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RECUEIL DE TRAVAUX DE GEOBOTANIQUE

3

SPONTANEOUS VEGETATION IN SETTLEMENTS

(Proceedings of the IAVS Symposium 1988)

Part Two

edited by A. UBRIZSY SAVOIA

1989

Département de Botanique et Ecologie de l'Université de Camerino
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L'ASSOCIATION AMICALE INTERNATIONALE DE PHYTOSOCIOLOGIE
ET DE L'ASSOCIATION INTERNATIONALE POUR L'ETUDE DE LA VEGETATION

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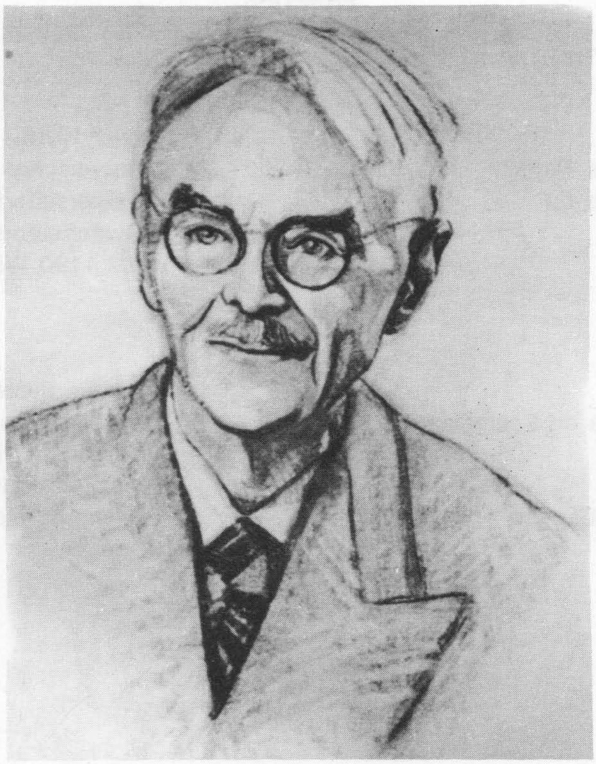

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CONTENTS (PART TWO)

Symposium IV -VEGETATION OF HISTORICAL AREAS AND ARCHAEOLOGICAL SITES

Symposium V - THE TECHNOLOGICAL IMPACT ON VEGETATION

Veränderte der Mesolithiker schon die Vegetation? Nachweis (Pollenanalyse) von Callunaheiden im Bereich eines mesolithischen Fundplatzes im Bremer Blockland

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Keywords: Callunaheiden, Mesolithikum, anthropogene Waldbrände.

Abstract

Caused by buliding measures a mesolithic site were carried out in the Blockland, district of Bremen, Federal Republic of Germany. Pollenanalytical investigations provided informations on the relationship between mesolithic people and vegetation. The forest fires had produced *Calluna* heath. Natural reasons or results of human actions were possible.

1. Einleitung

Die neolithische Landnahme läßt sich wo Moore als Archive von Mikrofossilien vorhanden sind – durch das Auftreten von Kulturzeigern und durch Rückgang der Baumpollenanteile in Pollendiagrammen überzeugend nachweisen. Auf dieselbe Weise werden spätere Zeitintervalle mit unterschiedlichen Siedlungsintensitäten deutlich.

Diesen, seit geraumer Zeit bekannten Tatsachen, steht die Frage nach pollenanalytischen Beweisen mesolithischen Wildbeutertums gegenüber.

Mesolithische Funde, die beim Bau der Bremer Universitäts-bibliothek zutage kamen, erlaubten es, dieser Frage nachzugehen; denn die nähere und weitere Umgebung war vor den umfangreichen Baumaßnahmen vermoort und forderte zu pollenanalytischen Begleituntersuchungen heraus und damit auch zur Klärung der damaligen Umweltsituation.

2. Untersuchungsgebiet

Landschaftskundlich zählt der Fundplatz und seine Umgebung zum Bremer Blockland, das als weitflächige Niederung neben ähnlichen ehemalige Sumpfgebieten (Hollerland, Werderland, Niedervieland u.a. das Bremer Becken mitprägt. Poli-

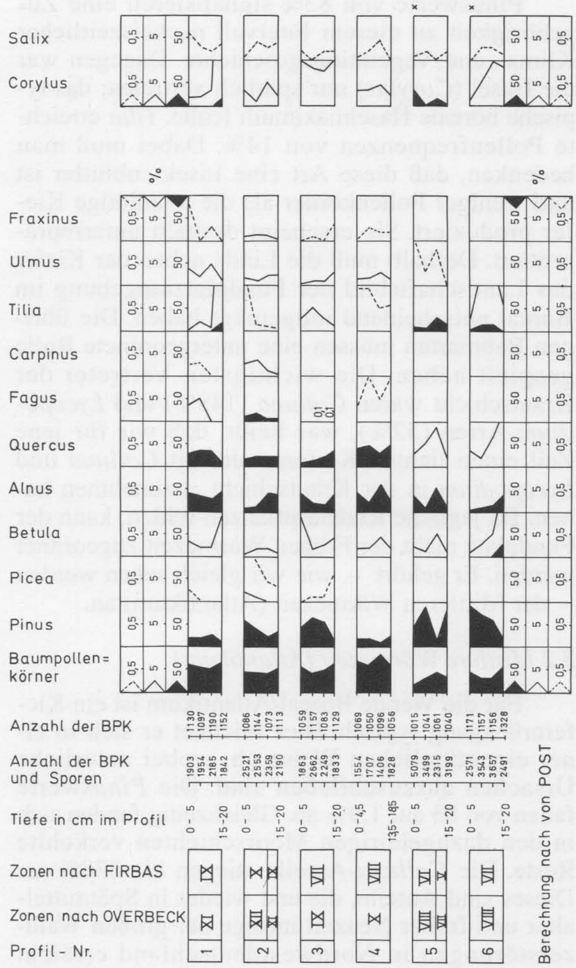

Fig. 1 - Pollendiagramm 1: Mesolithischer Fundplatz im Bremer Blockland (Universitätsbibliothek).
* Vegetationsänderung durch mesolithische Jäger und Sammler.

tisch gehört das Untersuchungsgebiet zur Freien Hansestadt Bremen. Es wird heute von der Bremer Universität eingenommen. Der eigentliche Fundplatz liegt 200 m westlich der Universitätsbibliothek.

3. Ergebnisse

3.1 Frühe Wärmezeit (Boreal)

Das Boreal war nach der mitteleuropäischen «Pollengrund-sukzession» die Zeit ausgedehnter Kiefernwälder und Haselgebüsche. Dieses trifft für das Untersuchungsgebiet nur teilweise zu. Zeitlich kann die Frühe Wärmezeit annähernd zwischen 7000 und 6000 v. Chr. eingegrenzt werden.

Pinuswerte von 83% signalisieren eine Zugehörigkeit zu diesem Intervall nacheiszeitlicher Klima- und Vegetationsgeschichte. Dagegen war die Hasel (*Corylus*) nur spärlich vertreten; das typische boreale Haselmaximum fehlte. *Tilia* erreichte Pollenfrequenzen von 14%. Dabei muß man bedenken, daß diese Art eine Insektenblütler ist und weniger Pollenkörner als die windlütige Kiefer produziert. Sie erscheint deshalb unterrepräsentiert. Deshalb muß die Linde neben der Kiefer das Landschaftsbild der Fundplatzumgebung im Boreal entscheidend mitgeprägt haben. Die übrigen Baumarten müssen eine untergeordnete Rolle gespielt haben. Die wichtigsten Vertreter der Krautschicht waren *Calluna* (148%) und *Lycopodium*-Arten (32%), was heißt, daß wir für jene Zeit einen lichten Kiefernwald mit *Calluna* und *Lycopodium* in der Krautschicht anzunehmen haben. Da jegliche Ruderalpflanzen fehlen, kann der Fundplatz nicht der Frühen Wärmezeit zugeordnet werden. Er gehört – wie wir gleich sehen werden – der Mittleren Wärmezeit (Atlantikum) an.

3.2 Mittlere Wärmezeit (Atlantikum)

Für die Wende Boreal/Atlantikum ist ein Kiefernrückgang typisch. Hier zeichnet er sich in einer eigentümlichen Weise ab, wobei natürliche Ursachen auszuschließen sind. Die *Pinus*werte fallen von 83 auf 1,9% ab. Gleichzeitig fanden sich in den dazugehörigen Moorschichten verkohlte Reste. Die *Calluna*-Anteile stiegen bis 338% an. Dieses sind Anteile, die erst wieder in Spätmittelalter und früher Neuzeit infolge der großen Waldzerstörungen in Nordwestdeutschland erreicht wurden. Bei Hochmooren könnte dabei an die standorteigene Pollenproduktion gedacht werden. Hier handelt es sich aber um Niedermoorschichten; demnach müssen die Pollenkörner von den höheren Kuppen mit nährstoffarmen Sanden eingeweht sein.

Dieses alles spricht für Waldbrände größeren Ausmaßes. Es könnten natürliche Brände gewesen sein, denen der Mesolithiker wegen des leicht begehbaren Jagdterrains folgte. Eine gezielte Brandlegung ist ebenfalls nicht auszuschließen, denn die dicht schließenden Wälder (feuchtes Klima) der Mittleren Wärmezeit waren schwer begehbar und der dürftige Unterwuchs (dichter Kronenschluß wegen des feuchten Klimas) verminderte das Angebot an jagdbarem Wild. Für eine Zuordnung zum aufgefundenen mesolithischen Fundplatz sprechen auch die Pollenkörner von Ruderalarten (*Chenopodiaceen*), während solche vom Getreide-Typ fehlen.

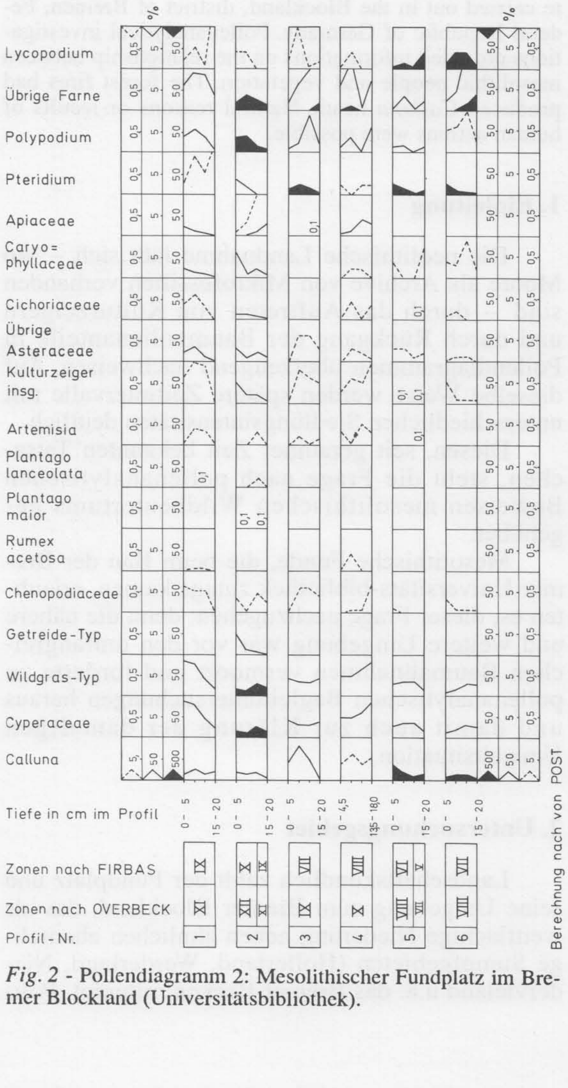

Fig. 2 - **Pollendiagramm 2: Mesolithischer Fundplatz im Bremer Blockland (Universitätsbibliothek).**

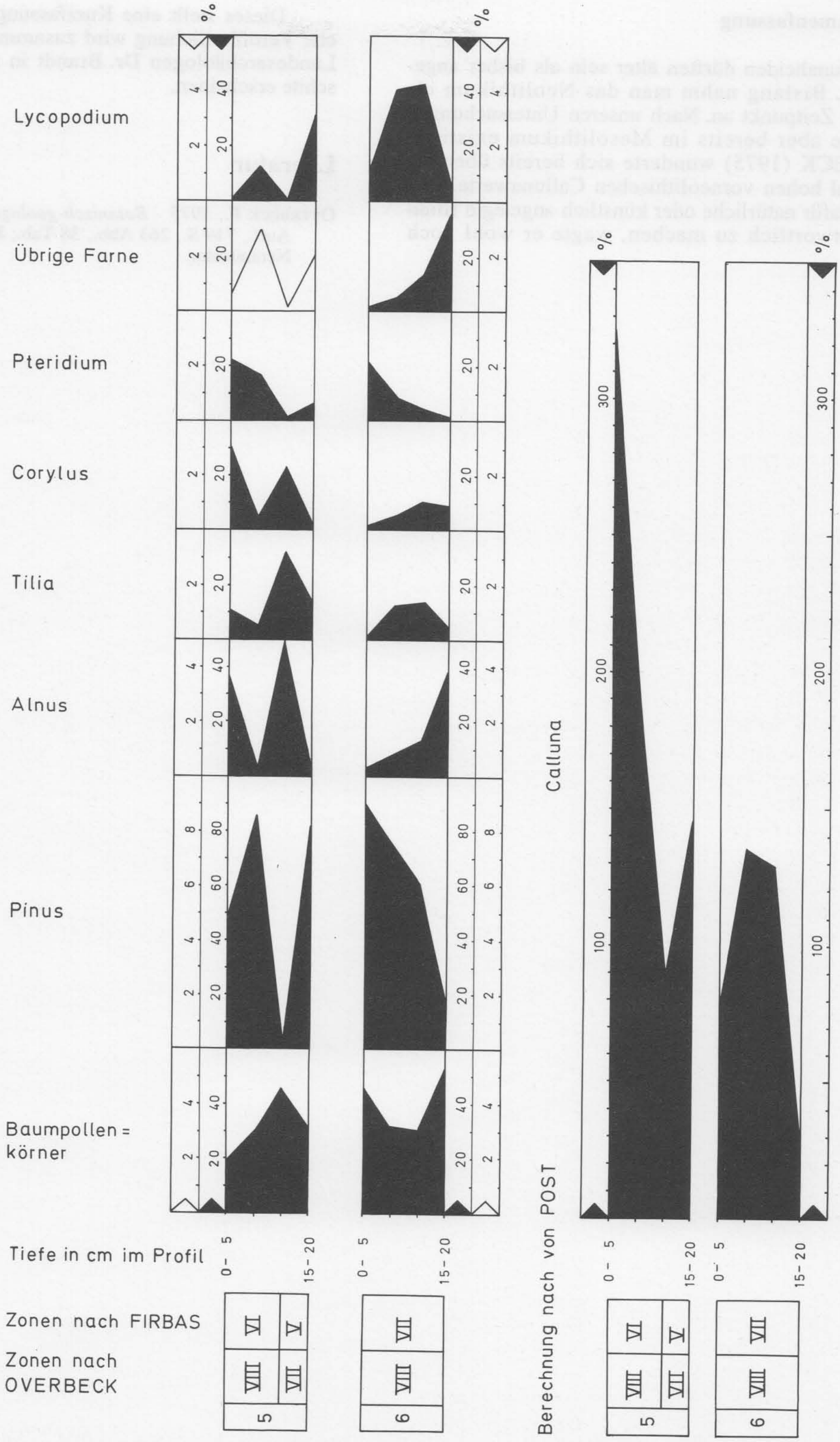

Fig. 3 - Pollendiagramm 3: Mesolithischer Fundplatz im Bremer Blockland (Universitätsbibliothek).

4. Zusammenfassung

Callunaheiden dürften älter sein als bisher angenommen. Bislang nahm man das Neolithikum als frühesten Zeitpunkt an. Nach unseren Untersuchungen haben sie aber bereits im Mesolithikum existiert. OVERBECK (1975) wunderte sich bereits über die manchmal hohen vorneolithischen Callunawerte. Den Schluß, dafür natürliche oder künstlich angelegte Brände verantwortlich zu machen, wagte er wohl noch nicht.

Dieses stellt eine Kurzfassung dar. Die ausführliche Veröffentlichung wird zusammen mit dem Bremer Landesarchäologen Dr. Brandt in den Zeitschrift Geschite erscheinen.

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Remnants of biogenic weathering as a tool for studying palaeoclimates

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Keywords: Biogenic weathering, fossil patterns, pits, root grooves, lithoflora, bacteria, fungi, cyanobacteria, lichens, climatic changes, 30,000 yr.

Abstract

Various organisms growing on limestone leave typical patterns of weathering. Bacteria, cyanobacteria, fungi, lichens, roots of trees and shrubs, and land snails were used in studies of biogenic weathering in Israel. The distribution of weathering patterns caused by these organisms was correlated with present day macro- and micro-climatic conditions. Rocks and detached stones that were uneaerthed in archaeologic and prehistoric sites were used to evaluate the climatic conditions of the time when the site was built. If the excavated weathering pattern is similar to that of rocks or stones today in the vicinity of the archaeological site, it is assumed that the climatic conditions of the past were similar to those of the present. If a more drought resistant lithobiont community or more mesophytic lithobiont community prevailed on the excavated rocks, we assume that the climate was accordingly drier or wetter than that of the present.

Stones and boulders found in Neolithic sites in the Jordan Valley showed that the climate 9-10,000 years ago was wetter than that of the present. This moist climate followed a period with drier climate that prevailed some 15-18,000 years B.P. The climatic regime of the present started some 6,000 years ago when in many sites rocks and stones displayed weathering patterns that are similar to those of the present.

Introduction

The use of fossils of plant and animal in palaeoecology through palaeobotany is an every day procedure. The aquatic environments, where best preservation of the organisms can be detected, are used so widely that it is not necessary to quote any specific paper or textbook. We had not found many references for *in-situ* fossils of micro- and macro-organisms of continental lithoflora of the last dozens of millennia (DANIN et al. 1982). We studied some typical weathering patterns that are caused on calcareous rocks by: bacteria, cyanobacteria, fungi, lichens, land snails and roots of trees and shrubs (DANIN et al. 1982; DANIN et al. 1983; DANIN, GARTY 1983; DANIN 1983, 1985, 1986a, 1986b; HUNGATE et al. 1987). Rocks and detached stones that were unearthed in archaeologic and prehistoric sites were used to evaluate the climatic conditions of the time when the site was built. In the present paper our palaeoclimatic research in Israel is reviewed.

Environment

Moisture regime seems to be the most important factor influencing the distribution of lithobionts on hard limestones and dolomites. We studied mainly rocks and detached stones with 0.5-2.0% water-holding capacity. *In-situ* rocks and detached stones differ remarkably in their moisture regime (DANIN, GARTY 1983). Detached stones are cooled during the night at a faster rate than *in-situ* rock and may therefore be supplied with considerable amounts of dew. In areas where dew is a common event there are marked differences in the lithobiont communities of *in-situ* rocks and detached stones (Danin 1985, 1986a). The distribution of the principal lithobiont communities as related to climatic conditions in Israel were presented by DANIN (1986a).

Paterns of weathering caused by lithobiont communities

The weathering types and the organisms that caused them were described in detail and illustrated in our previous papers. A short reference to these types is listed here.

Rock varnish on calcareous rocks is associated with the activity of manganese and iron oxidizing bacteria (Staley et al. 1983; Hungate et al. 1988). This life form prevails on calcareous rocks in areas with less than 100 mm mean annual rainfall and low amounts of dew.

Microscopic pits on elevated rock and stone faces with ascocarps were attributed to unidentified fungi (DANIN 1986a). These fungi from a few locations in Israel were recently determined as *Lichenothelia intermixta* Henssen (HENSSEN 1987, and personal communication). These fungi, or related taxa that induce a similar type of weathering, occur all over Israel from extreme deserts with 25 mm mean annual rainfall up to areas with more than 1,000 mm mean annual rainfall. They occupy specific micro-habitats in each climatic zone and can be used as leading fossils mainly in deserts.

Pits, 0.5-3 cm deep, with spongy floor (Fig. 1) are caused by the activity of coccoid cyanobacteria and microscopic cyanophilous lichens in dry habitats (DANIN et al. 1982; DANIN 1983, 1986a). In most cases these organisms develop in slightly wetter microhabitats than those of the fungi and succeed micro-pits that were induced on the substratum by *Lichenothelia*-like fungi. These cyanobacteria and cyanophilous lichens induce faster weathering rate than the preceding fungi. Under desert conditions or on cliffs in wetter areas they lead to development of pits in occasional depressions.

Spongy layer of about 0.1 mm prevails on rock faces in sub-Mediterranean conditions (150-350 mm mean annual rainfall). This layer is formed by dissolution of clobular microscopic holes surrounding coccoid cyanobacteria and cyanophilous lichens which are similar to those involved with the pits mentioned above. However, under conditions that are less extreme than in desert or on dry cliffs, they develop all over the rock surface. The rate of weathering over the rocks is at least similar throughout the rock surface and no pits are formed here.

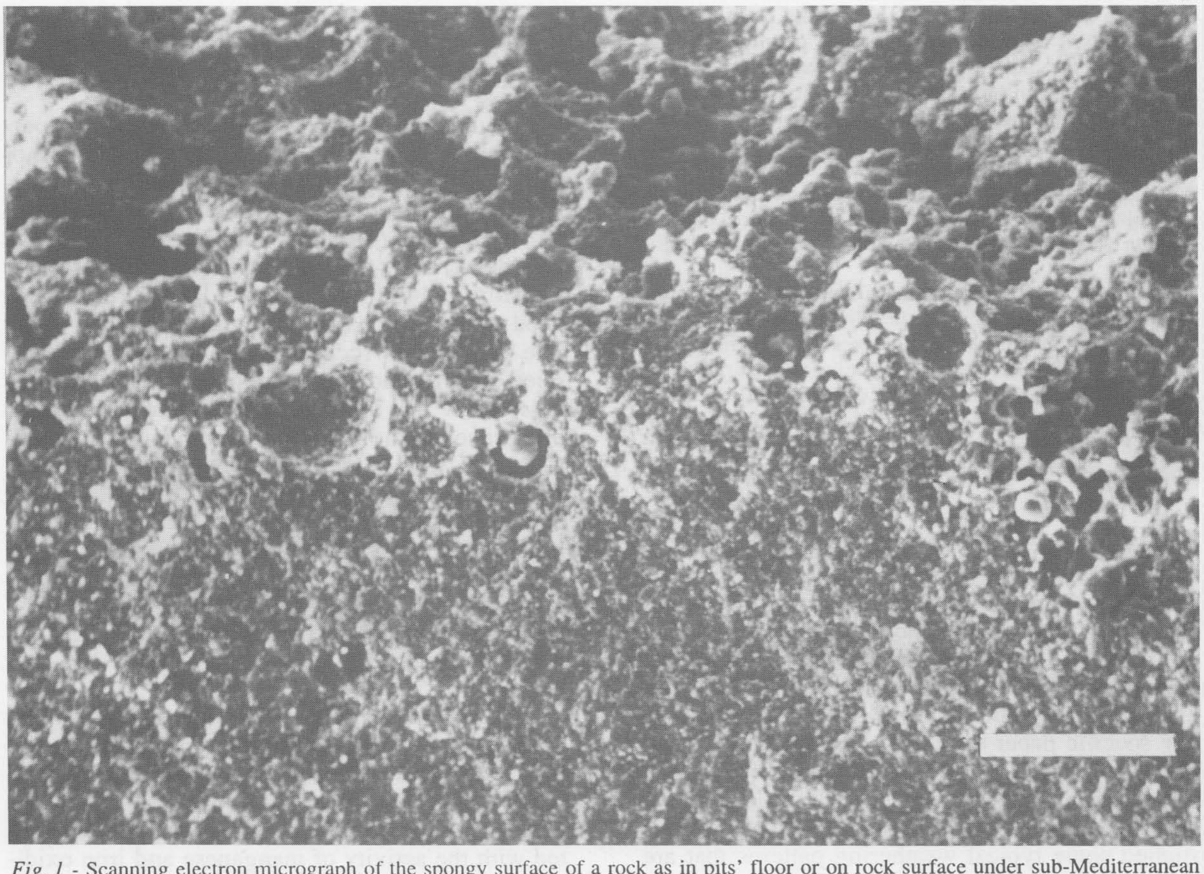

Fig. 1 - Scanning electron micrograph of the spongy surface of a rock as in pits' floor or on rock surface under sub-Mediterranean conditions. The lower half of the photo is perpendicular to the upper spong face, thus displaying a few globular organisms *in-situ*. (Bar = 200 μm).

Fig. 2 - Jigsaw-puzzle like pattern on a detached stone from the Negev Highlands near Sede Boqer. The pinhead holes are in place of the ascocarps of the endolithic lichens; the micro-grooves are in the meeting zone of two thalli with more efficient dissolution of the rock by the fungal component of the lichen.

Jigsaw-puzzle like pattern (Fig. 2) is induced by the activity of a few species of endolithic lichens. This pattern is found on south-facing slopes of rocks in the Mediterranean zone of Israel (400-1,000 mm mean annual rainfall) and on detached stones in areas with 80-1,000 mm mean annual rainfall and high amounts of dew. Land snails grazing on these lichens make their appearance more prominent (SHACHAK, GRANOT 1982; DANIN, GARTY 1983; DANIN 1986a, 1986b; SHACHAK, JONES, GRANOT 1987).

Foveolate pattern is formed by a few species of endolithic lichens in place of their ascocarps (Smith 1921; Danin 1985, Fig. 2).

Smooth-faced rock surfaces are formed below the crust of epilithic lichens. These lichens protect therock's surface from the destructing effect of rain drops. Water that passed the lichen crust reach the rock gradually and the relatively homogeneous complete cover of rock surfaces by these lichens leads to the formation of smooth faces.

Root grooves (Fig. 3) are formed in joints and between hard layers of limestones under Mediterranean conditions by trees or shrubs (DANIN, WIEDER, MAGARITZ 1987). Carbonate fillings of the root grooves can be analyzed and carbon- dated.

Honeycomb pattern with holes 2-3 cm in diameter are formed by land snails (DANIN 1986, 1986b). This pattern is formed mainly under Mediterranean conditions with 300-1,000 m mean annual rainfall.

Indications of palaeoclimates

Rock outcrops are populated in most places by one type of lithobiont community and cause simple pattern of weathering. Rocks that are expo-

Fig. 3 - Root grooves on a joint surface at the Judean Desert of Israel. These are remnants of the activity of trees or shrubs some 30,00 years ago.

sed for many thousands of years and «witnessed» climatic changes may display these changes on its surface as complex weathering pattern. A few case histories are listed below.

Simple weathering pattern

Massive limestone near Horvat Medin, northeastern Dead Sea area, display at present fungal micro-pits on elevated faces and pits of cyanobacteria and cyanophilous lichens in depressions. Detached stones display there mainly fungal micro-pits. The unearthed fort of the Hellenistic period at Horvat Medin is built up of large boulders, a few of which display the same pattern as the rocks on the slopes. Detached stones that were put among the boulders also display micro-pits (Danin 1985).

Rocks in the Negev Highlands support fungi in micro-pits and cyanobacteria and cyanophilous lichens on their south-facing slope as mentioned above for the Dead Sea area. Detached stones are covered by endolithic lichens that induce the jigsaw-pattern on their surface. Rocks and detached stones buried in the Byzantine period were found in a few sites in Nahal Haroa (Danin 1985). The weathering patterns on the excavated rocks had the same type of weathering as that of these habitats at present. This example and its preceding indicate that in both cases climate in the past was similar to that of the present.

Complex weathering pattern

Rocks and boulders in the vicinity of the Neolithic site of Netiv Hagdud, Jordan Valley (DANIN 1985), are covered at present by cyanobacteria and cyanophilous lichens that are associated with a spongy layer at the rock surface. Remnants of jigsaw pattern can be observed on many boulders. No living endolithic lichens that are associated with the latter pattern occur on these rocks. This patern of lines and pinhead holes typical for endolithic lichens indicates a period when the area was moister. The jigsaw pattern is situated in a few boulders in pits 1-3 cm deep. These were formed presumably when the climate was drier than that of the present. Boulders that were unearthed in the neighbouring prehistoric site did not have spongy pattern on the jigsaw pattern. However, the latter was found in a few places on pitted micro-relief. This means that the climate there in the Neolithic period was wetter than that of the present but was preceded by much drier period. Rock pieces found in a site15-18,000 years old, not far from Netiv Hagdud, displayed pits and micro-pits such as those described above for the dry area of the Dead Sea. Consequently the rocks near Netiv Hagdud indicate a period wetter than that of the present that prevailed in the area just before being covered by soil and buried in the site. These boulders also displayed a very dry period that preceded the Neolithic period.

Rate of weathering

Each lithobiont community has its own rate of establishment, growth and creation of its typical pattern. The rate of pitting by a community of cyanobacteria and cyanophilous lichens on limestone walls of Jerusalem was found to be 1 mm/200 yr (DANIN 1983). This rate represents the mean rate of pitting over a period of some 2,600 years. It is the rate of a composite process where lithobionts locally dissolve the rock and rain drops detach minute rock particles from its surface.

Climatic changes in Israel

The period covered partly by remnants of biogenic weathering patterns starts some 30,000 years ago. Root grooves found in the Judean Desert indicate that the wet climate of the Late Pleistocene terminated then (DANIN, WIEDER, MAGARITZ, 1987). The drought caused the death of the trees and shrubs on slopes of this area. We do not have evidence for what happened between 30,000 and 18,000 yr B.P., but during the latter period the climate was drier than that of the present (DANIN 1987). Between 10,000 and 9,000 years B.P. the climate was wetter than at present. The climate that is similar to that of the present started some 6,000 years ago. Our findings agree with conclusions from other fields of research, as discussed in our articles quoted above.

Summary

Physiological activity of various organisms living on or inside limestone rocks and stones lead to accelerated weathering of the rock near these organisms. Long term localized dissolution and splashing of minute rock particles by rain drops from the vicinity of circular patches where cyanobacteria and cyanophilous lichens live lead to the formation of pits with spongy floor. Such pits are formed under desert conditions because the organisms can not develop throughout the rock surface. Under moister conditions endolithic lichens develop and induce typical weathering pattern that looks either as an assemblage of pinhead holes, created by their ascocarps, or as jigsaw puzzle. The latter becomes more prominent after being differentially abraded by land snails. Land-snails that obtain from the rock, at least, part of the calcium carbonate needed for constructing their shell, leave dissolution holes that resemble honeycomb with deep and wide holes. Trees and shrubs, the roots of which penetrate into crevices of limestone, lead to the formation of root grooves. Each of the organisms mentioned above develop under determinable environmental conditions and thus leave typical patterns of weathering that may be associated with these conditions. The remnants of biogenic weathering may function as leading fossils indicating climates of the past. The main events of climatic changes in Israel during the last 30,000 years were correlated in the studies under review with weathering patterns found on rocks and stones that could be dated. Most dated amples were found on building stones that were buried in archaeologic or prehistoric sites. Carbonate fillings of root grooves were dated using isotopes of carbon.

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Botanisch-zoologische Beiträge zur historischen Stadtökologie - eine Übersicht -

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Keywords: urban ecology, palaeo-ecology.

Abstract

A survey of aims, methods and some results of landscape history, concerning flora, vegetation, fauna and ecotopes of settlement areas, is given in order to encourage those studies complementary to urban ecological research.

1. Problemstellung

Innerhalb der Landschaftsökologie hat sich durch intensive Forschungen im besiedelten Bereich die Stadtökologie klar herausgebildet (SUKOPP 1987). Entsprechend läßt die Landschaftsgeschichte, soweit sie sich mit der Floren-, Vegetations-, Faunen- und Standortgeschichte als historische Ökologie versteht, Ansätze zu einer historischen Stadtökologie erkennen (Abb. 1). Wie die Stadtökologie sich weitgehend landschaftsökologischer Methoden bedient, so sind auch die Methoden der historischen Stadtökologie zunächst diejenigen der Landschaftsgeschichte bzw. historischen Landschaftsökologie. Die Probleme liegen beim zeitlichen Querschnitt für die Bio- oder Ökotop- bzw. Parzellen- und Gebietsgeschichte in der räumlichen Unschärfe besonders der Fossilbefunde und beim zeitlichen Längsschnitt (pro-oder retrogressiv, JÄGER 1987) in

Abb. 1 - Ableitung und Funktion der historischen Stadtökologie. Ökochoren (stadtökologische Raumeinheiten) nach BÖCKER & al. 1987.

