot, again, associated pairs of taxa were restricted to the genus *Cortinarius*, whereas exclusions were found only in co-occurrence of *Entoloma alpicola*. Except of two positive relationships of *C. rusticellus* all other results were proved also by the Ochiai indices.

There were obtained additional significant values with the OI index (Tab. 28). Whereas only one positive association could be added (*C. diasemospermus* and *Russula norvegica*), the situation looked quite different for the exclusions. To the two already computed with the X^2 -test, 13 further allopatric pairs of macromycetes were located, of which seven were absolute exclusions. *Inocybe lacera* with six, *R. pasqua* with five and *Entoloma alpicola* with four negative associations were the most antagonistic species in this plot.

Plot 8: In the one *Polytrichetum* plot examined only two of the total of seven registered taxa were considered for analysis. Both, the X^2 -test and the Ochiai index demonstrated a significant positive association between the two species, viz. *Galerina chionophila* and *Psilocybe chionophila* (Tab. 28).

Taking all six *Salicetum* plots into account, two main conclusions may be drawn based on both statistical methods. First, that positive association appears distinctly more often within the genus *Cortinarius* and, second, that exclusions result predominantly if one, and only one, partner belongs to *Cortinarius* spp.

It is obvious that, compared with the mapping data (cf. chapter 3.7.), the X^2 -test overestimates the fact of positive association, whereas the Ochiai index overvalues exclusions. Nevertheless, based on the experience of the author, there is undoubtedly a better correlation between the Ochiai index and the mapped data based on the three consecutive years (1988-90).

These facts are further emphasized by the results of the correspondence analysis applied to three *Salicetum* plots (3, 7, 13). As an example, the visual presentation of the computed values based on two different data sets of plot 7 is given in Figure 26 (same data as used for the X^2 -test and the Ochiai index) and Figure 27 (data without *Inocybe* spp.).

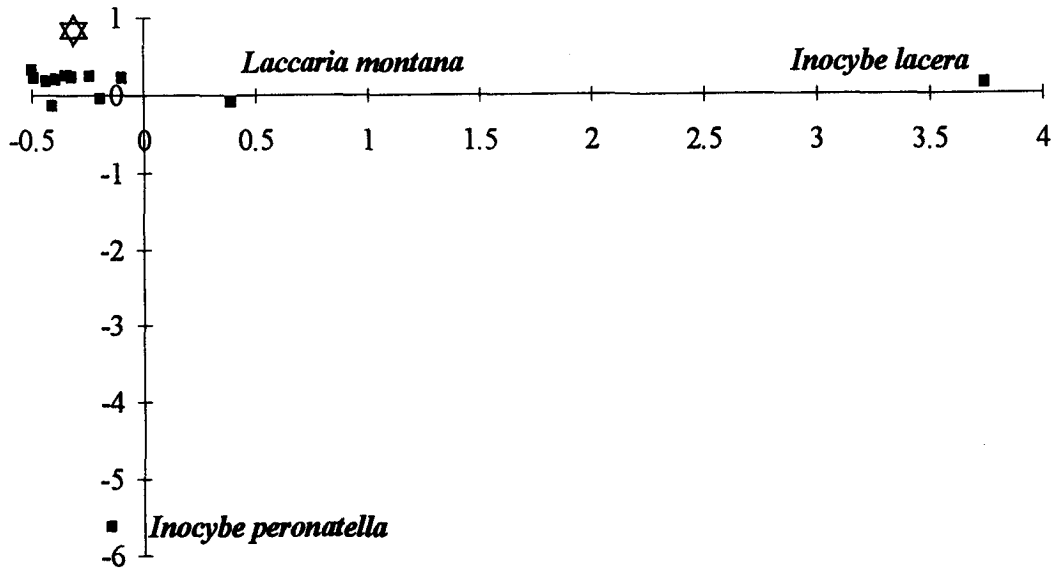


Fig. 26: Data of the correspondence analysis in visual presentation based on records (cf. Tab. 27) of plot 7, indicating interspecific relationships (strength of association) between the individual taxa. ☆ = additional 11 species presented in Figure 27 where *Inocybe* spp. were not considered. The first two axes explain 26.2% of the total inertia. Taking into account the second two axes, a total of 48.1% of the inertia is explained.

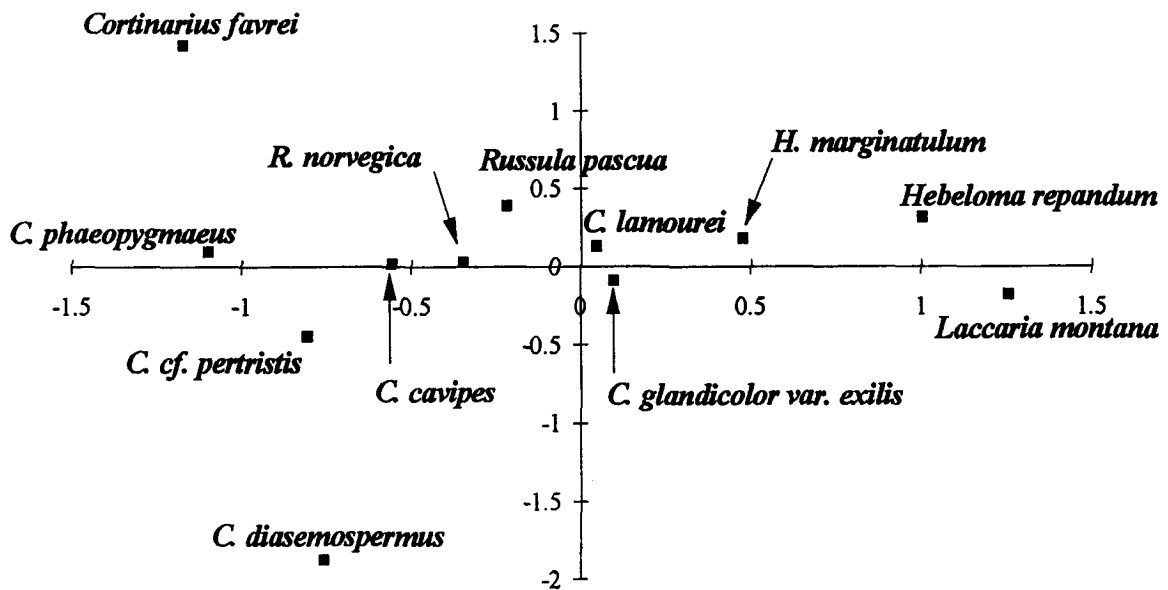


Fig. 27: Data of the correspondence analysis in visual presentation based on records (cf. Tab. 27) of plot 7, without considering *Inocybe* spp., indicating interspecific relationships (strength of association) between the individual taxa. The first two axes explain 29.6% of the total inertia. Taking into account the second two axes, a total of 54.4% of the inertia is explained.

The results of this method demonstrate the antagonistic behaviour of *I. lacera* and *I. peronatella* compared with all other analyzed taxa, as well as among themselves.

A very similar result was obtained with the Ochiai index, but no sign of exclusion was indicated by the chi-square test statistic, except between *I. lacera* and *R. pascua*. Concerning the still more or less antagonistic status of *L. montana* (Figs. 26, 27) the X²-test obtained better results than predicted by the Ochiai index, which has its reason probably in the rather even distribution of this macromycete (cf. chapter 3.7.). However, the fact that the X²-test also located a significant association between *L. montana* and *H. marginatulum* but positive association between the former and *C. cf. pertristis* is neither confirmed by the mapping data nor by the two correspondence analyses (Figs. 26, 27).

Similar accordances and tendencies were obtained by data evaluation performed with correspondence analyses, X²-tests and Ochiai indices from plot 3 and 13.

3.6.2. Diversity and species accordance

The Shannon index was applied to compare diversity among the investigated plots. Hence, the value of the Shannon index characterizing different plots, may result either from a high number of taxa with deviating abundances or from a low number of species with similar abundance (LUDWIG & REYNOLDS 1988). Accordingly, the corresponding evenness was calculated indicating the quality of the diversity (Tabs. 29, 30).

In the *Salicetum* plots, the diversity index (SI) was positively correlated with the evenness, except in plot 6 and 9 (Tab. 29). These two plots were noted with the lowest values for both indices. It was interesting that only they correlated with the results of SENN-IRLET (1987), who calculated diversity values between 1.2 and 1.95. Plot 3, 7, 11 and 13, however, showed significantly higher values (2.338 - 2.805) although in accordance with the evenness. In this connection, one has to be aware, that the total number of taxa found by SENN-IRLET (1987) was between 5 and 16 per plot compared with 19 to 43 registered in this study. The highest values both, in diversity and evenness in plot 3 and 7 were well correlated with similar numbers of species and carpophores. The mean of species accordance between the three year pairs compared was lowest in plot 6 with an index of 0.303 and highest in plot 3 with 0.675, but only slightly fluctuated around 0.5 in the other plots (Tab. 29). Lowest accordance was realized between 1988 and 1990 in four of the six *Salicetum* plots. Between 1989 and 1990 the species composition was most similar in three

plots, although with 0.544 the highest mean value was calculated for 1988 and 1989.

In the *Polytrichetum* plots correlation easy to recognize was found neither between diversity and evenness nor between these two parameters and the number of taxa and their abundance (Tab. 29). The highest diversity was noted with 1.369 in plot 10, where also the number of taxa was topmost. These results are interesting in combination with the fact that plot 10 is a transitional site between a *Polytrichetum* and a *Salicetum*. The lowest diversity and evenness indices were computed for plot 5. Comparing results of the three *Polytrichetum* plots with values calculated by SENN-IRLET (1987) it is again apparent, that hers (SI = 0.285, E = 0.411) are distinctly lower. Once more it is important to know that the results of SENN-IRLET are based on only two registered species, whereas in this study between 7 and 18 taxa were reported per plot from comparable plant associations.

The mean accordance of taxa during the investigation period of three years was similar in plot 5 and 8 but significantly lower in plot 10 (Tab. 29). Comparing the individual pairs of years, a distinct deviation was only noticed in plot 5 between 1989 and 1990, when the accordance was 1.0, i.e. absolutely identical.

Table 29: Diversity, evenness and species accordance indices: The Shannon index (SHANNON & WIENER 1949), the index for evenness (PIELOU 1977) and the Jaccard index comparing pairs of years for the *Salicetum* plots (3, 6, 7, 9, 11, 13) and the *Polytrichetum* plots (5, 8, 10), considering all taxa and all carpophores mapped during the three investigation years (1988-90).

plot	<i>Salicetum</i>						<i>Polytrichetum</i>		
	3	6	7	9	11	13	5	8	10
Shannon Index	2.805	1.670	2.802	1.971	2.338	2.751	0.856	0.985	1.369
Evenness	0.825	0.567	0.801	0.554	0.657	0.732	0.390	0.506	0.473
taxa (1988-90)	30	19	33	35	35	43	9	7	18
total carpophores	2827	858	2817	5317	2427	2673	1360	1498	1911
Jaccard Index									
1988/89	0.677	0.526	0.519	0.539	0.516	0.485	0.444	0.667	0.364
1988/90	0.643	0.133	0.412	0.364	0.606	0.514	0.444	0.714	0.357
1989/90	0.704	0.250	0.607	0.567	0.517	0.325	1.000	0.667	0.412
mean (1988-90)	0.675	0.303	0.513	0.490	0.547	0.467	0.630	0.683	0.378

Concerning the four plant associations not belonging to snow-bed communities (Tab. 30), diversity varied between 0.687 (*Caricetum*) and 2.496 (*Loiseleurietum*). The evenness indices ranged from 0.453 (*Oxyrietum*) to 0.841 (*Eriophoretum*).

The mean accordance values were 0.293 for the *Loiseleurietum* plot, 0.361 for the *Caricetum* plot, 0.422 for the *Eriophoretum* plot and 0.50 for the *Oxyrietum* plot. The highest divergences between the individual pairs of years compared were registered in the *Eriophoretum* with a JS index of 0.167 for 1988/89 and 0.60 for 1989/90. In the *Caricetum* plot these extreme values were 0.25 for 1988/89 and 0.50 for 1988/90 and in the *Loiseleurietum* plot with 0.267 for 1989/90 and 0.333 for 1988/89. In the *Oxyrietum*, however, there was no difference between the individual years and the JS index was 0.50 for all pairs of investigation years.

Table 30: Diversity, evenness and species accordance indices: The Shannon index (SHANNON & WIENER 1949), the index for evenness (PIELOU 1977) and the Jaccard index comparing pairs of years for the *Oxyrietum* (plot 1), the *Eriophoretum* (plot 2), the *Caricetum* (plot 4) and the *Loiseleurietum* (plot 12), considering all taxa and all carpophores mapped during the three investigation years (1988-90).

	<i>Oxyrietum</i>	<i>Eriophoretum</i>	<i>Caricetum</i>	<i>Loiseleurietum</i>
plot	1	2	4	12
Shannon Index	1.256	1.507	0.687	2.496
Evenness	0.453	0.841	0.496	0.808
taxa (1988-90)	16	6	4	22
total carpophores	3882	648	31	164
Jaccard Index				
1988/89	0.500	0.167	0.250	0.333
1988/90	0.500	0.500	0.500	0.273
1989/90	0.500	0.600	0.333	0.267
mean (1988-90)	0.500	0.422	0.361	0.293

3.7. SPATIAL DISTRIBUTION PATTERNS OF SELECTED MACROMYCETES

Mapping data of selected macromycetes recorded during the period from 1988 to 1990 are presented in two-dimensional (Figs. 28, 29) and three-dimensional graphs (Fig. 31), respectively.

Concerning the ectomycorrhizal representatives, the according host plant was the dwarf willow *Salix herbacea*. The moss *Polytrichum sexangulare* was the host of the two saprobic (parasitic) taxa, viz. *Galerina chionophila* and *Psilocybe chionophila*.

Isochiones mapped during the melting procedure in the spring 1989 and 1990 and during the three vegetation periods (summers) under review (1988-90) were compared with spatial distribution patterns of selected taxa in Figure 32.

3.7.1. Two-dimensional presentation of mapping data

Two-dimensional mapping cards have been employed to differentiate relationships between selected individual taxa in the snow-bed community plots (Figs. 28, 29). As already calculated with the X^2 -test and the Ochiai index (cf. chapter 3.6.), based on the same mapping data, obvious positive and negative associations were discovered.

Plot 3: *Cortinarius favrei* and *C. glandicolor* var. *exilis* showed a tendency for co-occurrence, with their carpophores restricted to the right side of the plot, whereas *Dermocybe crocea* was found only in the first half (Fig. 28). *Inocybe lacera* and *Russula norvegica* also had their main distribution in the first half of the plot and showed positive correlation between each other. However, *D. crocea* significantly excluded both of them. *Laccaria montana* was found clustered at the end of the plot, near the border and seemed to be negatively associated with all of the above-mentioned species, although *C. favrei* and *C. glandicolor* var. *exilis* were found in the immediate vicinity.

Plot 6: In this plot the more or less obvious association was detected only between *Cortinarius diasemospermus* and *Laccaria montana* (Fig. 28). The former was found most often in the first five meters, the latter clustered in the last five meters of the plot, separated by a zone of 15 m with only scattered carpophores of both species.

Plot 7: In this plot the most impressive associations were located especially concerning the following exclusions (Fig. 28). *Cortinarius favrei*, *Hebeloma*

marginatulum, *H. repandum*, *Inocybe lacera* and *I. peronatella* seemed to be all negatively associated with each other. The small transitional zone in common of both, *H. marginatulum* and *H. repandum* may have been the result of misidentifications of the carpophores in the field. All of the above-mentioned species were distributed more or less in clusters. *Cortinarius diasemospermus*, *Laccaria montana* and *Russula norvegica* showed a more scattered dispersion and therefore clear tendencies for positive association. Nevertheless, the two mentioned *Cortinarius* species excluded each other, which was also the case between *C. diasemospermus*, *L. montana* and *I. peronatella*.

Plot 9: *Laccaria montana* was distributed nearly homogeneously and accordingly showed more or less positive association with all other taxa (Fig. 28). Less pronounced was the distribution pattern of *Russula norvegica*, which nevertheless, was also positively correlated with the remaining species. A different situation was observed for *Cortinarius chrysomallus*, which was mapped but in one isolated spot of the plot except for two records. Hence, this taxon was negatively associated with most other ectomycorrhizal species as for example with *Astrosporina boltonii* and *Inocybe lacera*, but not with *L. montana* and *R. norvegica*. The two former species in contrast were detected as positively associated among each other. In this case, misidentifications of the carpophores in the field may again have influenced the result.

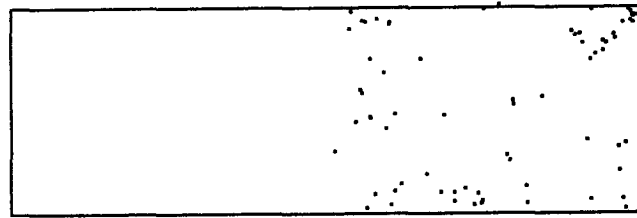
Plot 11: As in other plots *Laccaria montana* and *Russula norvegica* were the two taxa distributed most evenly throughout this observation area (Fig. 28). However, positive association was noted only between themselves. Furthermore, *Cortinarius favrei* and *C. diasemospermus* also showed a tendency for producing carpophores at the same spots. Conversely, *L. montana* and *L. proxima* were mapped in absolute exclusion. *Inocybe lacera* and *I. peronatella* were found in the immediate vicinity with a small border zone in common, but otherwise excluded each other. This phenomenon was already detected in plot 7. As these two species are impossible to distinguish in the field, misidentifications of the carpophores in the field may have biased the mapped distribution. Exclusion was further apparent between *C. favrei* vs. *I. lacera*, *I. peronatella*, *L. montana*, *L. proxima* and *R. norvegica* and also between *Inocybe* spp. and *Laccaria* spp.

Plot 13: In this plot exclusions were not that obvious at first sight (Fig. 28). *Entoloma alpicola* seemed to occur mostly isolated from all other species found. Further exclusions were noted between *Cortinarius favrei* and *Inocybe lacera*. *Cortinarius diasemospermus*, *Laccaria montana* and *Russula*

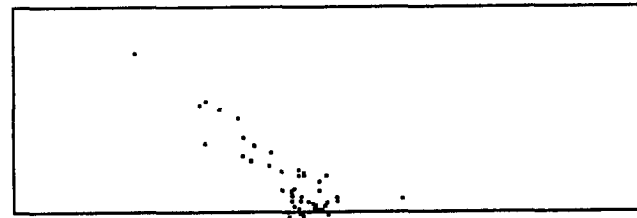
plot 3



*Cortinarius
favrei*



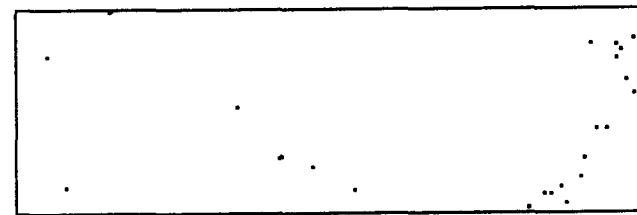
*Cortinarius
glandicolor
var. exilis*



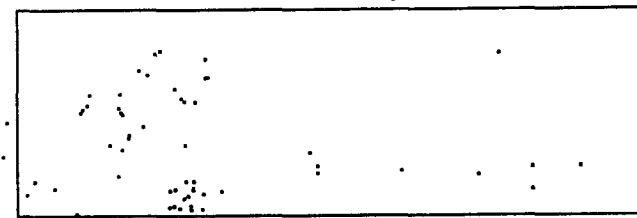
*Dermocybe
crocea*



*Inocybe
lacera*



*Laccaria
montana*



*Russula
norvegica*

Fig. 28: Two-dimensional distribution patterns of selected ectomycorrhizal species registered in snow-bed community plots from 1988 to 1990 (bar = 1 m).

plot 6



Cortinarius diasemospermus



Laccaria montana

plot 9



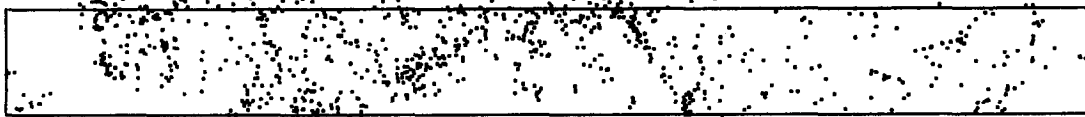
Cortinarius chrysomallus



Astrosporina boltonii



Inocybe lacera



Laccaria montana



Russula norvegica

Fig. 28: continued.

plot 7

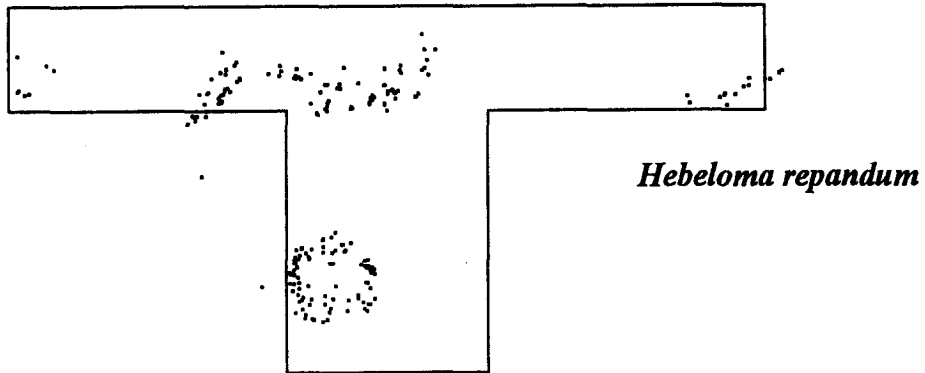
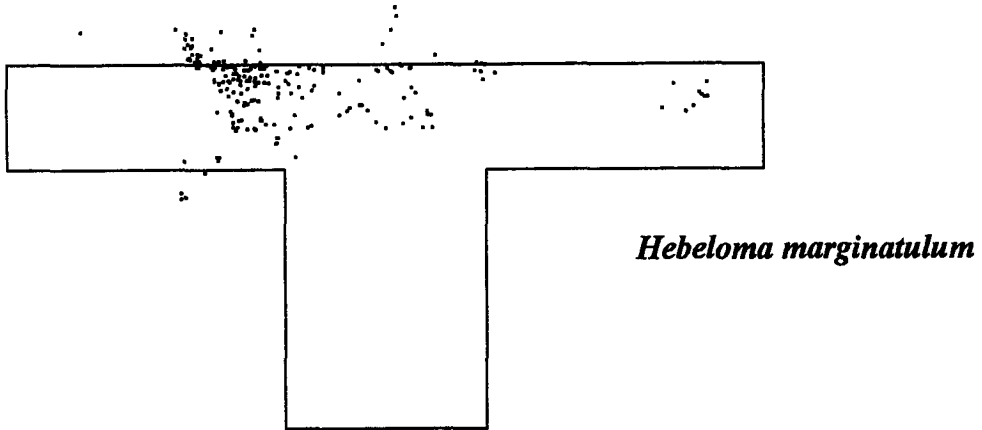
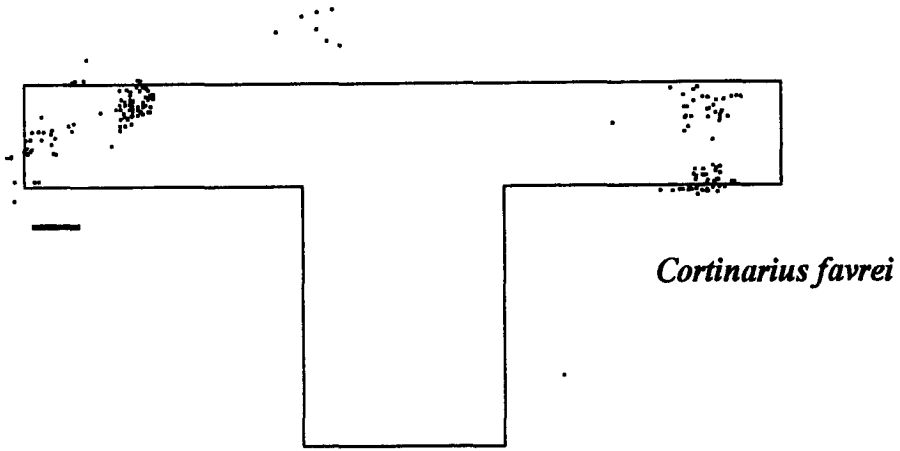


Fig. 28: continued.

