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The relation between the flooding regime and the distribution particularly of Pulegium vulgare Miller

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ABSTRACT

This paper describes the reaction of *Pulegium vulgare* and a number of species from the same locality upon the different flooding regimes of four consecutive years. These species mainly belong to the *Lolio-Cynosuretum* and the *Ranunculo-Alopecuretum*. The results show that the effect of a flood on the vegetation strongly depends on the month (the date of the year) during which the inundation occurs. A flood of shorter duration in late summer has a stronger impact than a longer inundation in spring and early summer.

Pulegium vulgare strongly decreased after being flooded in July and August and did not recover in the subsequent year. On account of the behaviour of the species after a summer inundation, seven groups were broadly distinguished.

ZUSAMMENFASSUNG

Die Arbeit beschreibt die Reaktion von *Pulegium vulgare* und einiger anderer Arten derselben Lokalität auf Überschwemmungen in aufeinanderfolgenden Jahren. Die Arten gehören hauptsächlich zum *Lolio-Cynosuretum* und *Ranunculo-Alopecuretum*. Die Ergebnisse zeigen, daß die Wirkung einer Überschwemmung auf die Vegetation stark vom Datum derselben abhängt. Eine kurze Überschwemmung im späten Sommer hat eine stärkere Wirkung als eine längere Überschwemmung im Frühling oder im frühen Sommer.

Pulegium vulgare ging nach einer Überflutung im Juli und August stark zurück und regenerierte sich im nächsten Jahr nicht. Auf Grund der Reaktion der Arten nach einer Überschwemmung im Sommer werden sieben Gruppen unterschieden.

INTRODUCTION

Pulegium vulgare (*Mentha pulegium* L.) is distributed over Southern, Western and Central Europe. It occurs northward to Ireland and Central Poland and extends to the Western and Southern Ukraine (TUTIN et al. 1972). Outside Europe it is naturalized throughout the temperate zone. Nowadays *Pulegium vulgare* is very rare in the Netherlands, severely endangered in Germany (KORNECK 1984), rare to very rare in Belgium (DE LANGHE et al. 1983) and very local in the British Isles (CLAPHAM et al. 1975). In the Netherlands its decline has probably been caused by a change in watercontrol and by eutrophication, especially enrichment with phosphorus (ADEMA 1980, SYKORA 1984).

Pulegium vulgare is a character species of the *Lolio-Potentillion anserinae* Tx. 1947 (SYKORA 1983) and consequently it is indicative of pastures inundated during winter and spring. It is also found in *Isoeto-Nanojuncetea* communities. According to OBERDORFER (1979) the species occurs on nutrient rich, calcium poor, sandy to clayey soils. *Pulegium vulgare* belongs to the trichohygrophyta: this means that germination and development occur in the terrestrial phase, when the soil is stil moist. A long limose phase offers favourable conditions and a secondary flooding is tolerated (HEJNY 1960).

Purpose of this paper is to describe the reaction of *Pulegium vulgare* and of a number of species from the same location on different flooding regimes.

METHODS

In 1978 a transect was established on the bank of the Molenkolk (municipality of Millingen, province of Gelderland, the Netherlands), a pool resulting from a former dike burst, now occurring on the landside of the dike and consequently without direct contact with the river Waal (a branch of the river Rhine).
The transect was made on a slope perpendicular to the waterline. Its length is 13 metre. The difference in level between the highest and the lowest part of the transect is 1,87 metre.

Sampling took place during four consecutive years (1978 to 1981) by means of 26 contiguous quadrats sized 2 x 0,5 metre, with their long side at right angles to the transect line. Besides contiguous quadrats sized 25 x 25 cm were sampled in order to detect the pattern of the species. Figures based on these small quadrats are presented (fig. 5).
The quantitative occurrence of each species was estimated using the BRAUN-BLANQUET scale as refined by BARKMAN et al. (1964; see also WESTHOFF & VAN DER MAAREL 1973).

The free water level of the Molenkolk as well as the soil water table was measured by H.M. VAN DE STEEG (figs. 2 and 3).

Soil samples were collected from April to October at intervals of four weeks in four sampling sites at both sides of each transect which gives a total of eight sampling sites for the whole transect. Each sample was composed of five subsamples. Location of the sampling sites was at both sides of the quadrats 1, 9, 18 and 26. As the majority of the roots was concentrated in the top 5 or 10 cms., all samples were collected from a depth of 1-6 cms. After extraction with bidest the samples were analysed for PO_4, NH_4, NO_3 and NO_2, using a technicon autoanalyser. Furthermore organic content, soil texture, pH, total N and P, $CaCO_3$ and pore volumes were determined only once.
The destruction of the samples used for analysing total N, was according to WALKLEY & BLACK (1934). Total N content was measured colorimetrically after KJELDAHL- destilation. H_2SO_4 and H_2O_2 were used for the destruction of the samples in case of the analysis for total P content. Total P content was measured colorimetrically as well. The $CaCO_3$ content was analysed according to SCHEIBLER & FINKENER. Pore volumes of 100 cc soil samples were measured by means of a vacuum air pycnometer according to LANGER.