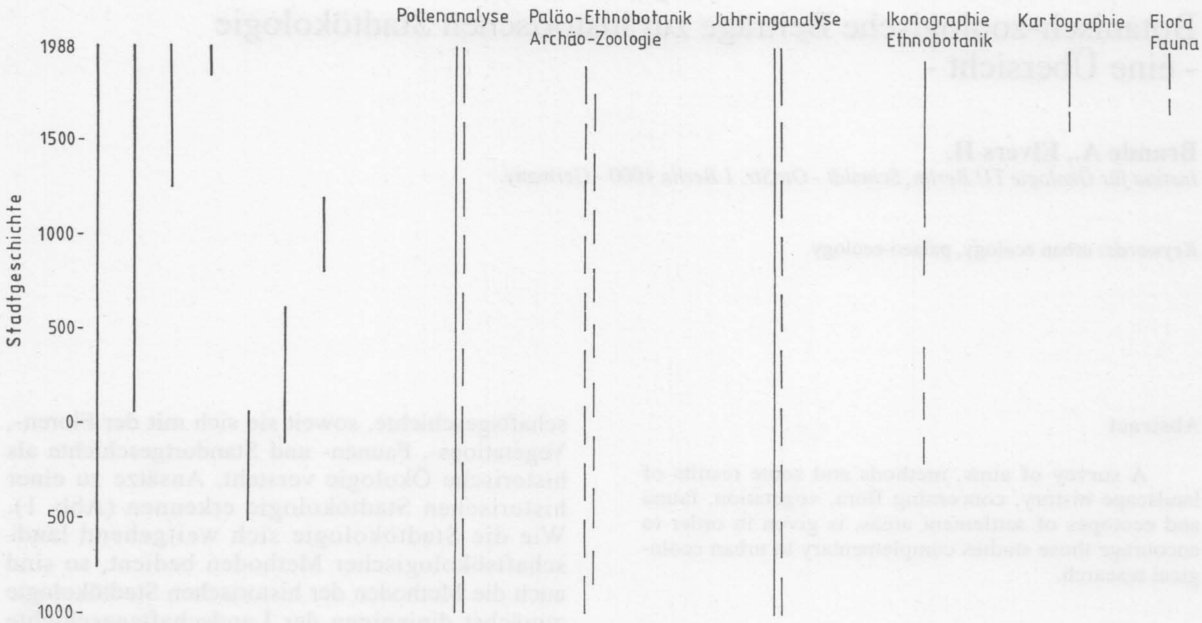

Abb. 2 - Methoden der historischen Stadtökologie und deren zeitliche Reichweite und Kontinuität. Stadtgeschichtliche Beispiele in Auswahl.

der oftmals mangelnden zeitlichen Kontinuität der Materialien, besonders im unmittelbaren Anschluß an die Gegenwart als dem entscheidenden Bezugssystem. Im Folgenden wird anhand von Beispielen eine Übersicht der Methoden und deren Anwendung in städtischen Siedlungen gegeben.

2. Methoden

Das Methodenspektrum, die methodenspezifisch unterschiedliche zeitliche Reichweite und die Kombination von Einzelmethoden bestimmen Art und Qualität der historisch-stadtökologischen Information (Abb. 2).

Die Palynologie liefert einerseits in zeitlicher Kontinuität den weiteren räumlichen Hintergrund und andererseits in unterschiedlicher Annäherung an die Siedlungen (BEHRE & KUCAN 1986) bis hinein in die eigentlichen Kulturschichten zeitlich begrenzte Nachweise, beides weit in vorstädtische und vordörfliche Siedlungsperioden zurückreichend bis in die Lagerplätze von Jägern, Fischern, Sammlern (BRANDE 1975, 1980/81). Für den ersten Ansatz ist die Siedlungs- bzw. Stadtlage in Niederungen oder an Seen Bedingung wie in Berlin (BRANDE 1978/79). Der zweite Ansatz ist an archäologische Grabungen in Kulturschichten unterschiedlicher Lage und Beschaffenheit gebunden (GREIG 1982, DIMBLEBY 1985, RENAULT-MISKOVSKY & al. 1985). In günstigen Fällen trifft beides zusammen (BEHRE 1986, BRANDE & al. 1987b), so daß auch die räumliche Schärfe zunimmt.

In der Regel aus archäologischen Grabungen und somit zunächst zeitlich diskontinuierlich, aber taxonomisch zumeist genauer und somit soziologisch-ökologisch weiterreichend als die Pollenfunde sind die Ergebnisse der Paläo-Ethnobotanik (WASYLIKOWA 1986, WILLERDING 1986a, 1987). Für Großregionen ergeben sie inzwischen ein zeitlich ziemlich geschlossenes Bild des Florenwandels unter anthropogenen Bedingungen (JENSEN 1985, 1987, WILLERDING 1986b), in das sich weitere archäobotanische Befunde einfügen. Aus gleichartigen Fundzusammenhängen stammt der größte Teil der archäozoologischen Daten. So ist die botanisch-zoologische Analyse von Kulturschichten aus den in den letzten Jahren stark zunehmenden stadtarchäologischen Grabungen (FRERICHS 1980, RÖTTING 1985, STEPHAN 1985) eine direkte Fortführung langjähriger archäobiologischer und paläoökologischer Forschungen (BOESSNECK 1969, DIMBLEBY 1977, SHACKLEY 1981).

Jahrgenaue Aussagen zur Wuchsgeschichte von Baumarten im näheren und weiteren Siedlungsbereich, und zwar lückenlos bis in die Gegenwart und bis in das Innere der Großstädte liefert die ökologisch arbeitende Dendrochronologie (von LÜHRTE 1981, MEYER 1982, SCHWEINGRUBER 1983, BRANDE & al. 1987b). Sie umgreift damit für die Standortgeschichte sowohl den paläoökologischen Ansatz wie Palynologie und Paläo-Ethnobotanik als auch den der historisch-archivalischen und aktuell-ökologischen Floren- und Vegetationsanalyse.

Eine direkte Ergänzung zur Florengeschichte aus Fossilanalysen einschließlich langlebiger Samen in archäologischem Material (ØDUM 1965) ergibt sich aus vielfach zeit- und z.T. ortsgleichen schriftlichen und ikonographischen Zeugnissen (WILLERDING 1984, 1986c). Das gilt auch für die Standortgeschichte im besiedelten Bereich unter Einbeziehung von Namenkunde (KRAUSCH 1979) und historischer Kartographie (RIEDEL 1978, FRANZ & JÄGER 1980), zumal als Ergänzung zu bodenkundlich-stratigraphischen Geländebefunden.

Historisch-floristische Untersuchungen nach Literatur- und Herbarbelegen der letzten 2 Jahrhunderte und teilweise darüber hinaus machen die Veränderungen und ihre Dynamik in Abhängigkeit von der Stadt- und Standortentwicklung und dem Artenzugang deutlich (SUDNIK-WOJCIKOWSKA 1987). Ähnliches betrifft den Faunenwandel in jüngeren Zeit und die Verstädterung von Tieren (WENDLAND 1971, BEZZEL 1982, KLAUSNITZER 1988), Vorgänge, die in günstigen Fällen an archäozoologische Befunde aus städtischen Siedlungen anschließen (MALTBY 1979, WILLERDING 1985, REICHSTEIN 1987). Auch Datensammlungen zum Floren- und Faunenwandel städtischer Teilgebiete wie in Gewässern lassen die Auswirkungen zunehmenden Großstadteinflusses erkennen (SUKOPP & BRANDE 1984/85). Für die jüngsten Jahrzehnte kommen auch in Städten floristisch-vegetationskundliche Wiederholungskartierungen und sukzessionsdynamische Beobachtungen hinzu (SUKOPP 1971, KOWARIK 1986) sowie planmäßige Faunenbeobachtungen, etwa bei Vögeln (WITT 1984).

Das heutige Verbreitungsmuster der Flora im besiedelten Bereich, insbesondere die Beziehung der Arten zu historischen Stadtstrukturen wie Stadtkernen, Befestigungsanlagen, Verkehrsflächen, Parks und Gärten besteht oftmals nicht in unmittelbarer zeitlicher Kontinuität, sondern ist vielfach durch Nutzungs- und Standortentwicklung sowie artspezifische Ausbreitungs- und Naturalisationsdynamik geprägt, wie Vergleichsuntersuchungen alter Siedlungsplätze zeigen können (LOHMEYER 1984). Darin die historische Komponente zu ermitteln wie für verwilderte Nutzpflanzen und andere Synanthropen bedarf eingehender Spezialuntersuchungen (SUKOPP & SCHOLZ 1965, 1966, 1968, KOWARIK & BÖCKER 1984).

3. Anwendungsbeispiele

Jede derartige historisch-ökologische Untersuchung liefert einen zeitlichen Ausschnitt der Hemerobieprozesse unter städtischen Bedingungen, bei manchen Methoden unter Einbeziehung des nichtstädtischen Umlandes. Diese Vorgänge sind auch nach einem Siedlungsabbruch durch Zerstörung, Verlagerung etc. bedeutungsvoll. Gerade an solchen archäologischen Objekten hat sich das paläoökologische Interesse an Siedlungen entwickelt.

Für das Imperium Romanum trifft das z.B. auf Pompeji mit seinen ikonographischen, schriftlichen, archäologischen, paläo-ethnobotanischen und palynologischen Zeugnissen von Pflanzenkulturen und ihrer Begleitflora in den städtischen Gärten, den Feldern und dem Grünland zu (JASHEMSKI 1977, 1979, MEYER 1987, GRÜGER in Vorber.). Ähnlich erbrachten palynologische Daten im Gebiet des antiken Narona die römerzeitliche Einführung, Kultivierung und z.T. spätere Verwilderung von *Juglans, Castanea, Platanus, Punica,* die Kultur der einheimischen Fruchtgehölze *Olea* und *Vitis,* bei nur geringem Getreideanbau, das Auftreten von Ruderalvegetation mit *Xanthium* sowie Walddegradation durch Holz- und Weidewirtschaft mit Ausbildung entsprechender Ersatzgesellschaften der Sibljak- und Garigue-Formation im Umkreis der Stadt (BRANDE 1973, 1976). Aus der Germania Romana bieten hauptsächlich paläo-ethnobotanische Analysen von Militärlagern und ihrem Einzugsgebiet, also den Keimzellen mancher späteren Stadt, reichlich floristisch-vegetationskundliches Datenmaterial (KNÖRZER 1970, KÖRBER-GROHNE & al. 1983).

Ansätze mittelalterlicher Stadtentwicklung aus befestigten Anlagen im slawischen und wikingischen Siedlungsgebiet waren schon mehrfach Gegenstand paläo-ethnobotanischer und palynologischer Untersuchungen (OPRAVIL 1978, WASYLIKOWA 1978, BEHRE 1983, LANGE 1986, BRANDE & al. 1987b), ähnlich wie in anderen Siedlungsgebieten Mitteleuropas (z.B. KÖRBER-GROHNE 1979). Doch nehmen solche Untersuchungen derzeit besonders in stadtarchäologischen Grabungen heutiger Stadtzentren zu (KÖRBER-GROHNE 1978, WIESEROWA 1978, KNÖRZER 1984, WILLERDING 1985, JENSEN

1986), im Einzelfall mit sehr umfassender historisch-ökologischer und quellenkundlicher Auswertung (WILLERDING 1986c) einschließlich des Vergleichs mit Florenverzeichnissen seit dem 17. Jahrhundert bis zur heutigen Stadtflora (MATTHIES 1986). Über mehrere Jahrhunderte bis in die Neuzeit (um 1700) sind in Turku durch vielseitige paläoökologische Analysen die Auswirkungen der Stadtentwicklung auf den zentral gelegenen Stadtsee und seine Umgebung verfolgt worden (PIHLMAN & al. 1985) einschließlich des Keimerfolges von nahezu 300 Jahre altem Samen von *Vicia tetrasperma*.

Methodisch umfassende historisch-ökologische Untersuchungen heutiger Stadtgebiete sind besonders in Parks vielversprechend, da hier die historische Quellenlage oftmals besonders gut ist, z.T. mit alten Pflanzenlisten (HANDKE & al. 1987), überkommenen Vegetationsstrukturen (BRANDE & al. 1988), kleinräumig faßbarem Nutzungs- und Standortwandel und der Möglichkeit gartenarchäologischer Grabungen (SEILER 1985). Zudem sind hier die historischen Zeigerarten oftmals sicherer zu ermitteln (SUKOPP 1968, 1981, NATH-ESSER 1986). Jedoch sollte ein gezielter Einsatz möglichst vieler historisch-ökologischer Methoden auch auf anderen städtischen Teilflächen unterschiedlicher Größe und Geschichte erprobt werden.

Summary

Historical urban ecology, as defined in Fig. 1, has the chance to develop in respect to intensive and comparative studies on urban ecology since the last few decades. Palynology, palaeo-ethnobiology, dendrochronology and documentary evidence, inclusive carto- and iconography, provide main tools with different scales in time, space and taxonomic level, to be focused on urban settlements (Fig. 2). Methodological aspects as well as examples of studies in the urban nature development, going back to Roman times, are quoted by selected citations.

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Native orchids in the main archaeological sites in Rome

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Keywords: Native Orchids, Archaeological Sites, Rome.

Abstract

Recent field research within the city of Rome has revealed the presence of an unespectedly high number of native orchids belonging to 33 different taxa. Two large archaeological sites, the Palatine Hill and Old Appian Way, were found to be very rich in species and specimens. In the first site, which lays near the center of Rome, orchids belonging to 12 different taxa have been observed. In the second site, at the periphery of the city, the observed taxa were 13, 7 of which in common with the Palatine area. Among these orchids it is worth mentioning the presence of three rare natural hybrids (*Ophrys* x *hoeppneri* Ruppert, *O.* x *grampinii* Cortesi, *O.* x *macchiatii* Camus) and of *Ophrys ciliata* Biv., which is a very uncommon species in the Italian peninsula.

The city of Rome still hosts a surprisingly high number of native orchids, both as species and as specimens (ROSSI & LIPPOLIS, 1984). This is mainly due to the presence within the city of ancient patrician villas and extensive archaeological sites. Among the latter, the Palatine Hill and the Archaeological Park of the Old Appian Way are the largest and also the richest in native orchids.

The evocative Palatine Hill lies near the city center. Orchids are still relatively abundant here amid the Roman ruins on the highest portion of the hill, inside the so called Diocletian's Hippodrome and the areas surrounding the Domus Flavia. In this archaeological site the following entities have been observed: *Ophrys bombyliflora* Link, *O.* x *hoeppneri* Ruppert, *O. incubacea* Bianca, *O. sphegodes* Miller, *O. tenthredinifera* Willd., *Orchis coriophora* L., *O. morio* L., *O. papilionacea* L., *Serapias lingua* L., *S. parviflora* Parl., *S. vomeracea* (Burm. fil.) Briq., *Spiranthes spiralis* (L.) Chevall. The most interesting of these twelve orchids is undoubtly *Ophrys* x *hoeppneri*, a natural cross between *O. bombyliflora* and *O. sphegodes*: as many as 22 plants of this very uncommon hybrid have been found inside Diocletian's Hippodrome, an area luckily not open to the public.

The Archaeological Park of the Old Appian Way begins inside Rome, but extends quite some distance from the city; for this research only that portion inside the city's ring road was considered. The 13 entities reported below have been found there, 7 of which have been mentioned already above, dealing with the Palatine Hill: *Ophrys apifera* Huds., *O. ciliata* Biv., *O. garganica* E. Nelson ex O. & E. Danesch, *O.* x *grampinii* Cortesi, *O. incubacea* Bianca, *O.* x *macchiatii* Camus, *O. sphegodes* Miller, *O. tenthredinifera* Willd., *Orchis coriophora* L., *O. laxiflora* Lam., *O. papilionacea* L., *Serapias vomeracea* (Burn. fil.) Briq., *Spiranthes spiralis* (L.) Chevall. Three of these orchids are very interesting: *Ophrys ciliata* is a very uncommon species in the peninsular portion of Italy; *O.* x *macchiatii*, a natural hybrid between *O. ciliata* and *O. sphegodes*, was described upon a single specimen found in Sardinia in 1908 and has not been found again until now (it was however obtained artificially); finally, the interest of *O.* x *grampinii* lies in the fact that this uncommon natural cross between *O. sphegodes* and *O. tenthredinifera* was originally described from specimens found on the roadsides of the Old Appian Way (CORTESI, 1904).

The presence of wild orchids in a city of over three milion people obviously poses serious conservation problems. On the Palatine Hill, for example, in recent years a drastic clean-up of the vegetation around the monuments has been carried out: this might even be auspicable, but it has obviously caused the rarefaction of certain species of orchids, one of which may have disappeared (*Serapias vomeracea*). To partially prevent this inconvenience those in charge of the archaeological site agreed to set aside two small areas near the Domus Flavia very rich in orchids. In these «orchid reserves» signboards were set up indicating the species present there and their flowering period. Unfortunately this praiseworthy initiative, which aroused curiosity and interest among the numerous visitors, had a short life. Luckily up to now herbicides have not been used. In Greece these chemicals have already caused the disappearance of a very rich assortment of native orchids from some of the equally famous archaeological sites in Athens.

The conservation problems of the orchids of the Old Appian Way are different. The greatest damage there comes from trampling by the very numerous tourists, from flower collecting by Sunday pic-nikers and, above all, from «orchid lovers», chiefly middle-europeans, who dig up the most rare and interesting plants complete with their underground parts. The latter practice is the worst threat: it suffices to remenber that on one occasion someone dug up three specimens of *Ophrys ciliata*, more or less half of all the specimens known in Latium. If we wish to preserve within the Eternal City this very peculiar and interesting natural inheritance, which has come down to us thanks to these archaeological areas, measures will have to be taken which will reconcile the conservation problems with the much more important historical and cultural aspects of this sites. The brief but succesful experiment on the Palatine Hill indicates one of the possible solutions.

Riassunto

Recenti ricerche effettuate all'interno della città di Roma hanno permesso di accertare la presenza di un elevato numero di orchidee spontanee appartenenti a 33 differenti entità. I due siti archeologici più vasti, il complesso del Colle Palatino ed il Parco Archeologico della Appia Antica, sono risultati molto ricchi sia di specie che di esemplari. Nel primo dei due siti sono state rinvenute orchidee appartenenti a 12 taxa, mentre nel secondo le entità accertate sono 13, 7 delle quali in comune con il Palatino.

Tra queste orchidee meritano particolare menzione tre ibridi naturali molto rari (*Ophrys* x *hoeppneri* Ruppert, *O.* x *grampinii* Cortesi, *O.* x *macchiatii* Camus) ed anche *Ophrys ciliata* Biv., una specie tra le meno comuni nella penisola.

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Ostia Antica and its Vegetation

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Abstract

A brief outline of flora and vegetation of the archaeological area of Ostia Antica and a historical interlude are given. Life forms of the flora and of the main vegetation types, chorology and seasonal changes in plant cover and species combination of a 3sqm surface with vegetation belonging to the Lolio-Plantaginetum are discussed in detail. Hints on correct management maintaining the aesthetic effect plants may offer within an archaeological area are given.

Introduction

In the Mediterranean Basin there are many archaeological areas, for instance in Greece, Southern Italy, Western Asia, Egypt etc. These archaeological sites present very special ecological conditions because of the abundance of stony substrates, excavation activities, heavy foot traffic and many other forms of human disturbance. In addition exotic species are introduced by man for aesthetic purpose or regreening of certain surfaces. Flora and vegetation consequently have some special features but until now very few investigations have been carried out on this subject. An archaeological area is indeed a very particular field of investigation for a botanist who besides the discoveries of its flora and vegetation will be constantly aware of the past with great respect and reverence.

Since the 19th century a few floristic lists of famous archaeological sites have been published (e.g. of the Colosseum in Rome and others): anthropogenous elements are prevailing in such artificial environments and natural vegetation is almost lacking (DEAKIN, 1855; FIORINI MAZZANTI, 1875-78).

Special phytosociological investigations have been published by RIVAS MARTINEZ (1978).

Our study was partly carried out as a thesis by the junior author during the years 1984-1986. The aim of it was to describe flora and vegetation of a large archaeological area and analyze some specific ecological factors of this very particular environment.

A historical interlude

Ostia Antica is a huge archaeological area about 23 km southwest of Rome which covers a surface of some 34 ha near the mouth and lefthand-bank of the Tiber on sandy, Holocene alluvial soils with high groundwater level. Today it is about 3 km from the coast of the Tyrrhenian Sea. Its name derives from Ostium (= mouth); by the way after the tradition (see Vergil: Aeneis) the mythical hero Aeneas is said to have landed there.

The foundation of Ostia Antica is ascribed by ancient Roman writers to Ancus Martius, a mythic King of Rome (7th cent. BC), and some evidences support this hypothesis. A matter of fact is that a fortified quadrangular citadel (125 by 193 m) was built during the 4th cent. BC, probably in 338, a so-called Castrum, with the aim to control the coast, the surrounding salt-works (saline) and the fluvial traffic on the Tiber. Remnants of the original wall of the Castrum can still be found in the centre of the archaeological complex.

From this strategically important port of the Roman Empire many a naval enterprise was started (for example in 211 BC P. Cornelius Scipio weighed the anchors for Spain with 30 quinqueremes). At the beginning Ostia Antica mostly served for defence and as a bulwark, soon it was used as a port of arrival for the wheat supply of Rome. By and by Ostia Antica changed its role and became an important commercial centre for the whole Mediterranean area. The Castrum was now too small, consequently it was transformed into Municipium in the 3rd cent. BC and grew to become about thirty times as big as it had been at the beginning. New walls of tufa were built under

Sulla with 3 entrances (Porta Romana to and from Rome, Porta Marina towards the sea, Porta Laurentina towards the settlement Laurentum, the area where today Castelporziano is situated).

The main road, in direction E-W, called Decumanus maximus, connected Rome with Ostia Antica, crossing the whole urban area from Porta Romana to Porta Marina, about 1.2 km long and the continuation of the via Ostiensis. Another important but shorter road, in direction N-S, was the Cardo maximus which crossed the latter connecting Laurentum with the harbour. Outside the walls – as this was the rule – the necropolis.

With the increasing commerce the number of public institutions of Ostia Antica was growing: grain- warehouses (Horrea), shops, taverns, housing for the poor, and villas for the rich showing an intersting urban phenomenon that sounds very modern indeed: vertical development instead of a horizontal one started mostly along the Decumanus maximus. Complexes of houses (Insulae, Fig. 1) connected by common courtyards were constructed which show some features similar to modern architecture and express the typical way of living of the labourers and the lower middle classes. Under Tiberius an aqueduct was built, closed sewers under the Decumanus maximus even sooner. Opulent villas in the Pompeiian style are rather rare.

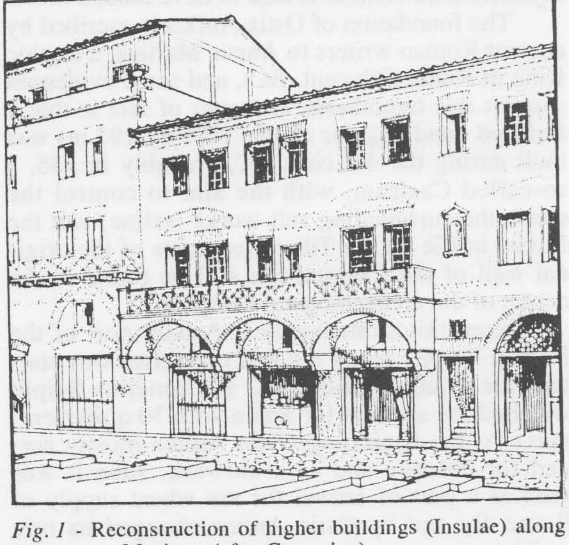

Fig. 1 - Reconstruction of higher buildings (Insulae) along Decumanus Maximus (after Carcopino).

After a description in Pliny the Elder, Jerome Carcopino writes about the Insulae of Ostia Antica: «Fast alle Fenster schmückten Topfblumen, sie bildeten die kleinen Gärten, von denen Plinius d. Ältere erzählt... Aus Ostia wissen wir, dass am Ende des 4. Jahrhunderts auch bescheidene Herbergen mit schattenspendenden Gebüschen umpflanzt wurden...» and again further on the same author writes «Die wesentlich ältere Casa dei Dipinti scheint von allen Seiten bis zum First mit Blumen umrankt gewesen zu sein... Die Rekonstruktion unter Berücksichtigung aller Anhaltspunkte erweckt das Bild einer Gartensiedlung... wie sie heute für die Handwerker und Kleinbürger unserer grossen Städte geschaffen werden...»

Ostia Antica is an example of the way how the artisans, craftsmen, labourers, clerks, police- and firemen, guards, merchants and slaves lived during the Roman era. In the flourishing period about 100 BC to 100 AD some 50.000 people were living here, among them also many foreigners, mostly oriental people; consequently many different religions such as the cults of Isis and Osiris, Ceres, Cybele, Attis, Serapis, Mitra etc. were represented. The Mitra cult is proved by the remnants of 16 Mitrei. Also one synagogue and the first Christian temples can be identified in the area.

The harbour by and by became insufficient and due to accumulation of sand inadapt, consequently a new one was built in the north under Claudius (42 AD) and Trajan (100-106). Claudius' try failed somehow but Trajan had built a hexagonal basin that offered shelter to cargo ships against seawinds and pirates and was connected with the sea and the Tiber by a channel. The harbour of Trajan is situated 4-5 km north of Ostia Antica, close to the site of the present airport of Fiumicino. Ostia Antica was connected to the new harbour by a new road crossing the so-called Insula sacra that became also a large necropolis.

During the 3rd cent. the importance of Ostia Antica faded by and by, and another settlement near the new harbour, simply called Portus, rose. During the 4th cent. AD most of the houses of Ostia Antica were falling into decay. The area was gradually abandoned, delinquency and malaria spread. In the 5th cent. AD it is not much more than a heap of ruins, and the natural vegetation of the surroundings invades the whole area. Procopios writes in 540 AD that «the via Ostiensis is untidy and woody and the Tiber without ships».

Ostia Antica by and by after a few centuries is covered by 5, 10, 12, 15 m of aeolian sand and completely buried. The first excavation started at the end of the 18th cent., but it was badly organized and a lot was ruined. Most of the important excavations were done systematically between 1938-1942 and are still going on. Today only half of the whole area of Ostia Antica has been excavated and explored.

Material and methods

In the area of Ostia Antica flora and vegetation have been investigated. The plant associations were analyzed with the phytosociological method. Ecological observations have been carried out with field measures. Nomenclature, life forms and chorotypes after PIGNATTI (1982).

Results

A) Flora and vegetation

After the archaeological areas were discovered the natural vegetation started taking over again, at least about 50 years ago. Where did the plants come from? Mostly from the immediate surroundings, from fields, meadows, vineyards and from open woodlands. Measures were taken by the authorities of the archaeological area to keep natural vegetation from invading the ruins and cleaning took place periodically. Nevertheless

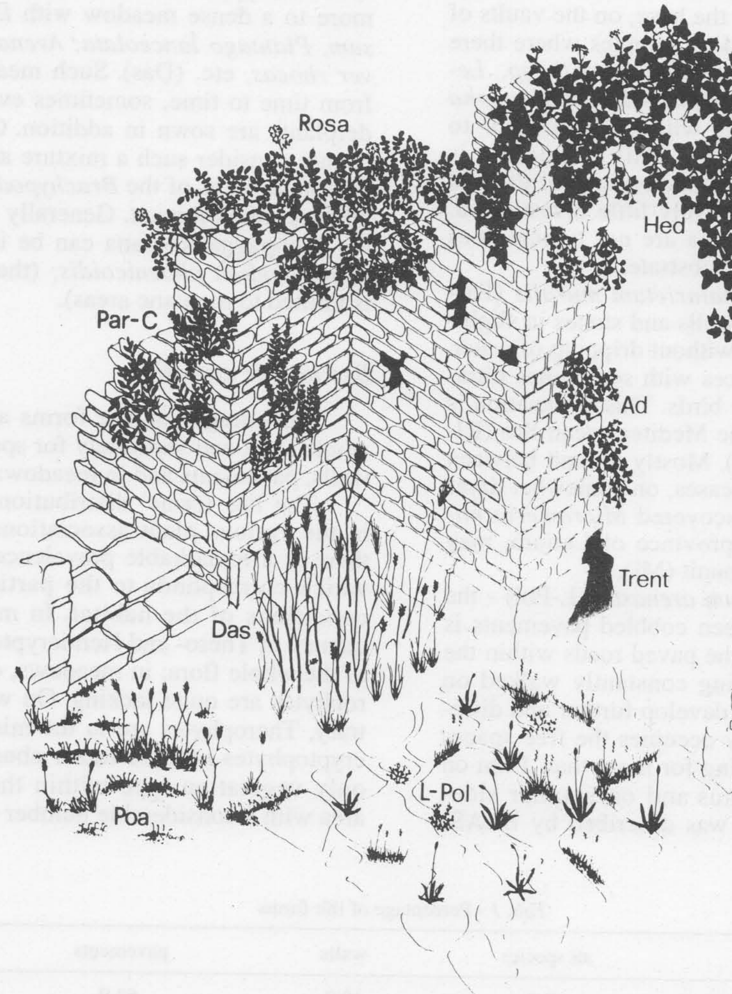

Fig. 2 - Main vegetation types within the archaeological area of Ostia Antica: Ad - *Adiantetum*, Trent - Subunit inside cisterns, Mitra temples etc. on humid walls with *Trentepohlia* sp., *Lepraria incurva, Marchantia polymorpha* etc. Par-C - *Parietario-Cymbalarietum muralis*. Mi - *Micromeria microphylla*-subunit. L-Pol - *Lolio-Polygonetum arenastri*. Poa - *Brachypodion phoenicoidis* with first colonizers like *Poa bulbosa, Barbula convoluta, Tortula muralis* etc. V - Xeric meadows with dominating *Vulpia ligustica* and *Brachypodium distachyum*. Das - Dense meadows with dominating *Dasypyrum villosum* etc. Hed and Rosa - Naturally occurring climbers like *Hedera helix* and wild or naturalized roses. (Drawing by Dr. Fabrizio Martini).

there is a seminatural flora and vegetation about which we shall talk briefly.

The flora is composed by 258 indigenous species and 34 introduced ones. Life forms and chorotypes have been investigated (see chapter B).

The most important habitats for the vegetation are walls, mortar, slates, bricks, crevices, cobbled pavements and the sandy soil around the ruins. The walls consist mostly of bricks and in some cases of tufa or marble. The pavements are constructed by volcanic stones. The vegetation is mainly composed by 4 vegetation types (Fig. 2):

1) *Adiantetum* (Ad) - dense populations of *Adiantum capillus veneris* are localized on shady, damp walls, mainly near the base, on the vaults of the cisterns and in the Mitra temples where there is usually dripping of water. *Trentepohlia sp., Lepraria incurva* and *Marchantia polymorpha* usually cover the surface with a dense light- to dark-green stratum (Trent). This vegetation is widespread in warm-temperate regions of the Old World but until now relatively little investigated. The aspects in Ostia Antica are not typical ones because of the manmade substrate.

2) *Parietario-Cymbalarietum muralis* (Par-C) - on vertical parts of walls and stones in slightly humid conditions but without dripping of water. The plants root in crevices with sometimes nitrate-rich soils manured by birds. This association is widespread all around the Mediterranean Sea (RIVAS MARTINEZ, 1978). Mostly on and between bricks and between staircases, on somewhat dryer habitats the recently discovered *Micromeria microphylla*, new for the province of Latium, may represent a particular subunit (Mi).