plot 7

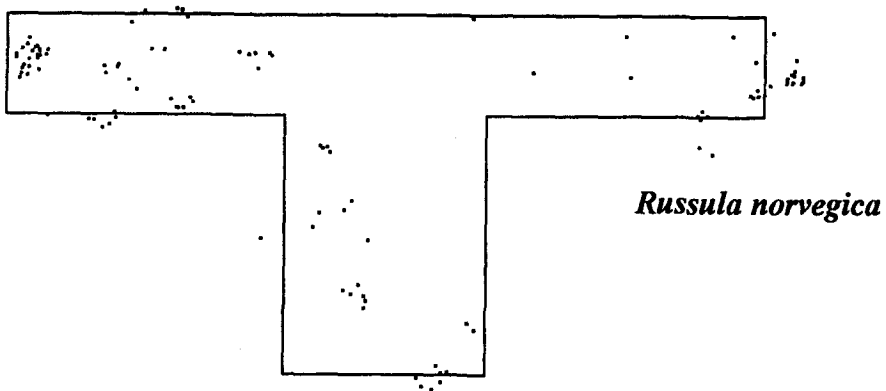
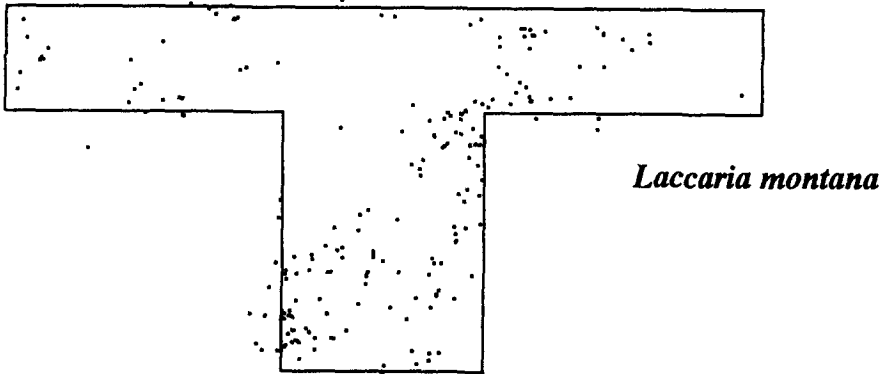
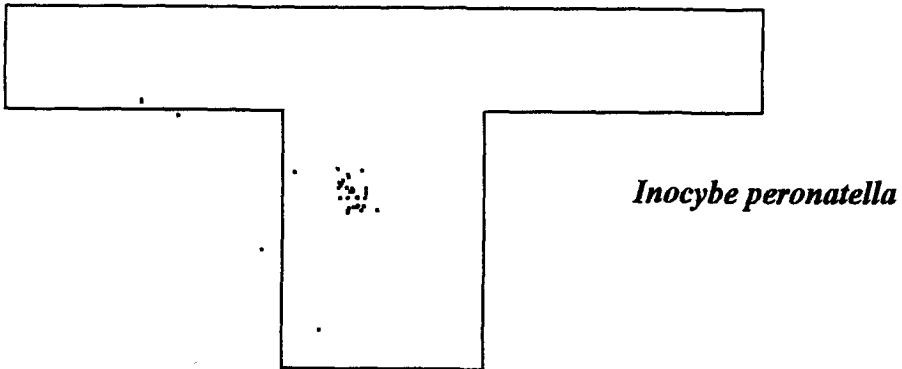
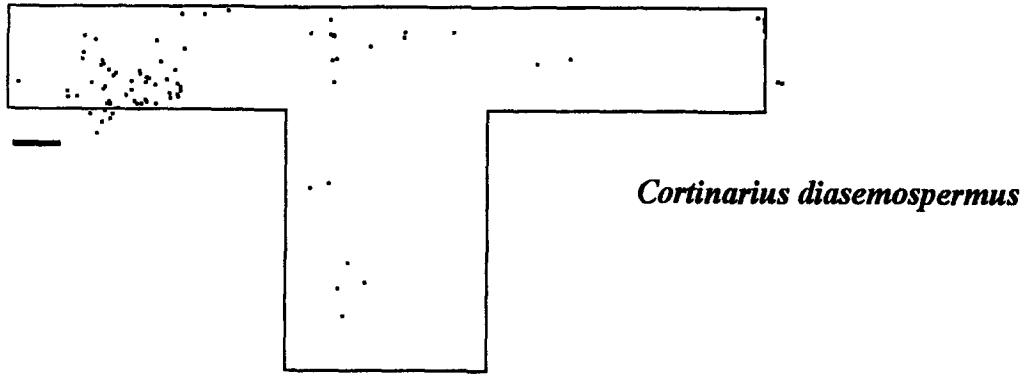
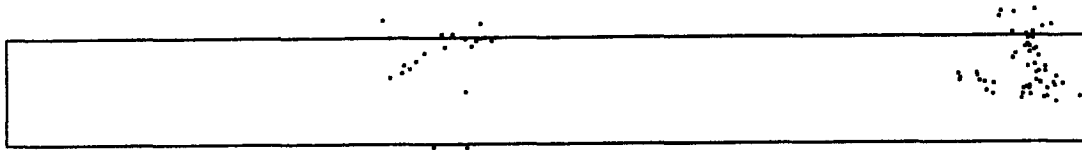
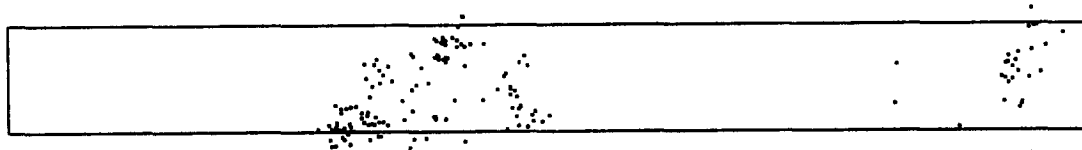


Fig. 28: continued.

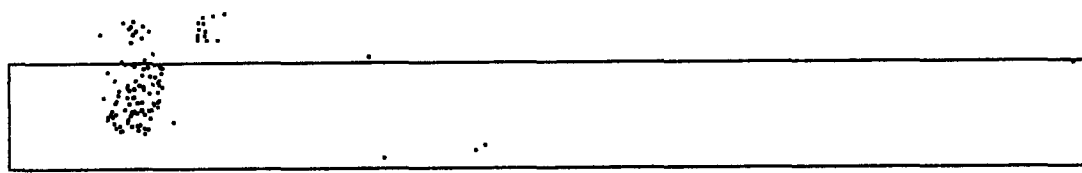
plot 11



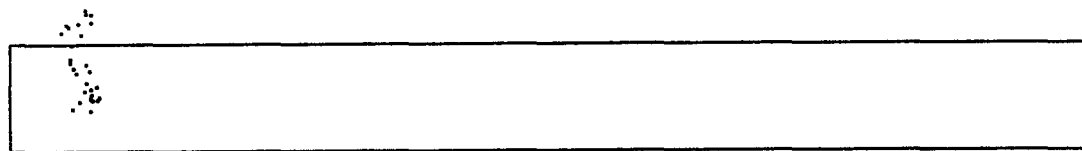
Cortinarius favrei



Cortinarius diasemospermus



Inocybe lacera



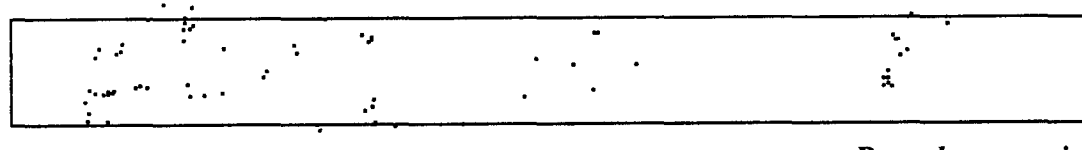
Inocybe peronatella



Laccaria montana



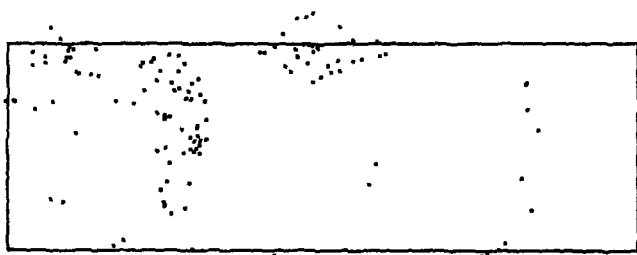
Laccaria proxima



Russula norvegica

Fig. 28: continued.

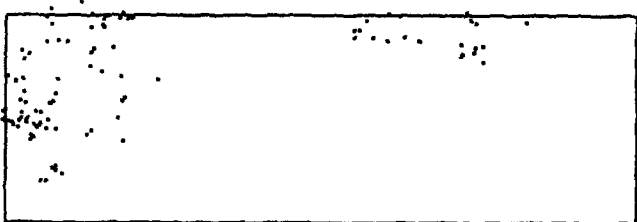
plot 13



*Cortinarius
favrei*



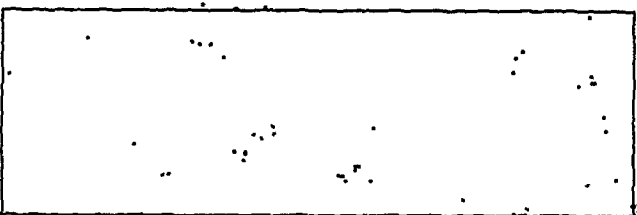
*Cortinarius
diasemospermus*



*Entoloma
alpicola*



*Inocybe
lacera*



*Laccaria
montana*



*Russula
norvegica*

Fig. 28: continued.

norvegica, which occurred more or less scattered throughout the plot were in general associated with the remaining species.

Plot 8: In the only *Polytrichetum* plot taken into consideration, the two most abundant taxa, viz. *Galerina chionophila* and *Psilocybe chionophila* were significantly positively associated (Fig. 29). Whereas the former was evenly distributed throughout the plot, the latter was mapped restricted to several semi-circular patches (GULDEN et al. 1985).

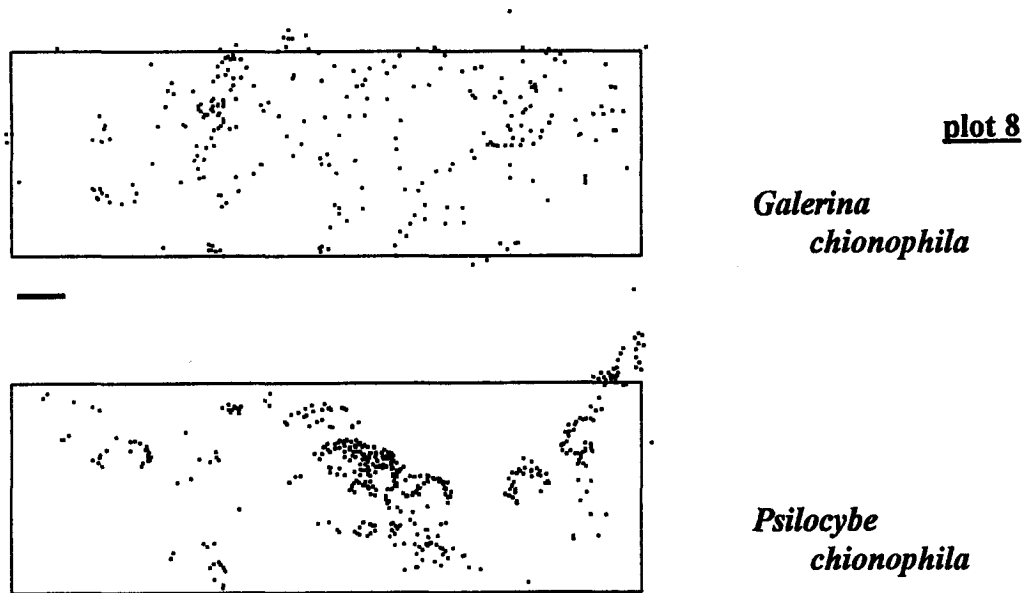


Fig. 29: Two-dimensional distribution patterns of selected saprobic (parasitic) species registered in snow-bed community plot 8 from 1988 to 1990 (bar = 1 m).

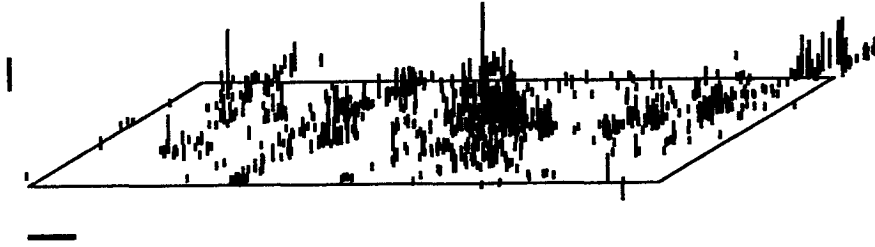
3.7.2. Three-dimensional presentation of mapping data

The evaluation of the records registered during the investigation period from 1988 to 1990 of different plant associations showed principal contrasts in frequency and abundance (Fig. 30). In this connection it has to be recalled that except for the snow-bed communities (6 *Salicetum* plots, 3 *Polytrichetum* plots) only one plot of 50 m² each has been investigated in the following associations: *Eriophoretum*, *Oxyrietum*, *Caricetum* and *Loiseleurietum*. Significantly higher abundances and frequencies of macromycetes were noted in the *Salicetum* and *Polytrichetum* plots. However, in the former association deviations were observed according to exposition and location of the plots. In plot 6, situated along the flat top of an ancient side moraine, the carpophore density was lowest, conversely to plot 9, embedded in a slight depression with a western exposure, which showed the highest carpophore density (cf. Tab. 22). In the *Polytrichetum* plots only minor differences were registered.

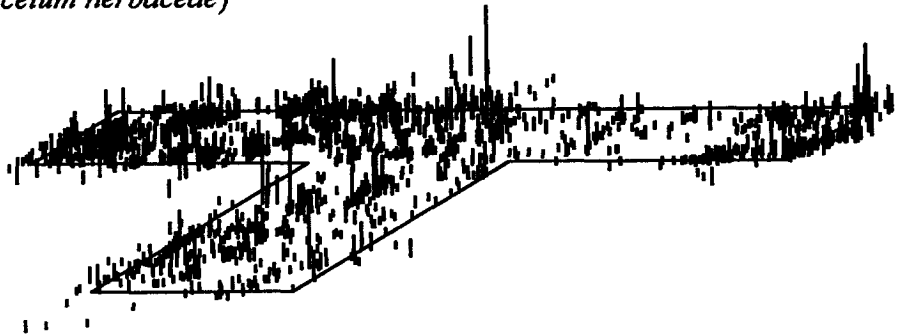
The comparison of a typical *Salicetum* (plot 7), *Polytrichetum* (plot 8) and the *Caricetum* plot 4 and *Loiseleurietum* plot 12 demonstrate particular contrasts in spatial distribution and density of the carpophores mapped during the three year investigation period (Fig. 30). The extremely high density of carpophores registered in the snow-bed communities stands in remarkable contrast to the low yield in the *Loiseleurietum* and the almost desert-like *Caricetum*. In the *Polytrichetum* (plot 8) the ectomycorrhizal taxa made up 10% of the abundance, whereas the remaining 90% referred to the two saprobic (parasitic) species *Galerina chionophila* and *Psilocybe chionophila*. In the *Salicetum* (plot 7) the ratio was exactly opposite, with 94% belonging to ectomycorrhizal taxa and only 6% to the saprobic (parasitic) *P. apeliculosa* and *P. chionophila*. Of the modest 31 carpophores mapped in the *Caricetum* plot only one non-mycorrhizal carpophore (3%) was registered, viz. *P. chionophila*. The remaining 97% pertained to ectomycorrhizal taxa of which *Laccaria proxima* was the most abundant (83%). Their host plant was *Salix herbacea* growing in the border region of the plot. In the *Loiseleurietum* plot the ratio between ectomycorrhizal (48%) and saprobic (parasitic) macromycetes (52%) was well balanced. The most frequent representative of the latter group was *Entoloma conferendum*, of the former group it was *Cortinarius diasemospermus*.

Furthermore, in Figure 31 dynamics of abundance and frequency during the investigation period (1988-90) of selected macromycetes are presented. In the *Salicetum* plot 9 an impressive increase in both frequency and abundance was noticed for *Cortinarius chrysomallus* and *Laccaria montana* (Fig. 31). Conversely, in the plots 3 and 13 a decrease was registered of *Inocybe lacera* in the former and of *C. diasemospermus* in the latter plot (Fig. 31). In plot 7 the records mapped of *Hebeloma repandum* increased from year to year.

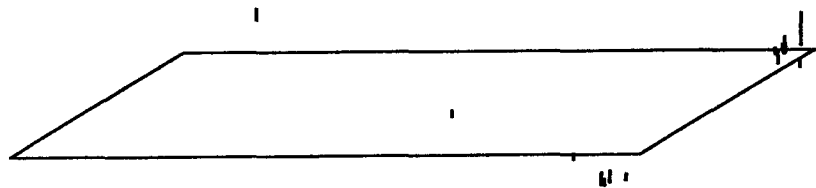
plot 8 (*Polytrichetum sexangularis*)



plot 7 (*Salicetum herbaceae*)



plot 4 (*Caricetum curvulae*)



plot 12 (*Loiseleurio-Cetrarietum*)

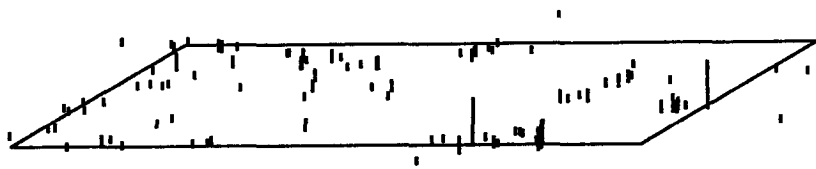
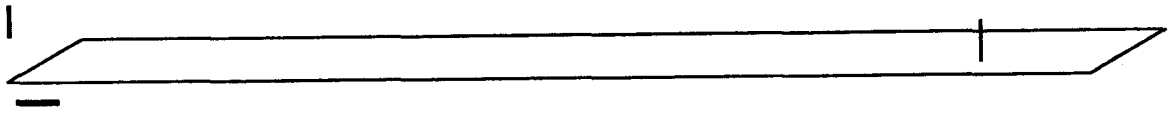


Fig. 30: Three-dimensional presentation of all records registered from 1988 to 1990 in four representative plots (50 m² each) of four different plant associations, viz. *Polytrichetum sexangularis* (plot 8), *Salicetum herbaceae* (plot 7), *Caricetum curvulae* (plot 4) and *Loiseleurio-Cetrarietum* (plot 12). Horizontal bar = 1m; vertical bar = 5 carpophores.

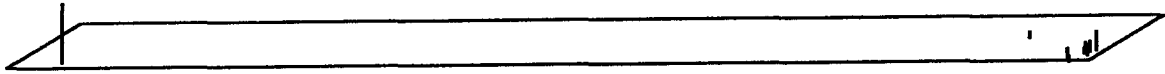
Cortinarius chrysomallus

1988

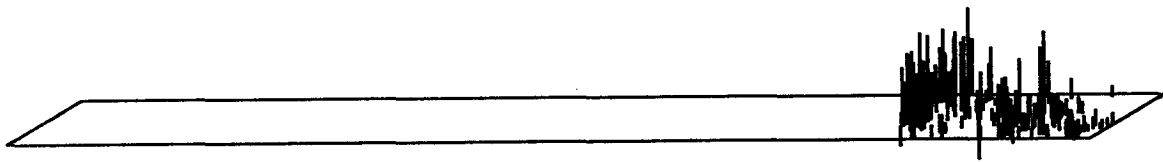
plot 9 (*Salicetum*)



1989



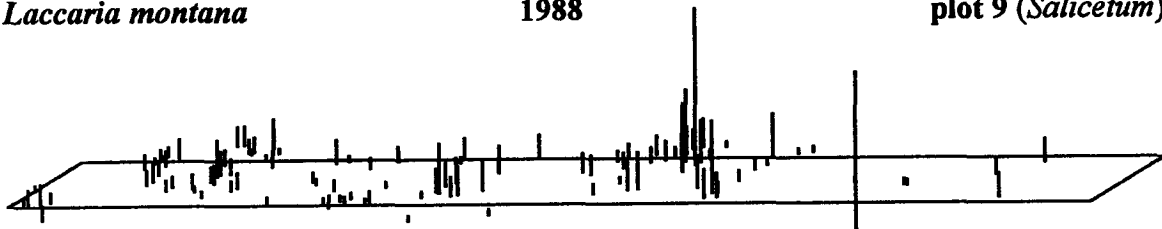
1990



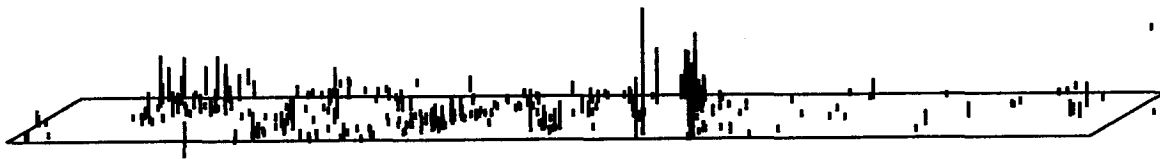
Laccaria montana

1988

plot 9 (*Salicetum*)



1989



1990

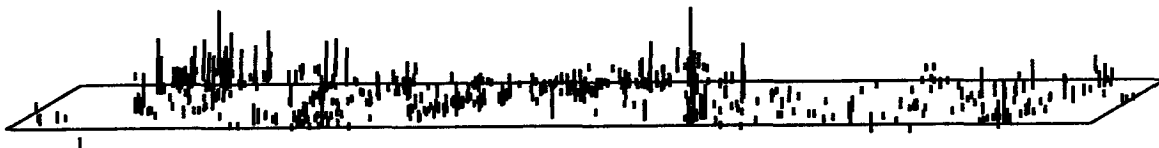
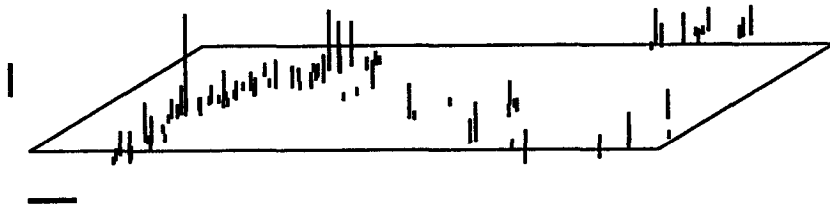


Fig. 31: Abundance and frequency of selected macromycetes in the three investigation years (1988-90) in snow-bed community plots. Horizontal bar = 1m; vertical bar = 5 carpophores.

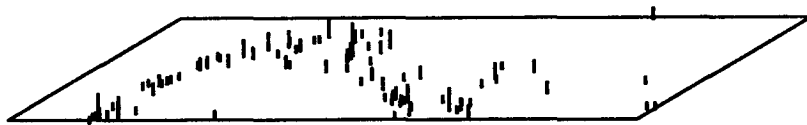
Inocybe lacera

1988

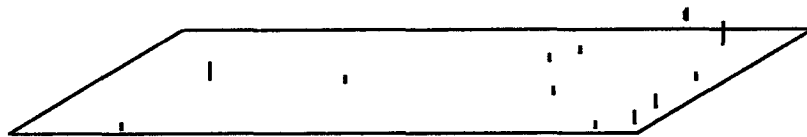
plot 3 (*Salicetum*)



1989



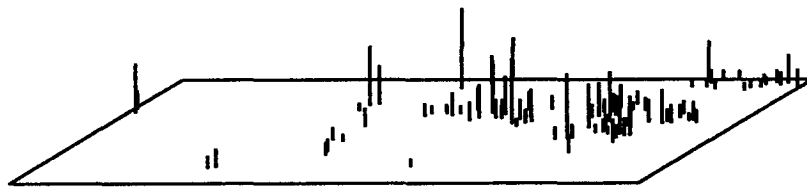
1990



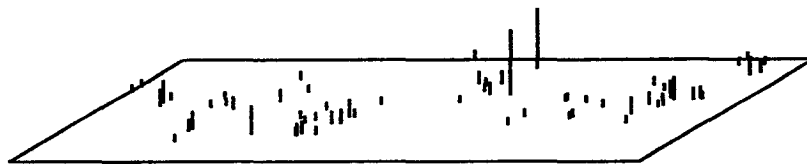
Cortinarius diasemospermus

1988

plot 13 (*Salicetum*)



1989



1990

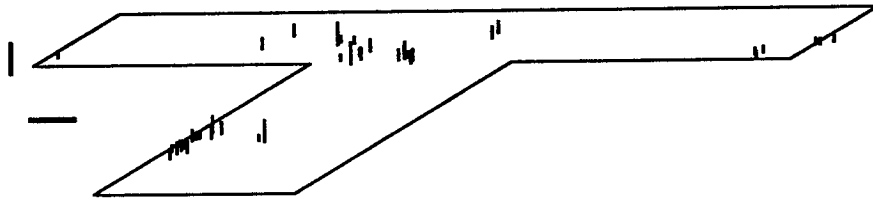


Fig. 31: continued.

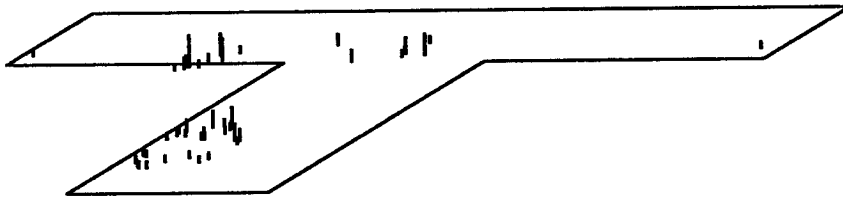
Hebeloma repandum

1988

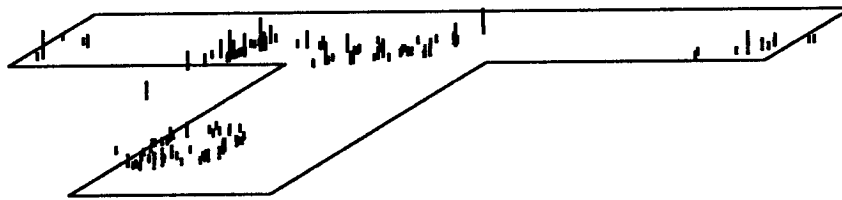
plot 7 (*Salicetum*)



1989



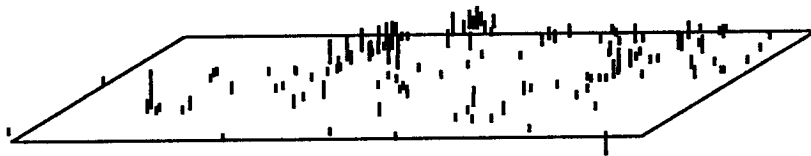
1990



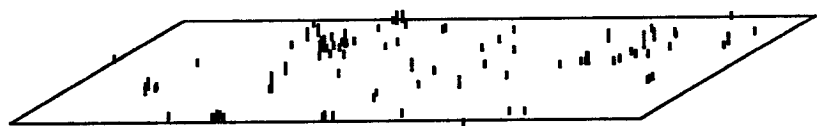
Galerina chionophila

1988

plot 8 (*Polytrichetum*)



1989



1990

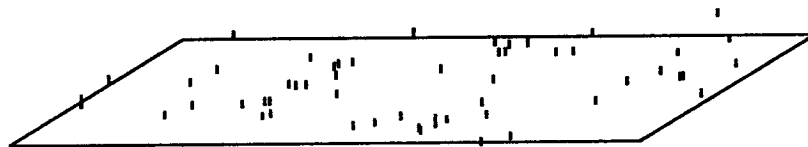


Fig. 31: continued.