Species nomenclature follows the Flora van Netherland (HEUKELS & VAN OOSTSTROOM 1975).

RESULTS

The soil

The soil texture varies from loamy sand to sandy loam, the organic matter between 4 and 9%. Although the total pore volumes (49-59%) are higher than the values found in a *Lolio-Cynosuretum* (45%) by BOEKER (1957), the air filled pore volumes of the lower quadrats are very low. Air-filled pore volumes (%) standard deviation (SD) and number (n) of samples are:

	2nd July 1979			19th September 1979		
	X	SD	n	X	SD	n
p.q.1	43	0.6	3	38	3	3
p.q.9	15	4	3	34	5	3
p.q.18	7	3	3	19	0.6	3

The $CaCO_3$ content varied from 2.1 to 4.6% of the soil weight and the pH ($SrCl_2$) from 7.1 to 7.3.

As the values for the remaining soil factors show a considerable and irregular spatial variation resulting in very high standard deviations, no correlation with the gradual change in the topography of the transect could be demonstrated.
The C/N ratio (mean value 14, SD= 3) indicates a fairly rapid mineralisation.

The vegetation

The vegetation presents a transition from the top downward from a *Lolio-Cynosuretum* into a *Ranunculo-Alopecuretum geniculati* subass. *rorippetosum sylvestris* Sykora 1983. The *Lolio-Cynosuretum* is a relatively intensive pasture on moist to relatively dry, fertile soils. The *Ranunculo-Alopecuretum geniculati rorippetosum sylvestris* belongs to the *Lolio-Potentillion anserinae* (*Agrostietalia stoloniferae* Oberd., Müller et Görs 1967, *Plantaginetea majoris* R. Tx. et Prsg. 1950). This alliance occurs on pastures inundated during winter and spring on nutrient rich to moderately nutrient poor soils. The *Ranunculo-Alopecuretum geniculati rorippetosum sylvestris* is confined to sites with a low ground water table and a dry top soil after the retreat of the water. The water table is often situated more than one metre below the ground level (SYKORA 1983).

In the lowest quadrats the proportion of bare ground is considerable and the number of species is low. *Trifolium repens*, *Lolium perenne*, *Plantago major*, *Poa pratensis*, *Ranunculus repens*, *Taraxacum officinale* and *Poa annua* are restricted to the upper and middle half of the transect, while *Achillea millefolium*, *Cynosurus cristatus*, *Ranunculus bulbosus*, *Crepis capillaris*, *Senecio jacobaea*, *Cardamine pratensis*, *Festuca rubra*, *Dactylis glomerata*, *Hypochoeris radicata*, *Bellis perennis*, *Leontodon autumnalis* and *Plantago lanceolata* occupy the uppermost quadrats. Species with their optimal development (highest cover-abundance value) somewhere in the middle part of the transect are *Poa trivialis*, *Ranunculus repens*, *Potentilla reptans*, *Alopecurus geniculatus* and *Trifolium fragiferum*. *Myosotis scorpioides* and *Pulegium vulgare* are optimally growing in the upper half of the lower part of the transect. *Agrostis stolonifera* is strongly increasing downward and is the main component of the lowest quadrats almost covering their whole surface. *Eleocharis palustris*, *Potentilla anserina*, *Ranunculus aquatilis*, *Polygonum amphibium*, *Rorippa sylvestris* and *Veronica catenata* are characteristic of the lower part of the transect. *Juncus compressus* occurs in the lower as well as in the middle part.

Hydrological dynamics

The hydrology of the river Waal is very dynamic. High floods mainly occur from the middle of December to the end of May, but may also occur in summer or autumn. The occurrence of a high water level is highly unpredictable. Plant communities exposed to this regime must either tolerate these extreme situations or they must show a considerable resilience.

As flooding during the growth season is of considerably more importance to the species than winter inundation (WALTHER 1977), the duration of submersion of each quadrat is given for the period 1 April to 1 October (fig. 1). With the exception of some quadrats the longest flood occurred in the growth season of 1978. In 1980 the flooding period lasted longer in almost all quadrats than in 1979 but shorter than in 1978. In 1981 in almost all quadrats the

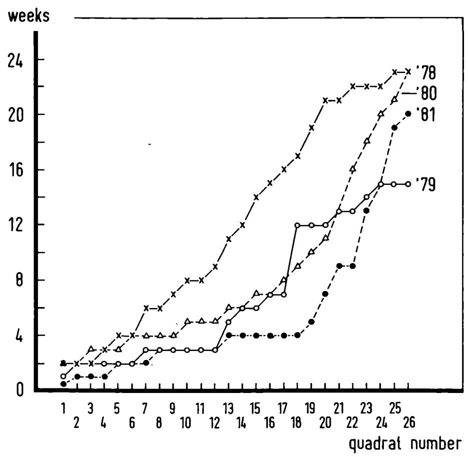


Fig. 1: Length of the period of submersion of the quadrats in the separate years.