3) *Lolio-Polygonetum arenastri* (L-Pol) - the vegetation on and between cobbled pavements is the most typical for all the paved roads within the archaeological area. Being constantly walked on by visitors it can hardly develop further and differentiate. The community occupies the free spaces in between basaltic paving for more than 1 km on the Decumanus maximus and on smaller side-streets. This vegetation was described by BLASI and PIGNATTI (1984) for similar pavements in the city of Rome. The species composition is typical for habitats with heavy foot traffic. *Lolium perenne, Polygonum arenastrum, Poa annua, Polycarpon tetraphyllum* and a few elements deriving from the neighbouring meadows such as *Trifolium* sp. pl., *Lophochloa cristata* etc. are common here.

4) *Brachypodion phoenicoidis* - sandy surfaces are at first colonized by *Poa bulbosa* and xeric mosses like *Barbula convoluta* and *Tortula muralis* (Poa): this is a short-lived plant-community in which Therophytes and small cushion-like mosses are dominant. The succession on deeper sandy soils leads to dry meadows with *Vulpia ligustica* and *Brachypodium distachyum* (V) and furthermore to a dense meadow with *Dasypyrum villosum, Plantago lanceolata, Avena barbata, Papaver rhoeas,* etc. (Das). Such meadows are mown from time to time, sometimes even seeds of fodderplants are sown in addition. Consequently we cannot consider such a mixture as a distinct association. Species of the *Brachypodion phoenicoidis* alliance are dominant. Generally all grasslands of the Campagna Romana can be included into the *Brachypodion phoenicoidis;* (the *Arrhenatherion* is limited to montane areas).

B) Floristic analysis

Percentages of life forms are given for the whole flora and separately for species growing on walls, pavements and in meadows (Tab. 1).

The life forms' distribution differs strongly in the various plant associations. On pavements there is a remarkable prevalence of Therophytes which corresponds to the particular ecological conditions of the habitat. In meadows the frequency of Thero- and Hemicryptophytes is similar to the whole flora; in meadows, of course, Phanerophytes are quite lacking. On walls, on the contrary, Therophytes are in the minority and Hemicryptophytes become rather abundant. This is the only vegetation type within the archaeological area with a considerable number of Phanerophytes

Tab. 1 - Percentage of life forms

	all species	walls	pavements	meadows
Therophytes	48.9	18.8	62.9	42.1
Hydrophytes	1.5	–	–	–
Geophytes	10.0	9.4	–	2.0
Hemicryptophytes	34.6	57.7	37.1	53.5
Chamaephytes	2.3	4.7	–	2.2
Phanerophytes	2.7	8.7	–	0.1

as far as they are allowed to grow under a controlled management.

Naturally occurring Phanerophytes in the area are: *Hedera helix* (Hed), *Ficus carica, Laurus nobilis, Pyrus amygdaliformis, Cercis siliquastrum, Euonymus europaeus, Cornus sanguinea, Salix alba, Ulmus minor, Crataegus monogyna, Rhamnus alaternus, Viburnum tinus, Sambucus nigra*. Such spontaneous woody species should be maintained wherever possible within the archaeological area.

The following species were introduced by man on aesthetic purpose. Some of them are without doubt badly chosen and do not fit in this environment at all: *Eucalyptus globulus, Pittosporum tobira, Platanus hybrida, Cupressus sempervirens, Thuja orientalis, Taxus baccata, Ilex aquifolium, Tamarix africana, Rosa* sp. pl. (Rosa), *Robinia pseudacacia, Nerium oleander, Lonicera japonica, Ligustrum japonicum, Parthenocissus quinquefolia, Punica granatum, Jasminum humile*.

The phytogeographic composition (Tab. 2) of this flora is characterized by the dominance of mediterranean elements: Stenomediterranean (i.e. bound to the series of the *Quercetum ilicis*) and Eurymediterranean (towards the north reaching the border of the *Quercetum pubescentis*). On walls only a few stenomediterranean species can be observed; in correspondence there is an increase of pantropical species (ferns, chiefly *Adiantum capillus-veneris*).

A second important group are cosmopolitan species which can be regarded as introduced and naturalized. Species of this group may reach 30% on walls, pavements and meadows, instead in the whole flora only 22.8%; this means that they are particularly bound to manmade habitats. All the other groups are less represented, particularly the eurasiatic and paleotemperate elements which are the natural stock of the European flora (below 20%, on walls only 4%). This distribution of phytogeographic elements may affirm the opinion that the here discussed vegetation is of mediterranean origin and probably was not much different in ancient times except that the archaeological area offers since the excavation time free space for introduced species.

C) Synecology and periodicity

A surface of 3 sqm of the Decumanus maximus in Piazza Vittoria (at the beginning of the archaeological area, near the visitors entrance) has been kept under constant observation by the junior author: its vegetation was studied and mapped over distinct periods, the microclimatic conditions were compared (moisture, evaporation, rainfall and temperature), in addition to the macroclimate already given. As a result seasonal changes in species density from February to July have been observed with growing cover of Hemicryptophytes, decreasing values of Therophytes.

Microclima: during a standard day of spring (4-21-1985) temperature in the meadow reaches its maximum between 10.30-12.30 with 20°C; at the same time on cobbled pavements temperature increases up to 25°C. The relative humidity in the meadow varies from 80-86% (except for a sudden and short dropping down at 10.30 because of a light breeze). The corresponding values on the pavement are 66-76%. The vegetation between pavements shows almost the same values as those of the stones: temperature is about 5°C higher, there are 10% less humidity. During the warmest hours of the day evaporation was registered 1.3-1.8 mm/hour and 1.5-2.5 mm/hour on the pavement and in the vegetation walked on by people. These data give already an idea of the severe conditions for the growing vegetation. Besides the continuous mechanical action of treading and trampling, water stress has to be supported around noon. These measures date back to the month of April, but of course, conditions will be still much severer in the middle of summer.

Tab. 2 - Percentage of chorotypes

	all species	walls	pavements	meadows
Medit.-mont. + Endem.	0.4	6.0	4.9	1.7
Stenomediterranean	20.8	11.4	17.4	20.2
Eurymediterranean	23.5	23.5	21.5	18.3
Eurasiat. + Paleotemp.	17.8	4.0	19.6	18.5
Medit.-Atlantic	3.5	2.0	5.7	4.9
Boreal	4.6	5.4	0.8	6.1
Pantropical	6.2	14.1	0.0	0.0
Cosmopolitan	22.78	33.6	30.2	30.4

Variations: changes in presence and cover of species are indicated in Tab. 3. Species composition differs slightly from the typical one of the *Lolio-Plantaginetum* in which *Cynodon dactylon*, a rhizome-geophyte, and a few other accompanying species normally are absent but as a whole many other species present which are lacking within the 3 m^2 observed and cannot be considered as a complete relevée.

The total number of species in the investigated surface is 20; at the end of the winter the recognizable species are only 9, species number increases up to a maximum in June and again decreases to 8 species in summer. These variations can be interpreted as changes in diversity and detected applying Shannon's formula. The data plotted in Fig. 3 show that diversity is increasing during spring and drops in summer, consequently spring can be regarded as the season with maximal development of the vegetation on pavements. The result is expressed in percentage (evenness). These seasonal changes are probably regular variations and fluctuations, due to the appearing or disappearing of Therophytes, while Hemicryptophytes remain more or less stable, except that there are strong differences in cover. The annual *Trifolium glomeratum* (Fig. 4) is co-dominant during the cooler months of spring and disappears after June, the perennial *Trifolium fragiferum* is relatively rare at the beginning of spring, but is spreading later on very vigorously.

The data of this investigation can be considered as a brief survey on the actual situation of the main subspontaneous vegetation types on walls, between cobbles, and in meadows within the archaeological area. No trace of the original vegetation is left and vegetation had to start growing

Tab. 3 - Percentage of cover

Date...	2-16-86	4-21-86	6-8-86	7-7-86
H *Lolium perenne*	53.80	52.07	55.87	62.35
H *Trifolium glomeratum*	38.40	33.96	9.00	12.81
H *Malva sylvestris*	1.81	1.47	1.83	0.70
H *Plantago lanceolata*	0.55	0.38	0.24	–
H *Trifolium fragiferum*	–	1.70	22.01	16.92
G *Convolvulus arvensis*	–	0.24	1.77	2.73
T *Crepis sancta*	2.70	0.57	–	–
T *Lophochloa cristata*	–	–	3.09	2.15
T *Polycarpon tetraphyllum*	–	–	2.01	2.14
T *Crepis setosa*	–		0.27	0.11
T *Veronica persica*	1.67	–	–	–
H *Trifolium repens*	0.83	–	–	–
H *Scabiosa maritima*	0.18	–	–	–
T *Senecio vulgaris*	0.06	–	–	–
T *Vulpia ligustica*	–	6.69	–	–
T *Sherardia arvensis*	–	2.63	–	–
T *Capsella rubella*	–	0.29	–	–
T *Trifolium resupinatum*	–	–	3.22	–
T *Trifolium campestre*	–	–	0.69	–
T *Euphorbia maculata*	–	–	0.09	–
Number of species ...	9...	10...	12...	8...

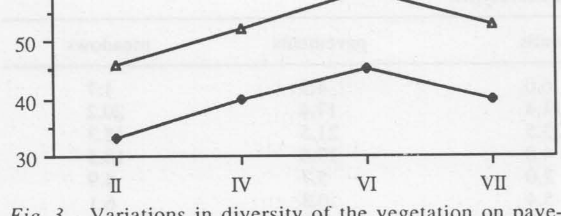

Fig. 3 - Variations in diversity of the vegetation on pavements during the period from February to July. Data are expressed as percentages of the maximum entropy (evenness).

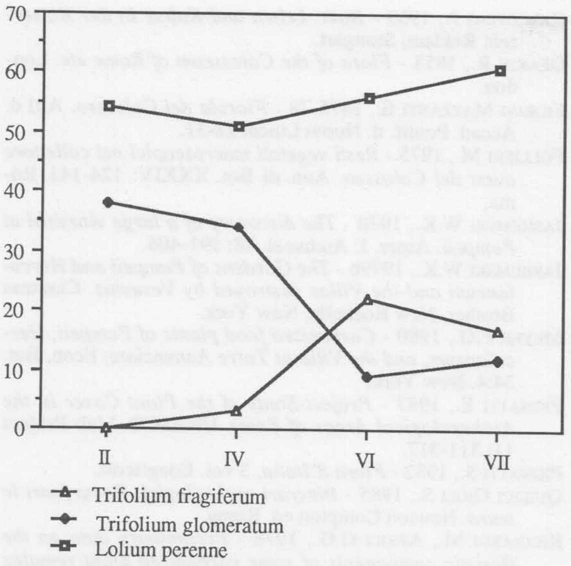

Fig. 4 - Variations in cover of the dominant species in the vegetation on pavements: *Lolium perenne* remains relatively constant whereas *Trifolium glomeratum* expands in early spring and is later substituted by *Trifolium fragiferum*.

right from the beginning where excavations were finished. How the vegetation and species composition might have been 2000 years ago we can only guess but we are inclined to affirm that, having the general features of the climate not changed to a great degree since then, the surrounding vegetation can be supposed to have been more or less similar. But this is only a hypothesis which cannot be proved. A lucky discovery was made in the archaeological area of Oplontis, about 20 km south of Naples where a bundle of hay was found well-preserved by the volcanic ash of Mt. Vesuvius in 79 AD; it was analyzed by RICCIARDI, APRILI (1978). 111 taxa were identified, a total of 88 determined to the species level, representing 69 genera and 26 families, 13 items to genus level and 10 without identification. Most of the reported species are still growing in the local flora (such as *Polycarpon tetraphyllum*, *Rumex bucephalophorus*, *Papaver rhoeas*, *Potentilla reptans*, *Daucus carota*, *Cynodon dactylon*, *Anthoxanthum odoratum*, *Sherardia arvensis*, *Quercus robur* s.l., *Vitis vinifera*, *Olea europaea* etc. etc.). They all may grow presently even in Ostia Antica. Thus it seems that 1900 years ago the wildgrowing species and even some cultivated ones like *Vitis* and *Olea* were very much the same near Naples and probably around Rome.

We know that there were beautiful gardens in Pompeii with ornamental and partly introduced species (JASHEMSKI, 1979); we know also after a description of Pliny the Elder that there were houses with gardens in Ostia Antica.

In Saint Augustine's «Confessions» the wonderful dialogue he had with his mother in Ostia Antica a few days before she faded away is described. This dialogue – a masterpiece of Christian mystic literature – took place in front of a window that opened on an inner garden of the house where they were staying. The first sentences (in German version) are these: «Als nun der Tag herannahte, an dem sie aus diesem Leben scheiden sollte - Du kanntest ihn, wir kannten ihn nicht - da traf sich's, wie Du auf Deine geheime Weise es wohl gefügt, dass wir beide, ich und sie, allein an ein Fenster gelehnt dastanden. Es schaute auf den inneren Garten des uns beherbergenden Hauses, dort bei Ostia am Tiber, wo wir fern vom Menschenschwarm uns von der Mühe der langen Reise erholten und auf die Seefahrt rüsteten. Da führten wir miteinander Aug in Auge ein herzerquickendes Gespräch, vergessend, was dahinter ist und ausgerichtet zu dem, das da vorne ist, fragten wir uns vor Dir, der Du die Wahrheit bist, wie wohl das ewige Leben der Heiligen sein werde, das kein Auge gesehen, kein Ohr gehört und das in keines Menschen Herz gekommen ist! Durstig öffneten wir unseres Herzens Mund den hoch daherströmenden Wassern Deiner Quelle, der Quelle des Lebens, die bei Dir ist, auf dass wir von ihr getränkt, soweit uns vergönnt, das hohe Ziel mit sinnenden Gedanken erreichen möchten...». This dialogue took place in 387 AD, 1600 years ago. Today a humble inscription on a marble plate commemorates St. Monica's death half way the Decumanus maximus.

Conclusion

The flora of the archaeological area of Ostia Antica is chiefly composed by mediterranean elements (both steno- and eurymediterranean) with a high percentage of cosmopolitan; many of them are naturalized. Generally this flora appears relatively similar to the surrounding one, also the vegetation, but nitrophilous and ruderal associations are mostly lacking within the archaeological area.

The flora contains a high percentage of annuals, only on walls and in meadows perennial species can become dominant. Hemicryptophytes are well represented, Geophytes are rare or lacking except in meadows, Chamaephytes are also not frequent and Phanerophytes are mostly controlled by man and their number and growth are artificially reduced.

The vegetation of the surrounding tends to invade the inner part of the archaeological area which may cause some problems for the management.

It is somehow possible to built up a hypothesis on the vegetation of former times. We can assume that the vegetation was similar to the present one but without many introduced species from other continents. In future introduced species should be more carefully chosen and a few of them excluded such as *Eucalyptus globulus, Pittosporum tobira, Robinia pseudacacia, Ligustrum japonicum* etc. because they really do not fit in; *Parthenocissus quinquefolia* should be at least controlled. An open problem is still to be seen in a correct management of the whole surface which has to remain an example of a well preserved archaeological area.

Zusammenfassung

Flora und Vegetation von Ostia Antica werden in dieser Arbeit ertsmalig zusammengefasst. Nach einem kurzen historischen Exkurs werden die wichtigsten Standorte und Pflanzengesellschaften, ferner Ökologie und Mikroklima, Fluktuationen während der Hauptvegetationsperiode und Diversität der Florula einer kleinen Untersuchsfläche erörtert. Das Problem der Landschaftspflege und des Erhaltens einiger ästhetisch wichtiger Arten innerhalb der archäologischen Zone wird erwähnt.

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Urban Lichen Studies in Italy. III. The City of Rome

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Keywords: lichens, urban ecology, air pollution.

Abstract

The epiphytic lichen vegetation of the city of Rome has been studied on the basis of 127 phytosociological relevés, carried out in 1982. The data have been analyzed by multivariate methods. The epiphytic lichen flora of the city of Rome consists of 34 species. The number of species tends to increase and the incidence of acidophytic species to decrease from the center to the perifery of the city. The lichen vegetation mostly belongs to the *Xanthorion*-alliance: two main relevé groups may be distinguished: the first, with more pronounced suboceanic affinities, is limited to the western part of the survey area, the other occupies the eastern part; this suggests the existence of a phytoclimatical border running through the town, separating a western part, still under maritime influence, from a drier eastern part. The lichen desert, plus the areas with dominant *Lecanora conizaeoides,* extend from the center south- and northeastwards, in correspondence with the two main winds blowing upon the city.

Introduction

The lichen flora and vegetation of the Latium region (Central Italy) are far to be exhaustively known. Only four studies have been published in recent times. Two of them deal, respectively, with the epiphytic lichen vegetation (NIMIS & SCHIAVON, 1986) and the total lichen flora (NIMIS, 1988) of the Castelporziano Estate, a few kilometres SW of Rome; one is devoted to a monographic treatment of the epilithic lichen flora and vegetation of archaeological areas (NIMIS & al. 1987), and the fourth (NIMIS & TRETIACH, 1987) is a short note on the lichens of Rome itself. Altogether, the area surrounding Rome is the part of Latium which is best known from the floristical point of view, with of more than 350 species.

This paper is the third of a series devoted to the study of epiphytic lichen vegetation in Italian urban environments. The first two papers dealed with the towns of Trieste (NIMIS, 1985) and Udine (NIMIS, 1986) in north eastern Italy. The present study is devoted to the city of Rome. The aims of this series are simply the analysis of the distribution of epiphytic species, the description of lichen vegetation, and its ecological interpretation. The study of the influence of air pollution on epiphytic lichens lies outside of the scopes of the series, although this factor is often taken into consideration in the interpretation of the results. The reason for this choice is that the main aim of this series is to provide a basis for further studies on the effects of air pollution on lichens in Italian towns.

Survey area, data and methods

The survey area includes the city of Rome and its immediate surroundings (Fig. 1). The climate of the area is intermediate between the suboceanic and the mediterranean climate-types, and is characterized by a generally high degree of air humidity. For further details on the climate of Rome see NIMIS & SCHIAVON (1986).

A reference grid has been superimposed to the map of Rome: the squares are the reference for drawing maps concerning the distribution of lichens, and each square has been visited to record lichen vegetation. As phorophytes, trees were selected whose bark is primarily acid. These are (in order of frequency): *Quercus ilex, Tilia* spp., *Quercus suber.* Relevés were taken at the north and south sides of the boles, at the base and at 1.5 m, within squares of 50 cm. A relevé consists in a complete species list, with cover values according to BRAUN-BLANQUET (1964). Sampling was carried out during 1982. Altogether, 127 relevés were carried out.

The matrix of species and relevés was submitted to multivariate analysis; the classification of relevés was based on binary data, using euclidean distance, with complete linkage clustering (Anderberg, 1973). Reciprocal ordering of species and relevés has been obtained by transforming the original data by deviation from expectation, and performing PCA on a cross product matrix, with

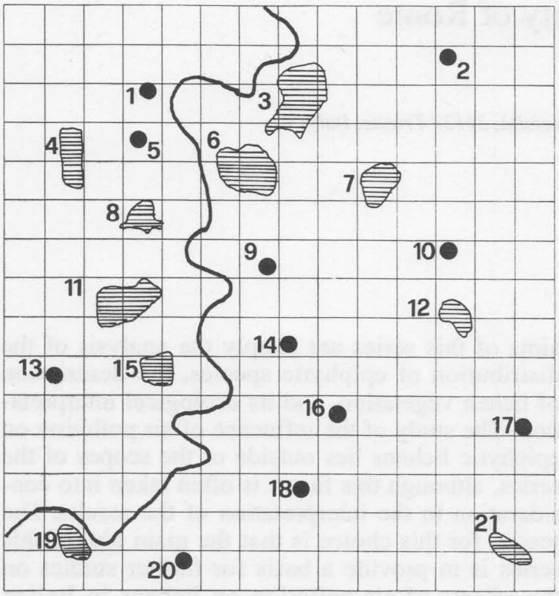


Fig. 1 - Reference map of the study area. 1: Stadio Olimpico, 2: Castel de' Pazzi, 3: Villa Ada, 4: Valle dell'Inferno, 5: M. Mario, 6: Villa Borghese, 7: Verano, 8: Vaticano, 9: Colosseo, 10: Prenestina, 11: Villa Doria, 12: Tor Pignattara, 13: F.te Bravetta, 14: P.ta Ardeatina, 15: S. Camillo, 16: Circo Massimo, 17: Cinecittà, 18: Forte Ardeatino, 19: Tor di Valle, 20: E.U.R., Pal. Sport, 21: Capannelle.

the package of programs by WILDI & ORLÒCI (1983).

A further data source, utilized for the ecological interpretation of relevé groups, are the ecological indices assigned to each species by WIRTH (1980). They concern: pH, nitrophytism and hygrophytism. The matrices reporting the relative occupancies, in each relevé group, of the species in the various index-classes have been analyzed by Canonical Analysis (FEOLI & ORLOCI, 1979). The same analysis has been applied to the matrix of the relevé groups and Operational Geographic Units (OGUs) obtained from the range diagnoses given by Wirth (1980). For further details on the elaboration of ecological indices and of OGUs, see NIMIS & SCHIAVON (1986).

Results

The classification of the matrix of species and relevés produced 5 main relevé groups (Fig. 2). Tab. 1 reports the frequency of each species in the 5 relevé groups. The relevé groups No. 1 and No. 4 represent a relatively rich epiphytic vegetation, which in both cases is dominated by *Xanthorion*-species such as *Hyperphyscia adglutinata, Parmelia subrudecta, Physcia adscendens, Physcia biziana, Physcia orbicularis, Physconia grisea, Xanthoria parietina*. Relevé group No. 1 is characterized by a higher incidence of relatively aerohygrophytic species, such as *Heterodermia obscurata, Collema nigrescens, Diploicia canescens, Evernia prunastri, Parmelia caperata, Par-*

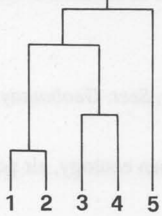


Fig. 2 - Dendrogram of the relevé groups.

Tab. 1 - Percent frequency of the 34 species in the 5 relevé groups

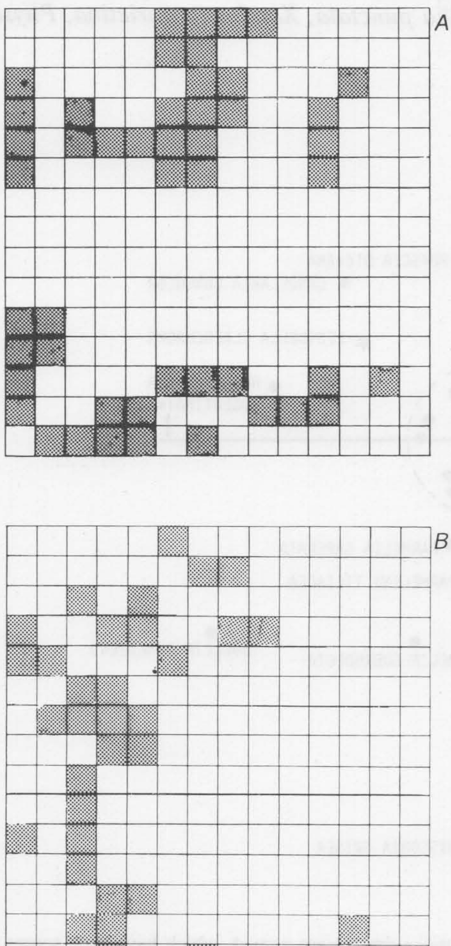
RELEVE GROUP No.	1	2	3	4	5
Lecania cyrtella	12.5	.	.	.	.
Parmelia sulcata	12.5	.	.	.	.
Collema nigrescens	12.5	.	.	.	.
Heterodermia obscurata	25.0	.	.	.	.
Parmelia tiliacea	50.0	10.0	.	.	.
Lepraria incana	12.5	10.0	.	.	.
Cladonia fimbriata	12.5	20.0	.	.	.
Parmelia caperata	25.0	20.0	.	.	.
Cladonia coniocraea	12.5	10.0	.	.	.
Lecanora hagenii	.	.	4.0	7.7	.
Caloplaca holocarpa	.	.	.	7.7	.
Caloplaca cerina	.	.	.	7.7	.
Lecidella elaeochroma	.	.	4.0	69.2	.
Candelaria concolor	.	.	12.0	53.8	.
Xanthoria parietina	25.0	.	12.0	92.3	.
Physcia aipolia	12.5	.	8.0	38.4	.
Caloplaca sp.	12.5	.	7.7	.	.
Candelariella xanthostigma	25.0	.	7.7	.	.
Arthopyrenia punctiformis	.	.	4.0	15.3	.
Lecanora chlarotera	12.5	.	15.3	.	.
Physcia biziana	12.5	10.0	.	30.7	.
Physconia grisea	87.5	9.0	.	38.4	.
Usnea sp.	.	.	.	7.7	.
Physconia perisidiosa	.	.	.	7.7	.
Arthonia radiata	.	.	.	7.7	.
Hyperphyscia adglutinata	12.5	.	.	30.7	.
Evernia prunastri	25.0	.	.	7.7	.
Buellia punctata	12.5	10.0	28.0	30.4	13.2
Physcia orbicularis	75.0	20.0	56.0	53.8	6.6
Parmelia subrudecta	37.5	20.0	.	23.0	.
Physcia adscendens	100.0	.	48.0	76.9	6.6
Lecanora conizaeoides	.	5.0	16.0	7.7	100.0
Scoliciosporum chlorococcum	.	20.0	20.0	.	33.3
Diploicia canescens	22.5	10.0	.	30.7	.

melia tiliacea, Physconia grisea (which often occurs only at the base of the trunks).

Considering the topology of the dendrogram (Fig. 3) and the floristic composition, the relevé groups no. 2 and 3 may be considered as impoverished facies of, respectively, relevé groups no. 1 and 4.

The relevé group no. 5 is species-poor, and is characterized by the constant presence of *Lecanora conizaeoides,* sometimes associated with *Scoliciosporum chlorococcum* and *Buellia punctata.*

Fig. 3 a-d shows the distribution of relevé groups 1-4 within the survey area: the groups no. 1 and 2 have mainly a western distribution, whereas the groups no. 3 and 4 are most frequent in the eastern part of the city. Fig. 3e reports both the areas with lichen desert and those with epiphytic vegetation belonging to relevé group no. 5: these areas, that have the scarcest lichen vegetation, ex-



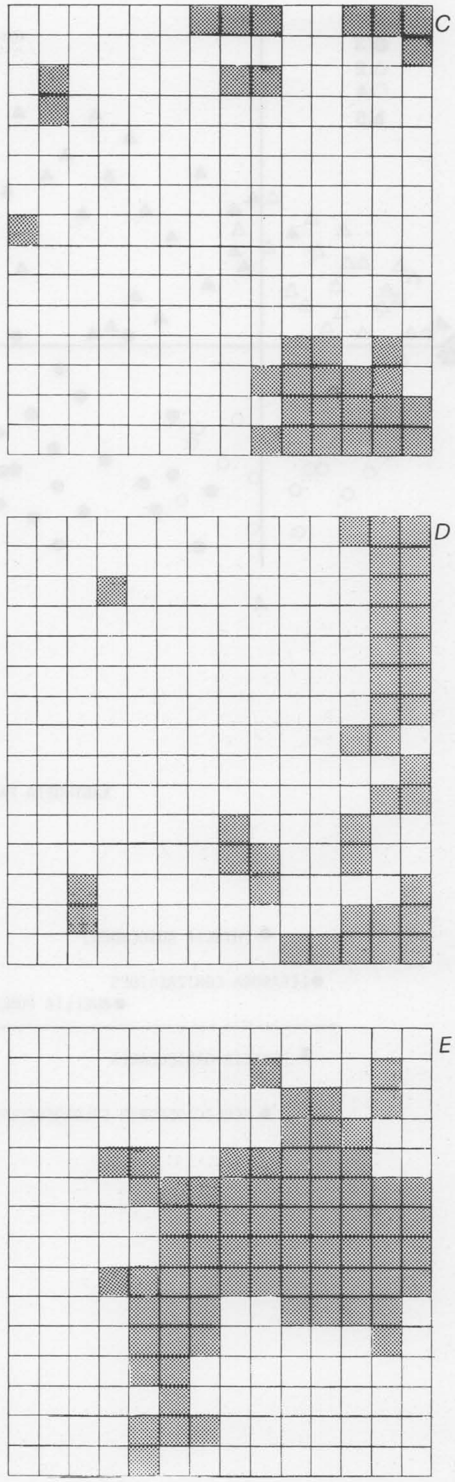
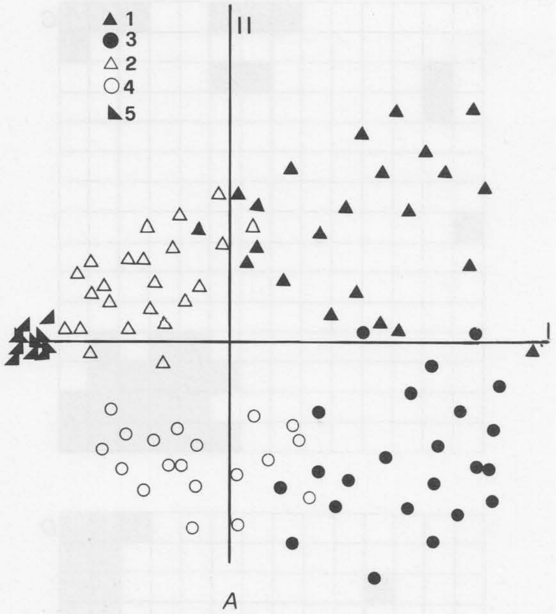


Fig. 3 - Distribution of the relevé groups in the survey area. a) Group 1, b) Group 2, c) Group 3, d) Group 4, e) Group 5, plus quadrants with lichen desert.



tend asymmetrically, in respect with the city centre, both southwards and northeastwards.

The results of the reciprocal ordering of the relevés and the species are shown in Fig. 4a (relevés) and 4b (species). In Fig. 4a the groups obtained by classification are still recognizable: the first canonical variate reflects a poleophoby gradient, from relevé group no. 5 (negative extreme) to relevé groups no. 1 and 4. The second variate separates relevé groups no. 1 and 2 from no. 3 and 4. Fig. 5 shows the relation between the poleophoby axis and the number of species in each relevé, which clearly tends to increase from the central to the peripheral areas. In the ordination of species (Fig. 4b) those species which are most significantly associated with the poleophoby gradient have high scores on the first canonical variate. They can be ordered on a poleophoby scale as follows (from the less to the most poleophobic): *Lecanora conizaeoides, Physcia orbicularis, Scoliciosporum chlorococcum, Physcia adscendens, Buellia punctata, Xanthoria parietina, Physconia*

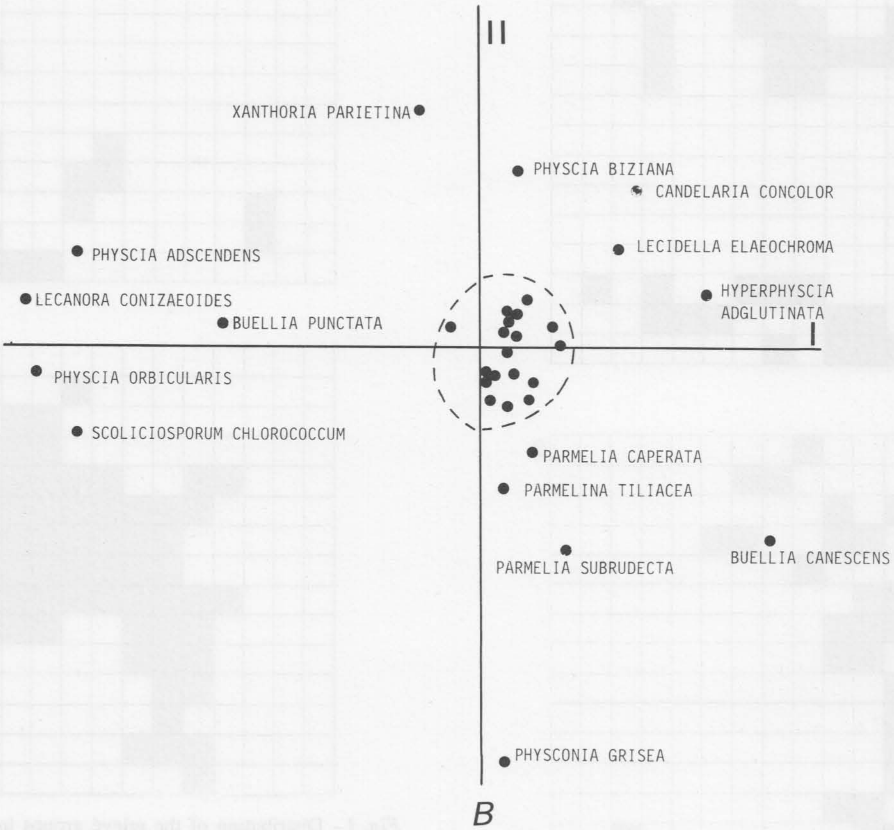


Fig. 4 - Reciprocal ordering of relevés (a) and species (b). In Fig. 4b only those species are named, which have high scores on the two first canonical variates (see text).