In the *Polytrichetum* plot 8 an obvious reduction of *Galerina chionophila* was noted with progressing investigation period (1988-90). In connection with this result it is interesting to mention that this tendency continued in the succeeding years, when ROEMER (1993) found only two collections in 1992 and one in 1993, respectively in the above-mentioned plot.

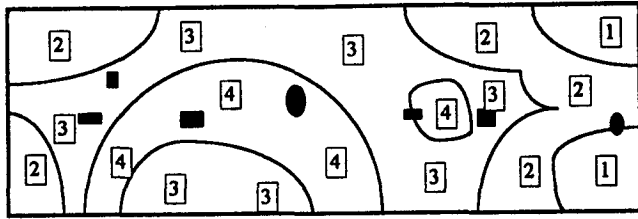
The presented mapping cards and further unpublished data of ectomycorrhizal taxa verify how difficult it is to draw conclusions concerning association of macromycetes and, in fact challenge the expressiveness of mycelia cards based only on observed carpophores during a relatively short investigation period (DAHLBER & STENLID 1990, EGLI 1992, GRIESSER 1992)

3.7.3. Relationships between isochiones and distribution patterns of macromycetes

The mapping of snow-melting zones (isochiones, cf. chapter 3.1.4.2.) and of macromycetes allowed to distinguish between species associated with host plants (*Salix herbacea*, *Polytrichum sexangulare*) growing at places where snow melted early or late in the season respectively (Fig. 32). In selected plots of snow-bed communities it has been attempted to correlate the distribution of macromycetes to host plants which differed in the time available for developing during the vegetation period.

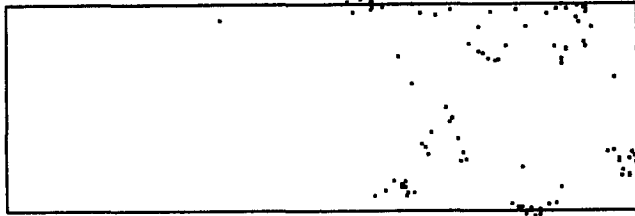
Plot 3: *Dermocybe crocea* and *Inocybe lacera* were predominantly found at places where snow melted at the end of the snow-melting process (Fig. 32). *Laccaria montana* conversely preferred the early snow-free zones. Concerning thaw, *Cortinarius favrei* mostly occurred at spots where the winter snow pack melted neither early nor late.

Plot 7: *Cortinarius favrei* was mapped in zones becoming snow-free only towards the end of the melting process (Fig. 32). *Hebeloma marginatum* preferred the early snow-free spots and therefore may be ecologically separated from *H. repandum*, which predominantly occurred in zones where snow melted late. *Inocybe lacera* clearly preferred the places in the plot having been snow-free at the end of the melting event. The two species with the most scattered distribution patterns, viz. *C. diasemospermus* and *Laccaria montana* showed a slight preference for places where snow melted neither too early nor too late.

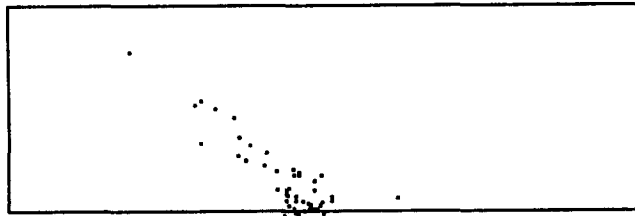


plot 3 (*Salicetum*)

isochrones from 1988 - 90



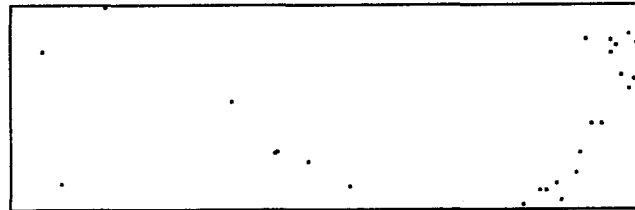
*Cortinarius
favrei*



*Dermocybe
crocea*

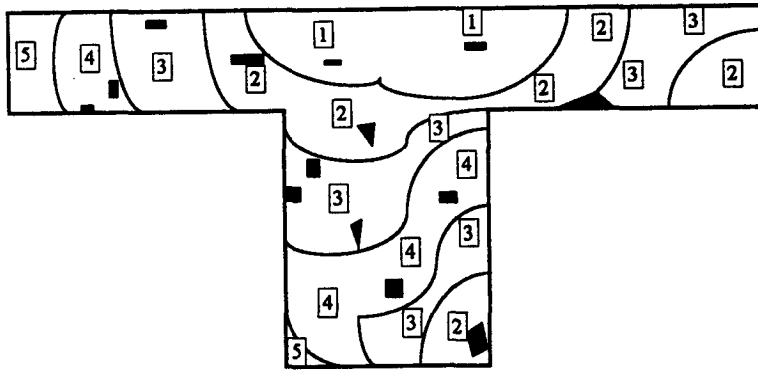


*Inocybe
lacera*



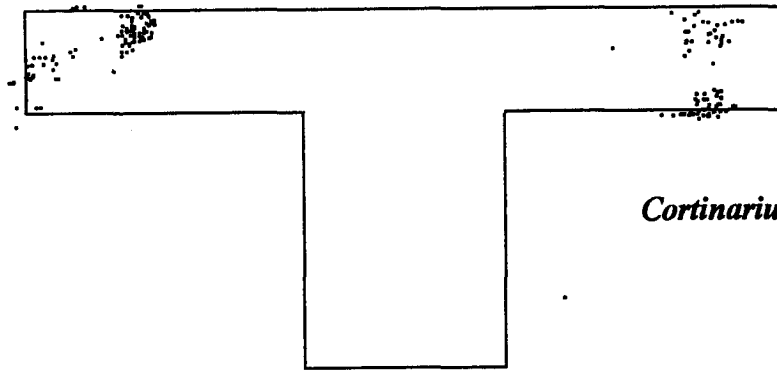
*Laccaria
montana*

Fig. 32: Isochrones compared with distribution patterns of selected macromycetes (1988-90) in snow-bed community plots. Numbers (1-6) indicate the sequence of the snow-melting process (1 = first snow-free spot, 6 = last snow-free spot). ● : bigger stones in the investigation plots. Bar = 1 m.

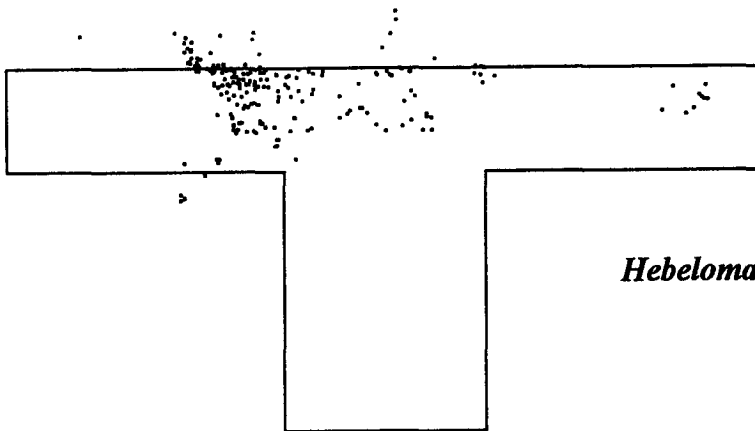


plot 7 (*Salicetum*)

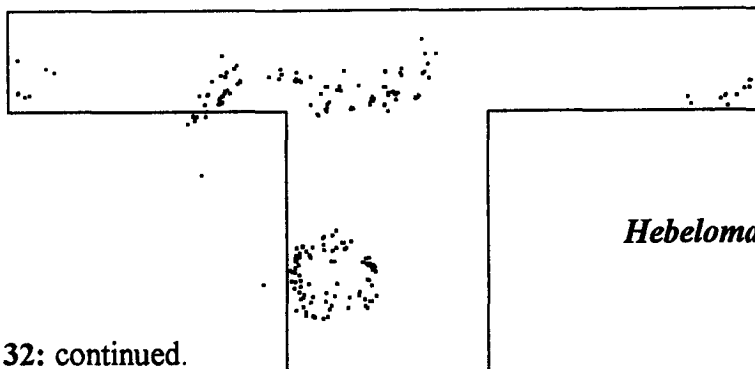
isochiones from
1988 - 90



Cortinarius favrei

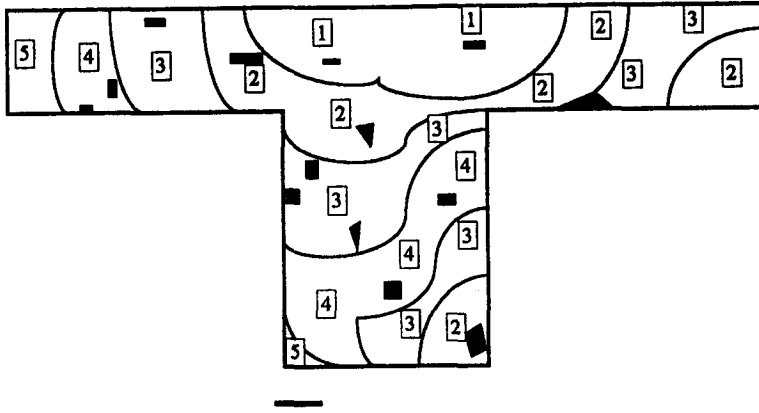


Hebeloma marginatum



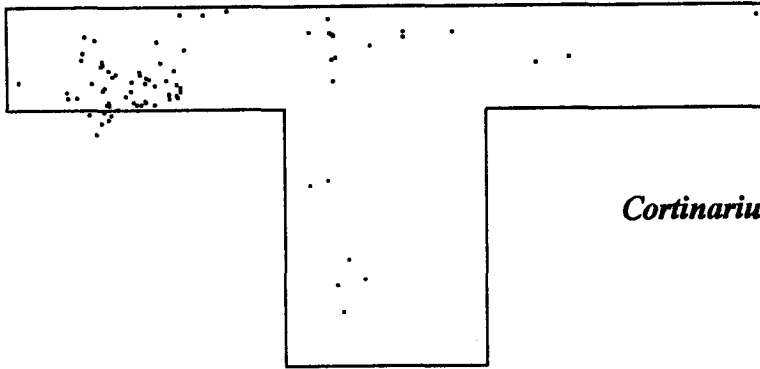
Hebeloma repandum

Fig. 32: continued.

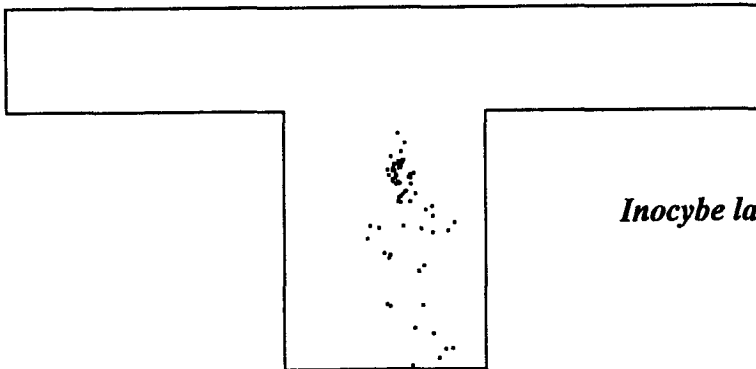


plot 7 (*Salicetum*)

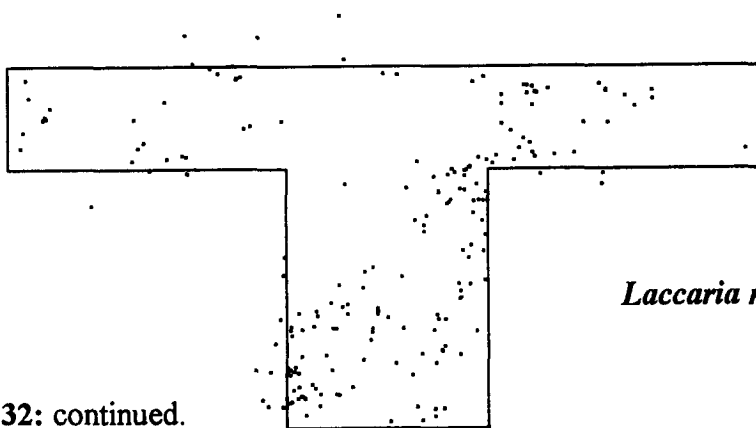
isochrones from
1988 - 90



Cortinarius diasemospermus

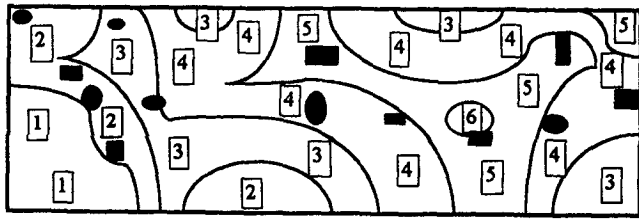


Inocybe lacera



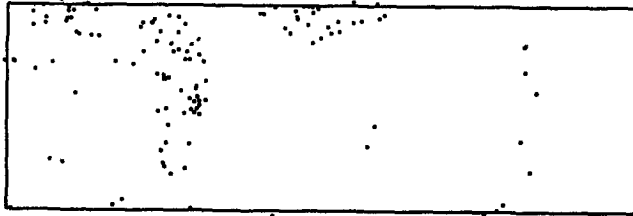
Laccaria montana

Fig. 32: continued.



plot 13 (*Salicetum*)

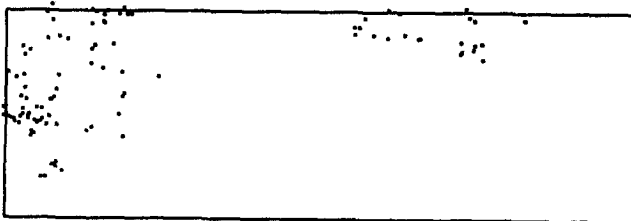
isochiones from 1988 - 90



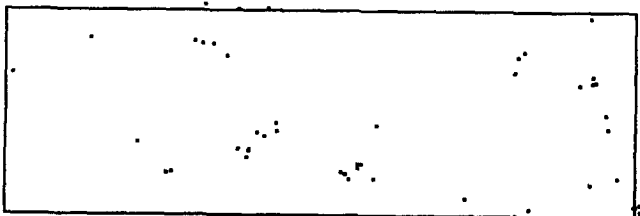
*Cortinarius
favrei*



*Cortinarius
diasemospermus*

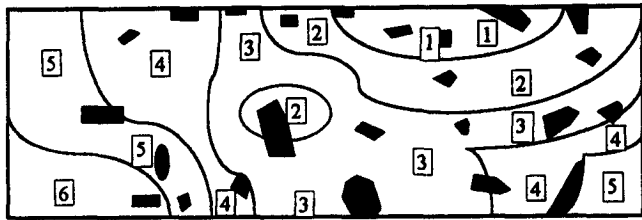


*Entoloma
alpicola*



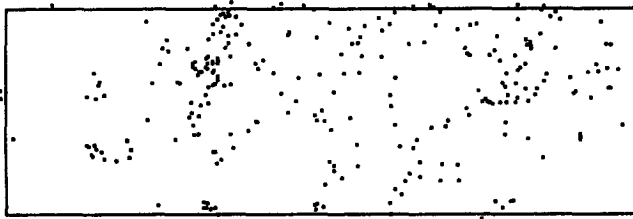
*Laccaria
montana*

Fig. 32: continued.



plot 8 (*Polytrichetum*)

isochrones from 1988 - 90



*Galerina
chionophila*



*Psilocybe
chionophila*

Fig. 32: continued.

Plot 13: In this plot the situation was not evident straightway (Fig. 32). Furthermore, data for isochrones were fewer than for the other plots because the installation took place only during the first vegetation period under review (28. August 1988). However, some tendencies have been recognized. *Cortinarius favrei* predominantly occurred in zones becoming snow-free rather late during the melting process, whereas *Cortinarius diasemospermus* clearly preferred spots becoming snow-free at the end of this event. The main occurrence of *Entoloma alpicola* was mostly registered in areas where the snow-melting process started early. *Laccaria montana* was constantly observed in regions where snow disappeared neither early nor late.

Plot 8: In the *Polytrichetum* plot both dominant species, viz. *Galerina chionophila* and *Psilocybe chionophila* were mapped with a preference for places where snow melted not too early and not too late. Whereas the latter taxon was restricted to these regions, the former species also occurred at spots becoming snow-free early.

Some of the relationships between the individual taxa and the isochrone mapping occurred in all the *Salicetum* plots. *Inocybe lacera* was found only at places where snow melted latest. Conversely, *Cortinarius rufostriatus*, *Dermocybe crocea*, *Entoloma alpicola*, *Hebeloma marginatum*, *I. calamistrata* and *Laccaria proxima* were only registered in the zones which were snow-free earliest. Furthermore, some taxa showed distinct preferences without having been restricted to a certain category. *Cortinarius favrei*, *H. repandum*, *L. montana* and *Russula norvegica* were predominantly registered in zones becoming snow-free towards the end of the melting process. *Astrosporina boltonii*, *A. giacomii*, and *C. chrysomallus* on the other hand occurred mainly in spots where the winter snow pack disappeared rather early. The merely fragmentary results of this particular investigation should be understood as an attempt better to comprehend differences in distribution patterns of ectomycorrhizal macrofungi associated with the host plant *Salix herbacea*.

3.8. ECTOMYCORRHIZA

3.8.1. Synthesis experiments with *Salix herbacea* and *Hebeloma repandum* compared with natural ectomycorrhizae

The *Salix herbacea*-*Hebeloma repandum* system had typical ectomycorrhizal rootlets, after 11 months under sterile conditions in the Erlenmeyer flasks and after 15 months in the pot, maintained in a greenhouse. The two-layered mantle structure and the paraepidermal Hartig net (Fig. 33) were more or less identical in both synthesized samples corresponding to the examined natural ectomycorrhiza. Concerning *Hymenogaster saliciphilus* no synthesis experiments were carried out because of lack of sufficient inoculum material (extremely low growth rate, see GRAF & HORAK 1993). Furthermore, *Cortinarius favrei* did not develop ectomycorrhizal structures neither in the Erlenmeyer flasks under sterile conditions nor in the pots maintained in the greenhouse. More results about ectomycorrhizal synthesis experiments and producing of cuttings are the subject of a further publication (GRAF & BRUNNER, manuscript in prep.)

Examined natural ectomycorrhiza types confirm that the structure of the above-mentioned *Hebeloma* synthesis is probably developed by most of the fungal partners of *S. herbacea*. It seems obvious to assume that the ectomycorrhizal structures are mainly dependent on the host plant. This is in accordance with observations of ANTIBUS et al. (1981) who examined synthesized and natural ectomycorrhizae of *Salix rotundifolia*. Synthesis experiments with aspen resulted in comparable assumptions (GODBOUT & FORTIN, 1985).

The examined natural ectomycorrhizae of *S. herbacea* with *H. repandum*, *C. favrei*, *Dermocybe crocea*, *Laccaria montana*, *Entoloma alpicola* and *Cenococcum geophilum* showed similar structures as the synthesis with *H. repandum* i.e. a two-layered mantle and a paraepidermal Hartig net.

3.8.2. Cuttings of *Salix herbacea*

Cuttings from naturally grown, as well as from plants maintained under sterile conditions, grew well. Fifteen months after inoculation of *H. repandum*, typical ectomycorrhizal structures have been formed. Several generations of leaves have been developed in both systems, with and without inoculation of *H. repandum*. However, there was a significant higher production of third generation leaves in the pot where *H. repandum* inoculum was added and ectomycorrhiza has been established.

During the first and second generation the plantlets grew all in vertical direction. Only at the end of the second and then with the developing of the third

leaf generation the plants did start to creep horizontally as they do in nature (Fig. 34).

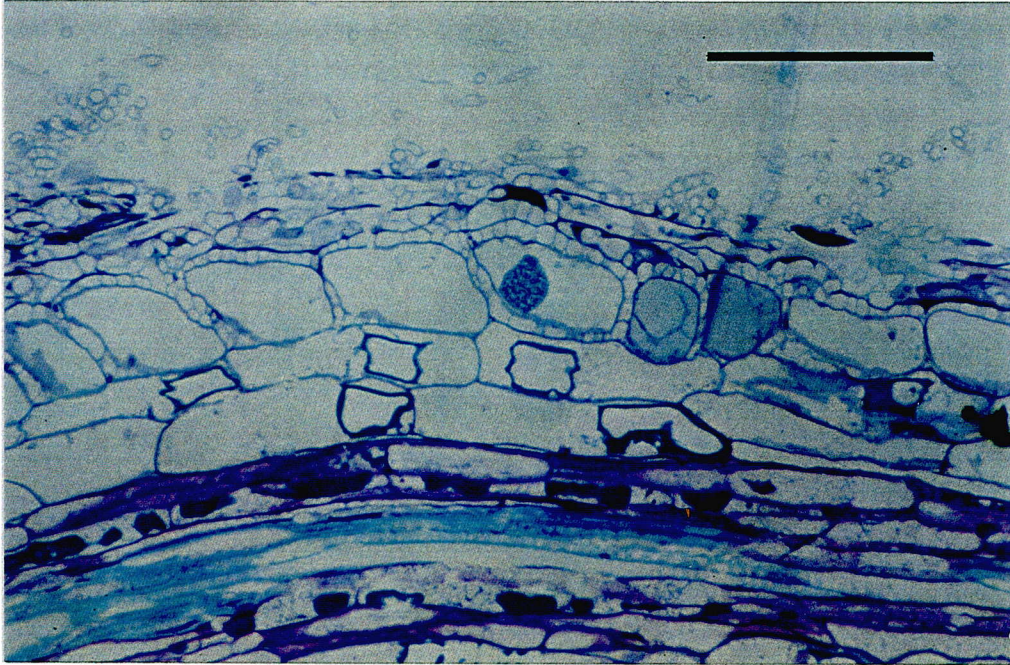


Fig. 33: Light micrograph of a longitudinal section of synthesized ectomycorrhiza of *Salix herbacea* with *Hebeloma repandum*. Fungal hyphae form a two layered mantle and an epidermal Hartig net. Scale bar = 50 μ m.



Fig. 34: Cuttings of *Salix herbacea* at the age of 12 months with the third leaf generation showing the typical leathery context. Most plantlets demonstrate their characteristic crepey growth habit. Scale bar = 1 cm.

4. DISCUSSION

4.1. SIZE OF THE INVESTIGATION PLOTS AND PERIOD OF OBSERVATION

During three years (1988-90) nine plots in snow-bed communities (*Salicetum herbaceae*, *Polytrichetum sexangularis*) and one plot each in four closely related plant associations (*Eriophoretum scheuchzeri*, *Oxyrietum digynae*, *Caricetum curvulae*, *Loiseleurio-Cetrarietum*) were investigated mycoecologically and mycosociologically. In the six plant communities the total of 94 registered macromycetes (cf. chapter 3.4.1., Tab. 20) were distributed as following:

<i>Eriophoretum scheuchzeri</i>	(1 plot: 87 m ²)	6 spp.
<i>Oxyrietum digynae</i>	(1 plot: 87 m ²)	16 spp.
<i>Salicetum herbaceae</i>	(6 plots: 596 m ²)	69 spp.
<i>Polytrichetum sexangularis</i>	(3 plots: 303 m ²)	23 spp.
<i>Caricetum curvulae</i>	(1 plot: 87 m ²)	4 spp.
<i>Loiseleurio-Cetrarietum</i>	(1 plot: 87 m ²)	22 spp.

Investigations in lowland habitats, both in forests (GRIESSER 1992) and in grasslands (BRUNNER 1987), confirm that data about the mycoflora registered in well defined plots generally depend on the size of the area investigated, on the duration of the observation period and on the frequency of the excursions during the vegetation period. For representative studies of macromycetes in forests WINTERHOFF (1984) proposes 1000 m² and a period of three years with periodical excursions as the necessary minimum. Several years of observation in grasslands following these propositions resulted in 50% (WINTERHOFF 1975) and 84% (BRUNNER 1987), respectively of the estimated total yield. Such results impressively demonstrate that the approach for investigations of mycoflora varies from case to case. Difficulties in field work, microscopical analysis of the sampled collections, unhomogeneity of the selected plant associations and irregular occurrence and high dispersion of macromycetes seriously influence the selection of appropriate investigation plots and the commitment for the period of observation (GRIESSER 1992, THOEN 1976, WINTERHOFF 1984). Concerning alpine habitats fundamental knowledge in this matter are even more limited (Tab. 31). For comparison with the present study only the investigations of EYNARD (1977) and of SENN-IRLET (1987) can be taken into consideration. Additional conclusions may be taken from the pioneer work of Jules FAVRE (1955) and, to a certain degree also from the investigations made in the arctic area by PETERSEN (1977). However, EYNARD (1977) was the only one who focused his interests specifically on the macromycetes in

snow-bed communities with *Salix herbacea*. Conversely, the *Salicetum herbaceae* was only a part of more extensive research projects for the remaining authors and, therefore, not treated with the same thoroughness.

Table 31: Relationships between number of plots, size of the investigated area, number of investigation years and excursions with the yield of species registered in snow-beds with *Salix herbacea* based upon data from five authors. ❶ = investigation area in the alpine zone of the SNP (no permanent plots); ❷ = sampling took place mainly in August; ❸ = three sites with 10 plots of 1 m² each; ❹ = number of the excursions in the second investigation year (1976), no exact information about the first year (1975); ❺ = number of investigation years and excursions varied from plot to plot.