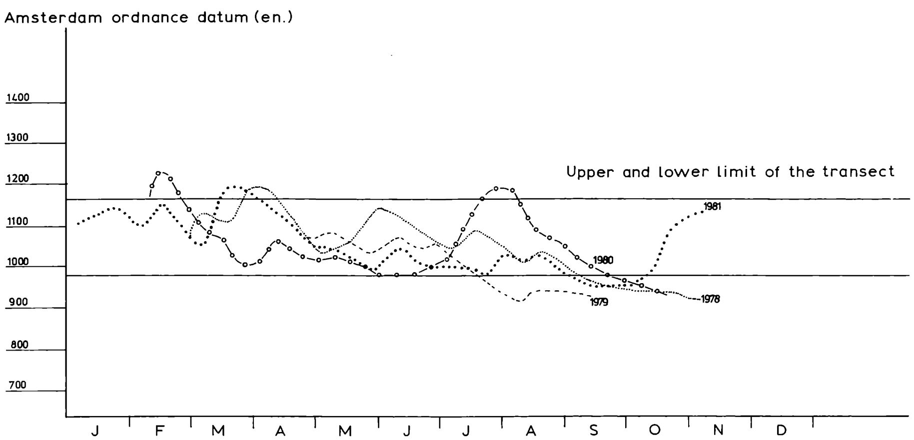


Fig. 2: Periods and depths of flooding in the transect. The highest and lowest level of the transect is indicated by horizontal lines.

period of inundation was shorter than in 1980. Many quadrats were flooded even shorter than in 1979.

The flooding regime also differed considerably (fig. 2). In 1978 the water level gradually descreased in an oscillating way from April to the end of August, with three successively lower peaks, respectively in the beginning of June, the end of July and the end of August. In 1979 the retreat of the water was more gradual. The transects were not reflooded after the end of June resulting in a considerably shorter flooding period and a considerably longer growth season. In 1980 only the lower quadrats were flooded during April and May, emerging during the month of June. Subsequently all quadrats were inundated once more during a summer flood, lasting from the beginning of July till the end of August. In 1981 only the lower quadrats were frequently flooded after the

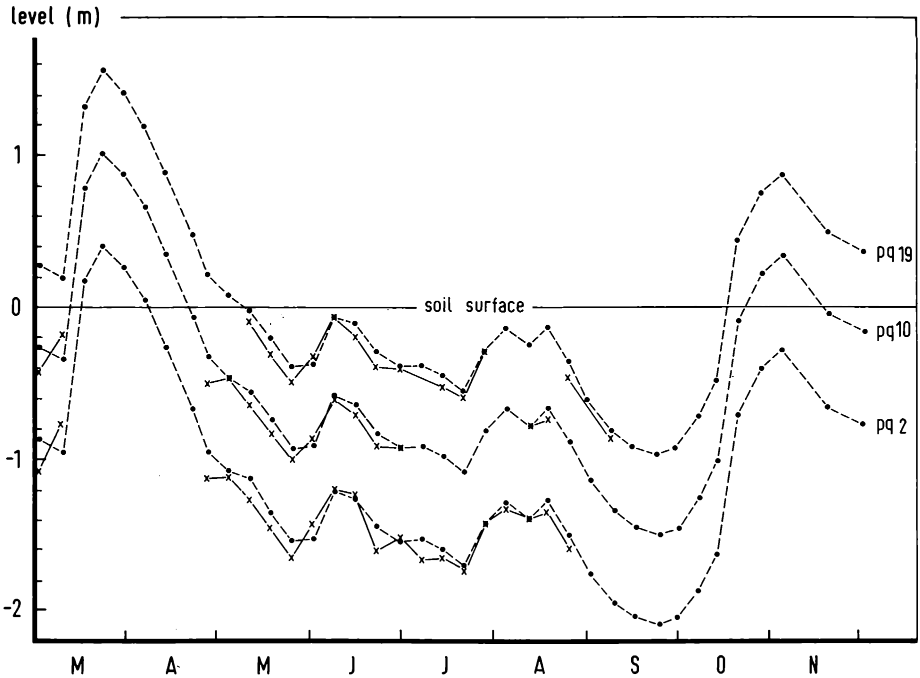


Fig. 3: The variation in the (ground) water level in the year 1981 in the quadrats 2, 10 and 19 (uninterrupted line). The waterlevel of the pool is indicated by the interrupted line.

month of April, emerging in September. In October most of the quadrats were submerged by a new flood.

The ground water level measured in the transect (fig. 3) corresponds with the free water level in the pool. In 1981 the deepest ground water levels for quadrats 2, 10 and 19 were respectively -210, -150 and -97 cm.