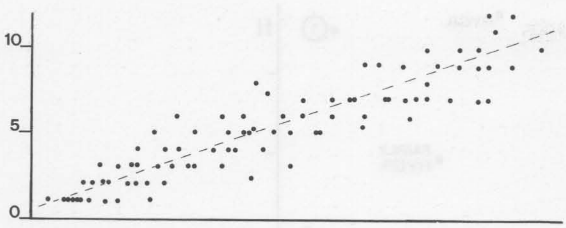


Fig. 5 - Relation between the scores of the relevés on the first canonical variate of reciprocal ordering (x-axis, see Fig. 4a) and number of species per relevé (y-axis).

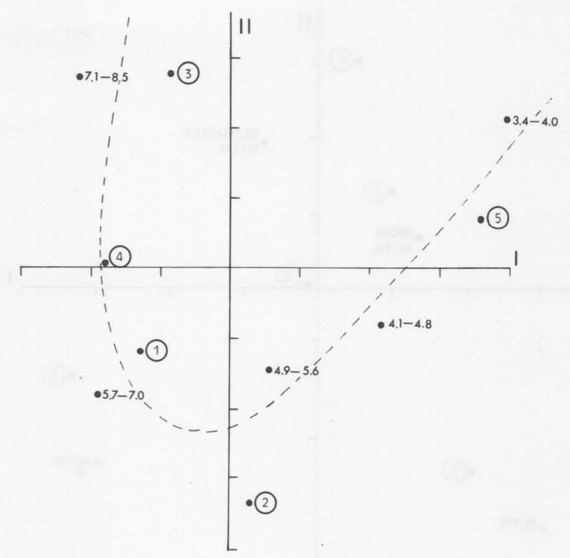


Fig. 6 - Scatter diagram relative to AOC, carried out on the pH data of Tab. 2. The numbers refer to the relevé groups.

grisea, Parmelia tiliacea, Physcia biziana, Parmelia caperata, Parmelia subrudecta, Lecidella elaeochroma, Candelaria concolor, Hyperphyscia adglutinata, Diploicia canescens.

Tab. 2 reports, for the 5 relevé groups, the relative frequencies in each class of the ecological indexes. The data relative to pH, nitrophytism and hygrophytism have been submitted to canonical analysis. The results are shown in Fig. 6 (pH),

Tab. 2 - Relative frequencies (calculated as percents of the total occupancies) of species with a given ecological index in the relevé groups

RELEVE GROUP No.	1	2	3	4	5
pH					
3.4-4.0	31.3	8.3	9.0	21.4	89.4
4.1-4.8	33.3	28.6	40.9	45.2	89.4
4.9-5.6	92.1	80.9	97.7	100.0	100.0
5.7-6.9	68.6	86.9	93.1	71.4	10.5
7.0	66.6	54.7	38.6	9.5	10.5
7.1-8.5	56.8	29.7	31.8	9.5	10.5
hygrophytism					
very hygrophytic	.	.	6.8	2.4	.
rather hygrophytic	19.6	16.6	40.9	45.2	38.9
moderately hygrophytic	50.9	46.4	61.3	50.0	89.4
mesophytic	94.1	85.7	70.4	50.0	100.0
rather xerophytic	100.0	82.1	70.4	69.0	100.0
xerophytic	41.1	25.0	36.3	64.2	84.2
nitrophytism					
very nitrophytic	58.8	20.2	31.8	19.0	10.5
rather nitrophytic	98.0	71.4	79.5	73.8	47.3
moderately nitrophytic	74.5	85.7	77.2	64.7	94.7
non nitrophytic	35.2	29.7	27.2	40.4	89.4

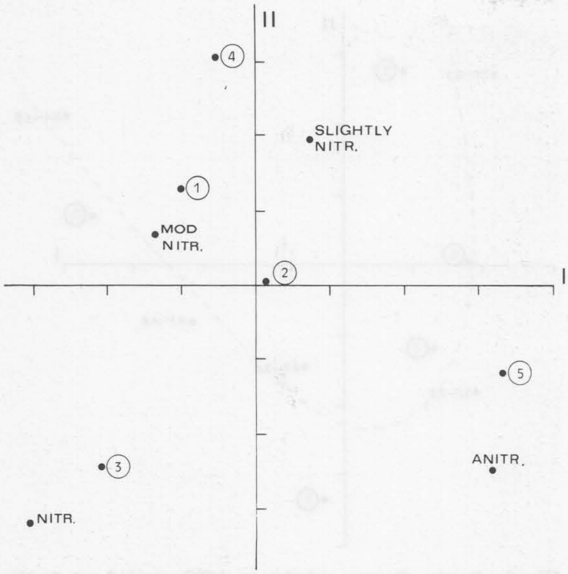


Fig. 7 - Scatter diagram relative to AOC, carried out on the nitrophytism data of Tab. 2. The numbers refer to the relevé groups.

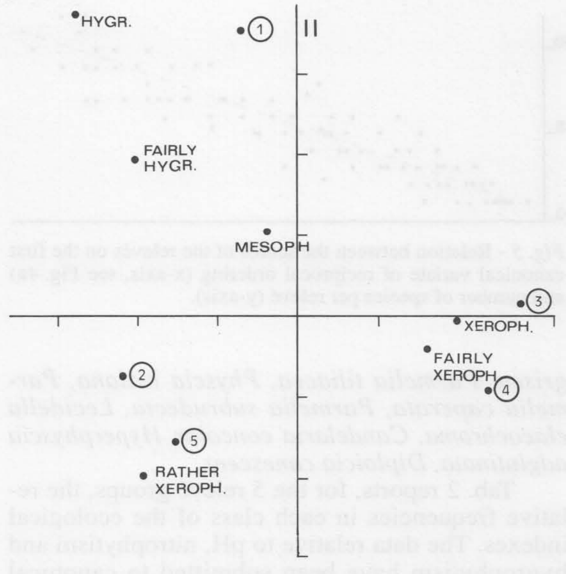


Fig. 8 - Scatter diagram relative to AOC, carried out on the hygrophytism data of Tab. 2. The numbers refer to the relevé groups.

Fig. 7 (nitrophytism) and Fig. 8 (hygrophytism). On the basis of these results, the five relevé groups may be ecologically characterized as follows.

Relevé group no. 1: subneutrophytic, moderately nitrophytic, fairly hygrophytic.

Relevé group no. 2: subacidophytic, rather mesophytic-rather xerophytic.

Relevé group no. 3: basiphytic, nitrophytic, xerophytic.

Relevé group no. 4: subneutrophytic, slightly nitrophytic, xerophytic.

Relevé group no. 5: acidophytic, anitrophytic, rather xerophytic. It should be noted that with increasing poleophoby the degree of acidophytism tends to decrease, which suggests an acidifying effect of urban pollutants on tree bark.

Tab. 3 - Relative frequencies of species in the OGUs, subdivided by relevé groups, calculated as percents of the total occupancies in each OGU. Further explanations in text

RELEVE GROUP No.	1	2	3	4	5
BOR	26.5	46.0	83.0	1.1	16.6
S'BOR	34.6	50.0	98.1	81.8	100.0
S-BOR.SUBATL	8.1	4.0	.	.	.
MIEUR	87.7	80.0	100.0	90.9	100.0
MIEUR.SUBATL	12.2	20.0	.	9.1	.
S'MIEUR	77.5	80.0	81.1	89.7	83.3
S'MIEUR.SUBATL	12.2	29.0	.	9.1	.
SMED	77.5	78.0	81.1	88.6	16.6
SMED.SUBATL	12.2	16.0	.	9.1	.
MED	85.7	96.0	81.1	93.1	16.6

Tab. 3 reports, for the five relevé groups, the relative incidence in the OGUs defined by the main European vegetation zones. The results of AOC, performed on the data of Tab. 3, are shown in Fig. 9: the fist canonical variate separates the western OGUs (those with subatlantic affinites) from the others, the second variate orders the OGUs according to latitude; the first variate reflects the water factor, the second the temperature factor. The relevé groups no. 1 and 2 confirm their western and southern afinity, whereas relevé group no. 5 includes species which extend up to the boreal zone.

Discussion and conclusion

Fig. 10 presents a synthesis of the distribution of epiphytic lichens in the city of Rome: the lichen desert (including the areas with vegetation corresponding to relevé group no. 5) has an extension which is well in accordance with the two main winds blowing upon the city of Rome: the Tramontana and the Ponentino, which, respectively, carry the gaseous pollutants towards the south, and towards north-east. A rather surprising fact is the presence of a west-east differentiation in the lichen vegetation: the western part of the

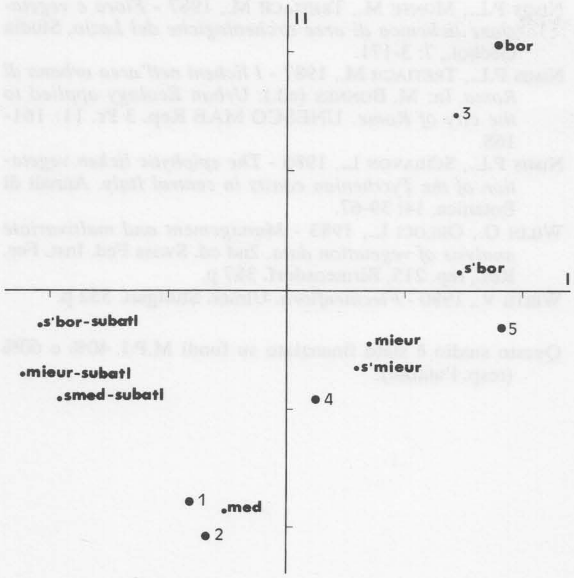


Fig. 9 - Scatter diagram relative to AOC, carried out on the phytogeographical data of Tab. 3. The numbers refer to the relevé groups.

city hosts a number of lichens with more pronunced suboceanic affinities. Probably this reflects the existence of a phytoclimatic border running through the city of Rome, which separates the western part, still under the influence of the humid western winds blowing from the Tyrrhenian Sea, from the eastern part, with a more subcontinental climate.

In the lichen herbarium of the University of Rome (RO) there are several samples collected during the last century within the limits of the survey area. Among the most interesting species the following may be cited: *Ramalina lacera* (Villa Borghese), *Ramalina farinacea* (Villa Borghese), *Parmotrema chinense* (Orto Botanico, Villa Doria Pamphili, Valle dell'Inferno), *Parmotrema reticulatum* (Villa Doria Pamphili) *Parmotrema hypoleucinum* (Orto Botanico, Valle dell'Inferno). All of these species are now absent from the survey area. Some of them are bound to a suboceanic climate, and are still present in the Presidential Estate of Castelporziano (NIMIS, 1988), ca. 20 km Sw of Rome, and in few relict sites along the Tyrrhenian coasts of Central Italy (NIMIS & SCHIAVON, 1986).

It is probable that in the last century the epiphytic lichen flora of the city of Rome was similar to the one present today at Castelporziano. The latter amounts at ca. 150 species. It follows that in the last 100-150 years the epiphytic lichen flora of Rome has probably lost ca. 80% of its species, mainly as a consequence of climatic changes brought about by urbanization, and of increasing air pollution.

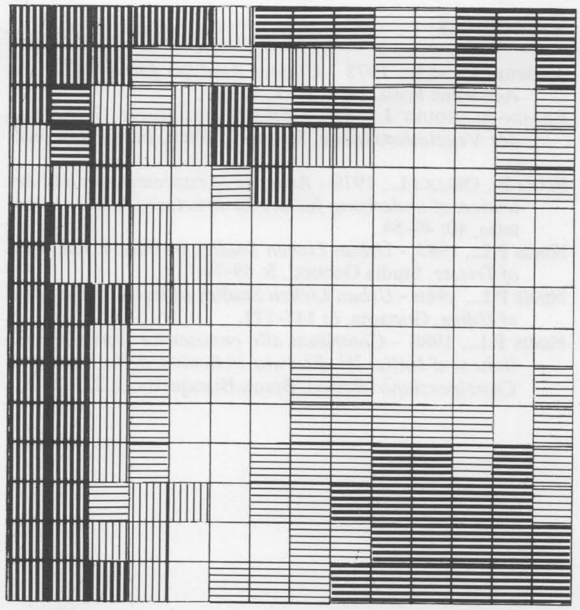


Fig. 10 - Synthetic rapresentation of the distribution of lichens in the city of Rome. White area: lichen desert or areas with *Lecanora conizaeoides*. Vertical stripes: lichen vegetation of groups 1 (thick lines) and 2 (thin lines). Horizontal stripes: lichen vegetation of groups 3 (thin lines) and 4 (thick lines). The thickness of the lines represents an increase in species richness. For further comments see text.

Riassunto

La vegetazione lichenica epifita della città di Roma, all'interno del raccordo anulare, è stata studiata sulla base di 127 rilievi fitosociologici, effettuati nel 1982. La matrice delle specie e dei rilievi è stata analizzata tramite programmi di analisi multivariata (classificazione ed ordinamento). La florula lichenica epifita della città di Roma consiste di 34 specie. Dalla periferia al centro della città il numero delle specie tende a diminuire, e l'incidenza di specie acidofitiche ad aumentare. La vegetazione lichenica in gran parte appartiene all'alleanza *Xanthorion parietinae*. È possibile distinguere due gruppi principali di rilievi: il primo, con una maggiore incidenza di specie aeroigrofitiche ad affinità suboceaniche, occupa la parte occidentale dell'area di studio, il secondo prevale nella parte orientale; ciò suggerisce l'esistenza di un confine bioclimatico che decorre all'interno dell'area urbana di Roma, separante una porzione occidentale, ancora sotto l'influsso marittimo, da una porzione orientale, più arida. Il deserto lichenico, che occupa le parti centrali della città, si estende verso sud e verso nord-est, in corrispondenza dei due venti principali che spirano sulla città di Roma.

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A hypogean algal association

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Keywords: algae association, hypogea biodeterioration, cyanophytes, light effets.

Abstract

The algal association present on some frescoes of the Domus aurea in Rome (Italy) was studied during four years in order to control the deterioration processes, as well as to observe the possible changes in the algal composition. Analysis of the pigment content, LM, SEM and TEM investigations were carried out on the algal community. The results showed that the filamentous cyanophytes *Leptolyngbya gracillima* and *Leptolyngbya hollerbachiana* were dominant in the association, while some changes occurred in the species composition of the community during the period considered. Variations were also observed in the pigment content of the samples, particularly phycobiliproteins, after the exposure of the frescoes to different light conditions.

Introduction

The presence of more than 10.000 m^2 of frescoed and stuccoed walls in the Domus aurea in Rome (Italy) compelled the Istituto Centrale del Restauro (I.C.R.) of Rome in the last years to start a conservative project in order to stop and prevent the damages to this hypogean archeological remain (MARTINES 1986).

Together with the physical and chemical factors which affect the integrity of the monument, different biological agents contribute to the progressive deterioration of the frescoes (GIACOBINI et al. 1986). Among the microorganisms the presence of algae has been previously observed in some rooms of the Domus aurea. Algal associations expecially developed after 1950, when the monument had been opened to visitors, and artificial lights had been employed to illuminate the frescoes. The presence, particularly near the light sources, of crusts of phototrophic microorganisms which covered the frescoes became so serious a problem that in 1981 the illumination has been stopped.

After that time, an algal community, that remained on the frescoes and on the walls of the 85th room without any artificial illumination, has been investigated in order to identify and characterize the algal components (ALBERTANO, GRILLI CAIOLA 1985, 1988; GRILLI CAIOLA, ALBERTANO 1986; GRILLI CAIOLA et al. 1987). The algal species found in the association together with moss protonemata indicated the advanced stage of colonization of the environment and represented at the same time the result of the selective conditions.

Considering the peculiarities of the algal composition, the physical characters of the environment with very high humidity and very low light levels, we continued our researches in the 85th room of the Domus aurea, in order to follow the possible changes in the algal composition and to study if, on the basis of the previous results, a further evolution of the association could be expected (DUPUY et al. 1975).

Moreover, since the illumination represents on of the serious problems in the deterioration of hypogean works of art by algae, there is the necessity to find a solution to the contrast arising from the use of illumination for visitors and the control of the algal growth that that is favoured by visible light. For these reasons, the I.C.R. installated new experimental lamps in the Domus aurea in the autumn 1987. The lamps, chosen on the basis of their particular emission spectra (SERRA-LERCHENTAL 1986), were successively switched on for technical works, and the 85th room was illuminated for about three months. The latter circumstance let us to check the effects of a period of illumination on the association, so we have to consider the changes occurred in the algal composition after seven monhs of dark and about three months of lighting. Light intensities were measured inside the 85th room of the Domus aurea, and samples collected in different years were studied by light microscopy, epifluorescence, electron microscopy and pigment analyses.

Material and Methods

Samples were collected on the north-eastern wall of the 85th room of the Domus aurea at the left (sample S) and right (sample D) of the point where the old lamp was installated. After the first sampling in April 1985, controls of the algal flora and light intensities on the frescoes were done in April 1986, April 1987 and January 1988.

The relative humidity (about 95%) and temperature (approximately 18°C) were rather constant during these years. The light conditions in the room varied from natural light coming through holes in the ceiling of the neighbouring rooms until the autumn 1987, to about 6 hours artificial light provided by a Osram Tungsten-Halogenic 70W lamp experimentally installated by the I.C.R.. Light intensities (lux) and photosynthetic active radiation (PAR) were recorded by a Li-Cor Quantum/ Radiometer LI-185 during sunlight mornings.

The samples freshly collected were divided in three aliquots: the first was observed with a Zeiss stereomicroscope and with a Leitz Orthoplan microscope equipped with a mercury lamp (excitation filter 546 nm and barrier filter 580 nm). For light microscopy and epifluorescence, six preparations from the same sample were examinated to approximately evaluate the quantitative presence of each algal species.

Part of the second aliquot was fixed for scanning electron microscopy (SEM) in glutaraldehyde 3% in cacodylate buffer 0.1 M pH 6.9, post-fixed in 1% osmium tetroxide, dehydrated, crytical point dried, gold coated and observed by a Jeol JSM-35CF. The remaining part was fixed for transmission electron microscopy (TEM) in 6% glutaraldehyde in phosphate buffer 0.2 M pH 7.2 with NaEDTA 2.5%, post-fixed in osmium tetroxide 1%, dehydrated and embedded in Epon. Ultrathin sections were double stained with uranyl acetate and lead citrate and observed by a Philips EM 300 at 60 kV.

Pigment content analyses were done using the third aliquot of the sample: chlorophylls were extracted in absolute methanol for 2h in the dark and their concentrations calculated according to MAC KINNEY (1941). Phycobiliproteins (PBP) were extracted in 0.05 M phosphate buffer pH 6.7 after repeated freezing and thawing and sonication; the concentrations of c-phycocyanin (PC), allophycocyanin (APC) and c-phycoerythrin (PE) were determined according to BENNET, BOGORAD (1973).

Tab. 1 - List of the algal species observed in the samples S and D during the last four years

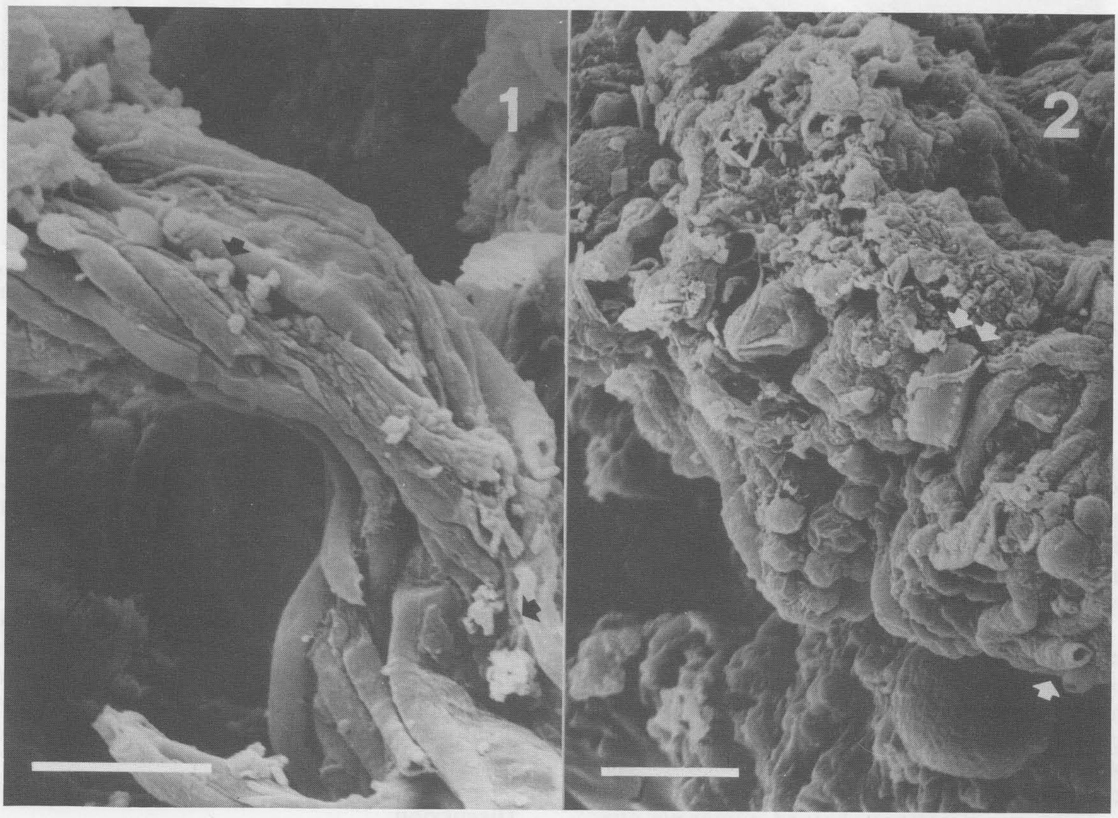
	1985		1986		1987		1988	
	S	D	S	D	S	D	S	D
Chroococcus sp.	–	–	0	–	0	–	0	–
Leptolyngbya hollerbachiana	●	●	●	●	●	●	●	●
Leptolyngbya gracillima	●	●	●	●	●	●	●	●
Leptolyngbya sp.	0	◐	–	–	–	–	–	–
Chlorococcum sp.	–	–	0	0	0	0	◐	◐
Chlorella sp.	–	–	◐	0	0	0	◐	◐
Pseudococcomyxa simplex	0	0	0	0	◐	◐	◐	◐
Stichococcus bacillaris	0	–			–		–	–
Pseudopleurococcus printzii	0	0	0	0	◐	0	◐	◐
Pseudopleurococcus sp.	–	–	–	–	–	0	◐	◐
Fragilaria pinnata	–	–	–	0	0	0	0	0

● more than 200 cells (or filaments) for each field observed.
◐ less than 40 cells " " " " " "
0 less than 5 cells " " " " " "

Results

During the period 1985-1987, the light intensity inside the 85th room of the Domus aurea was less than 10 lux in the center of the room, and approaching 0 lux on the frescoed wall, where samples have been collected. The PAR value at the same level resulted about 0.01 $\mu E \cdot m^{-2} \cdot s^{-1}$. At the beginning of 1988, the values recorded on the frescoes were 35 lux on sample S and 40 lux on sample D, both corresponding to 0.5 $\mu E \cdot m^{-2} \cdot s^{-1}$ PAR.

The stereomicroscopical observations of the samples revealed the presence of various coloured colonies among and on the fragments of the frescoes. In each sample blue-green and olive-green filamentous colonies were clearly distinguishable from the substrata. The epifluorescence allowed the first screening to determine the quantitave presence of cyanophytes in the samples. The light microscopy confirmed the constant presence in the association of abundant filamentous non-heterocystous cyanophytes belonging to *Leptolyngbya gracillima* Komárek et Anagnostidis (= *Lyngbya parva* Hoffmann) and *Leptolyngbya hollerbachiana* Komárek et Anagnostidis (= *Lyngbya pseudoramosa* Hoffman). The chlorophytes *Pseudococcomyxa simplex* (Mainx) Fott, and *Pseudopleurococcus printzii* Vischer were also present. The other taxa identified in samples of different years are reported in table 1. *Leptolyngbya* sp. characterized by a red pigmentation (ALBERTANO, GRILLI CAIOLA 1985, 1988) was not observed in samples from 1986, as well as *Stichococcus bacillaris* Nägeli. The cyanophyte *Chroococcus* sp., the chlorophytes *Chlorococcum* sp., *Chlorella* sp. and *Pseudopleurococcus* sp., and the diatome *Fragilaria pinnata* var. *robusta*



Figs. 1, 2 - SEM micrographs of samples.

Fig. 1 - Sample collected in 1987. Bundle of cyanophytes and actinomycetes with other bacteria (arrows) attached to the filaments.

Fig. 2 - Sample collected in 1988. Various vegetative cells and sporangia of coccal chlorophytes are visible over the filaments and the empty cyanophyte sheaths (arrows). One diatom is also present among the mineral fragments of the frescoes.

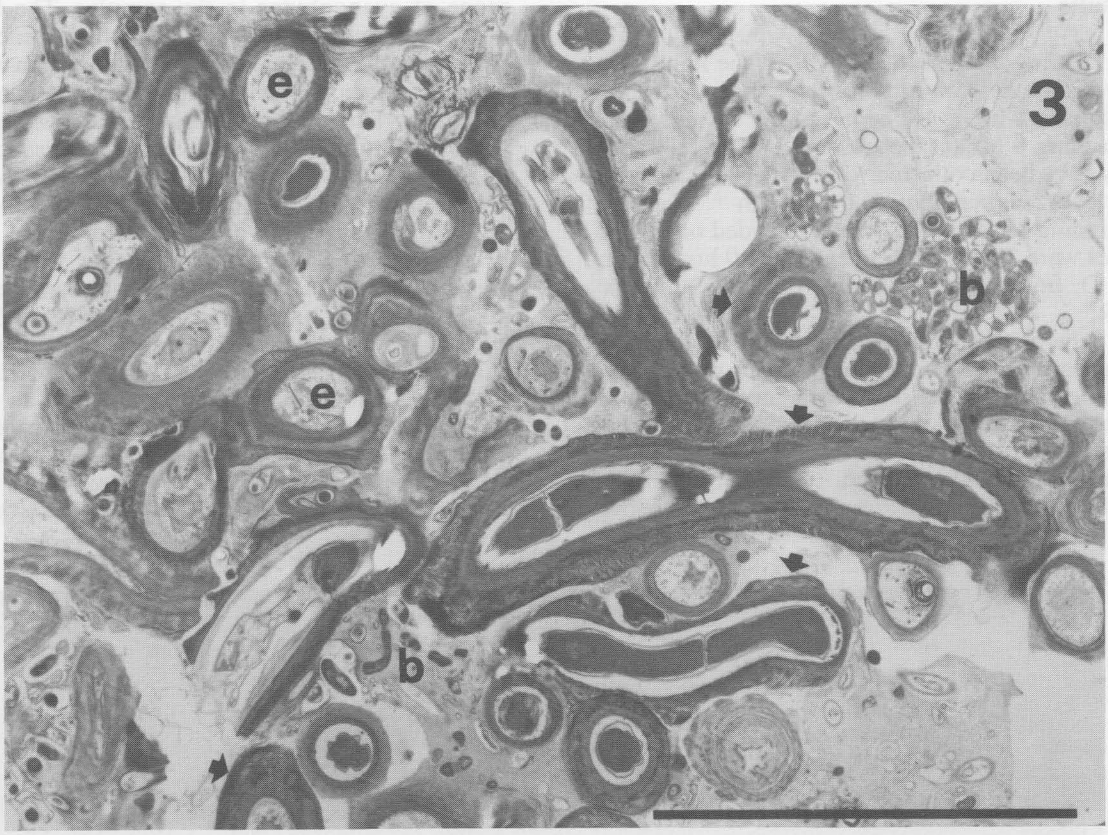


Fig. 3 - TEM micrograph of the sample collected on the left side (S) of the frescoes in 1986. Longitudinal and transverse section of filaments of *Leptolyngbya*. The trichomes appear surrounded by thick sheaths (arrows). Several empty cyanophyte filaments (e) and many bacteria (b) are present.

All scale bars = 10 μm.

(Manguin) Pèrou appeared in the association after 1986. The presence of chlorophytes became more conspicuous in 1988. Furthermore, moss spores and protonemata, rare in the samples up to 1987, increased their presence in 1988, when also some moss plantlets were observed.

SEM observations evidenced the presence of bundles of filamentous cyanophytes frequently twisted with filamentous bacteria, probably actynomicetes, and different types of bacteria (Fig. 1). Vegetative cells and sporangia of the various chlorophytes were mixed with the mineral fragments of the substrata (Fig. 2).

TEM investigations showed numerous cyanophyte filaments pressed each others (Fig. 3). Actinomycetes and coccoid bacteria were abundant among the cyanophytes. The trichomes of the two *Leptolyngbya* species were surrounded by very thick and structured fibrillar sheaths, that often appeared empty of trichomes. The *Leptolyngbya* showed the gram-negative cell wall, the thylakoids arranged parallel; to the cell wall at the cell periphery and a central nucleoplasm.

The pigment contents determined in the samples S and D in different years are reported in table 2. The results indicate a decrease in chlorophyll *a* and *b* in all samples since 1985, whereas the amounts of phycobiliprotein varied from higher values in 1986 to lesser ones in 1987, but greatly increased in the samples of 1988.

Discussion

Without any artificial illumination, the algal composition of the association present on the frescoes of the 85th room of the Domus aurea showed to be relatively constant. The dominance

Tab. 2 - Pigment content of the samples colleted on the left (S) and on the right (D) of the north-eastern wall of the 85th room of the Domus aurea. Chlorophylls (Chl a, Chl b) and phycobiliproteins (PC phycocyanin, APC allophycocyanin, PE phycoerythrin) have been determined in different years and expressed as µm/g of sample

Sample	year	Chl a	Chl b	PC	APC	PE
S	1985	158.59	37.31	10.70*	12.18*	4.48*
	1986	37.62	14.14	59.80	76.50	47.97
	1987	37.29	15.49	20.32	21.78	11.69
	1988	10.41	11.12	108·30	135·74	85·62
D	1985	81.92	10.27	9.20*	12.51*	6.57*
	1986	51.20	ND	35.87	129.98	49.50
	1987	27.35	13.95	15.22	18.34	11.11
	1988	5.73	7.16	208·98	249·30	85·80

* extracted without sonication
ND not determined

of *Leptolyngbya grocillina* and L. *hollerbachiana* over the other algae of the community was confirmed. Two chlorophytes were also continuously present in the samples, in spite of their limited number. Five new species appeared in the years 1986-1987, and two were not more observed.

After the short period of illumination in 1988, the filamentous cyanophytes were still dominant, but the five species of chlorophytes markedly increased the total presence of green algae in the association.