Author	plots	total m ²	years	excursions	number of taxa	min./max. number of taxa per plot
FAVRE (1955)	❶	❶	13	❷66	44	---
PETERSEN (1977)	❸30	30	3	51	25	5 / 15
EYNARD (1977)	7	230	2	❹13	39	10 / 21
SENN-IRLET (1987)	3	128	❺5	❺13	25	5 / 16
GRAF (present study)	6	596	3	47	69	19 / 43

Neither FAVRE's (1955) 66 excursions distributed over 13 years and mostly carried out during August throughout the alpine zone of the SNP, nor the investigation of the 30 plots (1 m² each) of PETERSEN (1977) resulted in the highest expected species numbers. Besides a high number of excursions and plots, important conditions are also the appropriate size of the patches and their permanent status in homogenous plant associations, periodical excursions in a high frequency (one- to two-weekly) during the entire snow-free vegetation period, and an observation period of at least three years. Within this scope the results of the present study proceeded from a distinctly higher diversity compared with the above mentioned investigations, which, and this has to be emphasized, are partly first results of more extensive research projects.

The limiting parameter for the plot size in alpine search of macromycetes is undoubtedly the homogeneity of coherent corresponding plant associations. In the case of snow-beds and alpine meadows it should be possible to find places of rather homogeneous patches between 30 m² and 50 m². With the proposition of a sufficient but necessary investigation area totalling about 300 m² this would require between six and ten permanent study plots. The recommended minimum observation period of three years is based on the propositions of WINTERHOFF (1984) and on the experience of this study. It is assumed that in most years the diversity of macromycetes is rather a poor reflection of its entirety, and that the maximum aspect is achieved only every fifth year in lowland communities (WINTERHOFF 1984) and about every seventh year in the alpine zone (HORAK pers. comm.). These problems suggest the need of long-

term investigations (HORAK 1985, HORAK & RÖLLIN 1988) to get representative results, especially regarding the alpine mycoflora. Considering these aspects, the present study would have been definitely more complete with additional investigation years. Concerning the list of macromycetes, this is confirmed by the fact that in the third (last) year of the investigation again 14 new taxa (20%) were registered in the six *Salicetum* plots (cf. chapter 3.5.2.; Fig 19 b). However, the interest to present first data without delay for practical use as for restoration in alpine habitats, and lacking financial support on the part of science, prevented a continuation of this project.

4.2. MYCOFLORA AND ENVIRONMENTAL PARAMETERS

4.2.1. Soil and vegetation

The chemical and physical soil properties and the corresponding vegetation of a site are important conditions for the particular composition of macromycetes (GRIESSER 1992, TURNER & BLASER 1977).

Soil: The edaphic parameters directly influence the occurrence of terricolous taxa. In this connection it is usually differentiated between species with a wide ecological amplitude concerning soil reaction (pH), nutrient content and soil humidity. Accordingly, these taxa are registered in various habitats and are usually geographically widely distributed. Conversely, soil specific macromycetes are closely related to clearly defined soil parameters. Therefore, their occurrence are indicators for particular soil characteristics. Similar to the indicator values of the phanerogams (LANDOLT 1977) especially ectomycorrhizal and terricolous-saprobic macromycetes are suitable for ecological differentiation (GRIESSER 1992). However, so far, limited data are available only for sites in lowland representatives. Concerning the *Salicetum herbaceae* in the Alps, information is fragmentary. Nevertheless, based on mapping data of the present study and the experience of five years in alpine mycology of snow-beds some indications may be drawn: *Astrosporina boltonii*, *A. mundula*, *Cortinarius anomalus*, *C. chrysomallus*, *C. cf. gausapatius*, *C. pauperculus* and *Russula norvegica* are the most characteristic species in sites of low humus content and low pH values. Taxa preferring low pH conditions, but less specific regarding the humus content, are *C. cf. pertristis*, *Hebeloma marginatulum*, *H. repandum* and *Inocybe peronatella*. A relatively high nitrogen and phosphate amount was positively correlated with the clustered occurrence of *C. cf. pertristis*, *Entoloma alpicola*, *H. marginatulum* and *H. repandum*. For further investigations additional data of the most common macromycetes registered in

co-occurrence with *S. herbacea* are presented in chapters 3.2.1., 3.4.1. and 3.5.5. However, information about soil specific characteristics given for the following species will certainly be increased with proceeding research. Additional references for comparison are found in: DEBAUD (1983), EYNARD (1977), FAVRE (1955), GULDEN (1975), GULDEN et al. (1985), GULDEN & LANGE (1971), HØILAND (1983), HORAK (1987 a), KÜHNER (1975 b), LAMOURE (1977 a, 1978, 1984), LAMOURE et al. (1982), PETERSEN (1977), SENNIRLET (1987).

1. *Astrosporina boltonii*: Mostly restricted to typical snow-bed communities (*Salicetum herbaceae*, *Polytrichetum sexangulare*), rarely also in other plant associations with scattered *Salix herbacea* (*Loiseleurio-Cetrarietum*); on acid soils (pH: 3.5-4.0), with poor to medium nutrient availability (N, P); on rather wet to moist soils, occasionally at places with sporadic dryness.
2. *Astrosporina giacomii*: Restricted to the *Salicetum herbaceae*; on acid soils (pH: 3.3-4.5), with poor to medium nutrient availability (N, P); preferably at rather dry spots.
3. *Cortinarius chrysomallus*: Restricted to the *Salicetum herbaceae*; on acid soils (pH: 3.5-5.0), with mostly poor nutrient availability (N, P); preferably at moist (occasionally even wet) spots.
4. *Cortinarius diasemospermus*: In co-occurrence with *Salix herbacea* in different plant associations; on acid to nearly neutral soils (pH: 3.3-6.0); with poor to rather good nutrient availability (N, P); indifferent to soil humidity.
5. *Cortinarius favrei*: Predominantly in co-occurrence with *Salix herbacea* but also reported in association with *S. retusa* and *S. reticulata* on calcareous soils in different plant associations; on acid to basic soils (pH: 3.3-7.6); with poor to rather good nutrient availability (N, P); indifferent to soil humidity.
6. *Cortinarius glandicolor* var. *exilis*: Predominantly in co-occurrence with *Salix herbacea* but also reported in association with *S. retusa* and *S. reticulata* on calcareous soils in different plant associations; on acid to basic soils (pH: 3.3-7.5); with medium to rather good nutrient availability (N, P); preferably at drier places but also rather frequent at moist spots.
7. *Dermocybe cinnamomeolutea*: Mostly restricted to typical snow-bed communities (*Salicetum herbaceae*, *Polytrichetum sexangulare*) rarely also in other plant associations with scattered *Salix herbacea* (*Loiseleurio-Cetrarietum*), occasionally reported in association with *S. polaris* and *Alnus incana*; on acid to nearly neutral soils (pH: 3.5-6.0), with mostly poor (to medium) nutrient availability (N, P); preferably on rather dry soils.
8. *Entoloma alpicola*: Restricted to the *Salicetum herbaceae*; on acid soils (pH: 3.7-5.0), with rather good nutrient availability (N, P); preferably at moist spots.
9. *Galerina chionophila*: Exclusively associated with *Polytrichum sexangulare* in typical snow-bed communities (*Salicetum herbaceae*, *Polytrichetum sexangulare*), on acid soils (pH: 3.5-4.5), with poor to medium nutrient availability (N, P), on moist to wet soils.
10. *Hebeloma marginatulum*: Found throughout the alpine belt associated with *Salix* spp. or *Dryas octopetala*; on acid to basic soils (pH: 3.3-7.8), with rather good nutrient availability (N, P); preferably at dry to slightly moist places.

11. *Hebeloma repandum*: Restricted to the *Salicetum herbaceae* but also (accidentally ?) reported in association with calciphilous *Salix* spp.; on acid soils (pH: 3.3-4.5 [-6.5?]), with poor to rather good nutrient availability (N, P); preferably at rather moist spots.
12. *Inocybe calamistrata*: Restricted to the *Salicetum herbaceae*; on acid soils (pH: 3.7-5.0), with rather good nutrient availability (N, P); preferably at moist spots.
13. *Inocybe lacera*: Restricted to the *Salicetum herbaceae* but also once (accidentally ?) reported with calciphilous *S. retusa*.; on acid soils (pH: 3.3-5.5), indifferent to nutrient availability (N, P); preferably at moist spots.
14. *Laccaria montana*: Found in different plant associations always associated with *S. herbacea*; on acid soils (pH: 3.3-4.5), indifferent to nutrient availability (N, P); preferably at moist to wet spots, occasionally also at rather dry places.
15. *Laccaria proxima*: Found in different plant associations with preferably dry soils, viz. *Caricetum curvulae*, *Loiseleurio-Cetrarietum*, always associated with *S. herbacea*; on acid soils (pH: 3.3-4.5), with medium to rather good nutrient availability (N, P); preferably at dry places.
16. *Psilocybe chionophila*: Exclusively associated with *Polytrichum sexangulare* in typical snow-bed communities (*Salicetum herbaceae*, *Polytrichetum sexangularis*), on acid soils (pH: 3.5-4.5), with poor to medium nutrient availability (N, P), on moist to wet soils.
17. *Russula chamiteae*: Mostly restricted to the *Salicetum herbaceae* but rarely also in the *Loiseleurio-Cetrarietum* associated with scattered *S. herbacea*; on acid soils (pH: 3.3-4.0), with medium to rather good nutrient availability (N, P); preferably at dry places.
18. *Russula norvegica*: Found in different plant associations with *S. herbacea*, occasionally reported also in co-occurrence with calciphilous *Salix* spp.; on acid to slightly basic soils (pH: 3.3-6.5), indifferent to nutrient availability (N, P); preferably at moist to wet spots, rarely at less humid places.
19. *Russula pascua*: Mostly restricted to the *Salicetum herbaceae* but rarely also in the *Loiseleurio-Cetrarietum* associated with scattered *S. herbacea*; on acid soils (pH: 3.3-4.0), with poor to rather good nutrient availability (N, P); at rather moist places.

One of the most limiting parameters in plant growth is the availability of nitrogen (PERRY et al. 1987). Various genera of bacteria fix nitrogen under the low oxygen tensions that occur in rhizospheres (FLORENCE & COOK 1984, GILLER & DAY 1985), and N-fixation may sometimes be enhanced by, or totally dependent on mycorrhizae (READ et al. 1988). Investigations of MOIROUD (1984) in marginal areas of glacier forefronts demonstrated that cyanobacteria were often present in deglaciated areas but the increase in nitrogen due to these free living nitrogen fixing organisms was extremely low or zero. The most important portion in freely disposable nitrogen resulted nearly exclusively from symbiotic bacteria of *Trifolium* spp. However, this genus and in fact the family of *Leguminosae* is not represented in the investigated area. In recent works the role of microbial grazers in cycling nutrients was examined (ANDERSON et al. 1985, CLARHOLM 1985 a, b, CURRY et al. 1985, INGHAM et al. 1985). The work consistently shows that nematodes, protozoa, amoebae, and microarthropods grazing fungal mycelia accelerate the release of nitrogen in a form

available to plants. PERSSON (1983) showed that nutrient fluxes resulting from grazing can be significant. A similar situation may be expected in alpine snow-bed communities where nitrogen fixation by bacteria is presumably low as mentioned by MOIROUD (1984) for pioneer sites on recently deglaciated soils. Therefore, regarding alpine restoration it may be important to focus research also on the soil fauna in connection with nutrient cycling. ABUZINADA & READ (1986) proved that ectomycorrhizal macromycetes are able to use ammonium, some amino acids, and protein as nitrogen sources in pure culture. The aptitude to use different nitrogen sources is decisive especially regarding the location of ectomycorrhizal roots. In alpine snow-beds this is primarily in the upper soil horizon, where microbial populations and decaying organic material are located and, therefore, much of the nitrogen available would be present in protein or other organic nitrogen compounds.

Vegetation: Within defined sites there is a close connection between plants and macromycetes. Different plant compositions are reflected accordingly in variations of the mycoflora (ARNOLDS 1981, 1982, DARIMONT 1973, WATLING 1981). The possible occurrence of obligate ectomycorrhizal macromycetes is strictly connected with the presence of the host plants (HARLEY & SMITH 1983, TRAPPE 1962). Furthermore, the presence of decaying organic material is responsible for the potential diversity of saprobic taxa. In the alpine zone ectomycorrhizal macromycetes are significantly more highly represented (FAVRE 1955, SENN-IRLET 1987) than in lowland habitats. Within arctic and alpine plant associations dominated by ectomycorrhizal host plants as *Salix* spp. or *Dryas octopetala* the symbiotic fungal species even occur in an impressive predominance (FAVRE 1955, EYNARD 1977, MILLER 1982, PETERSEN 1977, SENN-IRLET 1993). In snow-beds the number of plants is comparatively low, which implies a reduction of the niche diversity for the litter decomposers. As a result in the *Salicetum herbacea* as well as in the *Polytrichetum sexangularis*, wood-decomposing macromycetes were completely absent, a phenomenon already mentioned by VASSILKOV (1967) for tundra regions. PETERSEN (1977) supposes that the relative paucity in litter decomposing species is a general feature in the macromycete flora of the Arctic. FORD et al. (1980) and RÜCKER et al. (1990) also demonstrated that the mycoflora, especially ectomycorrhizal taxa, of a specific host differs depending on its age. So far, there are no such data available for the alpine zone, but it is assumed that this is also a common phenomenon in high altitude vegetations. An important indication which supports this assumption is traceable to the different yields of macromycetes in the *Salicetum herbaceae* plots and the pioneer vegetation of the *Oxyrietum digynae* with only young and scattered *Salix herbacea* plants (cf. chapter 3.4.1.; Tab 21, 22). In this latter plot the otherwise characteristic represen-

tatives of the genera *Cortinarius* and *Russula* were registered only with one single carpophore each. In contrast, *Hebeloma repandum*, *Inocybe nitidiuscula* and *Laccaria montana*, representatives of so called early stage genera (DEACON et al. 1983, FORD et al. 1980) were registered with considerable abundance.

SENN-IRLET (1987) mentioned that a high diversity in both plants and macro-mycetes is positively correlated. In the present study results rather support the observations of FAVRE (1955) that a well represented or an absent potential ectomycorrhizal host plant as *Salix herbacea* has a lasting effect on the number of occurring macro-mycetes. The investigation of the *Oxyrietum digynae* plot with 30 phanerogams resulted in 16 fungal taxa (cf. chapters 3.3.2., 3.4.2.). In the *Salicetum herbaceae* plot with the poorest diversity in phanerogams (17), 33 macro-mycetes were registered after all. However, within the same plant association (*S. herbaceae*) the highest diversity in phanerogams, mosses, lichens and macro-mycetes was positively correlated. Conversely, this was not true regarding the lowest diversity, for neither the one nor the other of the considered organisms. In all investigated plant associations the number of registered phanerogams surpassed the corresponding species number of macro-mycetes, except in the *Salicetum herbaceae* plots and in the *Polytrichetum sexangularis* plot 10, which formed a transitional stage between these two plant communities. These observations above stand in opposition to the results of EYNARD (1977) and SENN-IRLET (1987, 1988). Differences in the duration of the observation period and in methods of investigation may be an explanation for such divergences. The considerable number of 55 suspected ectomycorrhizal partners of *S. herbacea* found in the six *Salicetum* plots suggests many ecological micro niches mostly independent from plant diversity. During this study the most convincing explanations for the impressive diversity of ectomycorrhizal macro-mycetes of this dwarf willow turned out to be differences in climatic parameters and in the snow conditions (micro-topography) closely linked with the relief of the neighbouring vicinity of the investigated plots (TURNER & BLASER 1977).

There is much controversy about the status of macro-mycetes regarding the sociological characterization of associations (BARKMANN 1968, LISIEWSKA 1974). The identification of communities based on mycosociological data with or without consideration of the phanerogams (ARNOLDS 1988 a, BARKMANN 1976, DARIMONT 1973) seems to be well conceivable. However, especially in the alpine zone, the sporadic occurrence of the macro-mycetes, the lack of well defined characteristic taxa, and the time-consuming efforts to gain sufficient data about the species, still prevent a reasonable application (GRIESSER 1992, WINTERHOFF 1984).

4.2.2. Precipitation and temperature

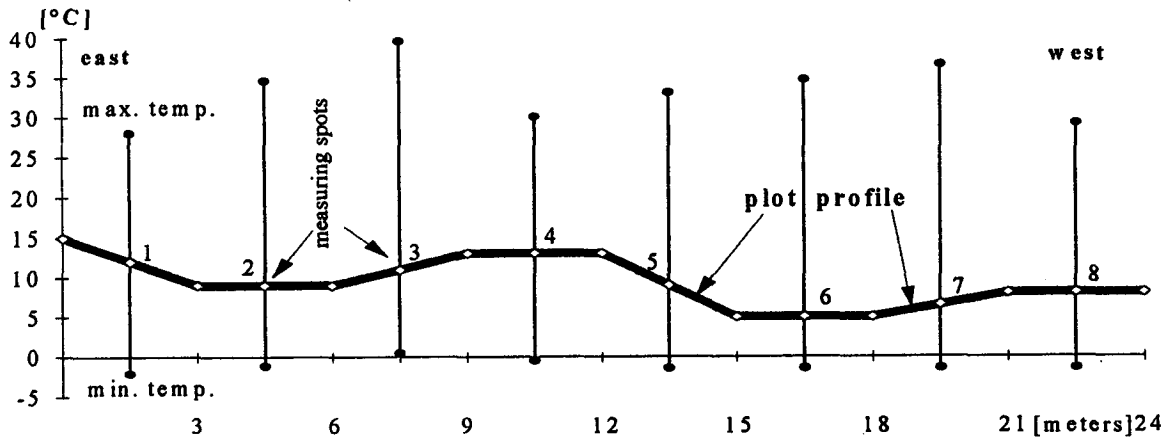
Different authors have attempted to relate climatic data to the phenology of macromycetes. WILKINS & PATRICK (1940) and WILKINS & HARRIS (1946) considered that in different lowland habitats variations during the vegetation period in the occurrence of macromycetes were influenced by environmental parameters including temperature and soil moisture. THOEN (1976) examined the effect of rainfall and soil temperature in areas of conifer scrub, where both parameters affected the phenology and productivity of macromycetes. During ten years LANGE (1978) investigated different areas of beech forests in Denmark considering the productivity of macromycetes. He found rainfall to be an important parameter in explaining carpophore occurrence. AGERER (1985) found distinct correlations between the maxima of weekly mean temperatures and the productivity of ectomycorrhizal macromycetes. Furthermore this author concluded that there exists a positive interaction between the carpophore productivity and preceding precipitation. However, ARNOLDS (1988 b) did not find any direct correlation between climatic conditions and the occurrence of carpophores in two heathlands in the Netherlands. EVELING et al. (1990) found a more or less positive correlation between productivity of macromycetes and precipitation with the maximum correlation occurring for a lag of 12 weeks using the mean value for precipitation over the preceding eight weeks. The data these results are based upon resulted from a study carried out over 14 years in a forest area in Northern Ireland investigating the environmental effects on carpophore productivity.

Precipitation: Based on the short investigation period of three years, the present study indicates a positive correlation between carpophore productivity and precipitation with a two to three-week lag for ectomycorrhizal macromycetes and a lag of about one week for saprobic (parasitic) species (AGERER 1985, AGERER & KOTTKE 1981, EVELING et al. 1990). However, in the alpine zone it was observed that such a correlation seems to depend on the time of the melting process of the winter snow pack (EYNARD 1977) and on snowfall during the early vegetation period (cf. chapters 3.1.4.; 3.5.4.). An early start of winter and a late thaw in the following spring as was observed in autumn 1989 and spring 1990, may prevent the production and development of primordia, respectively and result in a different response of the macromycetes regarding precipitation at the beginning of the fructification season (SENN-IRLET 1987). As precipitation in the research area does not seem to be a limiting parameter, it is hardly possible to estimate its effective influence on carpophore productivity (PETERSEN 1977). Differences in the influence on the carpophore productivity between rain and snowfall were not evident at first sight. HORAK (1963)

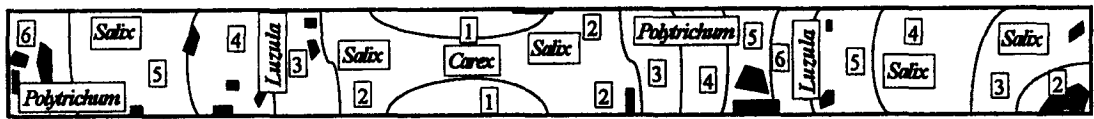
mentioned that precipitation in form of snow is more stimulating for fructification because the water quantities are greater and last longer than in the case of rainfall. Similar observations were made with snowfalls in the second period of the vegetation period (mid-August until start of winter). However, heavy snowfall at the beginning of the vegetation period (July to mid-August) resulted in a decrease of the carpophore productivity of ectomycorrhizal species (EYNARD 1977).

Maximum and minimum temperatures: Arctic and alpine Agaricales are well adapted to the harsh conditions of their habitat. Several investigations have revealed that typical alpine representatives of a genus have their growth optimum at considerably lower temperatures than their lowland relatives (MOSEER 1958, DEBAUD 1983, EYNARD 1977). PETERSEN (1977) found macromycetes in the arctic Godhavn area even when at the soil-litter interface the minimum temperature fell to below zero and the maximum temperature did not exceed 7.5 to 12.5 °C. The results of DEBAUD (1983) who demonstrated a significant relationship between remarkable drops of maximum temperatures and the occurrence of saprobic *Clitocybe* spp. in alpine habitats were confirmed in the present study for saprobic (parasitic) macromycetes occurring in July and August of the vegetation period. Furthermore, it was observed that carpophores were formed regardless of the negative weekly minimum temperatures during the entire fructification season. However, the main fructification batch of the ectomycorrhizal species associated with *Salix herbacea* started about three weeks after the weekly minimum temperature rose to above zero for the first and only time during the vegetation period (cf. chapter 3.5.4.3.). The speculation of HORAK (1963) that frosts in combination with snow may stimulate the development of primordia was not confirmed during the present study. In the alpine zone, where temperatures below freezing point occur nearly weekly in the fructification season and snowfall is a common phenomenon during the entire vegetation period, this hypothesis is still open to discussion. Comparing the mapping cards of selected ectomycorrhizal macromycetes with the results of a 28-hour measuring period of extreme temperatures read every hour, unregistered particular relationships (Fig. 35, I, II, III, IV). *Cortinarius favrei*, *Inocybe lacera* and *I. peronatella* predominantly occurred at the spots with the least differences in extreme temperatures. In the case of the two taxa of *Inocybe* this was in combination with long snow covering [II], whereas *C. favrei* was registered at places where snow disappeared early [I] in the season. *Laccaria montana* and *Russula norvegica* were mapped at places with high, as well as with low temperature amplitudes. However, the former was located predominantly at the periphery of well established *Salix herbacea* patches [III]. In contrast, the latter taxa and *C. favrei*, locally dominated the centres of

a)



b)



c)

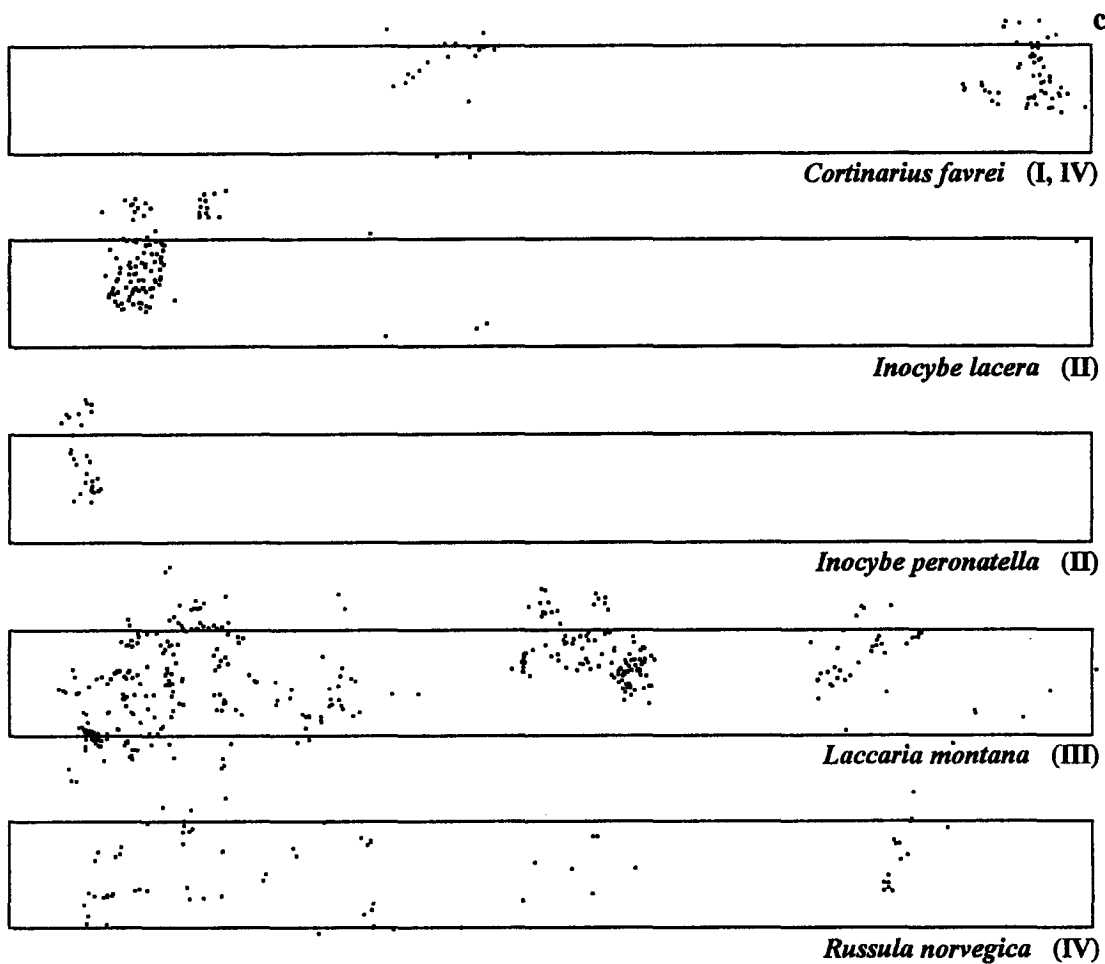


Fig. 35: Plot 11 (transsect): a) Extreme temperatures at eight (1-8) spots during a 28 hour measuring period (cf. chapter 3.1.2.4.; Fig. 8); b) Isochionenes (1= early, 6= late snow-free) from 1988 to 1990 (cf. chapter 3.1.4.2.; Fig. 11) and characteristic plants with their dominating spots; c) Mapping cards of ectomycorrhizal macromycetes (1988-89). I, II = at early, late snow-free spots; III, IV = early, late stage ectomycorrhizal partners.

the dwarf willow's distribution [IV]. Therefore, it may be speculated that *L. montana* is better adapted to high fluctuations in temperature and / or is a more competitive ectomycorrhizal symbiont of *S. herbacea* under pioneer conditions as an early-stage partner [III]. Conversely, *C. favrei* and although less distinctly *R. norvegica* represent the late-stage ectomycorrhizal macromycetes [IV] associated with *S. herbacea* (FORD et al. 1980, MASON et al. 1983).