Reaction of Pulegium vulgare and some other species

In all years *Pulegium vulgare* and *Myosotis scorpioides* are similarly distributed over the transect. In years in which both species have a clear optimum (1978 and 1979), these optima correspond (fig. 4).
Although in 1978 the period of submersion lasted considerably longer than in 1979, the influence on both species of this difference in the hydrology was absent or was only very slight. *Pulegium vulgare* somewhat increased in the zone of its optimal occurrence. In the growth season of 1978 *Myosotis scorpioides* was submerged over its total range during 4-23 weeks, while the zone of its optimal occurrence was flooded during between 15 and 22 weeks. Corresponding values for *Pulegium vulgare* are 0-23 weeks and 15-22 weeks. In 1979 the flooding period was reduced for *Myosotis scorpioides* to 2-15 weeks (total range) and 6-14 weeks (optimal range) and for *Pulegium vulgare* to 2-14 weeks and 6-13 weeks respectively.

In contrast to the situation described above, notwithstanding the fact that the total period of submergence in the growth season of

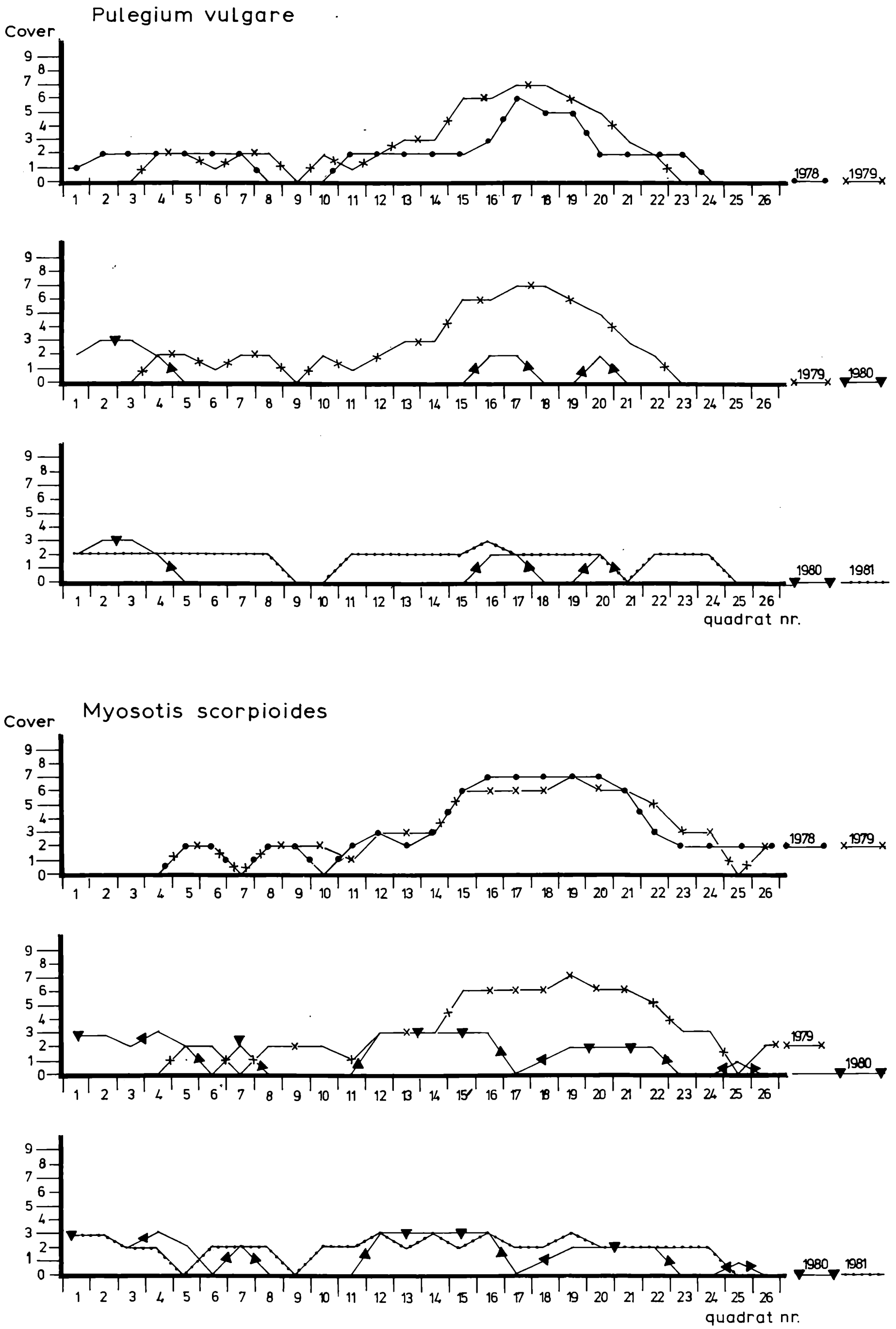


Fig. 4: Distribution of *Pulegium vulgare* and *Myosotis scorpioides* over the transect. Vertically the ordinal transformation of the BRAUN-BLANQUET scale as refined by BARKMAN et al. (1964) is given.