The changes observed between 1985 and 1988 in the chlorophyll contents of samples, only partially agree with the microscopical observations. The small amounts of Chl *a* found in samples of 1988 appear of difficult explanation. Analogously, no increase was detected in the amounts of Chl *b,* possibly due to the more abundant presence of chlorophytes in 1988. However, similar results were obtained from cultures of the samples collected in 1987, after three months of illumination provided by the same lamp installed in the Domus aurea (ALBERTANO et al. 1990). It is conceivable that the extremely low light in the environment greatly reduced the photosynthetic activity of the cyanophytes in the samples collected before 1988. Thus, the two *Leptolyngbya* species dominant in the association could change from phototrophic to heterotrophic metabolism (SMITH 1982), with a possible decrease in chlorophylls and phycobiliproteins contents. On the other hand, the increase of phycobiliproteins, due to the artificial illumination in 1988, can be caused by the emission spectrum of the lamp employed (ALBERTANO, GRILLI CAIOLA 1988; BENNETT, BOGORAD 1973). Nevertheless, further investigations on the pigment composition on the algae present on the frescoes would be necessary to confirm the data obtained.

The changes occurred in the algal composition, in the period between the first and last sampling, are probably due to the out-door coming of algal spores, that is favoured by the absence of doors in the room 85th, and to the competition among the organisms present on the frescoes (WRIGHT et al. 1985). Therefore, the changes observed must be considered as not occasional because of the peculiarity of the environment which probably acts as a strong selective factor.

In conclusions, the dominant *Leptolyngbya* species are characterized by the presence of very thick sheath, that can facilitate the growth of the organism in the environment (i.e. adherence to the substrata, uptake of water, etc.), but in the same time increase the deterioration of the frescoes. In fact, the presence of the sheaths can favourish the sticking of other microorganisms, and a greater development of heterotrophic bacterial populations on organic substrata (CANEVA, SALVADORI 1988), as well as the establishment of bacteria/cyanophyte mutualistic associations (PAERL 1982).

Thus, the advanced stage of colonization due to the presence of the algal association is confirmed (GRILLI CAIOLA et al. 1987), and becomes more evident because of the high number of the taxa interested and of their structural characters. Moreover, the presence of chlorophytes and mosses that considerably increase when more light is available, indicated the need of a constant control of the changes caused by light in this hypogean association.

Summary

L'associazione algale presente su alcuni affreschi della Domus aurea a Roma, è stata studiata nel corso di quattro anni col proposito di controllarne lo sviluppo e le eventuali variazioni della composizione algale. I risultati ottenuti hanno evidenziato la presenza dominante di due specie di cianofita appartenenti al genere *Leptolyngbya*, mentre sono state osservate variazioni nella presenza delle altre specie componenti l'associazione e nelle quantità di pigmenti fotosintetici dei vari campioni.

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Geobotany applied to the analysis and management of archaeological sites

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Keywords: Applied geobotany; archaeological parks; vegetation management; bioindicators archaeological prospections, monument conservation.

Abstract

Geobotanical studies related to knowledge and conservation of archaeological sites are described, both from the literature and original work.

From the ecological analysis of the present vegetation it is possible to establish correlations with environmental factors and determine the dynamic series both in the past and for the future. Single species and phytocoenosis can be used as bioindicators of the more important environmental factors in the site (e.g. soil humidity, salinity, presence of undergound walls, amounts of organic material). By reconstructing past dynamic series it is possible to determine past habitats. This contributes to paleobotanical studies through e.g. a division of botanical finds into autochthonous and allochthonous groups, on the basis of their compatibility with the dynamic series. It is also possible to use the dynamic series for predicting natural changes as well as the results of human intervention.

The negative (e.g. the problem of root growth) or positive (e.g. influence on the microclimate or on the water table) influences of vegetation on the conservation of archaeological sites are then described.

Some examples of applications to archaeological areas in Italy and the Middle East are given.

Introduction

The potential contributions of geobotanical investigations to archaeological problems are both numerous and diverse.

Such studies can in fact provide extremely important information both in the analysis stage of the biotic community that characterizes the site, and in the application stage entailed in managing the area.

Useful information concerning the past situation of archaeological sites, and that predictive of future trends, is yielded by suitably designed geobotanical studies based on correlations between vegetation and abiotic environment, which reconstruct the evolutionary dynamics in regressive and progressive senses.

We thus analyze the contributions of geobotany as applied to archaeology in terms of information, of application contributing to the conservation of these areas, and finally in terms of the planning phase for establishing an archaeological park.

The possible relations between the phases of the information level and the applied level are summarized in Fig. 1.

1. Contributions for the characterization of the site

We hold the interpretation of synecology of the plant community to be essential to the correct intervention in archaeological areas, in addition to the identification of the dynamic series in terms of the variation of certain both natural and induced environmental parameters.

As concerns the aims of the interpretation of an archaeological site, geobotanical investigations contribute both to the interpretations of the species or the plant associations as bioindicators, and to the possible reconstruction of the paleoenvironmental context of the site, by analyzing backwards the dynamic series of the vegetation.

1.1 *The use of bioindicators for superficial archaeological exploration*

The potential utility of vegetation as an indicator of buried archaeological remains has been known for a long time, the first observations dating to the sixteenth century.

They started from the observation of anomalies in the growth of herbaceous cultivated plants (e.g. wheat). Indeed, these plants, when in proximity to very superficial stoneworks, generally

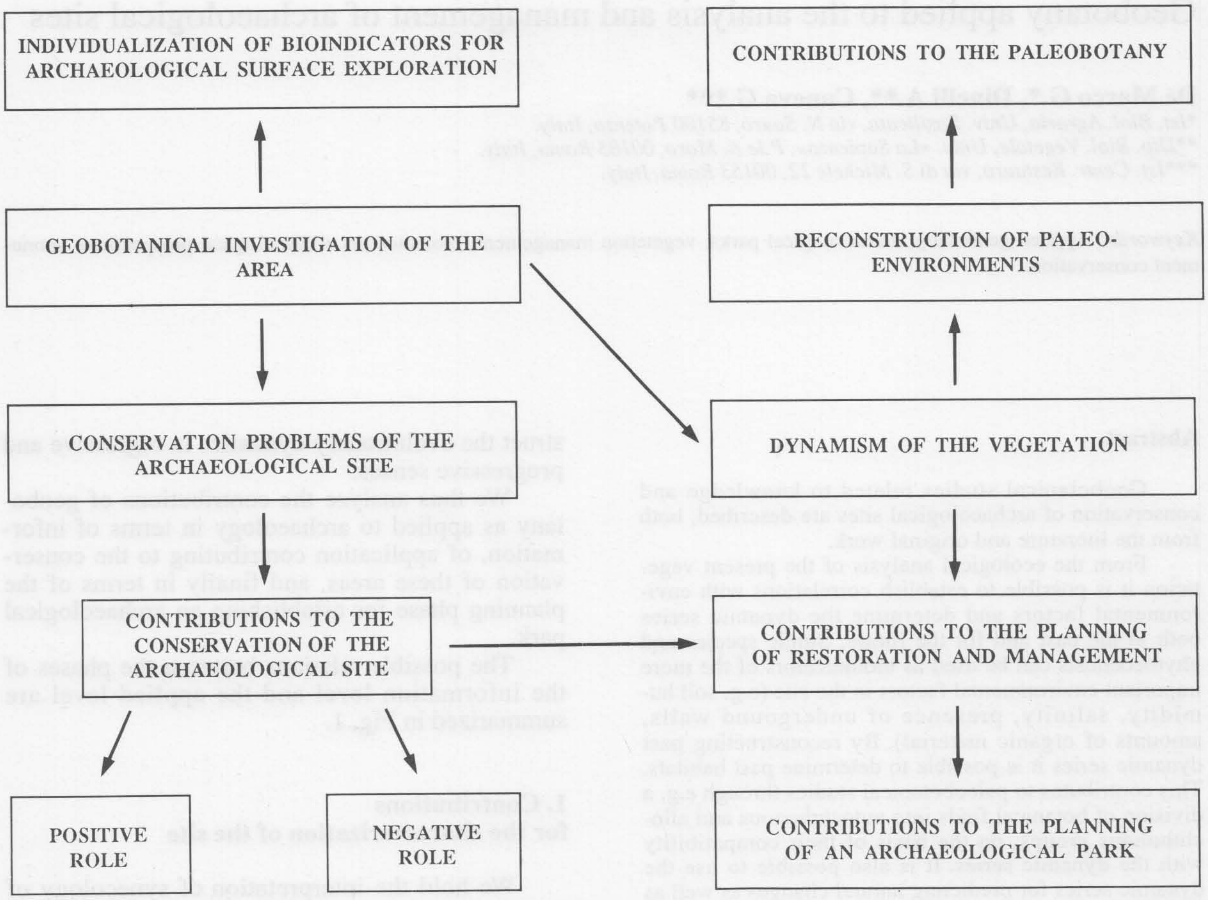

Fig. 1

grow fast at first, but then tend later to yellow and wither, or in any case show greater difficulty in growth. The explanation lies in the different hydric capacity of these soils with shallow underlying stoneworks and floors.

In effect, this phenomenon, which can be clearly interpreted scientifically, is particularly evident in more humid climatic conditions and has several times been confirmed by excavation.

In later observations it was found that, in the case of an area occupied by pasture, the vegetation develops more rapidly near the ancient ditches, and with greater difficulty above stoneworks.

This is shown in aerial photographs by the darker colour in the first case and lighter one in the second (cropmarks), varying in relation to the hydric capacity of the subsoil, the depth of the archaeological remains, the season and the type of plants.

It was found that, even in the case of pastureland, these traces can also be documented in aerial photographs (grass-weed mark), although generally with less clarity.

The effect is in any case clearer in situation of homogeneity of vegetation, and so clearest in agricultural settings.

However, it must be stressed that the information derived from the analysis of agricultural settings, in which the vegetation is artificial, can indicate discontinuities in the subsoil only in terms of colour changes, or variations in biomass.

In natural situations, or semi-natural ones, the indications provided by vegetation do not only relate to possible conditions of physiological stress (indeed, unsuited plants would simply disappear), or to greater or lesser abundance. Instead, indications are provided above all by qualitative and quantitative changes in the vegetation.

As suggested above, the reason for such changes must be relate to the presence of underground stoneworks, of foundations or floors, which causes situations of local discontinuity.

Indeed, one can find increases in the saline concentration in proximity of stoneworks, owing to the greater rise of mineral salts through capillary action along the construction.

In other cases one can, for example, find situations of asphyxia, owing to excessive water retention caused by the presence of impermeable structures such as a floor or a layer of clay. Therefore a plant distribution is observed which cannot be explained in terms of natural paramaters alone. Indeed, apparently non-natural line of halophyte or hydrophyte species can often be observed.

Sometimes it is the absence of certain types of vegetation which must be explained.

Thus changes in floristic and vegetational composition can, in expert hands, be used as a way of «reading» the subsoil.

As an example of plant species used as bioindicators, we consider the case of the archaeological site of Moen Jo Daro (Pakistan), in which a link was observed between *Capparis decidua* and the presence of superficial stoneworks. This correlation later made it possible to discover the alignment of hidden constructions by examining the distribution of this plant.

Another example is the case of many archaeological sites in the Iranian Sistan, where owing to soil profile, brought about by climatic and geological factors, there was an accumulation of salt in the superficial stoneworks.

These salt efflorescences became all the more considerable with the greater occurrence of stoneworks in the subsoil which facilitated the rise of the salts and their crystallization at the surface.

A different saline outcropping in this case therefore constitutes a physical indicator of these constructions in the subsoil, and it is quite easy to achieve a «reading» of their alignements using aerial photographs.

It is, however, equally easy to achieve this «reading» at the ground level by observing the specific distribution of relatively more halophilous plants.

Based on the hypothesis of the utility of bioindicators in this sector, the possibility is being examined of using them to identify the presence of underground floors in certain areas of the *Domus Aurea* (Rome). In these contexts one can observe a non-homogeneous distribution of hydrophyte plants and not as a function of shade gradients, such as to render plausible the hypothese of deductively identifying the occurrence or the greater outcropping of underground floors.

This fact is of clear archaeological interest since it can guide the choice of where to excavate.

Finally, in some cases even the absence of vegetation can be used as a bioindicator of specific characteristics of the subsoil. Even this has been verified in the archaeological site of Moen Jo Daro, where the occurrence in a zone without vegetation was such that it could be related to the greater outcropping of clay platforms placed at the foundation of the riverside town, which assured a degree of impermeability.

The superficiality of these clay platforms in fact created conditions of asphyxia in the rainy period, and of extreme aridity in the dry period, thus blocking the presence of hydrophyte and xerophyte species.

1.2 *Use of dynamic lines for the reconstruction of paleoenvironments*

The study of paleoenvironments is normally achieved through the identification of the micro- and macro-remains collected in the site and then interpreting its significance.

Geobotany can make a significant contribution to paleobotanical studies. It starts from an understanding of the autoecology and synecology of the species, in correlation with geomorphological and hydrological factors, and leads to a reconstruction of past vegetational situations by using the dynamic series.

This approach can be used in order to provide indication of the autochthony or allochthony of the archaeological findings, based on the compatibility of information derived from paleobotanical and geobotanical analyses.

It is thus possible to establish the significance and importance of findings, and so provide archaeologists and anthropologists who analyze socio-economic and cultural dimensions with a solid scientific foundation.

For example, in the protohistoric city of Shahr-i-Soktha, in the Iranian Sistan, evidence was collected of *Dalbergia sissoo* (whose present N limit does not exceed the 30th S parallel), a species incompatible in terms of autoecology with the reconstructed characteristics of the habitat. These specimens were thus surely imported.

This interpretation was confirmed by the presence of *Xancus pyrum* (L.), a species which is strictly limited to the coastes of peninsular India. This information, along with that concerning the ceramic industry, thus made it possible for the archaeologists to reconstruct the cultural and commercial ties with other peoples.

Geobotanical information is particularly important in those cases in which the site is presently contained in the distribution area of the species considered, but in which a habitat is not found, based on the reconstruction of the dynamic series, which is compatible with its autoecology.

2. Contributions to the conservation of archaeological sites

From the standpoint of the conservation of archaeological sites, the vegetation can have a positive role, in that it can be used as a protective element, or it can have a negative one, particularly owing to damage from roots.

It is especially this last consideration which is best known to conservationists who often must deal with the problem of weeding, in order to preserve the monuments and enhance their visibility.

The damage which ruderal vegetation can cause to monuments has long been known, even though often only at a qualitative level, and has been the topic of previous publications.

It is enough to remember that the alterations caused in the subsoil are essentially mechanical and chemical.

Owing to this type of problem, the contribution of geobotany is that of knowing the vegetation and its significance, and of predicting the dynamic evolution in such a way as to be able to intervene in a more opportune way in the planning of necessary works.

Instead in the case of vegetation introduced by man with the intention of creating an aesthetically appealing environment, it must be borne in mind that often a lack of understanding of autoecology, of environmental balances and of the growth potential of both hypogean and epigean biomass can lead to serious errors. This is not only in the choice of the species to be introduced, but especially in terms of not having considered the possible damage entailed by the expansion of the root biomass, both laterally and in depth.

Damage to stonework or stuccos is in fact not uncommon, owing to the thrust of tree roots planted either too near, or in soil which was too shallow.

Less known is instead the possibility of using vegetation safeguarding efforts, using the effects which cause on microclimatic and pedological parameters, especially concerning phenomena of wind erosion or accumulation, or the aggressive action of salts or pollutants.

As concerns the first example, the aim was to avoid the burial of some monuments in the depression of Dahane-Golaman by sand through the action of the wind. This required the use of plants which could deviate the movement of the dunes. The geobotanical investigation made it possible to establish the greater suitability of *Desmostachya bipinnata,* for the first the passive transplanting in the dune formation, considering its mechanical characteristis and its being easily found in the territory. Later the study suggested the choice of *Haloxylon persicum* and of *Tamarix passerinoides* active transplants, respectively in the dune complexes and the weak covering sands on clayey soils.

As concerns the experiences under way in Moen Jo Daro, the final goal is that of identifying plants that act chiefly as «biological pumps» and assist the mechanical pumping of wells, in order to lower the water table. They also lead to the creation of a suitable microenvironment in order to reduce the effect of the rising of water table along the stoneworks and the relative destructive crystalization of salt due to evaporation.

The geobotanical study also made it possible to identify of the plant comunities and their spatial distribution and thus also of the autoecological characteristics of the species to be transplanted, as a function of environmental paramenter identified through synecology.

3. Contributions to the planning of an archaeological park

In relation to the situation and the extension of the territory of the archaeological areas, a comparative analysis often acquires great importances as well as an interdisciplinary approach to the planning in the environmental setting, which cannot do without a geobotanical contribution.

In reality the problem of the botanical structure of archaeological areas has not been dealt with in great detail in the past, since intervention on the vegetation have often been conditioned by the cultural inclinations of certains historical periods and in any case only took into account aesthetic considerations.

We hold it to be of fundamental importance know the autoecological and synecological requirements of the species used in the territorial planning of archaeological areas.

In particular in these territories, which are replete with history, it is important to respect the original botanical landscape. With the same logic which guides restoration intervention, one must not introduce new elements which are alien to the environmental context.

Furthermore, as stated before, careful evaluation must be made of both damage potential and useful employment of vegetation, overcoming the embellishing logic idea and the purely visual effects.

The knowledge of growth potential and the ecology of the species must indicate the situations of compatibility and incompatibility between plants and archaeological remains.

Naturally requirements of a strictly landscape type, or «plastic» ones, which are important in these contexts, can be evidence in an interdisciplinary perspective.

Even in cases in which is held necessary to contribute with plants to the «rereading» of stonework patterns, both underground ones and as the completion of interrupted walls, the correct use of the vegetation must be carefully evaluated.

In conclusion, in a new and modern perspective of management of archaeological areas, it is important that geobotany contributes both in the phase of acquiring information on the site, and in the planning of the maintenance interventions, and in the evaluation of the botanical structure. This aspect along with those linked to educational aims and to a more complete use of the complex, must be seen not only in an exclusively architect-archaeological perspective, but in a perspective necessarily broadened to include naturalist components.

Riassunto

Partendo dalla'analisi della letteratura e sulla base di lavori originali, vengono descritti i contributi degli studi geobotanici rivolti alla conoscenza e alla conservazione di aree archeologiche.

Dall'analisi ecologica della vegetazione attuale è infatti possibile stabilire correlazioni con i fattori ambientali, ricostruire le serie dinamiche nel passato e prevedere l'evoluzione futura. Singole specie e associazioni vegetali possono essere utilizzate come bioindicatori dei più importanti parametri ambientali presenti nel sito (es. umidità del suolo, salinità, presenza di muri nel sottosuolo, accumuli di materiale organico). Ricostruendo le serie dinamiche verso il passato è possibile determinare quali fossero gli habitat corrispondenti.

Ciò dà un contributo agli studi paleobotanici, ad esempio permettendo di stabilire l'autoctonia o alloctonia dei reperti botanici, sulla base della loro compatibilità con le serie dinamiche. È anche possibile utilizzare le serie dinamiche per prevedere sia la dinamica naturale che quella indotta dall'intervento dell'uomo.

Vengono inoltre descritte le influenze negative (es. il problema dello sviluppo delle radici), o positive (es. l'influenza sui parametri microclimatici), della vegetazione nella conservazione delle aree archeologiche.

Vengono infine forniti alcuni esempi applicati ad aree archeologiche italiane e del Medio Oriente.

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Vegetation of the upper parts of some archaeological structures in Rome and related monument conservation problems

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Abstract

The upper parts of monuments, for the topographic characteristics and as they are often inaccessible for periodic treatments of maintenance, are characterized by a more developed and xeric vegetation.

In the following cases of Roman monuments that have been analysed, a very high frequency of species of the phytosociological class *Quercetea ilicis* are present, besides those of *Asplenietea rupestris* and *Parietarietea judaicae*. Ubiquitous or nitrophylous species of *Chenopodietea* and *Stellarietea mediae* are usually rare. This situation represents an evolutive stage of stone material colonization by plant growth in xeric and heliophic conditions in Mediterranean climate.

It is obvious that for monument conservation this kind of vegetation is detrimental. Before consolidating these structures, chemical treatment was carried out. Different herbicide compounds were tested on various phytocoenoses in order to compare the results.

Introduction

For a good conservation of monuments it is necessary to provide periodical treatments of cleaning, protection, consolidation and also control of biological growths. In fact the vegetation growing on monuments is more or less detrimental to the conservation of the building structures, due to the growths of the root system. For this reason it is necessary, at least in archaeological areas, where the priority is the conservation of monuments, opposed to the natural heritage, to plan treatments against this vegetation. The cycles of intervention are dependent on different factors conditioning the biological growths, such as petrographic characteristics and particularly the porosity of stone, climatic factors and also accessibility and economic problems. In fact due to the difficult accessibility of the upper part of monuments, in absence of scaffolding or other system of ascent, treatments of control are less frequent and the vegetation is more developed, also because it is less disturbed.

So it was that, during the conservation treatments arranged by the Archaeological Superintendence of Rome in some tracts of Aqueducts and Thermae, we had the opportunity to analyse this peculiar situation.

The research was carried out at first to analyse these vegetation aspects and to give indication of correct methodology of plant growth control.

Analysis of vegetation

The vegetation present on monuments, especially in those parts that are less accessible, is interesting from an ecological point of view, because monuments can be sites of refuge for plants in very anthropized contexts, like urban environments.

In the upper part of monuments the vegetation reaches more developed stages, besides the already cited factors of human disturbance, also due to the flattish morphology. That permits an easier deposition and germination of seeds and a greater water storage of the substrate with respect to vertical walls.

The height from the soil (between 18-20 m to 30 m in the analysed monuments), the lighting conditions and the lower content of nitrogen sources do not generally permit a great development of the more hygrophylous and sciaphylous associations of the *Parietarietea judaicae*.

Parietarietum judaicae (Arenes 1928) Oberd. 1977, *Parietario-Cymbalarietum muralis* Pignatti 1953 and *Cymbalario-Trachelietum coerulei* Rivas Martinez 1969, are instead frequent in the Roman monuments in the lowest parts and in septentrional expositions.

It is possible to observe in relation to the time of plant colonization, the development in the first stages of aspects with *Antirrhinum majus, A. tortuosum* and *Sonchus tenerrimus*, as dominant species, and of *Capparidetum rupestris* O. Bolòs e Molinier 1958, very common on walls with warm exposition.

It is interesting the presence of *Ruta chalepensis*, a thermophylous species of the *Oleo-Ceratonion*, in these pioneer stages and its disappearance when the vegetation reaches a close structure.

When the time of stone material colonization by plant growth becomes greater, with a consequent amount of porosity of the substrate, with a decay of the mortars covering the cacuminal parts, and with depositions of particles of soils or organic residuals of other pioneer populations, we can observe a decrease of the floristic component of the *Parietarietea judaicae* class.

At the same time the conditions become more favourable for the growth of Mediterranean thermophylous species of the *Quercetea ilicis* class and especially of the *Oleo-Ceratonion*. In fact, when the time after restoration or conservative treatment is more than 20-30 years, it is possible to observe a tendency towards more mature wooden thermophylous plant communities.

In the more developed stages there is a constant presence of *Teucrium flavum*, that can be considered a guide species, disappearing only when there is a total closing of the vegetation.

There is also frequent the presence of *Rhamnus alaternus* and *Asparagus acutifolius*.

In Tab. I, two groups of releves of vegetation are shown as a function of a gradient of maturity.

In this gradient *Ficus carica* holds an intermediate position showing a tendency to remain also a more mature situation.

The substrate composition of the analysed monuments, was generally of carbonatic nature, due to the layer of mortar over laid as a cover and cementing bricks. In the case of the Claudius Nero Aqueduct in Mandrione Street, under the mortar layer there were blocks of vulcanic rocks such as peperino and tufa, with higher porosity with regard to other monuments, thus favouring the plant colonization and their dynamism. Moreover some species, such as *Artemisia arborescens*, were exclusively found on this kind of pedogenetic substrate. Thus the more developed stages reached here by the vegetation seem to be conditioned by internal and external factors such as lower maintenance interventions.

Monument conservative treatments

After the analysis of the vegetation it was possible to decide the methods and the modality of treatment.

It was preferred to use chemical methods, eventually combined with mechanical ones in relation to the problems of accessibility, longer duration in time, economic parameters and to avoid mechanical damages due to the peeling off the plants.

Various products diluted in water, were tested by spraying them on different plant communities. In the case of ligneous plants it was preferred, whenever possible, to cut the plant at the base and inject directly the herbicibe compound into the roots, in order to minimize the quantity of product dispersed in the environment.

Various herbicides (gliphosate, tertbutylazine, secbumeton, picloram, hexazinone, imazapyr) were selected on the basis of specific technical, sanitary parameters, important for this kind of application.

This is principally the usefulness in relation to a possible negative interaction with the stone (problems of corrosivity or staining) and the activity at low doses for a long time. It was also considered a low level of toxicity and low values of translocability in relation to environmental hygienic aspects.

The research allowed evaluation of the usefullness of those products and the activity on some plant communities or on some specific species, also in relation to the modality of treatment. Detailed results of this specific aspect will be discussed elsewere.

As a preventive measure for a good conservation of monuments it would be better to repair periodically the layers of mortar and clean the surfaces from the earth and dust which deposits itself on the walls, thus disfavouring the dynamic evolution of the plant communities. The degree of stone weathering comes in fact together with the degree of maturity of plant communities.

The presence of plants on this substrate can be also acceptable for a certain time, because the first population are not too disruptive, but they prepare the substrate for more aggresive associations, if their dynamic tendency is not disturbed. It is possible to calculate that 20-30 years is sufficient for the development of evoluted stages in absence of disturbance of their growth.

Tab. 1 - Vegetation of the upper parts of some Roman monuments

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
N° rel.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Exposition			-	-	SE	SE	-	-	-	-	NNE	-	NNE	-	-	-	-	-	-
Inclination (%)			-	-	40	40	-	-	-	-	90	-	70	-	-	-	-	-	-
Cover (%)		50	40	100	40	40	40	40	95	95	70	80	80	95	80	95	90	80	100
H veg. (cm)		40	30	40	50	40	40	30	50	60	60	60	50	60	60	60	60	50	60
Surface rel. (m^2)		8	8	8	10	10	20	12	15	20	10	10	15	16	10	12	6	15	8
N° species		6	6	11	15	12	14	8	11	15	11	11	11	14	7	13	8	9	8
Locality		Cel	Cel	Car	Mas	Mas	ASS	ASS	Car	Car	Car	Car	Car	Car	Man	Man	Man	Car	Man
Car. PARIETARIETEA JUDAICAE (Rivas Martinez 1964) Oberd. 1977																			
Ch	Antirrhinum majus L.	.	.	+.2	.	.	.	1.2	.	2.2	.	.	.	.	.	.	.	.	.
Ch	Antirrhinum tortuosum Bosc	.	2.3	1.2	3.4	2.3	+.2	2.3	3.3	1.2	.	.	.	+	+	.	.	.	.
Pcaesp	Capparis spinosa L. v. inermis Turra	+	.	1.2	2.3	1.2	+.2	1.2	1.2	1.2	.	.	+.2	+.2	.	.	.	.	.
Pcaesp	Ficus carica L.	.	.	.	.	.	.	.	.	1.2	1.2	1.2	.	.	.	.	.	.	.
H	Sonchus tenerrimus L.	+.2	2.2	.	+	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.
H	Parietaria judaica L.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
H	Foeniculum vulgare Miller	+	.	.	.	.	.	.	.	.	.	.	+	.	.	1.3	.	.	.
Ch	Cheiranthus cheiri (L.) Crantz	.	.	.	.	.	.	.	+.2	+	.	.	.	.	.	.	.	.	.
Ch	Trachelium coeruleum L.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Car. BROMO-ORYZOPSION MILIACEAE O. Bolòs 1970 AND HYPARRHENIENALIA (Rivas Martinez 1978) Brullo stat. nov. 1984																			
Ch	Micromeria graeca (L.) Bentham	.	2.2	1.2	1.1	1.1	2.3	1.2	+	2.3	2.3	+	.	1.3	2.2	2.2	2.2	1.2	.
H	Oryzopsis miliacea (L.) Asch et Schweinf	.	.	2.4	+	2.2	1.2	3.3	+	1.2	+	+	1.2	2.3	.	+	.	.	.
H	Dittrichia viscosa (L.) Greuter	.	.	+	.	.	.	.	.	+.2	.	.	+	.	.	.	.	.	.
H	Diplotaxis tenuifolia (L.) DC	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	.
H	Ferula communis L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Car. OLEO-CERATONION sensu Br.-Bl. 1936, PISTACIO-RHAMNETALIA ALATERNI Rivas Martinez 1974 AND QUERCETEA ILICIS Br. Bl. 1947																			
Ch	Teucrium flavum L.	.	.	.	.	.	3.4	1.2	2.2	5.5	2.3	1.2	+.2	+	2.2	2.2	2.2	3.4	.
Pcaesp	Rhamnus alaternus L.	.	.	.	+.2	+	.	.	.	.	2.3	2.3	.	.	.	+.2	.	1.2	1.2
G	Asparagus acutifolius L.	.	.	1.2	.	.	+.2	.	.	.	.	.	1.2	2.3	+.2	1.2	.	+	1.2
Pcaesp	Lonicera implexa Ait.	.	.	+	.	+.2	.	.	.	1.2	.	2.4	.	+.2	.	.	.	.	1.1
NP	Coronilla emerus L. ssp. emeroides (Boiss and Spruner) Hayek	.	+.2	.	.	.	.	.	.	.	+	.	.	.	.	1.2	1.2	4.4	3.4
Ch	Ruta chalepensis L.	.	.	.	1.1	2.4	1.1	+	.	.	.	.	.	.	.	.	.	.	.
Pcaesp	Spartium junceum	.	.	.	.	.	.	.	.	.	.	.	2.3	3.4	.	+.2	3.4	.	4.4
Pcaesp	Artemisia arborescens L.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	2.2	1.2	.	.
NP	Olea europaea L.	.	.	.	.	.	.	.	.	.	.	.	.	+.2	.	.	.	1.2	.
Pcaesp	Pistacia terebinthus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4.4
NP	Laurus nobilis L.	.	.	.	.	.	.	.	.	.	.	+	1.2	.	.	.	.	.	.
Pcaesp	Phillyrea angustifolia L.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.3	1.3	.	.	.
Pcaesp	Pistacia lentiscus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	.	.
Pcaesp	Colutea arborescens L.	.	.	.	.	.	.	.	3.3	.	.	.	.	.	.	.	.	.	.
Ch	Prasium majus L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Pl	Smilax aspera L.	.	.	.	.	.	.	.	.	.	.	.	.	+.2	.	.	.	.	.
Pcaesp	Euonymus europaeus L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.12	.	.
Pcaesp	Crataegus oxyacantha L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.
OTHERS																			
Ch	Sedum sediforme (Jacq.) Pau.	+	+	+.2	.	.	+	.4.5		2.3	+	+	.	.	1.3	2.3	.	1.2	.
H	Scabiosa maritima L.	+	+.2	1.2	.	.	1.1	.	+	3.4	1.2	+	+	2.3	.	.	.	2.2	.
Ch	Reseda alba L.	.	.	.	.	.	+.2	.	+.2	1.2	.	.	.	+	.	.	.	.	.
Pl	Hedera helix L.	.	.	.	2.3	.	.	.	+	.	+	.	3.4	.	.	.	.	.	2.2
H	Melica arrecta O. Kuntze	.	.	.	+.2	.	1.2	1.2	.	.	3.3	+.2	.	.	.	.	.	.	.
G	Allium cfr. roseum L.	.	.	.	.	.	+.2	.	.	.	.	.	.	1.2	2.2	2.3	2.2	.	+.2
T	Bromus madritensis L.	.	.	2.4	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
H	Daucus carota L.	.	.	.	+	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.
H	Hypericum perforatum L.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
H	Picris hieracioides L.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pcaesp	Rubus fruticosus L.	.	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
T	Conyza canadensis (L.) Cronq.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch	Pinus pinea L. (Pl)	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
T	Catapodium rigidum (L.) Hubbard	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
H	Acanthus mollis L.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
H	Dactylis hispanica Roth.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
H	Silene angustifolia (Miller) Hayek	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	.	.	.	.

Cel = Claudius-Nero Aqueduct (at Celius hill); Mas = Basilica of Massentium; ASS = Arcades of Septimium Severus (at Palatinus hill); Car = Thermae of Caracalla; Man = Claudius-Nero Aqueduct (at Mandrione street).