4.2.3. Snow-melting zones (isochiones)

Among the rather rare ecological and sociological investigations considering alpine or arctic macromycetes only few went through the question about the influence of snow on the productivity and fructification behaviour of macromycetes. Both, EYNARD (1977) in the French Alps and PETERSEN (1977) in the arctic area of Godhavn, registered that a late disappearance of the winter snow pack was correlated with a decrease of the carpophore productivity in snow-bed communities. This phenomenon was observed especially in connection with ectomycorrhizal taxa. During the present study the postponement in 1990 of about one week of the melting process into the vegetation period had no negative influence on the productivity of ectomycorrhizal macromycetes. It seems more likely to be the influence of lower extreme temperatures and heavy snowfalls during the first few weeks (July to mid-August) of the vegetation period in 1989 that were mostly responsible for a low productivity of the symbiotic fungal species. A possible explanation may be the disturbance of the host plant development (*Salix herbacea*) at the beginning of the vegetation period. In 1989, consequently the dwarf willow reached maturity (seed production) about two weeks later than in 1988 and 1990. This delay eventually resulted in a postponement of the fructification process into late summer with unfavourable climate conditions, viz. low extreme temperatures and considerable snowfalls (cf. chapters 3.5.1.; 3.5.4.). As a result, the productivity of ectomycorrhizal macromycetes was distinctly lower than in the two other vegetation periods under review. Nevertheless, the saprobic (parasitic) species were rather stimulated by such conditions and responded with maximum carpophore productivity in 1989. This substantial increase in carpophore productivity was mainly due to *Psilocybe chionophila*, a weak parasite of the moss *Polytrichum sexangulare*. In this case the uncommonly harsh climatic conditions may have reduced the resistance of the moss against its parasite, resulting in more easily available nutrients and increasing the sexual reproduction of *P. chionophila*.

With help of the mapping cards it was observed that there might be a relationship between the snow-melting zones (isochiones) and the distribution patterns

especially of the ectomycorrhizal macromycetes. Throughout the *Salicetum* plots it was registered that certain symbiotic partners occurred predominantly at places where snow melted early and late in the season, respectively (GRAF & BRUNNER 1994). *Inocybe calamistrata*, *Entoloma alpicola* and *Hebeloma marginatum* are examples of the former group, whereas *Astrosporina boltonii*, several representatives of the genus *Cortinarius*, *Inocybe lacera* and *Hebeloma repandum* belong to the latter (cf. chapter 3.7.3.). Differences in time of thaw are correlated with the time available for the development of the ectomycorrhizal host plant *Salix herbacea*. The later the winter snow pack disappears, the less time is at hand for maturation. Plants which start their vegetation period later in the season find a different situation in nutrients, less favourable climate conditions, and more competitive pressure from those plants which started their development earlier. The fact that *S. herbacea* shows particular differences in the composition of ectomycorrhizal species in connection with isochiones (Fig. 35) raises the assumption that certain symbiotic partners of the dwarf willow are more competitive in sites with long snow covering. Furthermore, in the case of *Laccaria montana*, which was registered nearly everywhere in association with *S. herbacea*, it was observed that clustered occurrence of its carpophores was mostly restricted to border zones of the dwarf willow (Fig. 35, III) with mostly extreme climatic or edaphic conditions (snow-covering, soil properties, max.-min. temperatures). At places with well established patches of *S. herbacea* there was a significantly lower productivity of this macromycete. Similar observations were made for *Hebeloma* spp. and *Inocybe* spp. Conversely, *Cortinarius* spp., especially *C. favrei*, and *Russula* spp. (Fig. 35, IV) showed the opposite behaviour. These observations confirm their status as early and late-stage ectomycorrhizal partners, respectively (FORD et al. 1980).

4.3. STATISTICAL EVALUATION

The spatial pattern of ectomycorrhizal macromycetes of one and the same host plant (*Salix herbacea*) within a defined area seems to be an important characteristic of ecological communities. Three basic types of patterns are recognized in communities: random, clumped, and uniform. Random patterns in a population of organisms imply environmental homogeneity and / or nonselective behavioural patterns. On the other hand, non-random patterns, viz. clumped and uniform imply that some constraints on the population exist (LUDWIG & REYNOLDS 1988). Clumping suggests that individuals are aggregated in special niches of the habitat, which may be due to environmental heterogeneity, climatic differences or other reasons. Uniform dispersions result from negative inter-

actions between individuals. However, it should be kept in mind that nature is multifactorial; so many interacting processes (biotic and abiotic) may contribute to the existence of distribution patterns (QUINN & DUNHAM 1983). Depending on whether or not two species predominantly occur in close relationship, a certain pattern of interspecific association results. For studying the association of fungal species the chi-square (X^2) test statistic proposed by PIELOU (1977) has been very popular in ecological and sociological studies of macromycetes (BIERI & LUSSI 1989, BILLS 1985, FORD et al. 1980, GRIESSER 1992). Nevertheless, results based on this test should be interpreted with a certain care because it should be performed only on condition that the two species tested occur with the same probability among the sample units (FORD et al. 1980). In many cases, though regarding mycoecology, this condition is not met. In addition, depending on the size and shape of the sample unit, it is possible to influence the outcome of association. Such results, therefore can only be taken as indications of a trend in patterns. Furthermore, studies of interspecific association should consider not only the X^2 -test but also a measure (association indices) of the degree of strength of the association (BILLS 1985, LUDWIG & REYNOLDS 1988).

In the present study it has been demonstrated how vague the results of the X^2 -test may turn out in the case of distinctly deviating distribution-patterns among the species compared (cf. chapter 3.6.1.). Furthermore, the necessity of an association index (Dice, Jaccard, Ochiai index) has been illustrated in an impressive manner and it may be assumed that an analysis of interspecific association based only on the X^2 -test is not convincing. This speculation is further endorsed by the mapping cards and with the results of the correspondence analysis performed for selected plots (cf. chapter 3.7.1.). To sum up: the analysis of interspecific association data of ecological and sociological studies of macromycetes and especially of ectomycorrhizal species should be evaluated preferably with help of the correspondence analysis.

An important but often neglected parameter is the planning stage of mycosociological projects is the size and shape of the permanent investigation areas. With regard to statistical evaluation, care should be taken to choose plots of the same size and shape (BILLS 1985). In this study, three different contours were selected which later seriously aggravated the application of statistical methods and prevented direct comparison of the plots. Furthermore, carpophores occurring within one meter outside the plot borders were also considered for mapping resulting in deviations of the mapped surface per plot.

Such contradictions could easily be prevented by paying more attention to the planning stage of a research project. Evaluation of data should not only be discussed at the end of the field research, but also assist as a main support for drawing up the project.

4.4. THE PLANT- AND FUNGUS-SYSTEM (PFS)

In recent years different strategies for alpine restoration have been tested and described (CHAMBERS et al. 1984, 1988, GRABHERR et al. 1988, SCHÖNTALER 1980, STIMPFLI 1985, URBANSKA 1986, 1988, 1990). Concomittant numerous investigations have been carried out checking the aptitude for high altitude revegetation of many plant species (CHAMBERS et al. 1987, FLÜELER 1992, HASLER 1992, SCHÜTZ 1990). However, in this connection, only little is known so far about the fitness of ectomycorrhizal host plants and their fungal partners naturally established throughout the alpine zones. The present study has attempted to lay foundations for alpine restoration with such plant- and fungus-systems (PFS). Of the 55 macromycetes suspected to form ectomycorrhiza with *Salix herbacea* only a few are expected as potential and powerful partners for alpine restoration in combination with the dwarf willow. The main criteria for the selection are based on a wide distribution throughout the alpine zone, to form ectomycorrhiza under non-natural conditions, the ability to obtain auxenic cultures, and taxonomically more or less well defined species. Guided by these propositions the following PFS are proposed as potential for renaturation in the alpine zone where siliceous parent material is dominant: *Salix herbacea*-*Cortinarius favrei*, -*Entoloma alpicola*, -*Hebeloma marginatum*, -*H. repandum*, -*Hymenogaster saliciphilus*, -*Inocybe lacera*, -*Laccaria montana* and -*Russula norvegica*.

4.4.1. Plant material

There are not many alpine plants suitable for restoration on siliceous rock material and among the ectomycorrhizal dwarf shrubs only *Salix herbacea* theoretically fits the high demands of such a "mission".

This dwarf willow, adapted to long snow covering, shows a growth habit cut out to be a powerful tool for alpine restoration. Whereas only the young shoots and the leaves cover the ground as a low carpet, the woody branches and stems grow subterranean like the entire root system. This peculiar life form is an important parameter for survival on alpine ski slopes. There, snow lasts longer than normal, due to artificial compactness of the snow caused by ski run preparation. Furthermore, considerable danger of damage through ski edges has to be taken into consideration. Although in *S. herbacea* the vegetative propagation of about 30% (SCHIECHTL 1992) is relatively low compared with other representatives of the genus (*S. purpurea*, *S. daphnoides* up to 100%), it is, however, the second best considering alpine dwarf willows, surpassed only by *S. reticulata* (40-50%) on calcareous soils. Without any pre-treatment of

the seeds the germination rate under laboratory conditions was between 26% and 57% (GRAF & BRUNNER, manuscript in prep.), which more or less confirms the results of FOSSATI (1980), who found rates between 0% and 62%. Whereas with seeds stored at room temperature, the germination rate was drastically reduced within a few weeks; seeds stored at -20°C in the dark showed no significant loss of their vitality. Such phenomena were also observed by FLÜELER (1992) for *Leguminosae* and for different other plants by VILLIERS (1973) and WAREING (1966). Besides the vegetative and sexual reproduction *S. herbacea* shows a particular ability for producing viable cuttings (GRAF & BRUNNER, manuscript in prep.) a phenomenon known throughout the genus *Salix* (SCHIECHTL 1992). Compared with other phanerogams, this technique is certainly an important advantage of dwarf willows in alpine restoration. Differences in vitality of the produced cuttings were certainly due to deviating dates of the experiments during the life cycle of the mother plants. Since the investigations of GUMPELMAYER (1949) and RASCHENDORFER (1953), it is well known that the vegetative propagation depends on the development stage of the plant during the vegetation period. This rhythm is specific to the taxa and relies on the date of the cutting process (SCHIECHTL 1992). This fact is important for obtaining good results concerning rooting and increase of biomass (SCHIECHTL 1973). Consequently, the cutting process should take place during the wintry interruption of plant development (SCHIECHTL 1958, 1973). Compared with roots of monocotyledones and herbaceous dicotyledones *Salix* spp. are known for their tensile strength (HATHAWAY 1973, HATHAWAY & PENNY 1975), a distinctive and important feature for survival on bare soils typical of ski runs. Experiments of PAUL (1991) in reproducing different calciphilous alpine plants with in-vitro meristem-cultures established mostly promising results. Especially after the impressive success with *Dryas octopetala* it is not excluded that this technique may be of similar success with specific ectomycorrhizal host plants of the genus *Salix* needed for alpine restoration.

4.4.2. Fungal material

Ectomycorrhizae have several ecophysiological functions important to restoration. A very substantial one is that their extramatrical phase extends and interconnects the root system of their host plants. This network greatly increases the ability to absorb nutrients, such as phosphorus and moisture from the soil, especially when they are found in weak concentrations, or are relatively immobile (BIELESKI 1973, HARLEY & MCCREADY 1952, OLSEN & KEMPER 1968). The development of the fungal network and correspondingly the ability of

ectomycorrhizal plants to exploit soil nutrients and moisture depend on both, the macromycetes and the soil characteristics (FINLEY & READ 1986 b, c), and presumably also on the climatic situation, especially regarding the duration of snow covering (cf. chapters 3.1.4.; 3.7.3.). Recent investigations (FINLEY & READ 1986 a, FINLEY et al. 1986) demonstrated that ectomycorrhizal macromycetes interconnected plants of the same or different species and indicated that the carbon flux between the hosts is influenced by source-sink relationships. Ectomycorrhizal plants are further known to absorb more phosphorus (LANGLOIS & FORTIN 1978, 1984) and nitrogen (ALEXANDER & FAIRLEY 1986) than non-mycorrhizal plants. Ectomycorrhizal seedlings are usually more resistant to water stress (DUDDRIDGE et al. 1980, BOYD et al. 1986). Another important function of ectomycorrhizal macromycetes is the production of plant growth regulators and other secondary metabolites (FRANKENBERGER & POTH 1987, HANLEY & GREENE 1987). Besides, the hyphal mantle offers protection to the host plants against feeder root diseases (MARX 1973, PERRIN 1985, STACK & SYNCLAIR 1974). However, this enumeration of important effects of ectomycorrhizae has to be relativated in so far as macromycetes do different jobs for different hosts in different environments, and the diversity of ectomycorrhizal types is likely to contribute to seedling success (PERRY et al. 1987). Determining the most competitive set of ectomycorrhizal partners in a given situation may not be always evident. Therefore, for restoration, native populations should be maintained to assure an appropriate diversity, though seedlings are often confronted with unpredictable varying environments. Where native populations are reduced or non-existent, inoculation with several ectomycorrhizal species is a good strategy only if the set fits the actual conditions. To ensure such suitability intensive studies of the ectomycorrhizal flora of the corresponding host plants is required.

The most limiting parameter in restoration with ectomycorrhizal plants is undoubtedly the fungal partner. The absolute need of the fungal partner for a successful establishment of the plant especially in alpine habitats is confirmed by different investigations showing the distinct superiority of inoculated as against non-inoculated plants (LINDERMANN & CALL 1977, MOSER 1964) Promising revegetation results only if the specific host plant has been previously inoculated with one or several of its alpine ectomycorrhizal macromycetes (KROPP & LANGLOIS 1990, LE TACON 1990, MOSER 1958, 1965). For this reason it is necessary to produce auxenic cultures of the corresponding carpophores which, however, is only possible in a few cases (MOSER 1963 b). Most of the specific ectomycorrhizal species especially alpine strains have not grown under laboratory conditions so far. Until today, only few taxa associated with alpine *Salix* spp. have been successfully cultivated, e.g. *Cortinarius mucosus* (Bull.: Fr.) Kickx., *Entoloma sericeum* (Bull.) Quél., *Hebeloma pusillum* J.

Lange and *Lactarius lanceolatus* O. K. Miller & G. A. Laursen found with *Salix rotundifolia* Trautv. (ANTIBUS et al. 1981). HACSKAYLO and BRUCHET (1972) and DEBAUD (1983) cultivated several *Hebeloma* species (*H. marginatum*, *H. repandum*, *H. alpinum* (Favre) Bruchet, and *H. minus* Bruchet) collected in association with alpine *Salix* spp. or *Dryas octopetala* L. EYNARD (1977) isolated several ectomycorrhizal partners of *S. herbacea* for investigations of mycelium growth in auxenic cultures, viz. *Hebeloma marginatum*, *Cortinarius favrei*, *Dermocybe cinnamomeolutea*, *Entoloma sericeum* and *Lactarius nanus* J. Favre. During the present study three specific ectomycorrhizal taxa of this dwarf willow have been successfully isolated and maintained in auxenic cultures, viz. *C. favrei*, *H. repandum* and *Hymenogaster saliciphilus*. Despite this considerable number of specific alpine ectomycorrhizal species growing in cultures, successful synthesis experiments were carried out but in a few cases. ANTIBUS (1980) synthesized the ectomycorrhiza between *S. rotundifolia* and *E. sericeum* and *H. pusillum*. DEBAUD (1983) obtained the symbiosis between *D. octopetala* and *H. alpinum* and *H. marginatum*. The synthesis between *S. herbacea* and *H. repandum* resulting from the present investigations is the first reported with this dwarf willow and one of its specific alpine ectomycorrhizal partners. It stands to reason that in the case of *S. herbacea*, the way to reach a really powerful tool for alpine restoration is still long and strenuous. Nevertheless, the successful experiments of ANTIBUS (1980) and DEBAUD (1983) with comparable arctic-alpine plants raise hope that with further involvement the PFS set of *S. herbacea* may be completed. According to numerous publications of successful synthesis experiments between *Cortinarius* spp. and both coniferous (AGERER 1987, 1988, Egli 1992) and deciduous trees (GOUSBOUT & FORTIN 1983, 1985) the symbiosis between *C. favrei* and *S. herbacea* may be also promising. A similar scope can be reported for hypogeous macromycetes (MILLER & MILLER 1984, MALAJCZUK et al. 1987 a, b) which convincingly supports ectomycorrhizal synthesis experiments with *Hymenogaster saliciphilus* (GRAF & HORAK 1993). *Inocybe lacera* successfully isolated and tested in auxenic cultures by MOSER (1958) still awaits application for synthesis experiments. *Entoloma alpicola* and *Laccaria montana*, two further important partners of *S. herbacea* with a view to alpine restoration have not yet been isolated and maintained under laboratory conditions. However, prosperous synthesis experiments have been carried out with closely related taxa of both species (ANTIBUS et al. 1981, DANIELSON et al. 1984, GAGNON et al. 1987, MASSICOTTE et al. 1989). Furthermore, DEBAUD (1983) managed to cultivate among others *Russula nana* Killermann which suggests that experiments focusing on *R. norvegica* and *S. herbacea* may also be crowned with success.

To sum up one may say that it is rather promising to reach a powerful PFS set of *S. herbacea*, including important putative symbionts as *C. favrei*, *E. alpicola*, *H. marginatulum*, *H. repandum*, *L. montana*, *H. saliciphilus*, *I. lacera* and *R. norvegica*.

Conclusions: Based on the results of the present study, the taxa proposed as potential partners of *Salix herbacea* cover a wide range of its ecological spectrum (Fig. 35). Regarding alpine restoration at different appropriate places, different PFS would be most suitable (cf. chapter 4.2.1.). To state only a few examples, *Entoloma alpicola* as the one partner in areas with shorter snow covering is substituted by *Inocybe lacera* and / or *Hymenogaster saliciphilus* at spots with comparatively longest snow covering. *Hebeloma* spp. and *Laccaria montana* seem to be most competitive in open and poor vegetation, whereas *Cortinarius favrei* prefers rather closed vegetation with a higher plant diversity.

Further efforts should be undertaken in producing pure cultures of the proposed ectomycorrhizal macromycetes and in investigations of their specific responses to different environmental parameters, viz. nutrients, pH, soil moisture and snow covering. In this connection care should also be taken in the composition of the soil fauna and their influence in nutrient-cycling. NASCHBERGER & KÖCK (1983) and FLORINETH (1984) demonstrated that well dosed applications of organic fertilizer at restoration sites increase the biomass of the plants and stimulate the propagation of soil-inhabiting microorganisms (INSAM & HASELWANDTER 1985, LUFTENEGGER et al. 1986). With a better understanding of the soil microflora and the appropriate consideration and application of a selection of such a fauna concomitant with the planting of the suitable set of ectomycorrhizal and non-ectomycorrhizal phanerogams, fertilizing may be secondary or even superfluous.

To sum up it seems obvious that still essential research and extensive work has to be done (GRAF & BRUNNER 1994). Nevertheless, with a little enthusiasm and idealism, and of course, the appropriate financial support, these investigations could certainly lead to a successful recovery of nature.

L'HOMME QUI PLANTAIT DES ARBRES

Quand je réfléchis qu' un homme seul, réduit à ses simples ressources physiques et morales, a suffi pour faire surgir du désert ce pays de Chanaan, je trouve que, malgré tout, la condition humaine est admirable.....

(Jean GIONO 1980)

Summary

During a three year period (1988-90) macromycetes were investigated and mapped in 13 permanent plots of 50 m² each. The plots were situated in the Valley of Radönt (Grisons, Switzerland) between 2400 and 2500 m. Nine plots were located in snow-bed communities of which six in *Salicetum herbaceae* and three in *Polytrichetum sexangularis* associations. For comparison, one plot each was chosen in closely related plant communities, viz. *Eriophoretum scheuchzeri*, *Oxyrietum digynae*, *Caricetum curvulae* and *Loiseleurio-Cetrarietum*. The plant association analysis of the 13 plots resulted in 63 phanerogams, 23 mosses, 39 lichens, and one pteridophyte. The evaluation of the weekly recorded field data (in 1988 occasionally also fortnightly) provided the source material for the elucidation of the following mycoecological and mycosociological aspects:

- analysis of the influence of climatic (precipitation, maximum-minimum air temperatures) and edaphic parameters (physical and chemical soil properties) on carpophore phenology and productivity.
- abundance, frequency, dynamics, spatial distribution, and phenology of macromycetes in snow-beds on siliceous rock material, with focus on the species associated with *Salix herbacea*.
- relationships between snow-melting zones (isochiones) and spatial distribution of macromycetes, especially ectomycorrhizal partners associated with *S. herbacea*.
- synthesis experiments between selected ectomycorrhizal macromycetes and their natural host plant, *S. herbacea*.
- to check the aptitude of the dwarf willow in connection with its ectomycorrhizal partners regarding alpine restoration.

Besides the 35 field trips during winter time to check snow conditions, 47 collecting excursions to the 13 plots took place, lasting one to three days each. As a result, 94 fungal taxa were registered, represented by a total of 26'413 carpophores. Of those, 21'883 individuals were mapped in 10'497 records. The highest diversity was noticed for the Basidiomycetes which constituted 85 species (90%) followed by the Ascomycetes with 7 spp. (8%) and the Gastromycetes and the Myxomycetes with 1 sp. (1%) each. The ectomycorrhiza forming partners of *S. herbacea* were represented by 60 species (64%). The evaluation of the sampled data resulted in the following major characteristics for macromycetes in snow-beds with *S. herbacea*:

- dependence of the start of major carpophore production on a time sequence of minimum temperatures above zero and a slightly positive correlation between the productivity and precipitation.
- one single significant aspect of carpophore productivity with its maximum between the end of August and the beginning of September.
- overwhelming dominance of ectomycorrhizal species in the *Salicetum herbaceae* mostly belonging to the genera *Astrosporina*, *Cortinarius*, *Hebeloma*, *Inocybe*, *Laccaria* and *Russula*.
- absence of typical saprobic (parasitic) macromycetes in the *Salicetum herbaceae* except for scattered occurrence of *Entoloma atropellitum* and *Hypholoma myosotis* and of some moss specific species such as *Galerina* spp. and *Psilocybe* spp.
- relationships between snow (duration of permanent snow covering, melting process, and isochiones), fructification season of the macromycetes, and spatial distribution of selected ectomycorrhizal species.
- a check list of selected macromycetes with indicator function based on mapping cards of spatial distribution and results of soil analyses.

The study of pertinent literature about arctic and alpine macromycetes in Europe which are associated with *S. herbacea* proceeded in 296 species. The comparison with four mycoecological and mycosociological investigations carried out in the Alps resulted in 95 taxa

reported from the *Salicetum herbaceae* association of which 60 species were also registered during the present study. As a result of this comparison, 19 species (16 ectomycorrhizal partners of *S. herbacea*) with a significantly higher frequency are proposed as characteristic taxa of the *Salicetum herbacea*. Furthermore, interspecific association was tested between selected macromycetes resulting also in distinct negative co-occurrences with *Inocybe* spp. as one partner.

Three axenic cultures of potential ectomycorrhizal symbionts (*Cortinarius favrei*, *Hebeloma repandum*, *Hymenogaster saliciphilus*) of *S. herbacea* and sterile and non-sterile seedlings of the dwarf willow have been maintained. Furthermore, successful cutting experiments were carried out with *S. herbacea*. The ectomycorrhizal synthesis between *Hebeloma repandum* and *S. herbacea* was successful for sterile seedlings and sterile and non-sterile cuttings of the dwarf willow respectively.

Analysis and comparison between mapping cards of isochiones and ectomycorrhizal macromycetes and soil properties uncovered interesting relationships such as the restriction of *Entoloma alpicola* and *Inocybe lacera* to spots of shortest and longest snow covering, respectively. A selection of the most powerful ectomycorrhizal macromycetes regarding alpine restoration is proposed here. Depending on climatic and edaphic parameters these are the following combinations: *Salix herbacea* with *Cortinarius favrei*, *Entoloma alpicola*, *Hebeloma marginatum*, *H. repandum*, *Hymenogaster saliciphilus*, *Inocybe lacera*, *Laccaria montana*, and *Russula norvegica*.

Furthermore, during the present study two unknown macromycetes were discovered and described. In the case of *Hymenogaster saliciphilus*, it was the first time that in the alpine zone a hypogeous Basidiomycete had been registered associated with *S. herbacea*. *Sclerotinia glacialis* (Ascomycetes, Helotiales) was exclusively found in close association with *Ranunculus glacialis*.

Zusammenfassung

Ökologie und Soziologie von Makromyceten in Schneetälchen mit *Salix herbacea* L. (Krautweide) aus dem alpinen Radönter Tal (Graubünden, Schweiz).