1980 was shorter than in 1978 and was only slightly longer than in 1979, many species reacted heavily upon the summer inundation of the year 1980.

The total cover of *Pulegium vulgare* and of *Myosotis scorpioides* considerably decreased especially in the range where they used to have their optimal occurrence. This decrease was most drastic for *Pulegium vulgare* (figs. 4, 5).

Other species with considerable decrease over almost the whole range of their distribution are *Ranunculus repens*, *Trifolium repens*, *Plantago lanceolata*, *Lolium perenne* and *Bellis perrenis* (fig. 5).

Agrostis stolonifera considerably increased in the upper part of the transect and considerably decreased in the lower part. *Alopecurus geniculatus* disappeared from the middle and lower quadrats and now only occurred in the six uppermost quadrats. *Potentilla reptans* and *Poa trivialis* also increased in the upper part of the transect but the decrease in the lower part was only slight. *Eleocharis palustris* and *Juncus compressus* increased over the whole range of their occurrence. *Potentilla anserina* slightly decreased.

Although in 1981 the period of submersion in almost all quadrats was shorter than in 1980 and although no summer flood occurred, *Pulegium vulgare* and *Myosotis scorpioides* recovered only very slightly. Both species now occurred all over the transect but only with low cover values and a zone of optimal occurrence was still absent (fig. 4). For *Plantago lanceolata*, *Lolium perenne*, *Bellis perennis* and *Trifolium repens* the distribution pattern of 1979 was restored. The coverage of *Poa trivialis* in the upper quadrats decreased again to the level of 1979. *Potentilla reptans*, *Juncus compressus*, *Eleocharis palustris*, *Potentilla anserina* and *Agrostis stolonifera* approximately maintained the coverage obtained in 1980. The last mentioned species recovered in the lowest quadrats. *Ranunculus repens* slightly increased but did not recover to the level of 1979.

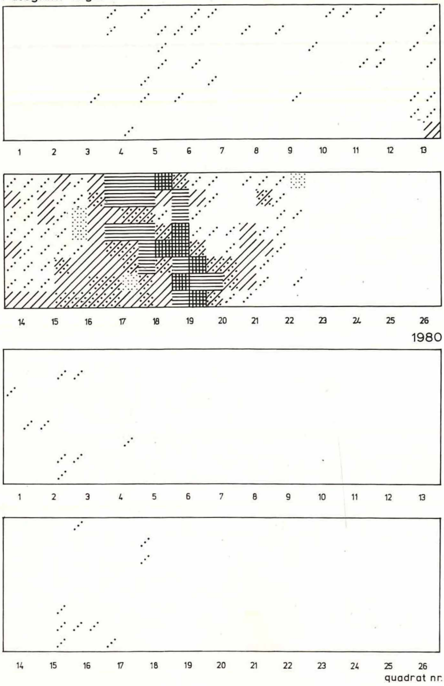
Ranunculus bulbosus, *Achillea millefolium*, *Cerastium fontanum*, *Festuca rubra* and *Dactylis glomerata* were not recorded again after 1979. *Trifolium fragiferum* showed a steady increase throughout the years 1978-1981. From 1978 to 1979 only the coverage increased while after the summer inundation of 1980 there was an extension of the distribution. In 1978 and 1979 *Trifolium fragiferum* occurred in 3 quadrats, in 1980 in 5 and in 1981 in 8 quadrats. *Alopecurus geniculatus* again extended its range to the lower and middle quadrats while the species decreased in the upper part of the transect.

CONCLUSIONS

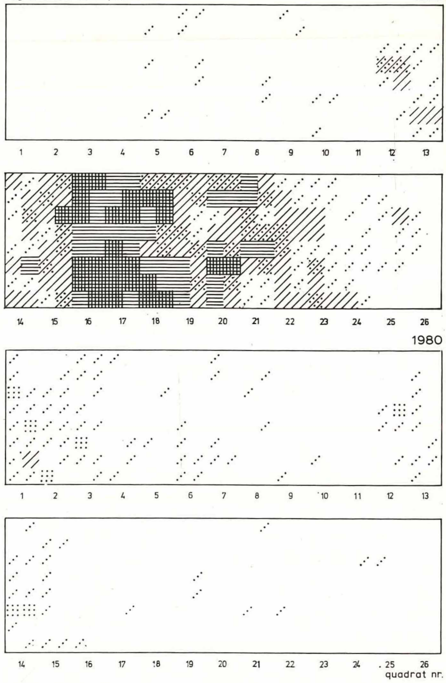
From the results presented in this paper it is apparent that data on the relation between species distribution and flooding period can only be used when carefully considering the month of the year during which the flood occurs. Flooding is not only of less importance to the species during the winter period than during the growth season, but even within the latter, the effects of a longer lasting inundation in spring and early summer (1978) are less pronounced than a flood of shorter duration in late summer (1980).