Riassunto

Le parti alte dei monumenti, essendo spesso inaccessibili per i trattamenti periodici di manutenzione, presentano una vegetazione più sviluppata e per le loro caratteristiche topografiche hanno caratteristiche di maggiore xericità.

Nei casi relativi ai monumenti romani, che vengono qui analizzati, è stata riscontrata una frequenza molto elevata di specie appartenenti alla classe fitosociologica della *Quercetea ilicis,* oltre a quelle delle classi *Asplenietea rupestris* e *Parietarieta judaicae*. Specie infestanti e nitrofile delle classi *Chenopodietea* e *Stellarietea mediae* sono generalmente rare. Questa situazione rappresenta uno stadio evolutivo finale della colonizzazione vegetale in condizione di xericità e di eliofilia nel clima mediterraneo.

È inoltre evidente che questo tipo di vegetazione è dannoso per la conservazione dei monumenti. Pertanto, prima di effettuare interventi di consolidamento delle strutture murarie sono stati eseguiti interventi di diserbo chimico. Sono stati saggiati diversi erbicidi sulle varie fitocenosi presenti al fine di compararne i risultati.

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Wall vegetation of some fortresses in the south-eastern Po plain (Italy)

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Keywords: Wall vegetation, Numerical analysis, Phytosociology, *Parietarietea judaicae*, Po plain.

Abstract

The vegetation occurring on the external brick walls of 5 fortresses (localy named «rocche») located in the southeastern Po plain (Northern Italy) was sampled by the Braun-Blanquet method. Vegetation types were defined by a numerical classification of relevés (average linkage clustering based on the similarity ratio). Two relevés groups were identified. From the syntaxonomical viewpoint they can be ascribed to the *Cappari-detum rupestris* O. Bolòs et Molinier 1958 and to the *Parietarietum judaicae* (Arénes 1928) Oberd. 1977, respectively. The former vegetation type occurs on S-exposed walls; the latter has a wider aspect range. The ecological and chorological features of both vegetation types were shortly discussed in comparison with the neighbouring Italian areas.

Introduction

Urban settlements are colonized by a spontaneous flora, occurring on different habitats, such as railway lines, river banks, pavements, old walls, ancient monuments and others. The species growing on old walls can form plant communities physiognomically and floristically well defined.

Moreover, these communities are characterized from the ecological viewpoint by several chasmo-nitrophilous species. On this basis they can be distinguished from the natural rock-face communities, where nitrophilous species generally are absent or rare.

In Italy wall vegetation was studied by the Braun-Blanquet approach since fifties (PIGNATTI, 1953; OBERDORFER, 1969, 1975; SEGAL, 1969; HRUSKA, 1979, 1982, 1986; BRANDES & BRANDES, 1981; BARTOLO & BRULLO, 1986).

HRUSKA (1987) suggested e general syntaxonomical scheme, largely drawn from these studies. In the until performed investigations little attention was made to ecological correlations.

In this paper I present some phytosociological data concerning the vegetation settled on the walls of some fortresses located in the Romagna region. A special attention was paid to the correlation between vegetation types and ecological features, detected by indirect gradient analysis.

Study area

The present research concerns the vegetation occurring on the external brick walls of some fortresses in the Romagna region (south-eastern Po plain, Northern Italy). These fortresses are locally named «rocche» (singular «rocca») and they were built or, in some cases, only modified during the Renaissance, owing to the introduction of the modern field artillery as a new war tecnique. From the architectonic viewpoint a «rocca» is based on a square or rectangular plan and consists of a inner courtyard surrounded by thick walls with four circular towers at the corners; in the middle of the courtyard the main tower (named «mastio») is erected.

The fortresses I considered for the present study were the following: the «rocca» Brancaleone of Ravenna, the «rocca» of Lugo di Romagna, the «rocca» sforzesca of Imola, the «rocca» malatestiana of Cesena and the «rocca» of Forlì.

Methods

Wall vegetation occurring on the above cited fortresses was sampled in spring 1987 by the Braun-Blanquet method (BRAUN-BLANQUET, 1964). Species nomenclature follows PIGNATTI (1982).

The set of 16 relevés (Table 1) was classified and ordered by numerical techniques (ORLOCI, 1978). Calculations were based on cover data corresponding to the transformations of the Braun-

Tab. 1 - Phytosociological table. Rel. 2, 4, 1, 3, 11, 5, 8, 16: *Capparidetum rupestris*; Rel. 15, 15, 10, 9, 13, 12, 6, 7: *Parietarietum judaicae*

Relevés number	2	4	1	3	11	5	8	16	14	15	10	9	13	12	6	7	Presences
Aspect	W	S	S	S	S	S	S	S	E	S	S	W	N	W	W	W	
Inclination (°)	80	80	80	100	80	80	80	80	80	80	80	80	90	90	90	90	
Area (m^2)	80	100	30	30	100	100	200	200	150	150	30	50	30	30	50	50	
Covered surface (%)	60	50	50	30	45	20	25	30	30	30	40	30	50	30	30	25	
Total number of species	9	8	11	9	16	6	7	12	11	9	17	14	11	10	14	5	
Character species of associations																	
Parietaria diffusa	1	+	1	1	2	1	1	1	2	2	2	2	2	2	3	2	16
Capparis spinosa	4	3	4	1	2	2	2	2	1	1	1	r	.	r	.	.	13
Character species of Centrantho-Parietarion judaicae																	
Centranthus ruber	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1
Character species of Parietarietalia and Parietarietea judaicae																	
Cymbalaria muralis	+	+	.	.	+	.	+	.	r	+	1	1	1	1	.	.	10
Erysimum cheiri	1	1	.	2	1	.	.	.	.	.	1	.	.	.	.	.	5
Antirrhinum majus	1	+	1	+	.	.	.	r	.	.	.	.	.	.	.	.	5
Ficus carica	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	1
Companions																	
Bromus madritensis	1	1	1	+	+	.	r	+	+	r	+	+	+	.	r	+	14
Catapodium rigidum	.	.	.	+	r	+	r	.	r	.	+	+	+	r	1	.	10
Arenaria serpyllifolia	.	.	r	r	r	+	r	.	.	.	r	r	.	r	1	.	9
Calamintha nepeta	.	.	.	.	+	.	r	.	r	+	+	+	+	.	1	.	8
Conyza bonariensis	.	.	+	.	.	.	.	r	.	r	.	.	r	+	+	.	6
Sonchus oleraceus	r	.	.	.	.	.	.	r	.	r	.	r	r	.	+	.	6
Diplotaxis tenuifolia	.	.	.	.	.	+	.	r	.	.	+	.	.	+	+	r	6
Rhamnus alaternus	+	1	1	r	+	.	.	.	.	.	.	.	.	.	.	.	5
Taraxacum officinale	.	.	r	.	.	.	.	.	.	.	.	r	r	+	.	.	4
Echium vulgare	.	.	.	.	r	.	.	r	.	.	r	.	.	.	.	+	4
Oxalis corniculata	.	.	+	.	.	.	.	.	.	.	.	r	.	+	.	.	3
Crepis sancta	.	.	r	.	.	.	.	.	r	r	.	.	.	.	.	.	3
Verbascum sinuatum	.	.	.	.	.	.	.	.	.	.	1	+	.	.	+	.	3
Poa trivialis	.	.	.	.	.	.	.	.	r	.	.	r	.	.	+	.	3
Melica transsylvanica	.	.	.	.	r	.	.	r	.	.	.	.	r	.	.	.	3
Hedera helix	.	.	1	.	.	.	.	.	.	.	.	.	.	.	+	.	2
Chenopodium album	r	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Cerastium semidecandrum	.	.	.	.	.	.	.	.	.	.	.	.	r	.	+	.	2
Parietaria officinalis	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	2
Petrorhagia saxifraga	.	.	.	.	.	.	.	.	.	.	.	.	r	.	.	1	2
Hypericum perforatum	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.	.	2
Inula viscosa	.	.	.	.	.	.	.	r	1	.	.	.	.	.	.	.	2
Daucus carota	.	.	.	.	.	.	.	.	r	.	+	.	.	.	.	.	2
Helichrysum italicum	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	2
Chelidonium majus	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	2

Blanquet scale as proposed by VAN DER MAAREL (1979). All species have been considered but for the rare ones occurring in only one relevés. For classification average linkage clustering between merged groups, ALCB (ANDERBERG, 1973), based on the similarity ratio was employed. The ordination of relevés was performed by principal components analysis, based on the Q algorithm, Q-PCA (ORLOCI, 1978). The results obtained by both classification and ordination were interpreted from the ecological viewpoint through the Shannon's function (SHANNON, 1948). This was applied to the contingency table including the presence values of the vegetation types in the four classes of aspect.

Results

The dendrogram obtained by ALCB is reported in Fig. 1. The two clusters distinguished at a similarity level of about 0.33 correspond to vegetation types floristically well defined and well recognizable in the field. From the syntaxonomical viewpoint they can be ascribed to the associations *Capparitedum rupestris* O. Bolòs et Molinier 1958 and *Parietarietum judaicae* (Arènes 1928) Oberd. 1977, belonging to the alliance *Centrantho-Parietarion judaicae* Rivas Martinez (1960) 1969 and to the order *Parietarietalia judaicae* (RIVAS MARTINEZ 1960) Oberd. 1977 (see BARTOLO & BRULLO, 1986).

Inference about the ecology of the studied vegetation can be drawn from the PCA. In the diagram of Fig. 2 the second principal component separates the relevés in two groups, corresponding to the *Capparidetum rupestris* (negative values) and to the *Parietarietum judaicae* (positive values). The ordination of these associations along the second principal component presumably corresponds to a gradient of incoming solar radiation, from the *Parietarietum judaicae* to the *Capparidetum rupestris*. This hypothesis was tested by Shannon's function applied to the contingency matrix of Tab. 2. Considering the H/Hmax ratio for the columns of Tab. 2 the *Capparidetum rupestris* seems to be more dependent from aspect than the *Parietarietum judaicae*. Moreover, the *Capparidetum rupestris* results confined to the warmer and drier S-exposed walls, while *Parietarietum judaicae* is distributed in all classes of aspect, with a fairly higher frequency in western exposures.

Concluding remarks

In Italy, southwards Northern Apennines, the *Capparidetum rupestris* is largely diffused on the S-facing old walls (see HRUSKA, 1987; BARTOLO & BRULLO, 1986). Before the present study no evidences were available about its presence in the Po Plain.

In the Romagna region the *Capparidetum rupestris* very rarely occurs and it can presumably be regarded as a wall association confined to refuge sites.

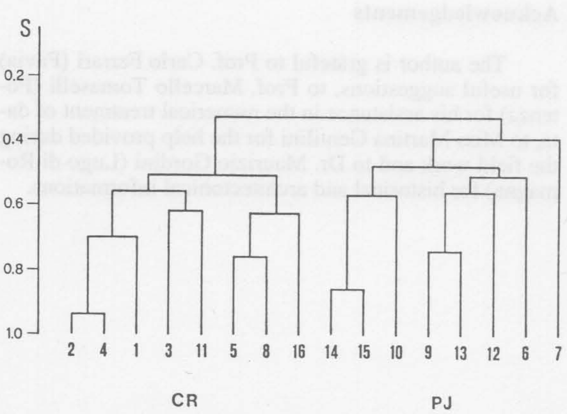

Fig. 1 - Classification dendrogram of the16 relevés of Table 1. S = similarity ratio; CR = *Capparidetum rupestris*; PJ = *Parietarietum judaicae*.

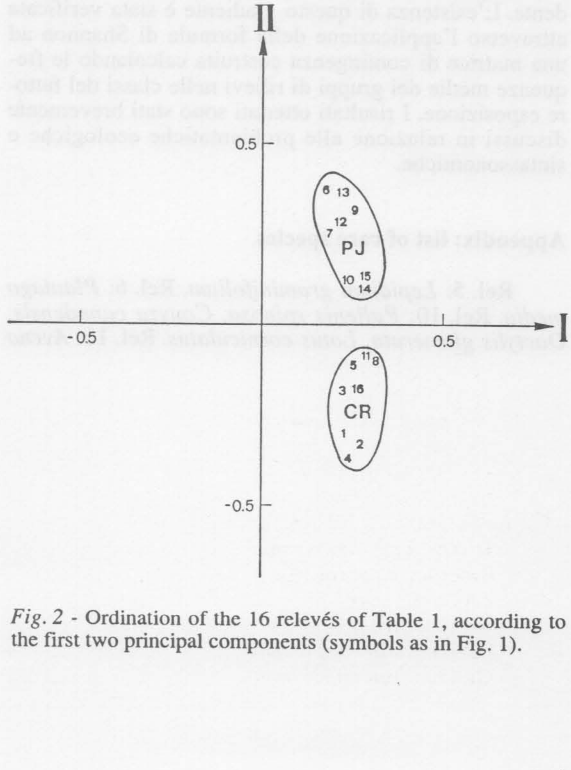

Fig. 2 - Ordination of the 16 relevés of Table 1, according to the first two principal components (symbols as in Fig. 1).

Tab. 2 - (a): contingency table (classes of aspect x vegetation types);
(b): Shannon's function and its application to Table 2 (a)

	CR	PJ
N	0	1
E	0	1
W	1	4
S	7	2

(a)

	CR	PJ
H	0.38	1.21
H/Hmax	0.27	0.87

Hmax = 1.39

H = R(K) /NR ln NR/R (K)
Hmax = ln NK

H = entropy
Hmax = maximal entropy
R(K) = number of samples belonging to k-class
NR = total number of samples
NK = number of factor classes

Summary

In questo contributo è stata presa in esame la vegetazione che colonizza i muri di mattoni di alcune rocche situate nella pianura padana sud-orientale. Sono stati eseguiti 16 rilievi col metodo di Braun-Blanquet, nel periodo maggio-giugno 1987. I tipi di vegetazione sono stati individuati mediante il metodo del legame medio, basato sul rapporto di somiglianza. I due gruppi di rilievi così individuati sono stati assegnati rispettivamente al *Capparidetum rupestris* e al *Parietarietum judaicae*. L'ecologia dei due tipi di vegetazione è stata indagata attraverso l'analisi indiretta di gradiente. Per questo scopo è stato eseguito un ordinamento basato sull'analisi delle componenti principali. Su questa base è stato ipotizzato un gradiente di radiazione solare incidente. L'esistenza di questo gradiente è stata verificata attraverso l'applicazione della formula di Shannon ad una matrice di contingenza costruita calcolando le frequenze medie dei gruppi di rilievi nelle classi del fattore esposizione. I risultati ottenuti sono stati brevemente discussi in relazione alle problematiche ecologiche e sintassonomiche.

Appendix: list of rare species

Rel. 5: *Lepidium graminifolium*. Rel. 6: *Plantago media*. Rel. 10: *Pallenis spinosa, Conyza canadensis, Dactylis glomerata, Lotus corniculatus*. Rel. 11: *Avena fatua, Foeniculum vulgare, Reichardia picroides*. Rel. 14: *Sonchus asper*. Rel. 15: *Setaria italica*.

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Historical trees in Villa Mondragone

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Keywords: Historical trees, Dendrochronological factors, Villa Mondragone.

«The italian feeling for sensation has been spoken of. Perhaps the best example of this is furnished by another Villa at Frascati, the great sixteenth-century pleasure-house of Mondragone...» (SITWELL, 1909).

The history of Villa Mondragone has been already reported in numerous literary and artistic works (ROGISSARD, 1706; GROSSI-GONDI, 1901; SEGHETTI, 1906) as well as in a recent work on the historical green of the Villa (GRILLI CAIOLA et al., 1988).

The last study suggests the interest of the Villa, in the past and present times, not only architecturally and artistically, but also for its green and especially for the arboreous component. The latter is supported by numerous historical prints, engravings and photos of archives (GRILLI CAIOLA et al., 1988).

The actual arboreous patrimony appears just partly changed as compared with that reported in ancient prints of Villa Mondragone. Numerous trees still perform the same function as in the 17th and 18th century. Their presence has induced us to study such arboreous patrimony, in order to enumerate the present specimens and to evaluate the age and the phytosanitary state of various trees.

A dendrochronological study and an arboreus census have been carried out on sections of branches and trunks, and on cores from appropriately selected samples both on the outside and inside area of the Villa (Courtyard inside, Courtyard by Vasanzio and Secret Garden).

It is known that it is not always simple to date a tree since the annual activity of the cambium is much affected by locale climate. However, our valutation is limited to trees of Villa Mondragone, a microenvironment in which the climatic differences would be extremely reduced. Therefore if the trees have undergone the same weather circumstance their growth should be homogeneous.

This note considers the methods used to prospect the age of the present various specimens. Some samples, of every present species, have been 'drilled' by a Pressler drill. A dendrochronological factor (D.F.) expressing the ratio between the radius of trunks (or of branches) and the numbers of annual rings counted in the cores has been found. The factors of every species have been reported in Tab. 1.

The annual rings and the value of the circumference and radius has been counted on sections of trunks and branches of recent lapping of *Quercus ilex* L. and *Castanea sativa* Miller.

Tab. 1 - Trees of Villa Mondragone with the number of actual specimens, the dendrochronological factor (D.F.) and the age groups (from 100 to 199, 200 to 299 and over 300 years old) of older samples

Species	N. specimens	D.F.	AGE GROUPS		
			100 199	200 299	Over 300
Quercus ilex	461	2.3	261	28	5
Quercus frainetto	9	1.2	2	4	3
Castanea sativa	6	3.2	–	6	–
Tilia cordata	27	2.0	17	3	–
Pinus pinea	25	2.0	3	–	–
Platanus sp.	5	2.3	3	–	–
Olea europaea	3010	1.3	3000	10	–

Even in this case it has been established a D.F. resulting by ratio between the value of radius of section and the number of rings counted.

The latter factors extimated, 2.7 and 2.2 respectively for *Quercus ilex* and *Castanea sativa,* appeared to be very near to the D.F. of the first method. For this reason and also for the lack of sections of all the specimens of Villa Mondragone it has been used the method of cores. Studies have not been carried out on *Cupressus sempervirens* L. because in literature (GROSSI-GONDI, 1901) already appears a date of the planting of the celebrated cypress avenue that, from the gate, points at the palace. The most part of this, represented in various prints, is preserved till now.

The results have shown the presence of 4300 trees belonging to 26 genera and 33 different species with hundreds of stately specimens of *Olea europaea* L., *Quercus ilex, Cupressus sempervirens, Tilia cordata* Miller, *Q. frainetto* Ten., *Castanea sativa, Pinus pinea* L., *Platanus* sp., forming avenues of approach (Fig. 1, 2) and small woods surrounding the Villa. In the Tab. 1 are reported also the age groups (from 100 to 199; 200-299 and over 300 years old) of various trees.

It is interesting to point out the presence of older specimens (1 *Q. ilex* about 400 years old and 1 *Q. frainetto* of 450 years old) in places where already in the Kircker's print (1671) were reported trees of great size.

For pines and planes we carried out a comparison with two monumental specimens of *Pinus pinea* and *Platanus orientalis* L. present in the near Villa Falconieri. These species, already cited by MONTELUCCI (1964) and well known for their longevity, on the basis of our calculation might be respectively 380 and 420 years old, while the specimens of Villa Mondragone appeared comparatively younger (about 150 years old).

The hystorical study showed, in the Ilex avenues (Fig. 1) of the Villa, the presence of many specimens in precarious phytosanitary conditions because of the presence of many cavities (Fig. 3) owing prevalently the xylophagous insects and

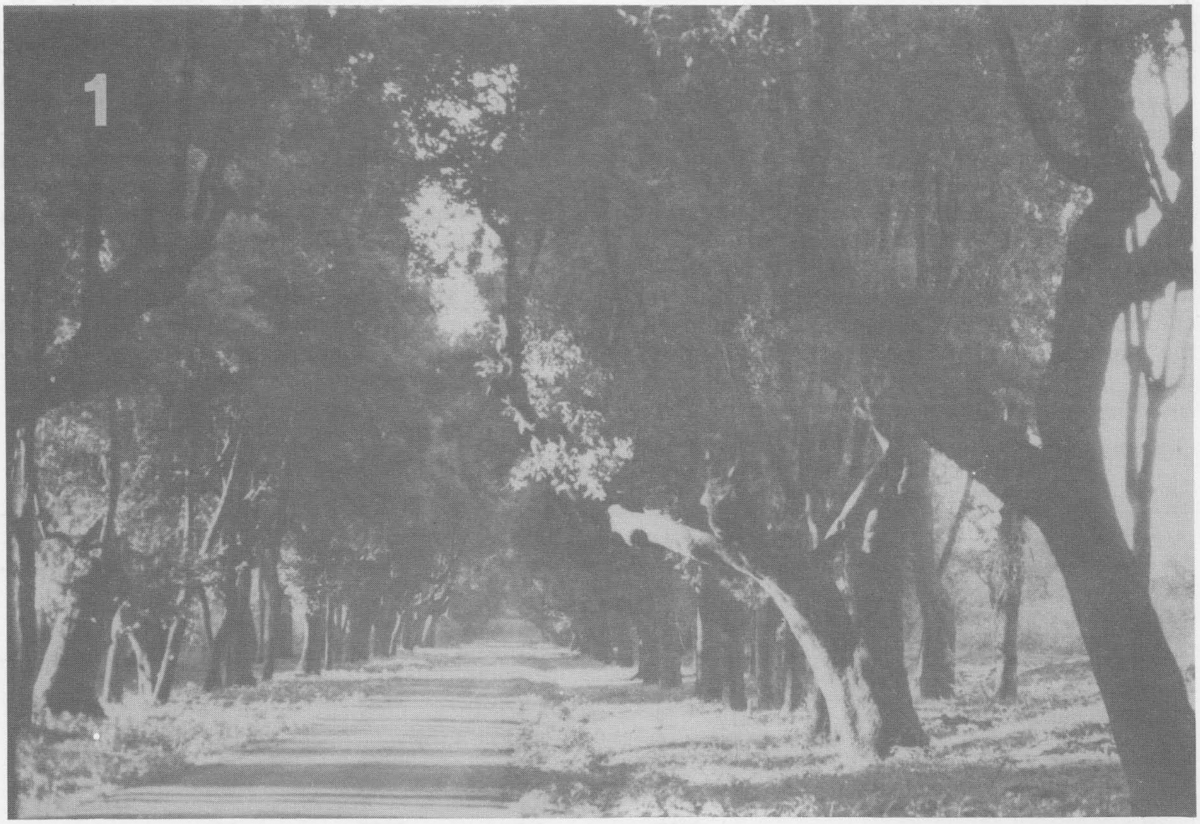

Fig. 1 - Ilex avenue that leads to the Villa.

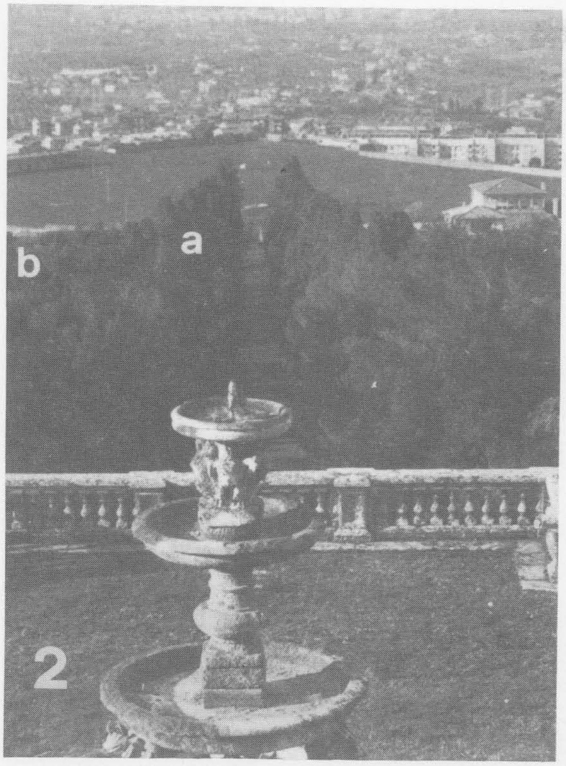

Fig. 2 - A view of cypress avenue (a) that, from the gate on the Monte Porzio Catone road, points at the palace; the surrounding olive-groves (b) and the panorama of the roman plain.

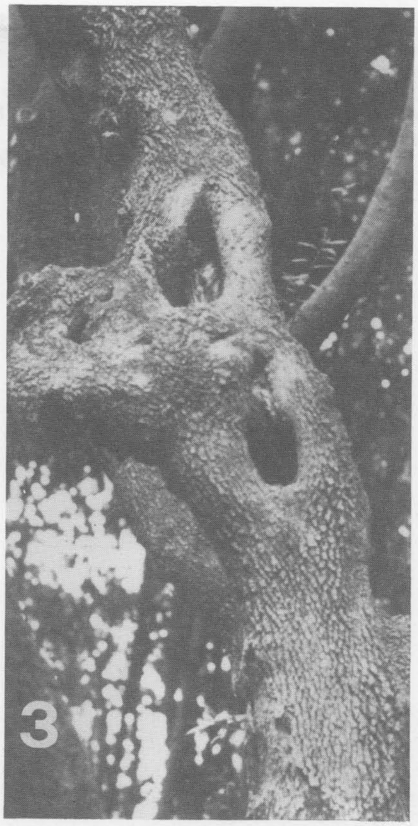

Fig. 3 - A trunk of *Quercus ilex* with evident cavities.

olive-fly. Also the olive-trees are damaged by frost and encroaching different *Rubus* sp..

We have already expressed in previous works (GRILLI CAIOLA et al. 1988) the hystorical value of arboreous patrimony of Villa Mondragone, and now we must recall the necessity of preservation. Together with the restoration of the artistic component of the Villa, already ahead since some years, it is appropriate to recall the necessity of a study of maintenance also green component that tends to safeguard especially the historical arboreous patrimony and assure its survival. The problem on how to preserve this patrimony is without doubt of difficult resolution and it requests a knowledge of its evolution since its origin to today.

By historical studies (GRILLI CAIOLA et al., 1988) we can affirm that the whole Villa can be considered a 'Historical Garden'. As it is a work of art it needs to be safeguarded with the definite rules as appeared in the 'Paper of Florence' (CATALANO e PANZINI, 1985).

Therefore it is necessary to intervene with works of lopping of curing making use of the present techniques of dendrosurgery especially on the species in condition of advanced decay.

The techniques of thermic and photographic infra-red should contribute, on the contrary to show the cavities not in macroscopical relief.

Riassunto

Nel parco della secentesca Villa Mondragone è presente un cospiquo patrimonio arboreo di elevato valore naturalistico. Viene effettuato il censimento di tutte le specie arboree e stimata la loro età sia mediante il Fattore dendrocronologico, espresso come rapporto tra raggio del tronco e numero dei cerchi annuali contati su alcune carotine estratte che su dati bibliografici.

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Botanical problems in Prato della Valle of Padua (North Italy)

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Keywords: Landscape & urban architecture, historical gardens, plane disease.

Abstract

The authors have studied the evolution of Prato della Valle area in the past 2,000 years. In particular they have analyzed the state of the planes existing in the middle of the square and presently badly infected by coloured cancer. Adequate solutions are suggested and recommendations for Local Administration are urged.

Prato della Valle, one of the largest squares in Europe, lays in the heart of Padua. It is a huge open area characterized by a large basin with an island in the middle and by an imposing complex of monuments and buildings all around.

The aerophotografic analysis shows traces of ancient river beds of Pre-Roman age delimiting the northern boundary of the square; in addition, a part of an ancient stream, later called Alicorno, is still visible close to St. Giustina Church.

As early as the «paleoveneta» age it was an important area. In Roman times, being the junction of two important roads, it held a theatre and a circus and was a place of monuments and capital executions.

In the early Middle Ages, Prato della Valle turned to marshland and was outside the town-walls. Nevertheless, it remained an important trade centre, the markets taking place in its south-eastern part.

In the XIV century, Prato della Valle was enclosed inside the new fortified town-walls built by the Carraresi, Lords of Padua.

The driest spot, close to St. Giustina church, became a drill-ground, a seat of great military and judiciary assemblies as well as miracle plays.

After the XVI century, under Serenissima Repubblica di Venezia domination, it was nothing but the natural seat of fairs, cattle markets, religious cerimonies, exceptional happenings.

We owe the first reclamation plan and the present lay-out of Prato della Valle to Andrea Memmo – a Venetian patrician and enlightned reformer – who acted as the Superintendent for Padua of Serenissima Repubblica di Venezia in the period 1775-1776.

In order to revive the town economy, he devised some restoration plans, where a total remodelling of Prato della Valle was also included. According to these plans, Prato della Valle was first thought of as an urbangarden and later as a fair-centre.

Domenico Cerato, an architect from Vicenza, carried out both the final plans and the work execution. Just in the middle of the area he realized

Fig. 1 - P. Chevalier: Il Prato della Valle di Padova (Pa. Civ. Libr.). In this print of 1831 to be noted the tree clump of 1815. In the beginning it consisted of about 24 planes (*Platanus hibrida* Brot.) and 76 yellow poplars (*Liriodendron tulipifera* L.).

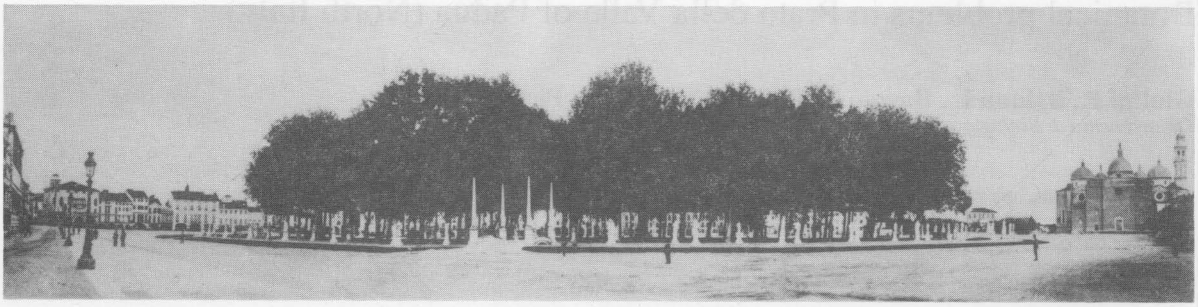

Fig. 2 - Isola Memmia at the end of XIXth century (Pa. Civ. Libr.). In spite of the blooming look of the planes to be noted how non homogeneous the foliages are.

an elliptical isle (called Isola Memmia), surronded by a little canal on whose banks he set up a double ring of 88 statues. The statues – representing professors of Padua University and people somehow related to the town – were to a great extent made by Paduan sculptors of the time. Andrea Memmo deemed that only fountains, statues, carved vases and pruned shrubs should decorate Isola Memmia. He unconditionally rejected the idea of planting high trunk trees as they would shut out the unitary view of the complex, being the horizontality of the basin and the verticality of the statues its peculiar features.

In 1815, totally disregarding the original plan and lacking in any background information and serious planning, unknown persons embedded about one hundred trees: 3/4 tulip trees (*Liriodendron tulipifera* L.) and 1/4 planes (*Platanus hibrida* Brot.).

In 1836, Giuseppe Jappelli, the famous architect, fearing the trees could damage the statues, urged their felling, maintaining that – safety apart – Isola Memmia would so turn out into a «grand» open space.

In 1839, in spite of his opinion, it was decided to keep the tree clump. Over the years it became too thick and caused more than a problem. Meanwhile, owing to their competition with the planes and the basis and little drained soil, the tulip trees began to die.

It could be the opportunity to thin out the trees, arranging them at right intervals, so that they could safely reach their final size. On the contrary there was no thinning whatever and the dead tulip trees were replaced by new planes. They were later indiscriminately pruned, which – in addition – produced unavoidable and deep rots even in their trunks.

The bad state of the planes worsened when they were infested by the wood fungi.

There was a general weakening, small diametric growth and rings badly visible even to the microscope.

However the couloured cancer (*Ceratocystis fimbriata* Davidson) is, at present, the most dangerous scourge.