Von 1988 bis 1990 wurden während der schneefreien Vegetationsperioden die Makromyceten in 13 permanenten Untersuchungsflächen von je 50 m² ökologisch und soziologisch analysiert. Alle Flächen wurden in Höhen von 2400 bis 2500 m im alpinen Radöntertal eingerichtet, welches sich nahe dem Flüelapass im Kanton Graubünden befindet. Neun davon wurden in Schneetälchen-Gesellschaften plaziert: sechs in die *Salicetum herbaceae* und drei in die *Polytrichetum sexangularis* Assoziation. Zu Vergleichszwecken wurde zudem je eine Fläche in nah verwandten Pflanzengesellschaften untersucht, bei welchen es sich um ein *Eriophoretum scheuchzeri*, ein *Oxyrietum digynae*, sowie um ein *Caricetum curvulae* und ein *Loiseleurio-Cetrarietum* handelte. Die pflanzensoziologische Untersuchung der 13 Flächen ergab insgesamt 63 Phanerogamen, 23 Moose, 39 Flechten und einen Pteridophyten. Die Auswertung der wöchentlich (1988, gelegentlich zweiwöchentlich) erhobenen Felddaten lieferte die Grundlagen für die Abklärung folgender mykoökologischer und mykosoziologischer Aspekte:

- eine detaillierte Analyse der Einflüsse klimatischer (Niederschlag, Maximum- und Minimum-Temperaturen), sowie edaphischer Parameter (physikalische und chemische Bodeneigenschaften) auf die Entwicklung und Produktion von Grosspilzen.
- eine genaue Erfassung von Abundanz, Frequenz, Dynamik, räumlicher Verteilung und Phänologie der Grosspilzflora von Schneetälchengesellschaften auf Silikat; insbesondere im Zusammenhang mit der Zwergweide *Salix herbacea*.

- für die Abklärung eventueller Zusammenhänge zwischen dem Ausaperungsprozess (Isochionen) im Frühjahr und der räumlichen Verteilung der Makromyceten, insbesondere der Ektomykorrhizapartner von *S. herbacea*.
- für die Durchführung von Synthese Experimenten zwischen ausgewählten Ektomykorrhizapilzen und deren Wirtspflanze *S. herbacea*.
- zur Abklärung der potentiellen Eignung der Zwergweide für Renaturierungsversuche in der alpinen Stufe.

In den drei Untersuchungsjahren wurden während der schneefreien Zeit 47 Sammelexkursionen von jeweils ein bis drei Tagen durchgeführt. Zusätzlich fanden 35 eintägige Exkursionen zur Erfassung der Schneebedingungen während der Winterhalbjahre 88/89 und 89/90 statt. Die mykologische Ausbeute ergab 94 Arten, welche mit insgesamt 26'413 Fruchtkörpern registriert wurden. Davon fanden 21'338 Individuen in 10'497 Fundpunkten Aufnahme in der Fruchtkörperkartierung. Die höchste Diversität wurde mit 85 Arten (90%) für die Basidiomyceten festgehalten, gefolgt von den Ascomyceten mit sieben Taxa (8%) und den Gastromyceten und Myxomyceten mit je einer Art (1%). Die Ektomykorrhiza bildenden Partner von *S. herbacea* wurden mit 60 Vertretern (64%) registriert. Die Auswertung der aufgenommenen und gesammelten Daten resultierte in den folgenden Resultaten und Charakteristika für Grosspilze in Schneetälchen mit *S. herbacea*:

- Der Hauptschub der Fruktifikationsperiode der Makromyceten und insbesondere der Ektomykorrhiza bildenden Arten steht in Abhängigkeit einer vorausgehenden Zeitspanne mit Minimumtemperaturen über dem Gefrierpunkt und ist schwach positiv mit Vorangangsniederschlag korreliert.
- Während der kurzen schneefreien Vegetationsperiode in der alpinen Stufe kommt es nur zu einem deutlichen Fruktifikationsaspekt, welcher in der Zeit von Ende August bis anfangs September sein Maximum erreicht.
- In den Saliceten dominieren die Ektomykorrhizapartner der Zwergweide, vor allem Vertreter der Gattungen *Astrosporina*, *Cortinarius*, *Hebeloma*, *Inocybe*, *Laccaria* und *Russula*.
- Typisch saprobe (parasitäre) Makromyceten im *Salicetum herbaceae* werden nur durch beschränkte Vorkommen von *Entoloma atropellitum* und *Hypholoma myosotis*, sowie durch vereinzelte Moos-spezifische Arten der Gattungen *Galerina* und *Psilocybe* repräsentiert.
- Die Vermutung einer Korrelation zwischen Schnee (Dauer der winterlichen Schneebedeckung, Ausaperungsprozess, Isochionen) und der Fruktifikationsperiode der Grosspilze und deren räumlichen Verteilung, insbesondere der Ektomykorrhizapilze, konnte untermauert werden.
- Eine Liste ausgewählter Pilzarten mit deren ökologischen Indikator-Funktion wurde aufgrund der Fruchtkörperkartierung und der Bodenanalysen aufgestellt.

Das Studium relevanter Literatur über arktisch-alpine Grosspilze in Europa, welche mit *S. herbacea* im Zusammenhang stehen, ergab eine Liste von 296 Arten. Der Vergleich von vier mykoökologischen und mykosoziologischen Arbeiten, die in den Alpen durchgeführt wurden, resultierte in 95 gesammelten Taxa aus der *Salicetum herbaceae* Assoziation, wovon 60 Arten im Verlaufe dieser Arbeit registriert wurden. Daraus werden 19 Taxa (16 Ektomykorrhiza bildend) mit deutlich höherer Frequenz als Charakterarten für das *Salicetum herbaceae* in den Alpen vorgeschlagen.

Zusätzlich wurden Assoziationsanalysen für ausgewählte Pilzartenpaare durchgeführt, welche, neben anderen Resultaten, eine signifikant negative Vergesellschaftung ergab, wenn eine Art der Gattung *Inocybe* angehörte.

Drei Reinkulturen von potentiellen Ektomykorrhizapartnern (*Cortinarius favrei*, *Hebeloma repandum*, *Hymenogaster saliciphilus*) von *S. herbacea*, sowie Keimlinge der Zwergweide unter sterilen und nicht sterilen Bedingungen, wurden erfolgreich synthetisiert. Zusätzlich waren Versuche zur Vermehrung von *S. herbacea* mit Stecklingen erfolgreich. Ektomykor-

rhiza-Syntheseversuche zwischen *S. herbacea* und *Hebeloma repandum* waren sowohl mit sterilen Keimlingen, als auch mit sterilen und nicht sterilen Stecklingen der Zwergweide erfolgreich.

Vergleiche von Fruchtkörperkartierungsdaten mit Isochinonenkarten und Resultaten der Bodenanalysen, resultierten in interessanten Korrelationen: so etwa die Beschränkung der Vorkommen von *Entoloma alpicola* und *Inocybe lacera* auf Kleinhabitate mit kürzester, respektive längster Schneebedeckung.

Im Hinblick auf die alpine Renaturierung wurde eine Auswahl der am besten geeigneten Ektomykorrhizapartner von *S. herbacea* getroffen. Abhängig von klimatischen und edaphischen Faktoren sind dies die folgenden Kombinationen: *Salix herbacea* mit *Cortinarius favrei*, *Entoloma alpicola*, *Hebeloma marginatum*, *H. repandum*, *Hymenogaster saliciphilus*, *Inocybe lacera*, *Laccaria montana* sowie *Russula norvegica*.

Zudem wurden während der Feldstudien der vorgestellten Arbeit zwei neue Pilztaxa gefunden und beschrieben. Im Falle von *Hymenogaster saliciphilus* handelt es sich um den ersten Fund eines hypogäischen Ektomykorrhizapartners von *S. herbacea* aus den Alpen. *Sclerotinia glacialis* (Ascomycetes, Helotiales) wurde in Vergesellschaftung mit *Ranunculus glacialis* entdeckt.

References

- ABUZINADA R.A. & READ D.J., 1986: Utilization of protein by ectomycorrhizal fungi and by their host plants. In: GIANINAZZI-PEARSON V. & GIANINAZZI S. (eds.), Physiological and genetical aspects of mycorrhizae: Proc. 1st ESM. 395-401.
- AGERER R., 1985: Zur Ökologie der Mykorrhizapilze. *Bibl. Mycol.* 97, 1-160.
- AGERER R., 1987: Studies on Ectomycorrhizae. X. Mycorrhizae formed by *Cortinarius obtusus* and *C. venetus* on spruce. *Mycologia* 79 (4), 524-539.
- AGERER R., 1988: Studies on Ectomycorrhizae. XIV. Mycorrhizae formed by *Cortinarius hercynius* and *C. varicolor* on *Picea abies*. *Can. J. Bot.* 66, 2068-2078.
- AGERER R. & KOTTKE I., 1981: Sozio-ökologische Studien an Pilzen von Fichten- und Eichen-Buchen-Hainbuchen-Wäldern im Naturpark Schönbuch. *Z. Mykol.* 47 (1), 103-122.
- ALEXANDER I.J. & FAIRLEY R.I., 1986: Growth and nitrogen uptake rates of ectomycorrhizal spruce seedlings. In: GIANINAZZI-PEARSON V. & GIANINAZZI S. (eds.), Physiological and genetical aspects of mycorrhizae: Proc. 1st ESM. 377-382.
- ANDERSON J.M., HUISSH S.A., INESON P., LEONARD M.A. & SPLATT P.R., 1985: Interactions of invertebrates, micro-organisms and tree roots in nitrogen and mineral element fluxes in deciduous woodland soils. In: FITTER A.H., ATKINSON D., READ D.J. & USHER M.B. (eds.), Ecological interactions in soil. Blackwell Scientific Publications, Oxford, U.K. 377-392.
- ANTIBUS R.K., 1980: Mechanisms of acclimation to lowered growth temperatures in isolates of arctic and temperate ectomycorrhizal fungi. PhD thesis, Virginia Polytechnic Institute and State University, Blacksburg. 171 pp.
- ANTIBUS R.K., CROXDALE J.E., MILLER O.K. & LINKINS A.E., 1981: Ectomycorrhizal fungi of *Salix rotundifolia*. III. Resynthesized mycorrhizal complexes and their surface phosphatase activities. *Can. J. Bot.* 59, 2458-2465.
- ARNOLDS E., 1981: Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, the Netherlands. 1. Introduction and synecology. *Bibl. Mycol.* 83, 407 pp.
- ARNOLDS E., 1982: Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, the Netherlands. 2. Autecology, 3. Taxonomy. *Bibl. Mycol.* 90, 501 pp.
- ARNOLDS E., 1988 a: Status and classification of fungal communities. In: BARKMAN J.J. & SYKORA K.V. (eds.), Dependent plant communities. SPB Acad. Publishing, The Hague. 153-165.
- ARNOLDS E., 1988 b: Dynamics of macrofungi in two moist heathlands in Drenthe, the Netherlands. *Acta Bot. Neerl.* 37, 291-305.
- AULITZKY H., 1961: Die Bodentemperaturen in der Kampfzone oberhalb der Waldgrenze und im subalpinen Zirben-Lärchenwald. *Mitt. Forst. Bundes-Versuchsanst. Mariabrunn* 59, 153-208.
- BARKMAN J.J., 1968: Das synsystematische Problem der Mikrogenesellschaften innerhalb der Biozönosen. *Ber. Sympos. Intern. Ber. Veget.-kd.* 1964, 21-53.
- BARKMAN J.J., 1976: Algemene inleiding tot de oekologie en sociologie van macrofungi. *Coolia* 19, 75-66.
- BAS C., 1977: Species concept in *Amanita* sect. *Vaginatae*. In: CLÉMENÇON H. (ed.), The species concept in Hymenomycetes. *Bibl. Mycol.* 61, 79-103.
- BAS C., 1982: Studies in *Amanita* - II. Miscellaneous Notes. *Persoonia* 11(4), 429-442.
- BEGUIN C. & THEURILLAT J.P., 1982: Une association végétale des zones humides périglaciaires de l'étage alpine sur silice: Le *Salici herbaceae- Caricetum lachenalii*. *Bull. Murithienne* 99, 33-60.

- BIELESKI R.L., 1973: Phosphate pools, phosphate transport and phosphate availability. *Annu. Rev. Plant Physiol.* 24, 225-252.
- BIERI CH. & LUSSI ST., 1989: Synökologie der Mykorrhiza-Pilze und anderer Makromyceten (Grosspilze) in wichtigen Waldgesellschaften des Berner Mittellandes. Lizentiatsarbeit am Systematisch-Geobotanischen Institut der Universität Bern. 233 pp. (copy).
- BILLS G.F., 1985: Ecological and taxonomic studies of the *Russulaceae* and other ectomycorrhizal Basidiomycetes in the high-elevation forests of the southern Appalachians. PhD thesis, Virginia Polytechnic Institute and State University, Blacksburg. 176 pp.
- BLASER P., 1980: Der Boden als Standortsfaktor bei Aufforstungen in der subalpinen Stufe (Stillberg, Davos). *Mitt. Eidg. Anst. Forstl. Versuchswesen* 56 (3), 529-611.
- BON M., 1985 a: Stage mycologie alpine Lanslebourg (Savoie) de 1 à 3 septembre 1984. *Bull. Féd. Myc. Dauphiné-Savoie* 96, 19-25.
- BON M., 1985 b: Quelques nouveaux taxons de la flore mycologique alpine. *FMDS*, No. 97, 23-30.
- BON M., 1988 a: Notes sur quelques récoltes intéressantes faites au stage de Pralognan et alentours (25-31 août 1987). *Bull. Féd. Myc. Dauphiné-Savoie* 110, 13-15.
- BON M., 1988 b: Clé monographique des *Russules* d'Europe. *Doc. Mycol.* 18, 1-120.
- BON M., 1989: Quelques Agaricomycètes intéressants de la zone alpine récoltés dans le Tessin. *Mycol. Helv.* 3, 315-330.
- BON M., 1990: Mycologie alpine. *Bull. Féd. Myc. Dauphiné-Savoie* 116, 25-30.
- BON M., 1991: Inventaires des espèces récoltées au stage de mycologie alpine. *Bull. Féd. Myc. Dauphiné-Savoie* 122, 25-28.
- BON M., 1992 a: Clé analytique des Cortinaires alpins. *Doc. mycol.* 22, 43-67.
- BON M., 1992 b: Quelques Inocybes alpins au stage de mycologie des Arcs. *Bull. Féd. Myc. Dauphiné-Savoie* 126, 1-22.
- BON M., 1993: Russules alpines nouvelles ou intéressantes. Station d'Etude en Baie de Somme. *Bull. Féd. Myc. Dauphiné-Savoie* 128, 20-24.
- BON M. & GEHU J.-M., 1973: Unités supérieures de végétation et récoltes mycologiques. *Doc. mycol.* 6, 1-140.
- BOYD R., FURBANK R.T. & READ D.J., 1986: Ectomycorrhizae and water relations of trees. In: GIANINAZZI-PEARSON V. & GIANINAZZI S. (eds.), *Physiological and genetical aspects of mycorrhizae*. Proc. 1st ESM. 689-693.
- BRANDRUD T.E., LINDSTROEM H., MARKLUND H., MELOT J. & MUSKOS S., 1990: *Cortinarius* Flora Photographica. *Cortinarius* HB, Klövervögen 13, Mattors, Schweden.
- BRAUN-BLANQUET J., 1948 a: Übersicht der Pflanzengesellschaften Rätians. *Vegetatio I* (1), 29-41.
- BRAUN-BLANQUET J., 1948 b: Übersicht der Pflanzengesellschaften Rätians. *Vegetatio I* (4/5), 285-316.
- BRAUN-BLANQUET J., 1949 a: Übersicht der Pflanzengesellschaften Rätians. *Vegetatio II* (1), 20-37.
- BRAUN-BLANQUET J., 1949 b: Übersicht der Pflanzengesellschaften Rätians. *Vegetatio II* (2/3), 214-237.
- BRAUN-BLANQUET J., 1964: Pflanzensoziologie; Grundzüge der Vegetationskunde. Springer, Wien, 3. Auflage. 865 pp.
- BRAUN-BLANQUET J., 1971: Übersicht der Pflanzengesellschaften der rhätischen Alpen im Rahmen ihrer Gesamtverbreitung. *Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* 46, 70 pp.
- BREITENBACH J. & KRÄNZLIN F., 1981: Pilze der Schweiz. 1. Ascomyceten. *Mykologia*, Luzern. 313 pp.
- BREITENBACH J. & KRÄNZLIN F., 1986: Pilze der Schweiz. 2. Nichtblätterpilze: Heterobasidiomycetes, Aphylliphorales, Gasteromycetes. *Mykologia*, Luzern. 416 pp.

- BREITENBACH J. & KRÄNZLIN F., 1991: Pilze der Schweiz. 3. Röhrlinge und Blätterpilze 1. Teil. Mykologia, Luzern. 364 pp.
- BRESADOLA G., 1927-32: Iconographica mycologica Milano. Vol. 1-28 (Suppl. I+II).
- BRUCHET G., 1970: Contribution à l'étude du genre *Hebeloma* (Fr.) Kummer; partie spéciale. Bull. Soc. Linn. Lyon 39 (6), 1-132.
- BRUCHET G., 1974: Recherches sur l'écologie des *Hebeloma* arcto-alpins; étude spéciale de l'aptitude ectomycorhizogène des espèces. Bull. Soc. Linn. Lyon, numéro spécial (R. Kühner) 43, 85-96.
- BRUNNER I., 1987: Pilzökologische Untersuchungen in Wiesen und Brachland in der Nordschweiz (Kt. Schaffhausen). Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 92, 241 pp.
- BRUNNER I., 1991: Comparative studies on ectomycorrhizae synthesized with various in vitro techniques using *Picea abies* and two *Hebeloma* species. Trees 5, 90-94.
- BRUNNER F. & BRUNNER I., 1990: A new method to produce numerous uncontaminated alder seedlings. Eur. J. For. Path. 20, 430-435.
- BURGA A., 1990: Vegetationsgeschichte und Palaeoklimatologie. Vierteljahresschr. Naturf. Ges. Zürich 135 (1), 17-30.
- CHAMBERS J.C., BROWN R.W. & JOHNSTON R.J., 1984: Examination of plant successional stages in disturbed alpine ecosystems: A method of selecting revegetation species. Proc. 6th HAR Workshop, Fort Collins. 215-224.
- CHAMBERS J.C., MCMAHON J.A. & BROWN R.W., 1987: Germination characteristics of alpine grasses and forb: A comparison of early and late seral dominants with reclamation potential. Reclam. Reveg. Res. 6, 235-249.
- CHAMBERS J.C., MCMAHON J.A. & BROWN R.W., 1988: Seedling establishment in disturbed alpine ecosystems: Implications for revegetation. Proc. 8th HAR Workshop, Fort Collins. 173-191.
- CLARHOLM M., 1985 a: Possible roles for roots, bacteria, protozoa, and fungi in supplying nitrogen to plants. In: FITTER A.H., ATKINSON D., READ D.J. & USHER M.B. (eds.), Ecological interactions in soil. Blackwell Scientific Publications, Oxford, U.K. 355-365.
- CLARHOLM M., 1985 b: Interaction of bacteria, protozoa, and plants leading to mineralization of soil nitrogen. Soil Biol. Biochem. 17, 181-187.
- CLÉMENÇON H., 1982 a: Kompendium der Blätterpilze. *Marasmius*. Z. Mykol. 48, 3-16.
- CLÉMENÇON H., 1982 b: Kompendium der Blätterpilze. Europäische omphalinoide *Tricholomataceae*. Z. Mykol. 48, 195-237.
- CLIFFORD H.T. & STEPHENSON W., 1975: An introduction to numerical classification. Academic Press, New York. 37-46.
- CURRY J.P., KELLY M. & BOLGER T., 1985: Role of invertebrates in the decomposition of *Salix* litter in reclaimed cutover peat. In: FITTER A.H., ATKINSON D., READ D.J. & USHER M.B. (eds.), Ecological interactions in soil. Blackwell Scientific Publications, Oxford, U.K. 393-397.
- DAHLBERG A. & STENLID J., 1990: Population structure and dynamics in *Suillus bovinus* as indicated by spatial distribution of fungal clones. New Phytol. 115, 487-493.
- DANIELSON R.M., VISSER S. & PARKINSON D., 1984: Production of ectomycorrhizae on container-grown jack pine seedlings. Can. J. For. Res. 14, 33-36.
- DANNEBERG O.H., JENISCH H.S. & RICHTER E., 1980: Der Humushaushalt eines Pseudogleys unter *Curvuletum*. In: FRANZ H. (ed.), Untersuchungen an alpinen Böden in den Hohen Tauern 1974-1978 Stoffdynamik und Wasserhaushalt. Universitätsverlag Wagner, Innsbruck. 295 pp.
- DARIMONT F., 1973: Recherches mycologiques dans les forêts de Haute Belgique. Essay sur les fondements de la sociologie des champignons supérieurs. Mém. Inst. Roy. Sci. Nat. Belgique 170, 220 pp.

- DEACON J.W., DONALDSON S.J. & LAST F.T., 1983: Sequences and interactions of mycorrhizal fungi on birch. *Plant and Soil* 71, 257-262.
- DEBAUD J.C., 1983: Recherches écophysiologicals sur des espèces alpines du genre *Clitocybe* et *Hebeloma* (Agaricales) associés à *Dryas octopetala* (Rosacées). Thèse d'état, Lyon. 206 pp.
- DEBAUD J.C., PEPIN R. & BRUCHET G., 1981a: Etude des ectomycorhizes de *Dryas octopetala*. Obtention de synthèses mycorrhiziennes et de carpophores d'*Hebeloma alpinum* et *H. marginatum*. *Can. J. Bot.* 59, 1014-1020.
- DEBAUD J.C., PEPIN R. & BRUCHET G., 1981b: Ultrastructure des ectomycorhizes synthétiques à *Hebeloma alpinum* et *H. marginatum* de *Dryas octopetala*. *Can. J. Bot.* 59, 2160-2166.
- DEMOULIN V., 1972: Espèces nouvelles ou méconnues du genre *Lycoperdon* (Gastéromycètes). *Lejeunia*, n. s. 62, 1-28.
- DENNIS R.W.G., 1978: *British Ascomycetes*. (3. Aufl.). Cramer, Vaduz. 585 pp.
- DISSING H. & SIVERTSEN S., 1983: Operculate Discomycetes from Rana (Norway) 5. *Rhodocypha* gen. nov. and *Rhodotarzetta* gen. nov. *Mycotaxon* 16, 441-460.
- DUDDRIDGE J.A., MALIBARI A. & READ D.J., 1980: Structure and function of mycorrhizal rhizomorphs with special reference to their role in water transport. *Nature*, London 287, 834-836.
- EGLI S., 1992: Der Anisklumpfuss, *Cortinarius odorifer* Britz.: Ökologie, Biologie und Ektomykorrhiza. *Mitt. Eidg. Anst. Forstl. Versuchswesen* 67 (3), 317-412.
- ELLENBERG H., 1986: *Vegetation Mitteleuropas mit den Alpen*. (4. Aufl.). Ulmer Verlag, Stuttgart. 989 pp.
- EVELING D.W., WILSON R.N., GILLESPIE E.S. & BATAILLE A., 1990: Environmental effects on sporocarp counts over fourteen years in a forest area. *Mycol. Res.* 94 (7), 998-1002.
- EYNARD M., 1975: L'influence de quelques facteurs physiques sur la fructification des champignons supérieures Basidiomycetes. *Bull. Soc. Linn. Lyon* 44 (9), 330-335.
- EYNARD M., 1977: Contribution à l'étude écologique des Agaricales des groupements à *Salix herbacea*. Thèse d'Etat, Lyon. 202 pp.
- FADERL C. & MOSER M., 1988: Einfluss des Wassergehaltes auf die Frostresistenz von *Flammulina velutipes*. *Z. Mykol.* 54 (2), 127-138.
- FAVRE J., 1948: Les associations fongiques des hauts-marais jurassiens. *Beitr. Kryptogamenfl. Schweiz* 10(3), 6-228.
- FAVRE J., 1955: Les champignons de la zone alpine du Parc National Suisse. *Ergebn. Wiss. Untersuch. Schweiz. Nationalparkes* 5, 1-212.
- FAVRE J., 1960: Catalogue descriptif des champignons supérieurs de la zone subalpine du Parc National Suisse. *Ergebn. Wiss. Untersuch. Schweiz. Nationalparkes* 6, 323-610.
- FINLAY R.D. & READ D.J., 1986 a: The structure and function of the vegetative mycelium of ectomycorrhizal plants. I. Translocation of C¹⁴ labelled carbon between plants interconnected by a common mycelium. *New Phytol.* 103, 143-156.
- FINLAY R.D. & READ D.J., 1986 b: The structure and function of the vegetative mycelium of ectomycorrhizal plants. II. The uptake and distribution of phosphorus by mycelial strands interconnecting host plants. *New Phytol.* 103, 157-165.
- FINLAY R.D. & READ D.J., 1986 c: The uptake and distribution of phosphorus by ectomycorrhizal mycelium. In: GIANINAZZI-PEARSON V. & GIANINAZZI S. (eds.), *Physiological and genetical aspects of mycorrhizae*: Proc. 1st ESM. 351-355.
- FINLAY R.D., SODERSTROM B. & READ D.J., 1986: Factors influencing the flux of carbon through ectomycorrhizal mycelium forming inter plant connections. In: GIANINAZZI-PEARSON V. & GIANINAZZI S. (eds.), *Physiological and genetical aspects of mycorrhizae*: Proc. 1st ESM. 301-306
- FLORENCE L.Z. & COOK F.D., 1984: Asymbiotic N₂-fixing bacteria associated with three boreal conifers. *Can. J. For. Res.* 14, 595-597.