The damage is proportional a) to the sensitivity of the species for flooding, b) to the temperature of the water as its oxygen content is negatively temperature dependent, c) to the depth of the water and d) to the duration of the flood. The damage is caused by oxygen depletion, mainly resulting from the high consumption of oxygen needed for the decomposition of the submerged orga-

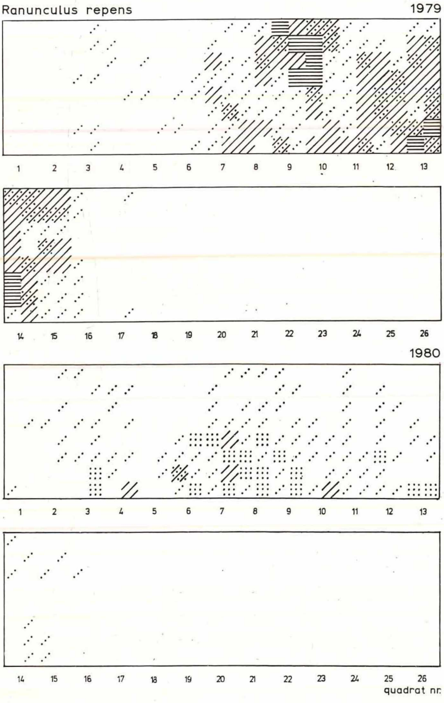
Pulegium vugare 1979



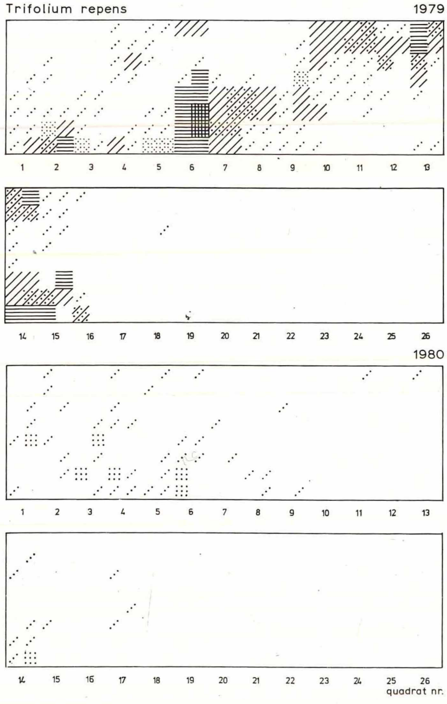
Myosotis scorpioides 1979

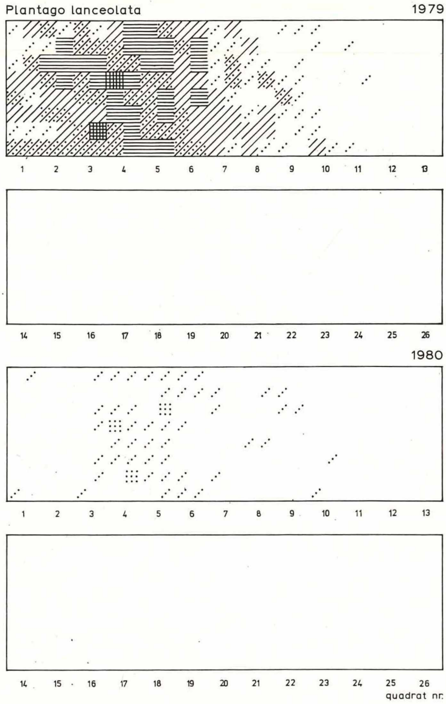


Ranunculus repens 1979

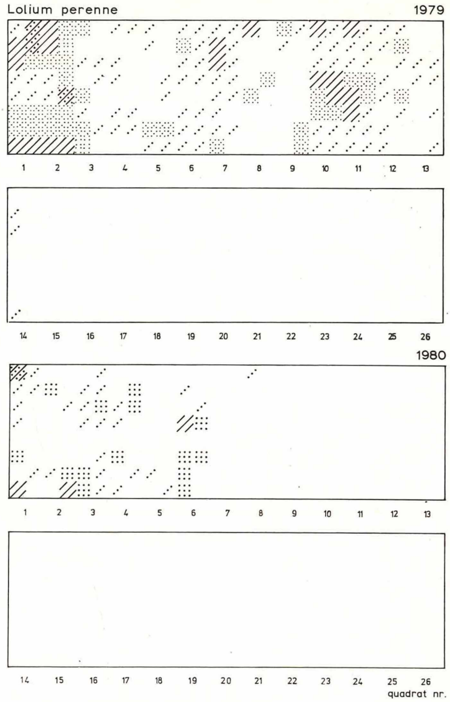


Trifolium repens 1979

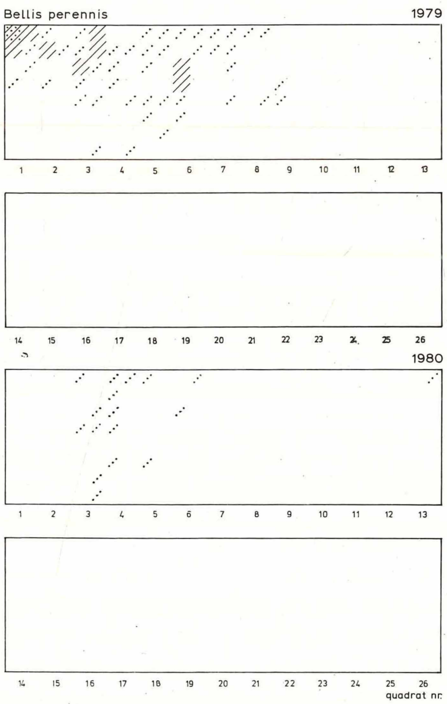




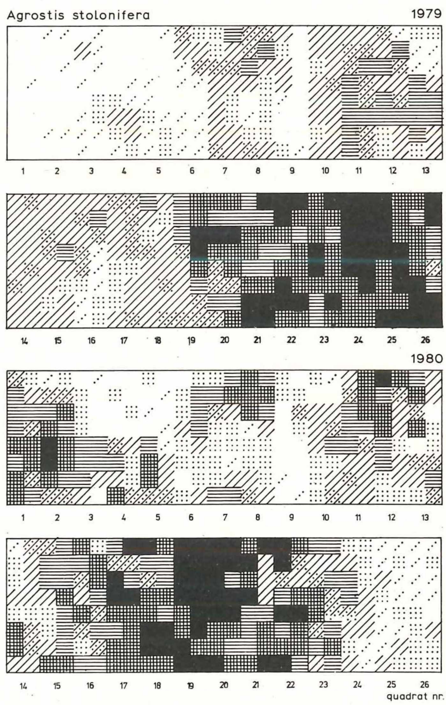