In 1978, the disease started spreading from a plane to another, through the radical apparatus (root system) and vandalic or fortuitous traumas as well. In some cases the disease spread through the necessary prunings, however carefully and using the right treatments they might be executed.

Fig. 3 - Present (1988) view of Prato della Valle showing the few planes (27) not yet infected by coloured cancer.

Fig. 4 - The first signs of the disease: coming out of cortical disorders caused by the fungus.

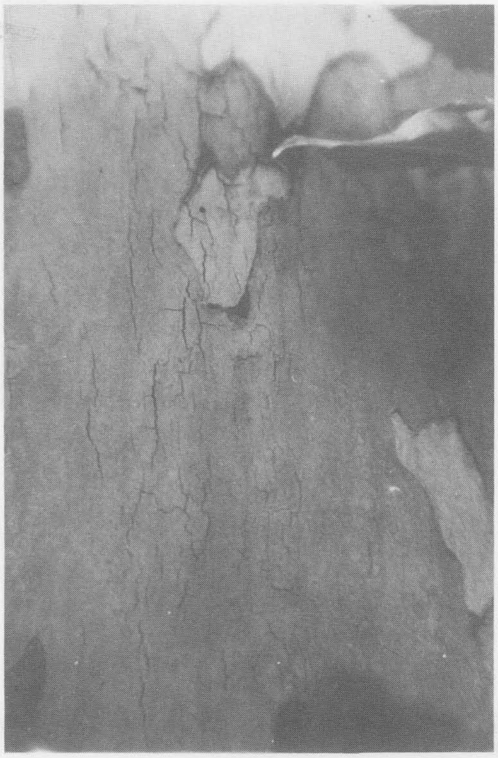

Fig. 5 - The infection spreads along the trunk.

In 1982, because of the coloured cancer, only 72 planes were left out of a hundred planes or so, originally embedded. Up to now 39 more have already been cut down and 5 are just about to be felled.

Padua Local Administration has now in mind to embed new planes after putting out the coloured cancer disease. The new planes might however be embedded only after sixteen months from the felling of the last diseased tree, this being the maximum time period during which the mycelium can survive in the area. Presently this possibility seems to be very far, as in the meanwhile many other planes might be infected.

To prevent the infection from spreading out throughout Italian territory, a decree with the force of law (decree No. 412) was issued on September 3, 1987. It prescribes strict rules as regards the pruning and felling of planes.

An experiment of biological fight made by reinfecting the diseased trees with an antagonistic fungus had the only result to slow down the spread of the infection but no success at all was obtained in defeating it.

Since all that might bring about the disappearance of the planes in Prato della Valle (3,6), an alternative proposal strangely unwelcome to the Local Administration has been presented: the progressive embedding of plants of different species, set at right intervals. A suitable tree might be the hornbeam (*Carpinus betulus* L.), long-lived, immune from this infection, 25 meters high to its maximum, dark green foliage, autochthonous and an essential element of *Querceto-carpinetum boreoitalicum* Pign, 1953.

In turn, the European hop-hornbeam (*Ostrya carpinifolia* Scop.), only slightly shorter but with the same characteristics, might be used.

From an aesthetic and maintenance point of view these species are of particular interest.

In comparison with the planes, their smaller size and darker foliage would be in stronger contrast with the light colour of the statues. The smaller diameter of their leafage would prevent the branches from damaging the statues. The small proportion of the fully developed trees would grant considerable maintenance savings, should prunings be necessary. The particular quality and hardness of the wood would save the trees from fungi attacks.

The plane epidemic death is not the only trouble Prato della Valle is suffering from, as – what is worse – it is undergoing a progressive decay. Owing to the heedlessness of Local Administration it is being badly exploited as the seat of exhibitions, markets, fun-fairs, car-parks etc.

Up to now no steps have been taken in order to state to what extent the area can be used and what might be done to increase its importance.

It is plain that Prato della Valle must be redesigned, keeping in mind its historical value and its relationship with the town. Andrea Memmo wanted the feature of this incomparable city area to be

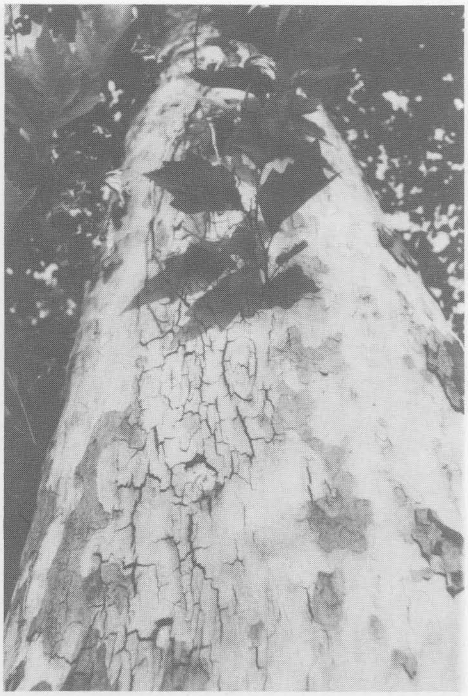

Fig. 6 - Trunk bark dried by cancer: on both sides sprigs sprouted as a result of the infection.

Fig. 7 - View of an infected plane.

its grand monumental space and it is imperative this peculiarity of its own must be regained.

We cannot but trust that for one time the Local Administration may be far-sighted and adopt enlightened decisions, determining to remake the structures of Prato della Valle in such a way as to restore its ancient beauty and we cannot but wish that – its foregone, practical utilization apart – in Prato della Valle cultural undertakings may prevail over simple entertainment and amusement performances.

Riassunto

Nel 1986, a cura della Signum di Padova, numerosi Autori hanno ricostruito gli ultimi 2 millenni della storia del Prato della Valle di Padova.

L'area ebbe un decisivo impulso monumentale nel 1775-76 per merito di Andrea Memmo, che concepì una monumentale isola circondata da un canale ellittico sulle cui rive furono poste 88 statue in pietra. Il Memmo non volle piante di alto fusto, ma nel 1815, senza nessuna seria progettazione, furono collocati un «centinaio» di alberi. Già nel 1836 Giuseppe Jappelli accese una disputa per la loro eliminazione.

Verso il 1978 il cancro colorato, infezione fungina mortale e specifica, si manifestò sui platani. Dei 72 esemplari attualmente ne sopravvivono 27 e l'infezione non accenna a rallentare.

L'intenzione ufficiale è quella di ripiantare platani non appena questa infezione sarà debellata.

Saremo però sicuri in avvenire da questo fungo così subdolo e pervicace?

Non sarebbe questa l'occasione per ristudiare l'architettura e le funzioni della piazza?

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The romantic Miari de Cumani park near Padua (North Italy)

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Keywords: Landscape architecture, census of historical gardens.

Abstract

The historical , geomorphological and architectural aspects of Miari de' Cumani park and villa have been examined. In particular the authors have studied the park evolution up to its present state identifying the species of every tree and shrub.

This study, even if developed as per the PG (Park Garden) instructions of Ministero dei Beni Culturali, has been worked out by the Giardini Storici Group of Padua University using their own methods. This Group receives a 40% contribution from Ministero della Pubblica Istruzione (Ministry of Education).

Many Historical Gardens are still existing in Veneto: some of them date back to the XVIII-XIX century. Moreover there are many records about the gardens of older times.

In the last century two architects, Giuseppe Jappelli and Francesco Bagnara, were very well renowned for the utmost level of their projects concerning romantic gardens. Osvaldo Paoletti, one of the numerous pupils of Jappelli's, designed the romantic park located in S. Elena D'Este (a little town near Padua), owned by the descendants of Conte Felice Miari de' Cumani.

The historical researches have been carried out through the huge collection of documents, carefully preserved by the present descendant.

The most ancient map (1648) shows a perspective of the main building, the boundary wall and the three entrance gates with swallow-tailed merlons on the top.

The records indicate that the building was restored in the past century and that several modifications and enlargements have been made thereafter. On the contrary, the boundary wall has remained unaltered in these three centuries.

Paoletti's plan was realized in the area previously taken up – as shown in the 1648 map – by the vegetable garden, the orchard and the fish-pond, whose outputs were used in past times as a payment in kind to de' Cumani's farm-workers.

The fish-pond area is presently visible as a linear depression marked by a row of ancient horse chestnuts (*Aesculus hippocastum* L.) that, according to the data obtained by coring them, seem to be some decades older than Paoletti's plant.

The geomorphological researches, carried out through the interpretation of the aerial photos, have shown the presence of ancient alluvial planes and of isolated river-beds in the wide area surrounding the park: which testifies the evolution phases of the Adige river. The villa and its park are located on the bifurcation of two ancient alluvial planes. The pedological substratum seems to be of silt-sand composition; however, the centuries-old presence of trees and shrubs has allowed the making up of a humus, rich in organic components.

The architectural researches have shown the main perspective lines and views defined during the planning phase and the meaning of the buildings in the park. The lake as well as the building connecting the «Isola del castellaccio» (the Dungeon Islet) with the «mainland» are of particular interest thanks to the originality of their design and the unusual effects of the composition. Instead of a simple bridge, Paoletti conceived and realized a charming and fascinating hollow structure – with a gothic-like entrance – which became a shelter for a small boat.

The hollow, reminding a nympheum, is lit up by the water reflections and by two circular openings. These ones dissolve the inner darkness so that a big niche, with a statue rising out of the water, can be dimly seen. A narrow, white and spectral neo-gothic staircase connects the interior of the hollow with the top of the bridge, making it impossible to reach the island this way.

Some more buildings exist in the area, such as a large ice-house with a fine entrance gate, an unadorned, neo-classical, tiny, little temple with the bust of Conte di Cavour inside, a fine and large green-house on the villa ground floor and a pillar, erected in later times, in memory of the failed drilling of an artesian well.

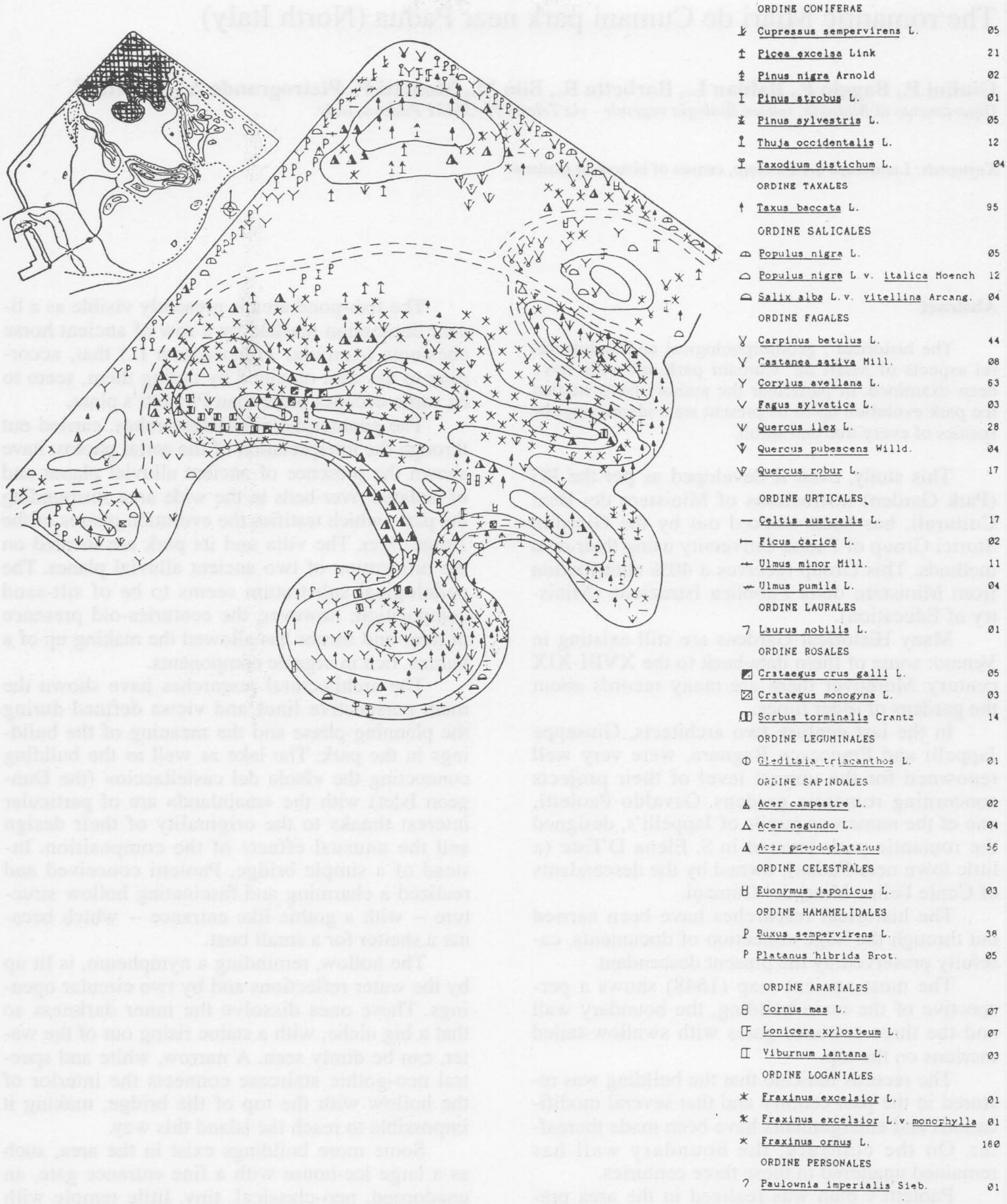

Fig. 1 – Map of the northern part of the park with the botanical census. The legend states: symbol, specific name and number of trees belonging to each species living there.

Moroever, on the original plan there is another big building which was never realized.

The analysis of the aerial photos taken in 1955 and 1984 points out the thickening of the foliage after the damages suffered during the World War II. The comparison with the original plan shows a lessening of the grasslands caused by the embedding of Norway spruces (*Picea abies* (L.) Karsten) and by the appearance of several infesting plants.

The botanical researches have shown the surviving plants of the original set out (core and statistical valuation method), the different vegetation stages, the man action effects (prunings, plantings, fellings), the present condition, the infestation (from trees and insects) and the infections.

The census of the perennial plants higher than two meters will allow, from this time onwards, to control and program any action to be taken and, as a consequence, to define the extent and the purpose of any general local or individual restoration. The blueprint of the census shows any single plant and states the species through a proven symbology used in the study of many parks, gardens, tree clumps, and urban open spaces.

The numerical data achievable from a census are of great importance to know the particular condition of a park. As far as the Miari de' Cumani park is concerned, some interesting relations exist between deciduous and evergreen plants, both species and single plants (61/21 and 2149/1092) and, even more, between angiosperms and gymnosperms (67/15 and 2847/394). This testifies that the original planning took the phytoclimatic situation of St. Elena d'Este area in a pretty right account.

The infestant arboreous plants are few in comparison with the other plants (4/78 and 63/3178) and this testifies that the park enjoys a good internal equilibrium preventing new plants from growing and that the owner takes a great care in well preserving this historical monument.

Riassunto

Questa ricerca segue le indicazioni della scheda PG del Ministero Beni Culturali, ma procede secondo proprie metodologie.

Il Veneto possiede nel suo territorio numerosissimi giardini storici di grande interesse architettonico e botanico.

Nel secolo scorso assunsero grande fama gli architetti Francesco Bagnara e Giuseppe Jappelli. Un allievo di questo, Osvaldo Paoletti, progettò il giardino sito a S. Elena d'Este proprietà dei discendenti del Co. Felice Miari de Cumani.

L'indagine storica ha preso in esame un nutrito corredo documentativo e quella geomorfologica ha evidenziato la vicinanza in passato dell'Adige e dei suoi meandri, l'ottima qualità del suolo ricco di humus.

L'indagine architettonica ha permesso di rilevare le prospettive previste in fase progettuale e il significato dei manufatti contenuti nel parco. L'indagine botanica ha evidenziato l'assetto vegetale originario (metodo del carotaggio e della stima statistica), il divenire della vegetazione (classi di età), gli interventi antropici (potature, impianti e abbattimenti), la situazione attuale. Il censimento delle piante perenni di altezza superiore ai m 2 consente d'ora in avanti il controllo e la pianificazione degli interventi e la programmazione del restauro. La carta derivante dal censimento riporta ogni individuo con l'indicazione della specie attraverso una simbologia originale ormai sperimentata nello studio di molti parchi, giardini, alberate e verde urbano.

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Moreover, on the original plan there is another big building which was never realized.

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A contribution to the knowledge of the algal flora of archaeological remains: the Foro Romano

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Keywords: algae, biodeterioration, archaeological remain, Foro Romano, Rome.

Abstract

Subaerial algae were collected in the Foro Romano, Rome. These include green and blue-green algae and numerous diatom species.

Introduction

The decay of exposed stoneworks can be attributed both to environmental factors such as rain, wind, air pollution and to biological agents such as bacteria, algae, lichens, fungi and plants.

The aim of the present paper is to examine the characteristics of the algal microflora that establish itself on archaeological remains of the Foro Romano causing the deterioration of stone.

The main requirements of the algae are a high moisture level, light, oxygen, carbon dioxide and traces of mineral salts, that are easily found on the exterior surfaces of the stone.

The colonization and proliferation of the algae cause disfiguring of the material with an aesthetic damage which may be so extensive as to render the monument unrecognisable. The colour and the morphology of alterations depending upon environmental parameters, nature of substrate and predominant taxa in the community.

It can be stated in general that algae occurring on stonework have a green colour in conditions of high humidity and a dark colour in dry conditions. It is also important to bear in mind that some algae can give a peculiar colour to the alterations they cause. In these cases the colour is related to the type of photosynthetic pigment found in greater quantity in the cells or their sheaths.

For this study we chose several archaeological remains, made of marble, tufa, travertine, and bricks, which showed different biodeterioration phenomena.

Material and methods

Samples were chosen on the basis of the type and degree of deterioration through macroscopic observation; the material was taken by means of sterile lancet and kept in sterile test-tubes. The presence of algae was ascertained by direct microscopic examination of samples. In order to facilitate the identification of some organisms, subsamples were placed into specific enrichment media (Bold Basal Medium and BG11, 1200-1500 lux, T=22°C) and culture material was also examined.

For diatom analysis, subsamples were boiled for several minutes in H_2SO_4 and HNO_3 1/1 v.v. to remove organic matter. These were rinsed several times in distilled water and were dried onto a microscope cover slip. These were mounted in Canada Balsam on standard microscope slides.

Results and discussion

On the basis of the analyses effected it was possible to identify 8 taxa of *Cyanophyceae*, 5 taxa of *Chlorophyceae* and 12 taxa of *Bacillariophyceae* (see Tab. 1). Most species found are broadly distributed in temperate regions and are typical of terrestrial environments. Particularly prevalent were the *Cyanophyceae*. These algae adapt themselves to extreme ecological conditions, and are highly favoured as compared to others in conditions of climatic variation owing to their fairly thick gelatinous sheaths which protects them from excessive drying. When coloured these sheaths also afford good protection against high light intensity.

When considering the damage caused by *Cyanophyceae* to the substratum, their ability to make use of carbonates must be borne in mind. The genera *Scytonema* and *Lyngbya* in particular cause these substance to precipitate around their sheaths; the genera *Gloeocapsa* and *Chroococcus* can render them soluble (TROTET et al., 1973).

It is also important to consider the mechanical distructive action effected by the *Cyanophyceae* equipped with a sheath. Once these algae have worked their way into the cracks and pores of the stonework, they exert damaging pressure owing to variations in the volume of their sheath (following water retention) as well as by the growth of the colonies. In this way they can cause microfractures which hasten the superficial degradation of the stoneworks.

Tab. 1 - Algal species collected from stoneworks in the Foro Romano

CYANOPHYCEAE	BACILLARIOPHYCEAE
Chroococcus sp.	Melosira sp.
Gloeocapsa sanguinea	Cyclotella ocellata
Myxosarcina sp.	Stephanodiscus astrea
Lyngbya autumnalis	Eunotia curvata
Lyngbya bourrellyana	Navicula atomus
Lyngbya foveolarum	Navicula contenta
Lyngbya versicolor	Navicula mutica
Calothrix sp.	Navicula nivalis
	Navicula sp.
	Pinnularia borealis
CHLOROPHYCEAE	Gomphonema acuminatum
Haematococcus pluvialis	Hantzschia amphioxys
Chlorella sp.	
Sticoccus bacillaris	
Ulothrix sp.	
Apatococcus sp.	

Account must also be taken of the massive proliferation of algae on stone surfaces which creates a favourable organic base for the installation and growth of moss and lichens. The presence of the latter, in turn, encourages the growth of *Pteridophytes* and *Spermatophytes* whose roots can effect significant damage on the structures (CANEVA, 1985).

It is thus necessary to ensure the elimination of the algal microflora responsible for such alterations through the use of biocide chemical substances (quaternary ammonium compounds, diazine, etc.).

It is, however, advisable to limit the use of these substances, and instead to act on the causes which allow algae to become attached in the first place.

The ideal method would entail controlling environmental conditions, but this would only be possible for stoneworks which can be contained in screened environments.

Finally, it is important to recall that a periodic check of the state of conservation of the stoneworks is indispensable in order to verify the efficacy and duration over time of the biocide tretments employed, and whether a fresh application of the treatment is necessary.

Summary

The characteristics of the algal flora that establish themselves on archaeological remains and cause the deterioration of stone has been studied.

The colonization and proliferation of the algae cause disfigurement of the material with an aesthetic damage prevalently.

For this study we have chosen some stoneworks which showed different morphology of alteration. The morphological variability depends on environmental parameters, nature of the substrate and species present in the biocenosis.

The predominance of *Cyanophyta* and *Chlorophyta* and later the addition of *Bacillariophyceae* are recognized.

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Plants at historical sites in Rome: a photographic comparison

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Keywords: Plants at historical sites, Rome, photographic-bibliographical comparison, ecological considerations

Abstract

Photographs taken of Roman ruins in the middle of the 19th century show a rich wall vegetation. A comparison between the vegetation in those photographs and the current plant cover, coupled with a comparison, based on bibliographical sources, of the flora of that period with that of ours, could give us some indication on the effects of pollution and changes in urban ecology. Since the best-known of Rome's antiquities, the Colosseum, and so on, are subject to continuous weed control by municipal and state agencies and changes in flora or vegetation give little information. On the contrary, photographs taken in the 1860's of the Cloaca Maxima and on the Porta Maggiore show a vegetation mass no bigger than wich we find at these two sites today, despite pollution. The wall vegetation one can identify in the photographs is similar to present vegetation, although the present vegetation has been enriched by ornamental species used in parks, road-side plantings and gardens.

What could the flora of ancient Rome consist of?

The classical Latin authors, – Cato, Varro, Virgil, Columella and Pliny – were the first to write about the flora and vegetation of Rome. The ancients believed that before the Latins settled Rome, the Seven Hills were covered by mixed forests, composed mainly of deciduous oaks, evergreen oak, maple, hornbeam trees and even beech. In between the forested hills there were marshy lowlands, such as that occupied by the Forum, while along the Tiber, there were meadows. Pliny wrote in his «Historia Naturalis» that *Myrtus communis* occupied the area where the City was founded: according to legend, during the Sabine war, the contestants used *Myrtus* branches to cleanse themselves before fighting. Latin toponymy explicitly indicates the presence of trees: the Caelian hill and gate were once known as «Quercetulanum» (This could also refer to the group of people named «quercetulani»), as is recalled by the via dei Querceti now day, while the Esquiline was once known as «Fagutale». The name «Viminal», stille in use, indicates the presence of willows, and so on. We know that the Pincio was covered with willows, the Vatican, Janiculan, and Aventine with woods of *Quercus ilex* and other oak species. There was an oakwood on the Capitoline. Of course, although the forests on the different hills presented some well-grown specimens of one or another of the species of a deciduous mixed-oak forest as a result of the exposure of the slope, the proximity of marshes or springs and so forth, hills so cloese to one another can not have been covered by such well-defined forest associations. Moreover, the soil of the Seven hills is a quite uniform volcanic soil, consisting of pozzolana, peperino, and travertine containing deposits of sedimentary rock. There is some evidence that winters in ancient times were more rigorous then today: Horace wrote about the snows on nearby Mt. Soracte, Livy about the Tiber freezing over in some winters, and Martial about an accident in the center of Rome in which a young man was killed by being hit by a block of ice. A cooler climate would explain the presence of deciduous mixed-oak forest. The wide-spread presence of porticos in ancient Rome may indicate a climate different from the current one: Tacitus says that the widening of the streets during the reconstruction of Rome after the famous fire of 64 A.D. allowed the suns's rays to penetrate more into the city «making the summer heat intolerable». According to the legend of the foundation of the basilica of S. Maria Maggiore, also knows as S. Maria della neve – of the snow – there was a snowfall on the Esquiline hill on 13 August, 352 A.D. On the other hand Rome does continue to experience heavy snowfalls, although only exceptionally. Pliny (23-79 D.C.) gives interesting historical information, though, of course, one must regard it with a certain amount of caution: he tells that according to Fenestrella, the olive was known neither in Italy nor in Spain in the year 173 after the foundation of Rome, in the reign of King Tarquinius Priscus while it had becose very common by Pliny's own time. He writes that in the year 680 after the foundation (i. e. 73 B.C.), there were no cherry trees in Italy and that Lucullus introduced them from Pontus. Again according to Pliny, the *Ziziphus jujuba* was introduced towards the

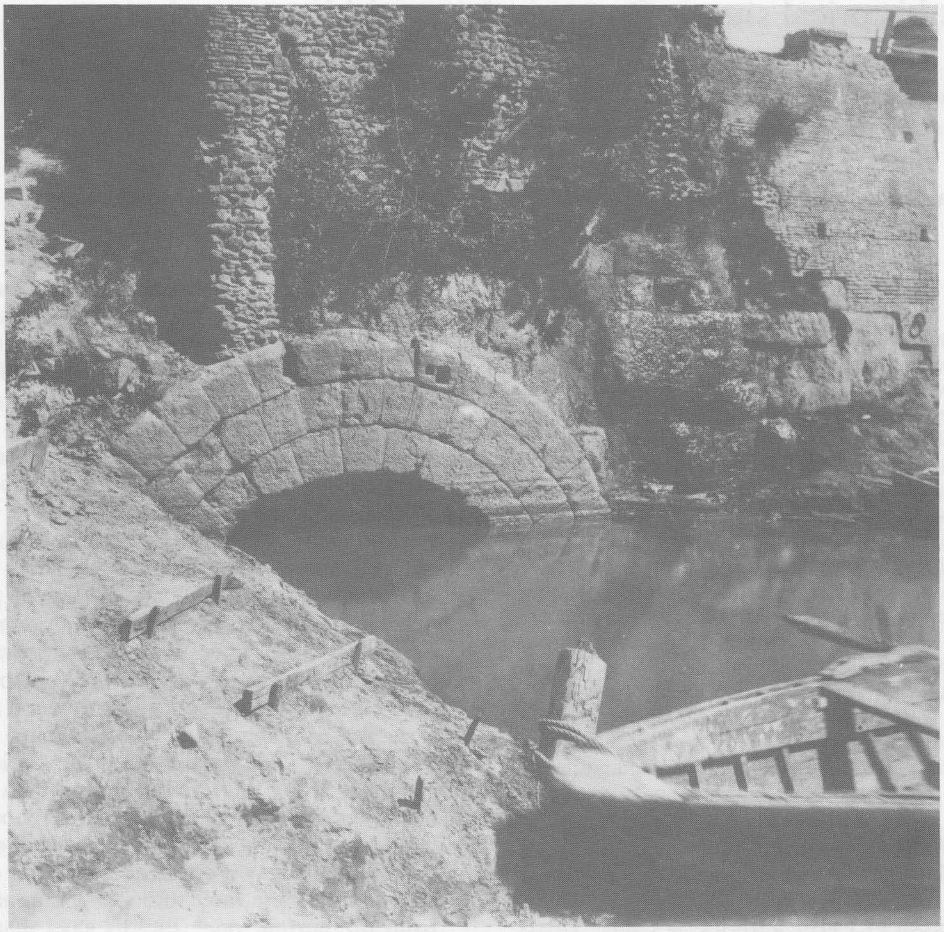

Fig. 1 - The mouth of the Cloaca Massima taken by R. Eaton in about 1860.

end of Augustus's reign by Sextus Papinius, whom Pliny himself knew, and it was used to cover the walls and the roofs of houses; the oleander, on the other hand, is said to have been imported from Greece (although it seems to be indigenous in Sicily, Sardinia and South of Italy, see PIGNATTI, 1982). Pliny further tells us of a fig-tree in the Forum, called the Ruminalis, which was an object of religious worship because legend had it that Romulus and Remus were suckled by the she-worf under its branches.

Among the plants used for ornamentation in the city, Pliny cites *Buxus sempervirens* which had been obtained from wild populations and was used as an evergreen hedge, cut into various shapes. He makes a sharp distinction between trees which grow spontaneously and those which confer benefits on the city, their fruit, or shade, or beauty, thus «showing themselves our friends» (Historia Naturalis Book XIV, ch. XXX). Among the indigenous fruit trees, he names the almond, the apricot, the *Ziziphus*, and the peach while he denies the presence of *Pinus sylvestris* and *Picea excelsa*, in the area of Rome. The *Celtis australis*, known in Rome as «lotus» because of its sweet fruit, grew spontaneously and was used to cover the walls of houses. The *Cupressus sempervirens*, imported from Orient, could be cut into elaborate shapes, hunt scenes or depictions of little fleets. As for the *Hedera* sp., Pliny tells us referring to Theophrastus, that it was imported from India by Alexandre the Great, consequently it was unknown in Italy as late as the year 440 after the foundation but this opinion seems not be supported by phytogeographicgal evidences. Pliny further makes a distinction between «forest trees» and «city trees» and the «ornamental trees» of gardens and parks. The less or more mysthic

Fig. 2 - The Cloaca Massima in 1988.

Kings of Rome (8-6 Centuries B.C.) cared for their gardens themselves, and in these gardens, besides fruit trees, there were green of many type: artichokes, cabbage, salad greens, cucumbers, pumphins, turnips, radishes, parsnips, various kinds of onions, red radishes, celery, wood sorrel, garlic, leeks, basil, spinach, mustard, fennel, coriander, poppies, marjoram, endive, curly hale, chickpeas, mint, and moreover, *Atriplex hortensis*, *Satureja hortensis*, *Lepidium sativum*, *Eruca sativa*, *Brassica rupestris* (These plants, if grown in graeter quality was required for sale in the windows of patrician homes.) – and flowers: violets, roses, lilies, saffron, *Helichrysum*, *Pulsatilla*, *Limonium*, *Centaurea cyanus*, *Vinca*, *Gladiolus*, hyacinths, and cyclamen were, according to Pliny, native plants, while the narcissus was imported. Many of the imported species, escaped from gardens, enticհed the synanthropic vegetation of ancient Rome.

The native mixed forest, composed of oaks, limetrees (*Tilia plathyphyllos*), hornbeams, maples such as *Acer campestre* and *A. monspessulanum* and other species mentioned above, shrank more and more as the city grew. Deforestation created space for buildings, roads, farms, pastures, and so on, and the timber harvested was used in construction and in ship-building (At the time of Scipio Africanus, in 199 B.C., the city had about 900.000 inhabitants; 171 years later, during the reign of Augustus, it had 1.336.680, although we are not sure whether slaves, of whom there were between one and four millions, were included in the census).

Nonetheless, little strips of the original forest were preserved in the gardens of the Roman plutocracy as places of holy cults (Ovid describes the wood of Asilio on the slops of Capitol, the wood of Vesta on the Palatine, the wood of Juno Lucina on the Esquiline). In Cicero's day, Pomponius Atticus had a villa on the Quirinal surrounded by a notable ancient forest which was probably a remnant of the woods on the Capitoline, since until Trajan's reign, the two hills were connected by a ridge which Trajan had knocked down in order to build the markets behind his forum (The Markets of Trajan). The city expanded not only because of population growth, but also because previous construction, and the resultant costs of demolition, made building in the city centre more expensive: thus Nero preferred to build his huge new palace, the Domus Aurea (Golden House) on the hitherto unsettled Oppian, where he could build a gigantic building, with hanging gardens, artifical lakes, enormous loggias, without the expense of demolition which would have been necessary in the centre.