- FLORINETH F., 1984: Erfahrungen in der Hochlagenbegrünung. In: ZAUGG H. (ed.), Hochlagenbegrünung im Skisportgebiet von Lech am Arlberg (Bericht der 3. Tagung für Hochlagenbegrünung). Der Gartenbau, Stuttgart 27, 1145-1147.
- FLÜELER R., 1992: Experimentelle Untersuchungen über Keimung und Etablierung von alpinen Leguminosen. Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 110, 149 pp.
- FORD E.D., MASON P.A. & PELHAM J., 1980: Spatial patterns of sporophore distribution around a young birch tree in three successive years. Trans. Brit. Mycol. Soc. 75, 287-296.
- FOSSATI A., 1980: Keimverhalten und frühe Entwicklungsphasen einiger alpiner Taxa. Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 73, 180 pp.
- FRAHM J.P. & FREY W., 1983: Moosflora. Ulmer Verlag, Stuttgart. 522 pp.
- FRANK A.B., 1888: Über die physiologische Bedeutung der Mycorrhiza. Ber. d. deutsch. bot. Ges. 6, 248-268.
- FRANKENBERGER W.T. & POTH M., 1987: Biosynthesis of indole-3-acetic acid by the pine ectomycorrhizal fungus *Pisolithus tinctorius*. Appl. Environ. Microbiol. 53, 2908-2913.
- FRANZ H., 1979: Ökologie der Hochgebirge. Ulmer Verlag, Stuttgart. 495 pp.
- FRANZ H., 1980: Untersuchungen an alpinen Böden in den Hohen Tauern 1974-1978: Stoffdynamik und Wasserhaushalt. Österreichisches MaB-Hochgebirgsprogramm Hohe Tauern. Band 3. Universitätsverlag Wagner, Innsbruck. 295 pp.
- GAGNON J., LANGLOIS C.G. & FORTIN J.A., 1987: Growth of containerized jack pine seedlings inoculated with different ectomycorrhizal fungi under a controlled fertilization schedule. Can. J. For. Res. 17, 840-845.
- GALLI R., 1985: Gli Igrofori delle nostre regioni. Edizioni La Tipotecnica s.n.c., S. Vittore, Olena (Mi). 164 pp.
- GENSLER G.A., 1978: Das Klima von Graubünden. Habilitationsschrift, Schweiz. Meteorol. Zentralanst. 122 pp.
- GERHOLD N., 1986: Zwei Nordtiroler Funde zum "Zwergstrauch-Scheidenstreifling", *Amanita nivalis* K. R. Greville 1822. Beitr. Kenntn. Pilze Mitteleuropas 2, 15-17.
- GILLER K.E. & DAY J.M., 1985: Nitrogen fixation in the rhizosphere: significance in natural and agricultural systems. In: FITTER A.H., ATKINSON D., READ D.J. & USHER M.B. (eds.), Ecological interactions in soil. Blackwell Scientific Publications, Oxford, U.K. 127-147.
- GIONO J., 1980: Jean Giono oeuvres romanesques complètes (tome 5). Bibliothèque de la Pléiade, Editions Gallimard.
- GODBOUT C. & FORTIN J.A., 1983: Morphological features of synthesized ectomycorrhizae of *Alnus crispa* and *A. rugosa*. New Phytol. 94, 249-262.
- GODBOUT C. & FORTIN J.A., 1985: Synthesized ectomycorrhizae of aspen: fungal genus level of structural characterization. Can. J. Bot. 63, 252-262.
- GOODALL D.W., 1978: Sample similarity and species correlation. In: WHITTAKER R.H. (ed.), Ordination of plant communities. W. Junk, The Hague. 247-286.
- GRABHERR G., MAIR A. & STIMPFLI H., 1988: Vegetationsprozesse in alpinen Rasen und die Chancen einer echten Renaturierung von Schipisten und anderen Erosionsflächen in alpinen Hochlagen. Jb. Ges. Ingenieurbiol. 94-113.
- GRAF F. & HORAK E., 1993: Taxonomy and ecology of a new hypogeous Basidiomycete, *Hymenogaster saliciphilus* sp. nov., from the alpine zone of the Grisons (Switzerland). In: PETRINI O. & LAURSEN G.A. (eds.), Arctic and Alpine Mycology 3 & 4. Bibl. Mycol. 150, 39-51.
- GRAF F. & BRUNNER I., 1994: Alpine dwarf willow and its ectomycorrhizal partners: a potential system for alpine ski slope restoration ! Proc. 11th HAR Workshop, Fort Collins. (in press).
- GRAF F. & SCHUMACHER T., 1994: *Sclerotinia glacialis* sp. nov. (Ascomycetes, Helotiales) from the alpine zone of Switzerland. Mycol. Res. (subm.).

- GREENACRE M.J., 1986: SimCa: a program to perform simple correspondence analysis. *American Statistician* 41, 230-231.
- GREENACRE M.J., 1988: Correspondence analysis on a personal computer. *Chemometrics and Intelligent Laboratory Systems* 2, 233-234.
- GRIESSER B., 1992: Mykosoziologie der Grauerlen- und Sanddorn-Auen (*Alnetum incanae*, *Hippophaëtum*) am Hinterrhein (Domleschg, Graubünden, Schweiz). Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 109, 235 pp.
- GROEGER F., 1987: Der Formenkreis des winzigen Fälblings, *Hebeloma pusilla*. Myk. Mitt. Bl. 30 (2), 37-48.
- GROEGER F., 1988: *Hebeloma stenocystis* Favre - Schmalbewimperter Fälbling. Myk. Mitt. Bl. 31 (1), 9-13.
- GROSS G., 1980: Über einige *Alpova*-Funde in den bayerischen Alpen. Z. Mykol. 46, 21-26.
- GROSS G., RUNGE A. & WINTERHOFF W., 1980: Bauchpilze (Gasteromycetes s.l) in der Bundesrepublik und Westberlin. Beih. Z. Mykol. 2, 1-220.
- GULDEN G., 1975: Mushroom inventory at Hardangervidda, autumn 1971: IBP in Norway. Ann. Rep. 1974, 371-380.
- GULDEN G., 1980: Alpine Galerinas (Basidiomycetes, Agaricales) with special reference to their occurrence in South Norway, Finse on Hardangervidda. Norw. J. Bot. 27, 219-253.
- GULDEN G., 1987: The genus *Galerina* on Svalbard. In: LAURSEN G.A., AMMIRATI J.F. & REDHEAD S.A. (eds.), Arctic and Alpine mycology II. Plenum Publishing Corporation. 177-204.
- GULDEN G. & LANGE M., 1971: Studies in the macromycete flora of Jotunheimen, the central mountain massif of South Norway. Norw. J. Bot. 18, 1-48.
- GULDEN G. & JENSSEN K.M., 1982: *Mycena* and related genera in alpine habitats of Southern Norway in the Hardangervidda at Finse. In: LAURSEN G.A. & AMMIRATI J.F. (ed.), Arctic and Alpine Mycology I. University of Washington Press, Seattle. 164-197.
- GULDEN G., JENSSEN K.M. & STORDAL J., 1985: Arctic and Alpine Fungi - 1. Soppkonsulenten, Oslo. 61 pp.
- GULDEN G. & JENSSEN K.M., 1988: Arctic and Alpine Fungi - 2. Soppkonsulenten, Oslo, 58 pp.
- GUMPELMAYER E., 1949: Die Bewurzelung von Stecklingen unter dem Einfluss von Heteroauxin im Jahresrhythmus. *Phyton* 1 (2-4), 154-169.
- HACSKAYLO E. & BRUCHET G., 1972: Hebelomas as mycorrhizal fungi. Bull. Torrey Bot. Club 99, 17-20.
- HALLGRIMSSON H., 1972: Islenzikr hattsveppir. I, II. Acta Bot. Isl. 1, 73-113.
- HALLGRIMSSON H., 1980: Islenzikr hattsveppir. V. Preliminary account of the Icelandic species of *Tricholomataceae*. Acta Bot. Isl. 6, 29-41.
- HANLEY J.L. & GREENE D.W., 1987: Gibberelin-like compounds from two ectomycorrhizal fungi and the GA₃ response on Scotch pine seedlings. Hort. Science 22, 591-594.
- HANSEN K., 1973: Microthermic observations in arctic vegetation. Meddel. Grønland 194 (6), 1-32.
- HANSEN L. & KNUDSEN H. (eds.), 1992: Nordic macromycetes vol. 2. Boletales, Polyporales, Agaricales, Russulales. Nordsvamp, Copenhagen. 474 pp.
- HANTKE R., 1978: Eiszeitalter Bd. 1, Ott Verlag Thun. 468 pp.
- HANTKE R., 1980: Eiszeitalter Bd. 2, Ott Verlag Thun. 702 pp.
- HARLEY J.L. & MCCREADY C.C., 1952: The uptake of phosphate by excised mycorrhizal roots of the beech. III. The effect of the fungal sheath on the availability of phosphate to the core. New Phytol. 51, 342-348.
- HARLEY J.L. & SMITH S.E., 1983: Mycorrhizal symbiosis. Acad. Press, London. 483 pp.
- HASLER R., 1992: Experimentelle Untersuchungen über klonal wachsende alpine Leguminosen. Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 111, 104 pp.

- HATHAWAY R.L., 1973: Factors affecting the soil binding capacity of the root systems of some *Populus* and *Salix* clones. M. Sc. thesis in Botany. Massey University, Palmerston/N.Z. (copy).
- HATHAWAY R.L. & PENNY D., 1975: Root strength in some *Populus* and *Salix* clones. N. Z. J. Bot. 13, 133-344.
- HENDERSON D.M., 1958: New and interesting Scottish fungi. I. Not. Roy. Bot. Gard. Edinburgh 22, 593-597.
- HESS H.E., LANDOLT E. & HIRZEL R., 1976-1980: Flora der Schweiz und angrenzender Gebiete. (2. Aufl.). Birkhäuser, Basel. 3 Bde. 2690 pp.
- HESSE R., 1891: Die Hypogaeen Deutschlands: Bd. I Die Hymenogastreen. Verlag von Ludw. Hofstetter. 140 pp. + 20 plates.
- HESSELMAN H., 1900: Om Mykorrhizabildningar hos arktiska växter. Bih. K. Svenska Vetensk.-Akad. Handlingar 26, 1-46.
- HØILAND K., 1976: The genera *Leptoglossum*, *Arrhenia*, *Phaeotella* and *Cyphellostereum* in Norway and Svalbard. Norw. J. Bot. 23, 201-212.
- HØILAND K., 1983: *Cortinarius* subgenus *Dermocybe* with special regard to the species in the Nordic countries. Opera Bot. 71, 1-113.
- HORAK E., 1960: Die Pilzvegetation im Gletschervorfeld (2290-2350 m) des Rotmoosferners in den Ötztaler Alpen. Nova Hedwigia 2, 487-507
- HORAK E., 1963: Pilzökologische Untersuchungen in der subalpinen Stufe (Piceetum subalpinum und Rhodoreto-Vaccinetum) der Rätischen Alpen (Dischmatal, Graubünden). Mitt. Schweiz. Anst. Forstl. Versuchswesen 39, 5-109.
- HORAK E., 1985: Die Pilzflora (Makromyceten) und ihre Ökologie in fünf Pflanzengesellschaften der montan-subalpinen Stufe des Unterengadins (Schweiz). Ergebn. Wiss. Untersuch. Schweiz. Nationalparkes. 12, 337-476.
- HORAK E., 1987 a: *Astrosporina* in the alpine zone of the Swiss National Park (SNP) and adjacent regions. In: LAURSEN G.A., AMMRATI J.F. & REDHEAD S.A. (eds.), Arctic and Alpine mycology II. Plenum Publishing Corporation. 205-234.
- HORAK E., 1987 b: Revision der von J. Favre (1955) aus der Region des Schweizer Nationalparks beschriebenen alpinen Arten von *Cortinarius* subgen. *Telamonia* (Agaricales). Candollea 42, 771-803.
- HORAK E. & RÖLLIN O., 1988: Der Einfluss von Klärschlamm auf die Makromycetenflora eines Eichen-Hainbuchen-Waldes bei Genf, Schweiz. Mitt. Schweiz. Anst. Forstl. Versuchswesen 64, 21-147.
- HUBALEK Z., 1982: Coefficients of association and similarity based on binary (presence-absence) data: an evaluation. Biol. Rev. (London) 57, 669-689:
- HULTEN E., 1958: The amphi-atlantic plants and their phytogeographical connections. Kungl. Svenska Vetenskapsakademiens Handlingar Fjärde Serien Bd. 7 (1), 340 pp.
- INGHAM R.E., TROFYMOW J.A., INGHAM E.R. & COLEMAN D.C., 1985: Interactions of bacteria, fungi, and their nematode grazers: effects on nutrient cycling and plant growth. Ecol. Monogr. 55, 119-140.
- INSAM H. & HASELWANDTER K., 1985: Die Wirkung verschiedener Begrünungsmassnahmen auf die mikrobielle Biomasse im Boden planierter Skipisten oberhalb der Waldgrenze. Z. Vegetationst. 8, 23-28.
- JACCARD P., 1908: Nouvelles recherches sur la distribution florale. Bull. Soc. Neuchâtoise Sci. Nat. 44, 223-270.
- JALAS J. & SUOMINEN J., 1976: Atlas Florae Europaeae. Distribution of vascular plants in Europe. 3. *Salicaceae* to *Balanophoraceae*. The committee for mapping the flora of Europe and Societas Biologica Fennica Vanamo, Helsinki. 128 pp.
- JAMONI P.G., 1991 a: I funghi nell' ambiente alpino. 2. Funghi e Ambiente 56, 17-29.
- JAMONI P.G., 1991 b: I funghi nell' ambiente alpino. 3. Funghi e Ambiente 57, 17-22.
- JAMONI P.G., 1991 c: I funghi nell' ambiente alpino. 4. Funghi e Ambiente 58, 17-22.

- JAMONI P.G. & BON M., 1991: Note di micologia alpina. Reperti rari e nuovi della zona alpina del massico del Monte Rosa. 1. *AMB* 34, 225-274.
- JAMONI P.G. & BON M., 1992: Note di micologia alpina. Reperti rari e nuovi della zona alpina del massico del Monte Rosa. 2. *AMB* 35, 21-32.
- JENNY-LIPS H., 1930: Vegetationsbedingungen und Pflanzengesellschaften auf Felsschutt. Phytosoziologische Untersuchungen in den Glarner Alpen. *Beih. Bot. Centralbl.* 46, 119-296.
- JÜLICH W., 1984: Kleine Kryptogamenflora. II b/1. Die Nichtblätterpilze, Gallertpilze und Bauchpilze. Fischer, Stuttgart/New York. 626 pp.
- KIRNBAUER R. & BLÖSCHL G., 1993: Wie ähnlich sind Ausaperungsmuster von Jahr zu Jahr? *DGM* 37 (5/6), 113-121.
- KNUDSEN H. & BORGEN T., 1982: *Russulaceae* in Greenland. In: LAURSEN G.A. & AMMIRATI J.F. (ed.), *Arctic and Alpine Mycology I*. University of Washington Press Seattle. 216-244.
- KNUDSEN H. & BORGEN T., 1987: *Agaricaceae, Amanitaceae, Boletaceae, Gomphidiaceae, Paxillaceae* and *Pluteaceae* in Greenland. In: Laursen G.A., Ammirati J.F. & Redhead S.A. (eds.), *Arctic and alpine Mycology II*. Plenum Publishing Corporation. 235-253.
- KNUDSEN H. & BORGEN T., 1992: New and rare taxa of *Russula* from Greenland. *Personia* 14, 509-517.
- KOBAYASI Y., HIRATSUKA N., OTANI Y., TUBAKI., UDAGAWA S., SUGIYAMA J. & KONNO K., 1971: Mycological studies of the Angmagssalik region in Greenland. *Bull. Nat. Sci. Mus. Tokyo* 14, 1-96.
- KOHN L.M., 1979: A monographic revision of the genus *Sclerotinia*. *Mycotaxon* 19 (2), 365-444.
- KREISEL H., 1959: Beiträge zur Pilzflora Bulgariens. *Fedd. Rep.* 62, 34-43.
- KREISEL H., 1967: Taxonomisch-pflanzengeographische Monographie der Gattung *Bovista*. *Beih. Nova Hedwigia* 25, 1-244.
- KROPP B.R. & LANGLOIS C.-G., 1990: Ectomycorrhizae in reforestation. *Can. J. For. Res.* 20, 438-451.
- KÜHNER R., 1935: Le genre *Galera* (Fries) Quélet. *Lechevalier, Paris. Encycl. Mycol.* 7, 240 pp.
- KÜHNER R., 1972 a: Agaricales de la zone alpine. Genre *Galerina* Earle. *Bull. Soc. Myc. Fr.* 88, 41-118.
- KÜHNER R., 1972 b: Agaricales de la zone alpine. Genre *Galerina* (suite) et *Phaeogalera*. *Bull. Soc. Myc. Fr.* 88, 119-153.
- KÜHNER R., 1975 a: Agaricales de la zone alpine. Genre *Lactarius* D.C. ex S.F. Gray. *Bull. Soc. Myc. Fr.* 91, 5-69.
- KÜHNER R., 1975 b: Agaricales de la zone alpine. Genre *Russula*. *Bull. Soc. Myc. Fr.* 91, 313-390.
- KÜHNER R., 1977 a: Agaricales de la zone alpine. Genre *Hygrocybe* (Fries) Kummer. *Bull. Soc. Myc. Fr.* 93, 53-115.
- KÜHNER R., 1977 b: Agaricales de la zone alpine. Genre *Hygrophoracées*. *Bull. Soc. Myc. Fr.* 93, 117-144.
- KÜHNER R., 1977 c: Agaricales de la zone alpine. Genre *Rhodophyllus* Quélet. *Bull. Soc. Myc. Fr.* 93, 445-592.
- KÜHNER R., 1981: Agaricales de la zone alpine. Genre *Alnicola* Kühner. *Trav. Sci. Parc Nat. Vanoise* 11, 113-134.
- KÜHNER R., 1988: Diagnoses de quelques nouveaux *Inocybes* récoltés en zone alpine de la Vanoise. *Doc. Mycol.* 19 (74), 1-28.
- KÜHNER R. & BOURSIER J., 1932: Notes sur le genre *Inocybe*. I. Les *Inocybes* goniosporés (suite). *Bull. Soc. Myc. France.* 48, (2), 118-161.

- KÜHNER R. & LAMOURE D., 1972: Agaricales de la zone alpine. Pleurotacées. *Le Botaniste* 55, 7-37.
- KÜHNER R. & LAMOURE D., 1986: Catalogue des Agaricales (Basidiomycètes) de la zone alpine du Parc Nationale de la Vanoise et des régions limitrophes. *Trav. Sci. Parc Nat. Vanoise* 15, 103-187.
- KÜHNER R. & ROMAGNESI H., 1953: Flore analytique des champignons supérieurs. Masson et Cie., Paris. 557 pp.
- KÜHNER R. & ROMAGNESI H., 1977: Compléments à la "flore analytique". *Bibl. Mycol.* 56, 478 pp.
- KUYPER T.W., 1986: A revision of the genus *Inocybe* in Europe. I. Subgenus *Inosperma* and the smooth-spored species of subgenus *Inocybe*. *Persoonia suppl.* Vol. 3, 1-247.
- LAMOURE D., 1969: Un Cortinaire alpin: *Cortinarius (Telamonia) subtorvus* sp. nov. *Schweiz. Zeitschr. Pilzkde.* 47 (9), 165-169.
- LAMOURE D., 1973: Agaricales de la zone alpine. *Mycena ochrogaleata* Favre. *Le Botaniste* 56, 55-58.
- LAMOURE D., 1974: Agaricales de la zone alpine. Genre *Omphalina* (1ère partie). *Trav. Sci. Parc Nat. Vanoise* 5, 149-164.
- LAMOURE D., 1975: Agaricales de la zone alpine. Genre *Omphalina* (2ème partie). *Trav. Sci. Parc Nat. Vanoise* 6, 153-166.
- LAMOURE D., 1977 a: Agaricales de la zone alpine. Genre *Cortinarius* Fr., sous-genre *Telamonia* (Fr.) Loud. Première partie. *Trav. Sci. Parc Nat. Vanoise* 8, 115-146.
- LAMOURE D., 1977 b: Agaricales de la zone alpine. *Psilocybe chionophila* sp. nov. *Bull. Soc. Linn. Lyon* 46, 212-217.
- LAMOURE D., 1978: Agaricales de la zone alpine. Genre *Cortinarius* Fr., sous-genre *Telamonia* (Fr.) Loud. Deuxième partie. *Trav. Sci. Parc Nat. Vanoise* 9, 77-101.
- LAMOURE D., 1982 a: Alpine and circumpolar *Omphalina* species. In: LAURSEN G.A. & AMMIRATI J.F. (ed.), *Arctic and Alpine Mycology I*. University of Washington Press Seattle. 201-215.
- LAMOURE D., 1982 b: Agaricales de la zone alpine du Parc National des Ecrins. *Trav. scient. Parc Nat. Ecrins* 2, 119-123.
- LAMOURE D., 1984: Agaricales de la zone alpine. Genre *Cortinarius* Fr., sous-genre *Dermocybe* Fr. ss. Fayod. *Trav. Sci. Parc Nat. Vanoise* 14, 55-59.
- LAMOURE D., 1986: A propos de petits *Telamonia* sombres, à odeur de pélargonium, récoltés en zone alpine. *Bull. Féd. Myc. Dauphiné-Savoie* 102, 25-28.
- LAMOURE D., 1987: Agaricales de la zone alpine, genus *Cortinarius* Fr., subgenus *Telamonia* (Fr.) Loud. part III. In: LAURSEN G.A., AMMIRATI J.F. & REDHEAD S.A. (eds.), *Arctic and alpine Mycology II*. Plenum Publishing Corporation. 255-259.
- LAMOURE D., 1991: Notes critiques sur les *Telamonia* de la zone alpine (genre *Cortinarius* Fr., Agaricales). I. Quelques espèces à odeur de *Pelargonium*. *Bull. mens. soc. Linn. Lyon* 60 (5), 152-156.
- LAMOURE D., LANGE M. & PETERSEN P.M., 1982: Agaricales found in the Godhavn area, W-Greenland. *Nord. J. Bot.* 2, 85-90.
- LANDOLT E., 1977: Ökologische Zeigerwerte zur Schweizer Flora. *Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* 64, 208 pp.
- LANDOLT E., 1984: *Unsere Alpenflora*. (5. Aufl.). Verlag Schweizer Alpen Club. Brugg. 318 pp.
- LANGE J.E., 1935-1940: *Flora agaricina danica*. Copenhagen. 5 Bde.
- LANGE M., 1946: Mykologiske indtryk fra Lapland. *Friesia* 3, 161-170.
- LANGE M., 1948-57: *Macromycetes. The botanical expedition to West Greenland 1946; 3 parts in 1 (aus Meedeldser om Grønland 147 + 148)*. *Getr. Pog. Abb. København, Reitzels*. 1-125.

- LANGE M., 1978: Fungus flora in August. Ten years' observations in a Danish beech wood district. *Botanisk. Tidsskrift* 73, 21-54.
- LANGE M., 1984: Flechy fungi in grass fields. II. Precipitation and fructification. *Nord. J. Bot.* 4, 491-501.
- LANGE M. & SKIFTE O., 1967: Notes on the Macromycetes of northern Norway. *Acta Borealia. A. Scienta* 23, 1-51.
- LANGLOIS C.-G. & FORTIN J.A., 1978: Absorption of phosphorus [^{32}P] by excised ectomycorrhizae of balsam fir from low concentration of H_2PO_4 . *Nat. Can.* 105, 417-424.
- LANGLOIS C.-G. & FORTIN J.A., 1984: Seasonal variation in the uptake of [^{32}P] phosphate ions by excised ectomycorrhizae and lateral roots of *Abies balsamea*. *Can. J. For. Res.* 14, 412-415.
- LARSEN, M.J., 1968: Tomentolloid Fungi of North America. Technical Publication No. 93 State University College of Forestry of Syracuse University. 157 pp.
- LAURSEN G.A. & AMMIRATI J.F. (eds.), 1982: Arctic and Alpine Mycology I.- University of Washington Press, Seattle & London. 559 pp.
- LAURSEN G.A., AMMIRATI J.F. & REDHEAD S.A. (eds.), 1987: Arctic and Alpine Mycology 2.- Plenum Press, New York & London. 364 pp.
- LAUTENSCHLAGER E., 1989: Die Weiden der Schweiz und angrenzender Gebiete: Bestimmungsschlüssel und Artbeschreibung für die Gattung *Salix* L. Birkhäuser Verlag, Basel. 72 pp.
- LE TACON F., 1990: Les possibilités de mycorhization contrôlée en sylviculture tempérée. *Bulletin de la vulgarisation forestière* 74 (2), 29-41.
- LINDERMAN R.G. & CALL C.A., 1977: Enhanced rooting of woody plant cuttings by mycorrhizal fungi. *J. Amer. Soc. Hort. Sci.* 102(5), 629-632.
- LISIEWSKA M., 1974: Macromycetes of beech forests within the eastern part of the *Fagus* area in Europe. *Acta Mycol.* 10, 3-72.
- LÜDI W., 1958: Beobachtungen über die Besiedlung von Gletschervorfeldern in den Schweizeralpen. *Flora* 146, 386-407.
- LUDWIG J.A. & REYNOLDS J.F., 1988: Statistical ecology, a primer on methods and computing. Wiley, New York. 337 pp.
- LUFTENEGGER G., FOISSNER W. & ADAM H., 1986: Der Einfluss organischer und mineralischer Dünger auf die Bodenfauna einer planierten, begrüneten Schipiste oberhalb der Waldgrenze. *Z. Vegetationst.* 9, 149-153.
- MAAS GEESTERANUS R.A., 1980 a: The *Mycena epipterygia*-group. *Proc. K. Ned. Akad. Wet., Ser. C* 83(1), 65-79.
- MAAS GEESTERANUS R.A., 1980 b: Studies in Mycenas 1-8. *Proc. K. Ned. Akad. Wet., Ser. C* 83(2), 167-186.
- MAAS GEESTERANUS R.A., 1983: Studies in Mycenas 73-92. *Proc. K. Ned. Akad. Wet. Ser. C*, 86, 385-399.
- MAAS GEESTERANUS R.A., 1984: Conspectus of the Mycenas of the northern hemisphere. 3. Section *Filipedes*. *Proc. K. Ned. Akad. Wet., Ser. C* 87(4), 413-447.
- MAAS GEESTERANUS R.A., 1986: Conspectus of the Mycenas of the northern hemisphere. 8. Sections *Intermediae*, *Rubromarginatae*. *Proc. K. Ned. Akad. Wet., Ser. C* 89(3), 279-310.
- MAAS GEESTERANUS R.A., 1988: Conspectus of the Mycenas of the northern hemisphere 9. Section *Fragilipedes*, species I-R. - *Proc. K. Ned. Akad. Wet. Ser. C*, 91, 129-159.
- MAGNES, M. & HAFELLNER J., 1991: Ascomyceten auf Gefäßpflanzen an Ufern von Gebirgsseen in den Ostalpen. *Bibl. Mycol.* 139, 1-182
- MALAJCZUK N., DELL B. & BOUGHER N.L., 1987 a: Ectomycorrhiza formation in *Eucalyptus*. III. Superficial ectomycorrhizas initiated by *Hysterangium* and *Cortinari* species. *New Phytol.* 105, 421-428.