Plantago lanceolata
1979
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
1980
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
quadrat nr.



Lolium perenne
1979
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
1980
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
quadrat nr.

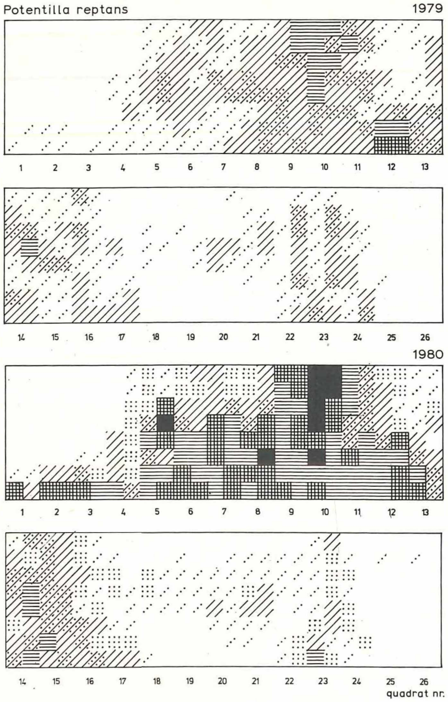


Bellis perennis
1979
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
1980
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
quadrat nr.

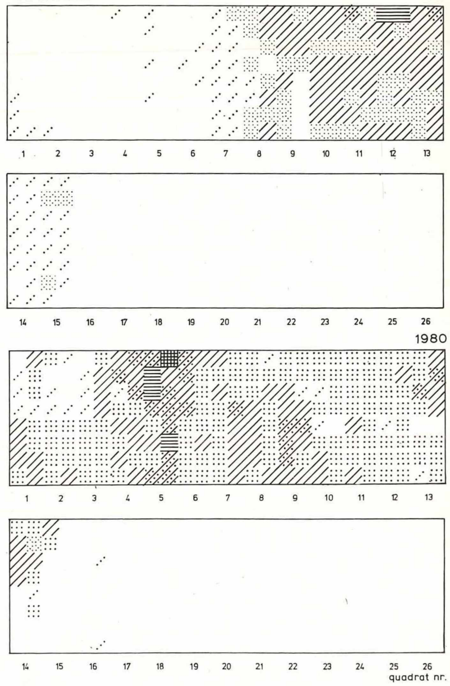


Agrostis stolonifera
1979
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
1980
1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 17 18 19 20 21 22 23 24 25 26
quadrat nr.

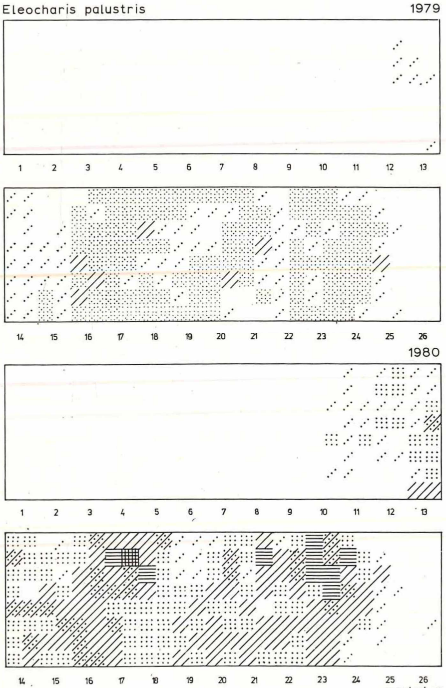
Potentilla reptans 1979



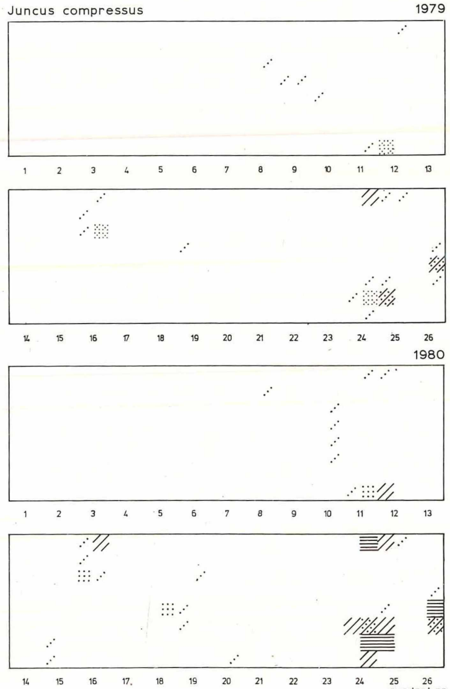
Poa trivialis 1979



Eleocharis palustris 1979



Juncus compressus 1979



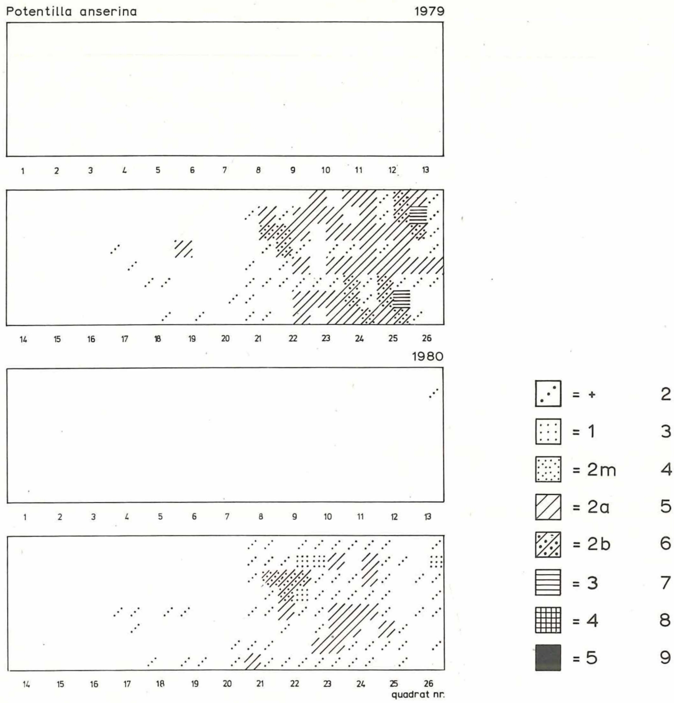


Fig. 5: Distribution of some plants over the transect in the years 1979 and 1980.

nic matter (KLAPP 1965). Plant activity and consequently the need for oxygen is stimulated by higher temperatures.
Although *Pulegium vulgare*, belonging to the trichohygrophyta tolerates a secondary flooding, its above ground organs can withstand inundation with relatively warm water only shortly (HEJNY 1960).

On account of the behaviour of the species after a summer inundation the following groups can be distinguished:

a) species decreasing after the summer inundation and not or hardly recovering in the subsequent year (e.g. *Pulegium vulgare*, *Myosotis scorpioides* and *Potentilla anserina*).
b) species decreasing after a summer inundation and recovering in the subsequent year (e.g. *Plantago lanceolata*, *Trifolium repens*, *Lolium perenne*, *Ranunculus repens* and *Bellis perennis*).
c) species increasing after the summer inundation and aproximately remaining on the same level in the subsequent year (e.g. *Potentilla reptans*, *Juncus compressus* and *Eleocharis palustris*).
d) species increasing in the upper part and decreasing in the lower part of the transect after the summer inundation and approximately remaining on the same level in the upper quadrats while recovering in the lower quadrats in the subsequent year (*Agrostis stolonifera*).
e) species expanding their range towards the upper quadrats in the year of the summer inundation and decreasing again in this part of the transect in the subsequent year (e.g. *Poa trivialis*, *Alopecurus geniculatus*). *Pulegium vulgare* and *Myosotis scorpioides* although considerably decreasing in cover after the summer inundation expanded their range towards the upper quadrats but did

not decrease in this part of the transect in the subsequent year (see a)).

f) species disappearing after the summer flood and not reappearing in the subsequent year (e.g. *Ranunculus bulbosus*, *Achillea millefolium*, *Cerastium fontanum*, *Festuca rubra* and *Dactylis glomerata*).

g) species extending their range after the summer inundation and continuing this extension in the subsequent year (*Trifolium fragiferum*).

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