- MALAJCZUK N., TRAPPE J.M. & MOLINA R., 1987 b: Interrelationships among some ectomycorrhizal trees, hypogeous fungi and small mammals: Western Australian and north-western American parallels. *Austral. J. Ecol.* 12, 53-55.
- MARTIN G.W. & ALEXOPOULOS C.J., 1969: The Myxomycetes. Univ.Iowa Press, Iowa City. 561 pp.
- MARX D.H., 1973: Mycorrhizae and feeder root diseases. In: MARKS C.G. & KOZLOWSKI T.T. (eds.), *Ectomycorrhizae: their ecology and physiology*. Academic Press, New York. 351-382.
- MARX D.H. & BRYAN W.C., 1975: Growth and ectomycorrhizal development of loblolly pine seedlings in fumigated soil infested with the fungal symbiont *Pisolithus tinctorius*. *For. Sci.* 21, 245-254.
- MASON P.A., WILSON J. & LAST F.T., 1983: The concept of succession in relation to the spread of sheathing mycorrhizal fungi on inoculated tree seedlings growing in unsterile soils. *Plant and Soil* 71, 247-256.
- MASSICOTTE H.B., PETERSON R.L. & MELVILLE L.H., 1989: Hartig net structure of ectomycorrhizae synthesized between *Laccaria bicolor* (Tricholomataceae) and two hosts: *Betula alleghaniensis* (Betulaceae) and *Pinus resinosa* (Pinaceae). *Amer. J. Bot.* 76 (11), 1654-1667.
- MENGIS B. & GRAF F., 1989: DOGMA ©: Data organizer and graphics manager. Mengis-Software, Mühlehofstrasse 14, CH-6030 Ebikon, Switzerland.
- MERRIAM R.A., 1973: Fog drip from artificial leaves in a fog wind tunnel. *Water Resources Research* 9, 1591-1598.
- MILLER O.K., 1968: Interesting fungi of the St. Elias Mountains, Yukon Territory and adjacent Alaska. *Mycologia* 60, 1190-1203.
- MILLER O.K., 1982: Mycorrhizae, mycorrhizal fungi and fungal biomass in subalpine tundra at Eagle Summit, Alaska. *Holarct. Ecol.* 5, 125-134.
- MILLER O.K., 1987: Higher fungi in tundra and subalpine tundra from the Yukon Territory and Alaska. In: LAURSEN G.A., AMMIRATI J.F. & REDHEAD S.A. (eds.), *Arctic and alpine Mycology II*. Plenum Publishing Corporation. 287-297.
- MILLER S.L. & MILLER O.K. JR., 1984: Synthesis of *Elaphomyces muricatus* + *Pinus sylvestris* ectomycorrhizae. *Can. J. Bot.* 62, 2363-2369.
- MÖRIKOFER W., 1935: Klimatische Verhältnisse des Flüelapasses. In: EIDG. POSTVERWALTUNG (ed.), *Schweizerische Alpenposten, Flüelapass*. 10-14.
- MOIROUD A., 1984: Rôle de la fixation biologique d'azote dans l'évolution des marges glaciaires. *Documents d'Écologie Pyrénéenne III-IV*, 377-382.
- MOSER M., 1958: Der Einfluss tiefer Temperaturen auf das Wachstum und die Lebensfähigkeit höherer Pilze mit spezieller Berücksichtigung von Mykorrhizapilzen. *Sydowia* 12, 386-399.
- MOSER M., 1962: Die Rolle des Wassers im Leben der höheren Pilze. *Schweiz. Z. Pilzkde.* 40 (9), 129-141.
- MOSER M., 1963 a: *Kleine Kryptogamenflora (Gams). Ila. Ascomyceten (Schlauchpilze)*. Fischer, Stuttgart. 147 pp.
- MOSER M., 1963 b: Die Bedeutung der Mykorrhiza bei Aufforstungen unter besonderer Berücksichtigung von Hochlagen. In: RAWALD W. & LYR H. (eds.), *Mykorrhiza*, Fischer, Jena. 407-424.
- MOSER M., 1964: Die Mykorrhizafrage bei der Anzucht von Forstpflanzen für das Hochgebirge. In: *Forstsamengewinnung und Pflanzenanzucht für das Hochgebirge*. BLV, München. 225-231.
- MOSER M., 1965: Künstliche Mykorrhiza-Impfung und Forstwirtschaft. *Allg. Forstz. (München)* 20, 6-7.
- MOSER M., 1978: *Fungorum rariorum icones coloratae, Pars VII*. Cramer Vaduz. 48 pp.

- MOSER M., 1983 a: Kleine Kryptogamenflora (Gams). IIB/2. Die Röhrlinge und Blätterpilze. (5. Aufl.). Fischer, Stuttgart/New York. 533 pp.
- MOSER M., 1983 b: Notizen zu einigen Cortinarien aus der Untergattung *Telamonia*. Mycol. Helv. 1, 1-16.
- MOSER M., 1987: Fungi (Agaricales, Russulales) from the alpine zone of Yellowstone National Park and the Beartooth Mountains with special emphasis on *Cortinarius*. In: LAURSEN G.A. & AMMIRATI J.F. (eds.), Arctic and alpine Mycology II, Plenum Publishing Corporation. 299-317.
- MOSER M. & RAMESEDER M., 1993: An alpine *Collybia* species associated with *Loiseleuria procumbens*: *Collybia loiseleurietorum* spec. nov. In: PETRINI O. & LAURSEN G.A. (eds.), Arctic and Alpine Mycology 3 & 4. Bibl. Mycol. 150, 171-178.
- MOSIMANN TH., 1985: Untersuchungen zur Funktion subarktischer und alpiner Geoökosysteme (Finnmark [Norwegen] und Schweizer Alpen). Physiogeographica (Basel) 7, 488 pp.
- MUELLER G.M., 1991 a: The swedish taxa of *Laccaria* (*Tricholomataceae*) with notes on their distribution. Nord. J. Bot. Copenhagen 10, 665-680.
- MUELLER G.M., 1991 b: *Laccaria laccata* complex in North America and Sweden: Inter-collection pairing and morphometric analyses. Mycologia 83 (5), 578-594.
- MUELLER G.M., 1992: Systematics of *Laccaria* (Agaricales) in the Continental United States and Canada, with discussions on extralimital taxa and descriptions of extant types. Fieldiana, Bot. 6(30), 75-83.
- MUELLER G.M. & VELLINGA E.C. 1986: Taxonomic and nomenclatural notes on *Laccaria* Bk. & Br. *Laccaria amethystea*, *L. fraterna*, *L. laccata*, *L. pumila* and their synonyms. Persoonia 13 (1), 27-43.
- MÜLLER M., 1983: Bodenbildung auf Silikatunterlage in der alpinen Stufe des Oberengadins. Diss. ETH Zürich, Nr. 7352. 79 pp.
- NASCHBERGER S. & KÖCK L., 1983: Erfahrungen über die Wirkung von Biosol beider Begrünung von Skipisten. Z. Vegetationst. 6, 33-36.
- NESPIAK A., 1953: Mycotrophy of the alpine vegetation of the Tatra Mountains. Acta Soc. Bot. Pol. 22, 97-125.
- NOORDELOOS M.E., 1979: *Entoloma* subgenus *Pouzaromyces* emend. in Europe. Persoonia 10, 207-243.
- NOORDELOOS M.E., 1980: *Entoloma* subgenus *Nolanea* in the Netherlands and adjacent regions with a reconnaissance of its remaining taxa in Europe. Persoonia 10, 427-534.
- NOORDELOOS M.E., 1984: *Entolomataceae* (Agaricales, Basidiomycetes) in Greenland - 1. The Genus *Entoloma*. Persoonia 12 (3), 263-305.
- NOORDELOOS M.E., 1987: *Entoloma* (Agaricales) in Europe. Beih. Nova Hedwigia 91, 1-419.
- NOORDELOOS M.E. & GULDEN G., 1989: *Entoloma* (Basidiomycetes, Agaricales) of alpine habitats on the Hardangervidda near Finse, Norway, with a key including species from northern Europe and Greenland. Can. J. Bot. 67, 1727-1738.
- OBERDORFER E., 1977: Süddeutsche Pflanzengesellschaften. Teil I. (2. Aufl.). Fischer Verlag. Stuttgart, New York. 311p.
- OBERDORFER E., 1978: Süddeutsche Pflanzengesellschaften. Teil II. (2. Aufl.) Fischer Verlag. Stuttgart, New York. 355 pp.
- OCHIAI A., 1957: Zoogeographic studies on the soleoid fishes found in Japan and its neighbouring regions. Bull. Jap. Soc. Sci. Fisheries 22, 526-530.
- OHENOJA E., 1971: The larger fungi of Svalbard and their ecology. Ann. Univ. Turku A II, Rep. Kevo Subarctic Res. Stat. 8, 122-147.
- OHENOJA E., 1993: Effect of weather condition on the larger fungi at different forest sites in northern Finland in 1976-1988. Acta Universitatis Ouluensis series A: Scientiae rerum naturalium 243, 97 pp.

- OLSEN S.R. & KEMPER W.D., 1968: Movement of nutrients to plant roots. *Adv. Agron.* 20, 91-151.
- ORTON P.D., 1960: New check list of British agarics and boleti. Part III. Notes on genera and species in the list. *Trans. Brit. Mycol. Soc.* 43, 159-439.
- ORTON P.D., 1969: Notes on British agarics, III. *Notes Roy. Bot. Gard. Edinburgh* 29(1), 75-128.
- PALLMANN H. & HAFTER P., 1933: Pflanzensoziologische und bodenkundliche Untersuchungen im Oberengadin mit besonderer Berücksichtigung der Zwergstrauchgesellschaften der Ordnung *Rhodoreto-Vaccinietalia*. *Ber. Schweiz. Bot. Ges.* 42, 357-466.
- PAUL L., 1991: Vegetationsveränderungen an der alpinen Waldgrenze. Teilprojekt: Kulturen in vitro. Ludwig-Maximilians Universität München, Forstbotanik: Schlussbericht F-E Vorhaben Nr. 108 03 046/46. 31 pp. (unpubl.)
- PERRIN R., 1985: L'aptitude des mycorhizes à protéger les plantes contre les maladies: panacée ou chimère? *Ann. Sci. For.* 42, 453-470.
- PERSSON H., 1983: Influence of soil animals on nitrogen mineralization in a northern Scots pine forest. In: LEBRUN PH., ANDRE H.M., DE MEDTS A., GREGOIRE-WIBO C. & WAUTHY G. (eds.), *New trends in soil biology*. Dieu-Brichart, Louvain-La-Neuve. 117-126.
- PERRY D.A., MOLINA R. & AMARANTHUS M.P., 1987: Mycorrhizae, mycorrhizospheres, and reforestation: current knowledge and research needs. *Can. J. For. Res.* 17, 929-940.
- PETERSEN P.M. 1977: Investigations on the ecology and phaenology of the macromycetes in the arctic. *Meddel. Grønland* 199 (5), 1-72.
- PEYRONEL B., 1930: Simbiosi micorrizici tra piante alpine e Basidiomiceti. *N. Giorn. Bot. Ital.* 37, 655-663.
- PIELOU E.C., 1977: *An introduction to mathematical ecology*. (2. edition). Wiley, New York. 286 pp.
- POELT J., 1969: *Bestimmungsschlüssel europäischer Flechten*. Cramer Verlag, Vaduz. 757 pp.
- POELT J. & JÜLICH W., 1969: *Omphalina grisella* ein weiterer lichenisierter Blätterpilz der Alpen. *Herzogia* 1, 331-336.
- POELT J. & VEZEDA A., 1977: *Bestimmungsschlüssel europäischer Flechten, Ergänzungsheft I*. Cramer Verlag, Vaduz. 258 pp.
- POELT J. & VEZEDA A., 1981: *Bestimmungsschlüssel europäischer Flechten, Ergänzungsheft II*. Cramer Verlag, Vaduz. 390 pp.
- QUINN J.F. & DUNHAM A.E., 1983: On hypothesis testing in ecology and evolution. *Amer. Naturalist* 122, 602-617.
- RASCHENDORFER I., 1953: Stecklingsbewurzelung und Vegetationsrhythmus. Einige Versuche zur Grünverbauung in Rutschflächen. *Forstw. Centralblatt* 72 (5,6), 159-171.
- READ D.K., LEAKE J.R. & LANGDALE A.R., 1988: The nitrogen nutrition of mycorrhizal fungi and their host plants. In: BODDY L., MARCHANT R. & READ D.J. (eds.), *Nitrogen, phosphorus and sulphur utilization by fungi*. Cambridge University Press, Cambridge / New York. 181-204.
- REID D., 1972: *Fungorum rariorum icones illustratae. Pars V*. Cramer Vaduz. 64 pp.
- RICHARD F., LÜSCHER P. & STROBEL T., 1978-1983: *Physikalische Eigenschaften von Böden der Schweiz*. Eidg. Anst. Forstl. Versuchswesen, Birmensdorf. (3 vol.).
- ROEMER N., 1993: *Oekologie und Systematik alpiner Arten der Gattung Galerina Earle*. Diplomarbeit Geobotanisches Institut, ETH Zürich. 79 pp. (copy).
- ROSTRUP E., 1891: Tillaeg til Grønlands svampe (1888). *Medd. om Grønland*. 3, 591-643.
- RÜCKER T., 1987: Ultrastruktur der Sporen bei *Hebeloma* (Pers.: Fr.) Kummer (Agaricales). *Z. Mykol.* 53 (1), 59-72.
- RÜCKER T., WITTMANN H. & PEER T., 1990: *Mykozoenologische Untersuchungen in Fichtenwäldern im Bundesland Salzburg, Österreich*. *Mycol. Helv.* 4, 75-98.

- SCHÄRER-BIDER W., 1951: Beobachtungen über die Verbreitung einiger höherer Pilze im Wallis. Ber. Geobot. Inst. ETH, Stiftung Rübel, Zürich (1950), 38-44.
- SCHEFFER F., SCHACHTSCHABEL P., 1984: Lehrbuch der Bodenkunde. Enke, Stuttgart. 442 pp.
- SCHIBLER W., 1937: Flora von Davos. Bischofberger & Co., Buchdruckerei Untertor. 216 pp.
- SCHIECHTL H.M., 1958: Grundlagen der Grünverbauung. Mitt. Forstl. Bund. Vers. Anst. Wien 55. 273 pp.
- SCHIECHTL H.M., 1973: Sicherungsarbeiten im Landschaftsbau. Grundlagen - lebende Baustoffe - Methoden. Georg D. W. Callwey Verlag, München. 244 pp.
- SCHIECHTL H.M., 1992: Weiden in der Praxis. Patzer, Berlin. 130 pp.
- SCHLICHTING E. & BLUME HP., 1966: Bodenkundliches Praktikum. Parey, Hamburg. 209 pp.
- SCHÖNTALER K.E., 1980: Probleme der Hochlagenbegrünung unter besonderer Berücksichtigung der Schipisten einschliesslich vorläufiger Versuchsergebnisse. Z. Vegetationst. 3, 38-42.
- SCHROEDER D., 1984: Bodenkunde in Stichworten. (4. Aufl.). Hirt, Würzburg. 160 pp.
- SCHÜEPP M., 1967: Lufttemperatur. 3.-4. Teil. Klimatologie der Schweiz. Beih. Ann. Schweiz. Meteorol. Zentralanst. 7C, 63-106.
- SCHUMACHER T., 1990: The genus *Scutellinia* (*Pyronemataceae*). Opera Bot. 101, 107 pp.
- SCHUMACHER T., 1992: New or noteworthy Discomycetes. 2. Five new operculate Discomycetes (Pezizales) from the Dovre mountains, central South Norway. Mycotaxon 43, 33-47.
- SCHUMACHER T., 1993: Ecology and distribution of the genus *Scutellinia* in Norway. In: PETRINI O. & LAURSEN G.A. (eds.), Arctic and Alpine Mycology 3 & 4. Bibl. Mycol. 150, 215-233.
- SCHÜTZ M., 1990: Keimverhalten alpiner *Caryophyllaceae* und ihre Eignung zur Begrünung von Skipistenplanierungen oberhalb der Waldgrenze. Z. Vegetationst. 2, 79-83.
- SCHWÄRZEL CH., 1975: Beitrag zur Hypogaeenflora des Kantons Basel-Stadt und seiner näheren Umgebung. Schweiz. Z. Pilzkde. 11, 161-168.
- SENN-IRLET B., 1986: *Galerina chionophila* (Agaricales, Basidiomycetes), eine neue Art aus der alpinen Stufe der Schweizer Alpen. Mycol. Helv. 2, 43-48.
- SENN-IRLET B., 1987: Oekologie, Soziologie und Taxonomie alpiner Makromyceten (Agaricales, Basidiomycetes) der Schweizer Zentralalpen. Diss., Universität Bern. 310 pp.
- SENN-IRLET B., 1988: Macromycetes in alpine snow-bed communities - mycocoenological investigations. Acta Bot. Neerl. 37, 251-263.
- SENN-IRLET B., 1992: Botanischer Reichtum am Weg von Davos über die Berggüter Furgga zum Albula. 6. Makromyceten (Basidiomycota, Agaricales, Aphyllophorales). Bot. Helv. 102, 49-59.
- SENN-IRLET B., 1993: The mycoflora of alpine mire communities rich in *Salix*. In: PETRINI O. & LAURSEN G.A. (eds.), Arctic and Alpine Mycology 3 & 4. Bibl. Mycol. 150, 235-249
- SENN-IRLET B., JENSSEN K.M. & GULDEN G., 1990: Arctic and Alpine Fungi - 3. Soppkonsulenten, Oslo. 58 pp.
- SHANNON C.E. & WIENER W., 1949: The mathematical theory of communication. University Illinois press, Urbana. 117 pp.
- SINGER R., 1977: Die Gruppe der *Laccaria laccata* (Agaricales). Plant. Syst. Evol. 126, 347-370.
- SKIFTE O., 1979: Storsopp pa Svalbard. Ottar 110, 29-39.
- SKIFTE O., 1989: *Russula* of the island Bjørnøya (Bear Island), Svalbard. Opera Bot. 100, 233-239.

- SMITH A.H. & SINGER R., 1964: A monograph of the genus *Galerina* Earle. Hafner Publishing Company, New York, London. 384 pp.
- SMITH A.J.E., 1980: The moss flora of Britain and Ireland. Cambridge University Press, Cambridge. 706 pp.
- SNEATH P.H.A. & SOKAL R.R., 1973: Numerical taxonomy. Freeman, San Francisco, CA. 573 pp.
- SÖHNER E. 1962: Die Gattung *Hymenogaster* Vitt. Beih. Nova Hedwigia 2, 1-113.
- SPAENHAUER F., BARTH P., EUGSTER H., STRECKEISEN A. & LEUPOLD W., 1935: Geologischer Atlas der Schweiz (1:25000) Blatt 423 Scaletta. Hrsg.v.d. Geolog. Kommission der Schweiz. Natf. Ges.
- STACK R.W. & SINCLAIR W.A., 1974: Protection of Douglas-fir seedlings against *Fusarium* root rot by a mycorrhizal fungus in the absence of mycorrhiza formation. Phytopathology 65, 468-472.
- STANGL J., 1989: Die Gattung *Inocybe* in Bayern. Hoppea 46, 1-409.
- STANGL J. & VESELSKY J., 1974: Beiträge zur Kenntnis seltener Inocyben. Nr.4, *Inocybe boltonii* Heim in der Variationsbreite ihrer Formen. Česká Mycol. 28, 143-150.
- STEUHLING L., 1965: Pflanzenökologisches Praktikum. Parey, Hamburg. 262 pp.
- STICHER H., SCHMIDT H.W. & GEISSMANN T., 1971: Agrikulturchemisches Praktikum für Landwirte und Förster. (2. Aufl.). Verlag der Fachvereine ETH, Zürich. 81 pp.
- STIMPFLI H., 1985: Zur Bedeutung der Reproduktionsstrategie autochthoner und standortfremder Arten für die ingenieurbioologische Berasung hochalpiner Erosionsflächen. Diss. Leopold-Franzens-Univ. Innsbruck. 194 pp. (copy)
- SVRCEK M., 1960: Tomentelloideae Cechoslovakiae. Genera resupinata familiae Thelephoraceae s. str. Sydowia 14, 170-245.
- THOEN D., 1976: Facteurs physiques et fructification des champignons supérieurs dans quelques pessières d'Ardenne meridionale (Belgique). Bull. Soc. Linn. Lyon 45, 269-284.
- TRAPPE J.M., 1962: Fungus associates of ectotrophic mycorrhizae. Bot. Rev. 28, 538-606.
- TRIMBACH J., 1978: Materiél pour une "check-list" des Alpes Maritimes (suite). Doc. Mycol. VII, 29, 39-53.
- TURNER H. & BLASER P., 1977: Mikroklima, Boden und Pflanzen an der oberen Waldgrenze. Terra Grischuna / Bündnerland 3, 158-160.
- URBANKSA K.M., 1986: High altitude revegetation research in Switzerland - problems and perspectives. Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich 87, 155-167.
- URBANKSA K.M., 1988: High altitude revegetation research in the Swiss Alps: experimental establishment and performance of native plant populations in machine-graded ski-runs above timberline. Proc. 8th HAR Workshop, Fort Collins. 115-128.
- URBANKSA K.M., 1990: Standortsgerechte Skipistenbegrünung in hochalpinen Lagen. Z. Vegetationst. 2. 75-78.
- VASSILKOV B.P., 1967: On the macromycetes of the Soviet Arctic (in russian). Mikol. Fitopatol. 1(1), 17-25.
- VESTERHOLT J., 1989: A revision of *Hebeloma* sect. *Indusiata* in the nordic countries. Nord. J. Bot. 9, 289-319.
- VESTERHOLT J. & WEHOLT O., 1985: *Hebeloma* sect. *Hebeloma* in Skandinavia. Agarica 6 (12), 158-177.
- VILLIERS T.A., 1973: Ageing and the longevity of seeds in field conditions. In: HEYDEKKER W. (ed.), Seed Ecology. Univ. Park, Pennsylvania State Univ. Press. 265-388.
- VUAGNEUX R., 1983: Glazialmorphologische und Gletschergeschichtliche Untersuchungen im Gebiet Flüelapass. Physische Geographie 10, 1-249.
- WAREING P.F., 1966: The ecological aspects of seed dormancy and germination. In: HAWKES J. (ed.), Reproductive biology and taxonomy of vascular plants. Pergamon, New York. 103-121.

- WATLING R., 1977: Larger fungi from Greenland. *Astarte* 10, 61-71.
- WATLING R., 1981: Relationships between Macromycetes and the development of higher plant communities. In: WICKLOW D.T. & CAROLL G.C. (eds.), *The fungal community. Its organisation and role in the ecosystem*. Dekker Verlag, New York & Basel. 427-458.
- WATLING R., 1982: British fungus flora, agarics and boleti. 3. *Bolbitiaceae: Agrocybe, Bolbitius & Conocybe*. Roy. Bot. Gard., Edinburgh. 139 pp.
- WATLING R., 1985: Observations on *Amanita nivalis* Greville. *Agaricia* 6, 327-335.
- WATLING R., 1987: Larger alpine fungi in Scotland. In: LAURSEN G.A., AMMIRATI J.F. & REDHEAD S.A. (eds.), *Arctic and Alpine Mycology II*. Plenum Publishing Corporation. 17-45.
- WATLING R., 1992: Macrofungi associated with British willows. *Proc. Roy. Soc. Edinburgh Sect. B - Biol. Series* 98, 135-147.
- WATLING R. & GREGORY N.M., 1987: British fungus flora, agarics and boleti. 5. *Strophariaceae & Coprinaceae* p.p.: *Hypholoma, Melanotus, Psilocybe, Stropharia, Lacrymaria & Panaeolus*. Roy. Bot. Gard., Edinburgh. 121 pp.
- WILDI O. & EWALD K., 1986: Der Naturraum und dessen Nutzung im alpinen Tourismusgebiet von Davos. Ergebnisse des MAB-Projektes Davos. Ber. Eidg. Anst. Forstl. Versuchswesen, 336 pp.+ 8 maps.
- WILKINS W.H. & PATRICK S.H.M., 1940: The ecology of the larger fungi. IV. The seasonal frequency of grassland fungi with special reference to the influence of environmental factors. *Ann. Appl. Biol.* 27, 17-34.
- WILKINS W.H. & HARRIS G.C.M., 1946: The ecology of the larger fungi. V. An investigation into the influence of rainfall and temperature on the seasonal production of fungi in a beechwood and a pinewood. *Ann. Appl. Biol.* 33, 179-188.
- WINTERHOFF W., 1975: Die Pilzvegetation der Dünenrasen bei Sandhausen (nördliche Oberrheinebene). *Beitr. Naturkundl. Forsch. SW-Deutschld.* 34, 445-462.
- WINTERHOFF W., 1984: Analyse der Pilze in Pflanzengesellschaften. In: KNAPP R. (ed.), *Sampling methods and taxon analysis in vegetation science*. Junk, The Hague. 227-248.
- WIRTH V., 1980: Flechtenflora. Ulmer Verlag, Stuttgart. 552 pp.
- WIRTH V., 1987: Die Flechten Baden-Württembergs, Verbreitungsatlas. Ulmer Verlag, Stuttgart. 528 pp.
- ZAK B., 1973: Classification of ectomycorrhizae. In: MARKS C.G. & KOZLOWSKI T.T. (eds.), *Ectomycorrhizae: their ecology and physiology*. Academic Press, New York. 43-78 pp.

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