The Romans made remarkable changes in the city's landscape. For instance, Tarquin built the Cloaca Maxima partly to complete the draining of the marshes in the valley occupied by the Forum (The Cloaca also served an hygienic purpose). The valley between the Palatine and the Aventine was deforested to make room for the Circus Maximus.

From the fall of the Empire on, (In 476 A.D., Rome had only 300.000 inhabitants). Rome was sacked several times by barbarians, and for many centuries thereafter, the inhabitants lived among the ruins of building, squares, roads, and acqueducts of Roman times. Some of these ruins were re-utilized as bases or material for buildings of the Middle Ages and the Renaissance. Others were leveled by the forces of decay, atmospheric agents, earthquakes, and plant cover, and became grasslands and pastures or gardens, orchards, and vineyards. In 1377, Rome had only 17.200 inhabitants.

Nor did the situation change much in the following centuries, even though some restoration projects were carried out. A kind of archaeological preservation went on in the gardens of some aristocratic families: in the Colonna's palace gardens on the Quirinal, first laid out in 1421, there were for instance preserved hypogea and a temple of the sun in a little wood. The plants growing on the historical walls and in their fissures were considered weeds and removed, but the wood, which may have contained remains of Pomponius Atticus's ancient wood, was left undisturbed. In 1527, the city had 33.000 inhabitants.

The wall vegetation of the city is influenced, as ANZALONE asserts (1951), by the differing possibilities offered by various wall types for plants to take root. In the 4th Century B.C., lime appears, and, from then on, the Romans built

Fig. 3 - The Porta Maggiore was the gate to the road to Praeneste (modernday Palestrina). The gate supported a tract of the Claudian aqueduct. The photos taken in 1864-66 show the walls covered by a rich vegetation composed mostly of *Rubus* bushes, fig-shrubs and in the fissures *Parietaria, Cymbalaria, Asplenium*, etc., and many caper-bushes of which the 'fruits» (the buds) has been harvested.

compact wall masses: in the beginning, from the 2nd Century B.C. to the time of Caesar, smooth on one side only, then, from the time of Caesar to the late Empire, in 'opus reticulatum' – regular blocks of tufa in oblique layers –. The Colosseum, for example, is made of 'opus quadrum' – large blocks of squared tufa or travertine, placed on top of each other without cementing material using only some lead cramps –. Brick was used to cover buildings» walls, but sometimes slabs of travertine or marble were used as covering means. Brick is easily broken down by plants, a process abetted by poor maintenance of monuments. Rock slabs are a type of wall-covering in which plants take root less easily.

Bibliographic data on urban flora in Rome

Records of the urban flora of Rome are included in many botanic works:

from the 16th Century sparce data in works by Bauhin, Gessner, Mattioli and other naturalists of Renaissance (see PIROTTA & CHIOVENDA, 1901), and in unpublished manuscripts of Ulisse Aldrovandi (University of Bologna);

from the 17th century, those of Tobia Aldini (P. Castelli) (1625), of Domenico Panaroli (1643), of Roggeri, – published by Donzelli (1697);

from the 18th, the «Agrostographia» of Johann Scheuchzer, written in 1718 but based on observations made in 1711, in wich the author notes 8 plant species on the walls of the Colosseum, the Baths of Caracalla and the Castel S. Angelo, and the manuscript «Itineraria Botanica» of Pietro Antonio Micheli, who visited Rome between 1708 and 1733 and noted 19 wall-growing plants on the Arch of Costantine, the Colosseum, and the basilica of S. Croce in Gerusalemme, among other monuments.

Jacques Barrelier (1714) notes the *Eragrostis barrellieri* among others in Rome. Plants living in Rome are described in many manuscripts (kept now in the Rome's Libraries), herbaria (for ex. Sabbati's, Triumphetti's, Audiffredi's, etc.) and cathalogues like that by Liberato Sabbati (1745) (for further information see PIROTTA & CHIOVENDA, 1901);

from the beginning of the 19th century on, (In 1815, Rome had 118.000 inhabitants, in 1870, 226.022) there are more precise reports on the plants at the monuments of Rome from scientific documents: Francesco Caetani (1803), by Sebastiani & Mauri (1818), by Maratti (1772 and 1822), Fiorini Mazzanti (1823 and 1828), and by Sanguinetti (1864), as well as the monographical works on the Colosseum by Sebastiani (1815), deakin (1873) and Fiorini-Mazzanti (1875-78) in addition, a number of literary sources, photographs, paintings and drawings.

Maratti's «Flora Romana» (wrote before 1777, published in 1822) which indicates 42 wall-growing species among 2276 taxa described in the whole work, found on the walls of the monuments, mainly the Colosseum, the Crypta Rubra, and the Thermae of Diocletian: Mauri (1820) considered most of these indications as scientifically unreliable.

Sebastiani and Mauri (1818), note 74 species growing on the walls among 1185 taxa described in total, of the major monuments (the Colosseum, the Thermae of Diocletian, the Castrum Praetorium, the Porta S. Pancrazio, St. Peter's, and so forth).

Mauri (1820) indicates 8 wall-growing species among 100 taxa, and ANZALONE (1951) confirms 2 of this 8.

Fiorini-Mazzanti (1823, 1828) adds 100 wall-growing species to those described by Sebastiani and Mauri.

Sanguinetti (1837) among 300 taxa notes 2 wall-plants; 27 years later, in 1864, in his «Florae romanae prodromus alter», he notes 118 wall-growing species (of which Anzalone confirms 73) among 2284 taxa.

While all for these works despite their titles concerned not only the flora of the city of Rome but that of the present day province and more, the monographs about the flora of the Colosseum are concerned exclusively with the local flora. The first of these was Panaroli's (1643) work and G.B. Triumfetti's unpubliched pamphlet, «Amphitheatralium Stirpium Catalogus» written in 1681-2 (See PIROTTA & CHIOVENDA, 1901); in 1815, Sebastiani published his «Romanarum Plantarum Accedit Enumeratio Plantarum Amphitheatri Flavii» listing 261 species, of which Anzalone confirms 6. Deakin in his «Flora of the Colosseum of Rome» (1855) describes 510 taxa. Fiorini-Mazzanti (1875-8) lists 338 taxa in the Colosseum, including mosses, lichens, and fungi (Of the higher plant species Anzalone confirms 35). Cortesi and Senni (1896) describe 100 species on the Roman monuments other than the Colosseum (Of which Anzalone confirms 35).

In interpreting the great difference between the plants described by the above authors and those confirmed by modern observation (Anzalone), one should not rush to use ecological explanation: first of all, one must consider that many species cited by those authors can not be identified with current taxa due to the lack of precise descriptions or ambiguous synonyms, and that furthermore these authors made misidentifications and mistakes confusing subspecies and other inferior taxa with species which greatly diminish the number of species described. Furthermore one must remember that many of the wall-plants (muricole), unless we are told specifically of their where abouts, may have been noted outside of Rome. ANZALONE (1951) notes 385 wall-growing species of which he found 115 described by nineteenth-century authors. He was unable to confirm 24 entities found in bibliographical sources. This may be due to the fact that, as a result of preservation and maintenance projects, many monuments and tourist sites (see below) are currently cleared of vegetation but were not so cleared in the 19th century.

Photographic documents on urban flora in Rome

Photographic documents offer us the posibility of comparing the mass of wall vegetation:

Fig. 4 - The Arco di Druso taken in 1867-68 covered by a rich vegetation.

– 2 photos of the mouth of the Cloaca Maxima (and the Temple of Vesta), one taken by R. Eaton in about 1855 and the other taken in about 1860 (*Ferula, Rubus, Rhamnus, Parietaria, Ficus* species can be recognized), (fig. 1 and 2);
– a photo of the Porta Maggiore, which while serving as a gate, also suported a tract of the Claudian aqueduct. The photo, taken between 1864-1866, shows the walls covered by a rich vegetation, consisting mainly of *Rubus* bushes, fig shrubs, and, in the fissures, *Parietaria, Cymbalaria, Asplenium, Capparis*, and so forth (fig. 3);
– a photo of the Arch of Drusus taken in 1867-1868 which shows the arc covered by a rich vegetation, consisting mainly of *Capparis inermis, Rubus ulmifolius, Phagnalon sordidum, Sedum nicaeense, (Fig. 4 and 5).*

At the time photographs were taken, the city did not yet have modern sewage or drainage systems. Horses and other domestic animals passed continually through the unpaved streets. Domestic waste was thrown on the fields and gardens in the city. These factors contributed to widespread and continuous «manuring» of the ruderal and wall vegetation which, consequently, must have been richer that it is at present. The present vegetation

Fig. 5 - The Arco di Druso in 1988 (no wall vegetation because of the weed-control).

as shown in the photos taken in 1987-88 of the same subjects of the historical photos could be influenced by the following:

- the lack of «manuring» (see above);
- the maintenance of Rome's historical monuments by the city government and the Ministry of Cultural Heritage. In fact, Anzalone noted in 1951, «Another obstacle to my research is the periodic clearings to which many of Rome's monuments are subjected. At least once a year, the vegetation which covers the most frequented monuments is removed»;
- pollution.

We might suppose that given these problems, the ruderal and wall vegetation of Rome would be lesser today that it was in 1860's.

In fact a comparison of photographic documents indicates that where no weed-control or maintenance is carried out, – on the mouth of the Cloaca Maxima, or the walls of the Porta Maggiore – the vegetation is as rich as it was a century ago. On the other hand, where the monuments are «weed-controlled», the vegetation consists, by necessity, only of annual plants which after the monuments have been cleared return to the walls quickly and create a vegetation which is changed only in that those plants sensitive to such treatment have disappeared. No doubt, this process explains the disappearance of some of the wall plants described in the 19th century.

Certainly, pollution is also a limiting factor but, from our photographic comparison, it seems to limit only the flora and not the vegetation (In fact, the list of present flora is much impoverished). Atmospheric pollution (The ENEA – The National Bureau of Alternative Energy – measured 60 microgr/m3 of atmospheric pollution at the south of the city and 70 microgr/m3 in the city-centre in 1988) has encouraged the expansion of less sensitive species, a list of which we could extract from a comparison of bibliographical data with recent censi; in fact, a comparison of the 19th century plant lists with the wall vegetation found on the «untreated» monuments is the only reasonable source for ecological deductions, i.e. for deductions about which plants are sensitive to the effects of modern urban expansion. None of the places taken over by urbanization in the last century offers us the same advantage. Many place have been bare of vegetation for many decades as a result of urban expansion. And in the city many of the squares which once had a rich ruderal vegetation as a result of their traditional pavements have no vegetation now both because well-cared for asphalt leaves no room for plant life and because of the effects of automobile traffic, such as oil and carburator fluid run-off.

Among ecological factors, we must also consider the fact that Rome is an island of urban heat, like every metropolis: the minimum winter temperature has risen since 1831, in relation to the growth of the city and its population. (In 1901, the population was 403.282, and the average winter temperature from 1831 to 1910 was 4,1 grC; while in 1971 the population was 2.356.490 and the average winter temperature in 1964-1975 had risen to 5,7 grC) From 1831 to 1910, there was almost no home heating in the city and no automobile traffic, while today every home, office, and store is heated, and the thermal effect of this heating is multipled by the city's automobile trafic.

The heat and pollution, or rather filth, attract certain species of animals. Beyond rats, we could cite the explosion of the Starling population, so noticeable in winter in places such as Piazza dei Cinquecento and Piazza Indipendenza. Some populations could also explode as a result of a lack of predators.

In on the one hand, the city's flora has been unpoverished, on the other hand, the planting of ornamental trees frequently of exotic species (Gilii wrote about the earliest introduction of some exotic plants among them *Broussonetia papiryfera* Vent. which Cardinal Doria introduced in 1784 and which was noted in the city between 1949 and 1951 by Anzalone, Cacciato, and Montelucci) and hybrid or exotic shrubs can enrich the ruderal and wall vegetation. Of course, these species could also compete with the just present vegetation.

Riassunto

Le fotografie riprese verso la metà del secolo scorso su monumenti romani mostrano una ricca vegetazione murale. Il confronto tra questa vegetazione e quella attuale completato da un esame dei dati bibliografici sulla flora dall'epoche storiche fino ad oggi può dare indicazioni sui cambiamenti ecologici urbani. Monumenti regolarmente mantenuti (con regolare diserbo) come il Colosseo danno risultati poco indicative mentre altri siti meno curate (p.e. Porta Maggiore) mostrano una vegetazione muricola relativamente folta tanto sulle foto fatte nel 1860 quanto su quelle attuali. Cambiamenti emergono piuttosto dalla flora che è in parte impoverita e in parte cambiata per l'entrata di specie esotiche alla flora locale.

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Tree roots and hypogean conservation

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Keywords: Tree roots, root damages, vegetation management, hypogean monument conservation.

Abstract

The problem of the growth of tree roots in archaeological areas is analysed in relation to the conservation of hypogeous monuments. A collection of data on the frequency of root penetration into underground walls of monuments in Rome and their capacity to grow in depth is presented. Other observations of this phenomenon, especially in tombs (Etruscan necropolises in Tarquinia and Chiusi) and catacombs are mentioned.

Some species such as *Pinus pinea, Pinus roxburgii, Quercus ilex*, etc. proved to be dangerous for underground constructions, because of the extension of their root biomass.

On the basis of this study and of a critical analysis of the literature, a methodology is proposed for studying these kinds of alterations.

Indications for avoiding them, especially through correct planning of vegetation in archaeological areas, are given.

Introduction

In archaeological areas root growth can be dangerous for the conservation of historic structures not only owing to the presence of vegetation on wall and floor structures, but also owing to the overly close occurrence of trees. It is indeed known that the roots of woody plants can reach a considerable lateral and vertical extension, thus seriously destabilizing structures which obstruct their path.

The damage caused to the foundation of buildings by tree roots is well documented in the literature, especially in clayey soils (BOZOZUK, BURN, 1960; BOZOZUK, 1962; LEGGET, CRAWFORD, 1965; BURN, 1973; CUTTLER, 1974; KELSEY, 1977; BIDDLE, 1979; COUTTS, 1979; FLORA, 1979; PRYKE, 1979; REECE, 1979; CUTTLER, RICHARDSON, 1981). In these soils the presence of absorbing roots creates imbalances in volume owing to the swelling-contraction of the clay, which can seriously compromise the stability of foundations. Moreover, in these cases damage can also occur at a considerable distance from the trees.

Also cited in the literature, and well known to all of us, are cases of damage to street pavements which often derive from a mistaken choice of tree species planted in asphyxial and unsuitable soils.

We should also mention damage entailed by the blockage of sewers, and that caused to canals and dams (OPPENHEIMER, 1954, 1957; BURA, 1970).

Less is instead known about the in-depth growth of tree roots and interaction with hypogeous structures. This phenomenon is of importance in archaeological areas where underground constructions are found, either owing to original projects (e.g. tombs, catacombs, mithraic temples), or to historical developments (e.g. partial distruction of buildings and covering with earth).

In densely constructed urban areas this problem is of obvious importance in the construction of underground parking areas, metropolitan transport systems, etc.

Damage caused by vegetation in hypogeous archaeological areas is reported for the Etruscan tombs of Tarquinia (CESARI, ROSSI, 1972; I.C.R. communication, 1972) and Chiusi (VLAD BORELLI, 1954), or in the case of various Roman hypogeous structures (CANEVA, 1985, in press).

It is interesting to note that in the case of Tarquinia (thickness of overlying soil = 2.5 m circa) the vaults of the Etruscan tombs (Cardarelli, Bartoccini, Guerriero, Giocolieri, Auguri, Leonesse, etc.) were even perforated by herbaceous vegetation. Since woody plants were absent, the identification of the species responsible for the alteration was achieved on the basis of a simple examination of the overlying vegetation (which in fact does not always bring sure results - in this case the species found were *Scolymus hispanicus* L. and *Lupsia galactites* O. Kuntze; cfr. CESARI, ROSSI, 1972), or on the basis of results obtained after meristematic culture of the root apexes (leading in this case to the identification of *Reseda lutea* v.

mucronata by Prof. Tripodi, Botanical Institute Naples; I.C.R. communication, 1972). In this case the roots had reached the frescos via prospecting holes, or through the dromos area, clearly exploiting the zones in which the soil offered the least resistance.

In the case of the necropolis of Chiusi, damage was caused by the ill-advised planting of a specimen of *Pinus pinea* directly over the tomb (tomb of the Colli). The expansion of the roots caused the frescos to become completely detached, so obliging their removal. In this instance the planting of the tree, performed by the owner of the land, was intended to indicate the location of the tomb; this is a common practice in the area and does not take into consideration the future expansion of the root biomass.

In previous cases reported by the writer, the stress way laid in a general manner on the role of vegetation in the decay of wall structures, examining both the problem of the vegetation on the outcropping structures, as well as the problem of the occurrence of trees as concerns the conservation of hypogeans. In regard to the latter issue the methodological aspects of investigation were examined and a summary of data reported. A detailed evaluation of this problem was only treated in the analysis of the relation between the vegetation of the Orti Farnesiani on the Palatine and the underlying structure of the *Domus Tiberiana* (CANEVA, 1985).

In the present paper the already proposed methodological approach is again adopted and expanded, and the data of the various cases are analytically reported.

It should also be borne in mind that in two other cases damage caused by vegetation in archaeological areas was mentioned by several authors in various countries (DELVERT, 1963; FUSEY, HYVERT, 1964; KARSCHON et al., 1976; LOPEZ COLLADO, 1976; GOELDNER, 1984; WARNOCK et al., 1985), but essentially concerned the problem of infesting or ruin specific vegetation found on wall structures. In these cases the destructive role of the vegetation growing on constructions was described, but little attention was paid to the interaction between roots and underground structures.

Study methodology

A scientific approach to this type of problem must, in the first place, identify of the causes of the alteration, i.e. the species to which the roots collected belong. It must then evaluate the future evolution of the situation, and finally must propose, as an applied measure; a botanical project consistent with conservation requirements.

A previously proposed study methodology for the identification of the roots responsible for damage was based on the anatomic characteristics of the root wood (CUTLER, 1974). It must be remembered that the wood of roots often shows different anatomic characteristics from those of the trunk, so identification is frequently difficult and limited to the family. In some cases, colour and structural particularities of the cortex and the phelloderm were found to be of great diagnostic value (OPPENHEIMER, 1957).

A tree root survey has also been proposed by the Royal Botanical Garden in Kew (CUTTLER, 1974; CUTTLER, RICHARDSON, 1981).

The scheme proposed here represents a useful means for data collection, and is essentially suited to cases of isolated damage. In more complex situations, such as archaeological areas, it may be preferable to use different systems of data collection and information organization.

This study methodology, already proposed (CANEVA, 1985), is divided into four phases which are illustrated below.

1. *Vegetation collection* (field phase)

hypogeous environment	epigeous environment
– check for root presence – cartographic position of outcropping areas – root collection (if possible woody)	– floristic survey of overlying vegetation – cartographic position of tree and shrubs species

It should be noted that in large environments, where a through inspection could be too lengthy, the choice of the area to be checked can be made in terms of the relation between epigeous and hypogeous situations, thus identifying more critical areas on the basis of the overlying tree cover.

2. *Identification of the spcies responsible for damage* (laboratory phase)

woody roots	nonwoody roots (if necessary)
– cut thin sections based on fundamental plans – identification based on wood anatomy	– merismatic growth of root apexes

It is preferable always to collect woody roots, and possibly at a more advanced age, in order to make identification on the basis of anatomy easier. Meristema culture can be limited to cases where no woody roots are found, since it is then clear that they belong to herbaceous plants.

Tab. 1

ROMAN HYPOGEAN MONUMENTS ANALYSED	Presence of roots
1 Domus aurea (Oppius hill)	**
2 Seven sales (Oppius hill)	*
3 Nymphaeum of Nero (Oppius hill)	
4 Nymphaeum at Annibaldi street	
5 Domus Tiberiana (Horti Farnesiani)	**
6 Gryphons house (Palatinus hill)	*
7 Crypt of St.Bonaventura (Palatinus hill)	*
8 Beauty house (Laventinus hill)	-
9 Dolocoenum in St. Domenico street (Laventinus hill)	***
10 Decian Therms (Laventinus hill)	-
11 Tomb of the Scipioni (Appia street)	*
12 Mausoleum of Lucilius Petus (Salaria street)	*
13 Tomb of the Nasoni (Flaminia street)	*

* localised presence of damages

** presence of damages

*** high lesions

\- absence of roots

3. *Determine the potential risk* (documentation phase)

Based on the literature, estimate the expansion potential of the roots of the species found, applying the principal variables to the cases considered. Aside from the type of species, the following must be established for the various individuals found:

– age (based on historical documentation or eventual drill);
– vigor and health;
– possible gardening and maintenance intervention, e.g. pruning.

As concerns the environmental conditions of the site evaluation must be made of:

– soil thickness between hypogean and overlying ground level;
– type of soil;
– average climatic conditions.

It should be noted that danger for the conservation of a hypogean located under a tree also arises in relation to the biomass itself, particularly weight, which in some cases is of several tons, concentrated on a limited surface area (in this case roots have a positive role in that they help distribute the weight).

4. *Indication of action aiming to safeguard hypogeous structures* (Processing phase)

Estimate the best type of intervention on plants:

– pruning
– removal
– felling
– transplant to pots

Evaluation of environment modification, and works aiming to consolidate and waterproof archaeological structures.

Further complications arise when the overlying vegetation has naturalistic or historical value, as often occurs in these cases, so that consideration also has to be given to this aspect, in order to arrive at the best compromise solution possible.

A scheme is thus proposed which is useful in the field phase and the successive ones of processing and documentation, with the ultimate aim of planning intervention.

Experimental examples

The data are provided for some cases studied in the city of Rome (Tab. 1) which represent only a part of the city's enormous underground archaeological patrimony. Among these cases two typical ones were chosen as representative of different situations which pose the problem of correct vegetational planning:

– *Domus Aurea Neronis* (a large hypogean situated under a public park with localized presence and serious root damage);
– *Dolocoenum* in S. Domenico Street (small hypogean, situated under an public city street with thin overlying soil and extremely severe tree root damage).

Domus Aurea

The archaeological complex of the *Domus Aurea*, a vestige of the immense villa of Emperor Nero (1st century A.D.), represents one of the most important monuments of antiquity existing today. We limit ourselves to recalling that, by an irony of fate, its survival is linked to its burial by Emperor Trajan for the construction of his Thermae, that from antiquity obliterated its presence.

The systematic excavation of this complex began early in this century in order to remove the earth inside the rooms. Today it has an area of some 10,000 sq.m. and is situated below Trajan's Park on the Oppio Hill. The building of this park was realized in the years 1935-36 (only a few trees date to an earlier period).

Considering that the soil above the vault of the *Domus Aurea* is only between 2.5 and 3.5 m thick, the danger of root damage from trees is ob-

Tab. 2

Locality (Province and Common) Rome : Oppius hill - Thermae of Traian

Hypogean Domus Aurea Surfaces (mq) 10.000

Climatic characteristics Mediterranean humid (Emberger) mm of rain 729,1

Soil type soundy texture with high carbonatic content Soil depth (m) 3.5 - 4

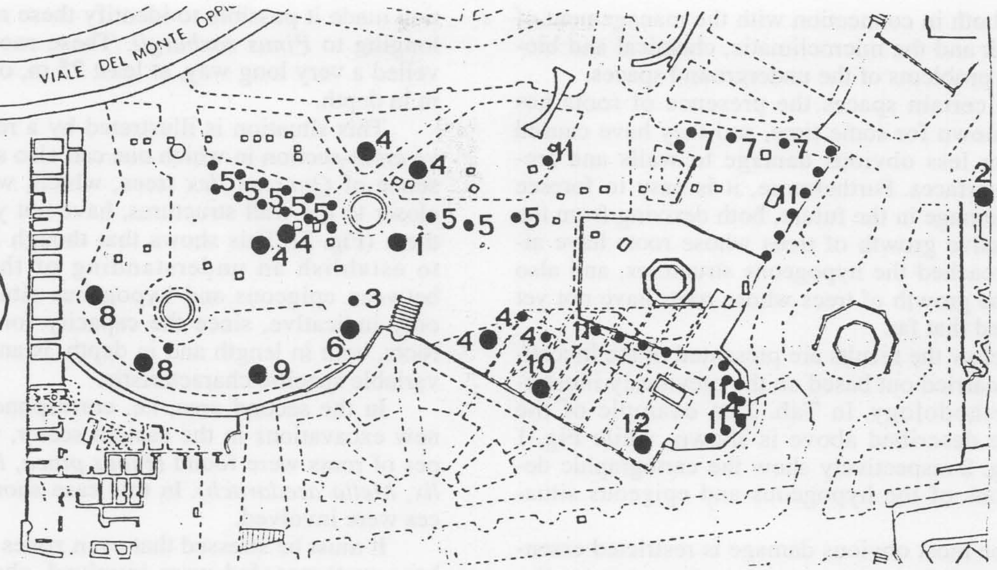
Cartographic releves (in addition) see FIG.1 and 2

Vegetation (floristic list)	Actual root presence	Future (hypot.) root presence	Roots Characteristics	Age (°)	Strenght	Hazard parameter
Pinus roxburgii Sarg.	+	+	extenses and deepth roots	89 (1898)	+++	+++
Pinus pinea L.	+	+	" "	68 (1919)	+++	+++
Pinus nigra Arnold	–	–	generally not deepth	++	++	+
Cedrus atlantica (Endl)Carr.	–	+	vigorous root system	+++	+++	+++
Melia azedarach L.	+	+	" "	30	++	++
Quercus ilex L.	–	+	" "	++/+++	+++	++
Robinia pseudoacacia L v. umbraculifera	–	–	superficial roots	+/++	+	+
Ulmus minor Miller	–	–/+	generally superficial roots	++	+	+
Prunus dulcis (Miller)D.A. Webb	–	–	superficial roots	+++	+	+
Phoenix canariensis Chabaud	+ (occasional)	+	" "	++	++	+
Laurus nobilis L.	–	–	generally not depth	+/++	++	+
Washingtonia robusta Wendl.	–	–	superficial roots	+++	++	+

Legenda + = low
++ = medium
+++ = high

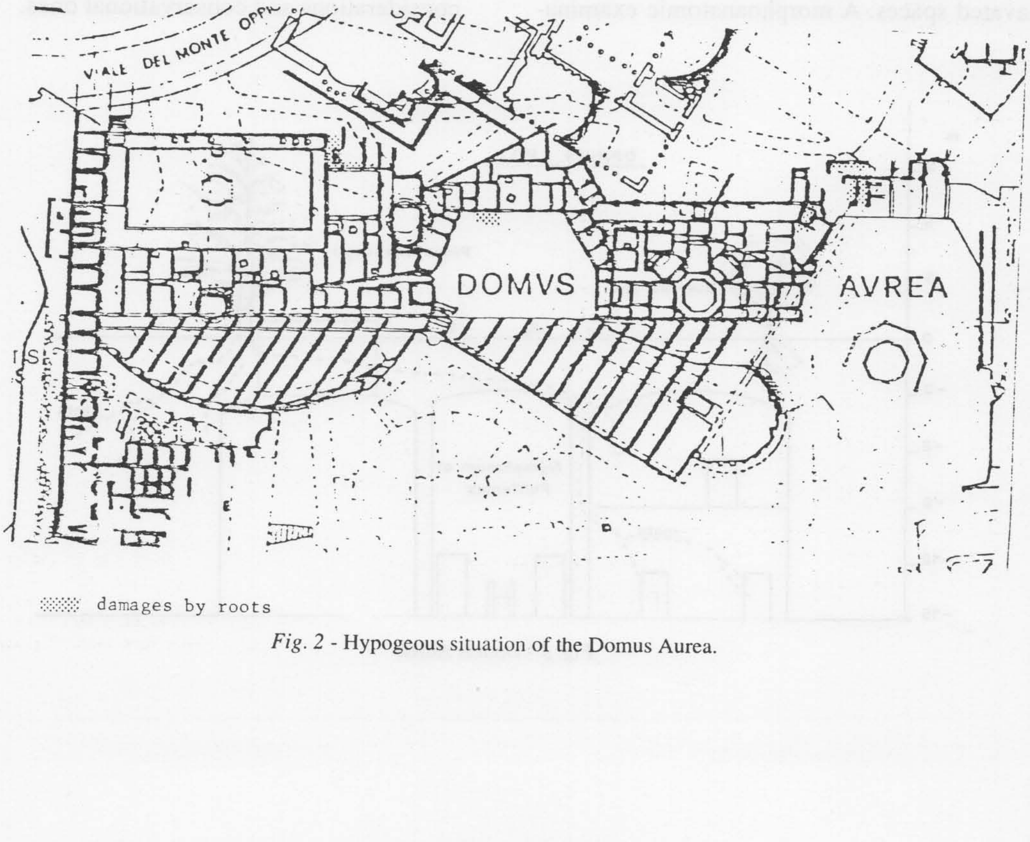
+ = presence / – absence

(°) The exact age is indicated when drills were made
+ = less than 20 years
++ = between 20 and 50 years
+++ = more than 50 years



1 = Pinus roxburgii Sarg. ; 2 = Pinus pinea L. ; 3 = Pinus nigra Arnold ; 4 Quercus ilex L. ; 5 = Robinia pseudoacacia L. v. umbraculifera ; 6 = Cedrus atlantica (Endl)Carr; 7 = Melia azedarach L. ; 8 = Ulmus minor Miller ; 9 = Prunus dulcis (Miller) D.A.Webb 10 = Phoenix canariensis Chabaud ; 11 = Laurus nobilis L. ; 12 Washingtonia robusta Wendl . (Shrubs species are omitted)

Fig. 1 Park of the Oppius hill.



damages by roots

Fig. 2 - Hypogeous situation of the Domus Aurea.

vious, both in connection with the management of the park and the microclimatic, chemical and biological problems of the underground spaces.

In certain spaces the presence of roots has been known for some time, and they have caused more or less obvious damage to walls and frescoed surfaces. Furthermore, it is easy to foresee more damage in the future, both deriving from the progressive growth of trees whose roots have already reached the hypogeous structures, and also from the growth of trees whose roots have not yet extended that far.

Below the results are presented of the investigation carried out based on the previously illustrated methodology. In Tab. 2 an example of the scheme described above is shown, while Fig. 1 and Fig. 2 respectively show the cartographic descriptions of the hypogeous and epigeous situations.

The most obvious damage is restricted essentially to two areas: one contiguous to the Nymphaeum of Polifemus and the other concerning new excavations in the eastern sector. In the first zone extensive damage is observed in a space recently excavated which is raised above the floor level of the other rooms. The breaking through of root apexes is also found almost at the floor level, even though not so extensively as to constitute a concern for the conservation of the walls. The presence of such root apexes, in fact, is found only in areas where are gaps in the constructed surface, i.e. in parts which are not connected with unexcavated spaces. A morphoanatomic examination made it possible to identify these roots as belonging to *Pinus roxburgii*. These roots had travelled a very long way, at least 25 m, of which 15 m in depth.

This situation is illustrated by a representative cross-section in which one can also see the presence of *Quercus ilex* trees, which, while being closer to the wall structures, have not yet reached them (Fig. 3). This shows that though it is useful to establish an understanding of the relation between epigeous and hypogeous situation, it is only indicative, since the capacity for growth of roots, both in length and in depth, is an extremely variable specific characteristic.

In the second area, i.e. corresponding to the new excavations in the eastern sector, various types of roots were found *(Pinus pinea, Hedera helix, Melia azedarach)*. In this case shorter distances were involved.

It must be stressed that even zones which had been waterproofed were involved, showing that such treatment does not constitute an effective barrier against roots. Finally, in the last zone, part of the foundations of the Thermae of Trajan (6th and 7th grottos), the sporadic occurrence was found of *Phoenix canariensis* roots, which had worked their way into cracks in the wall, utilizing of old Roman channels.

These findings, and consideration of the future evolution of the situation, point to the need for new botanical planning in the area, trying for now to establish a compromise between naturalistic considerations and conservational ones.

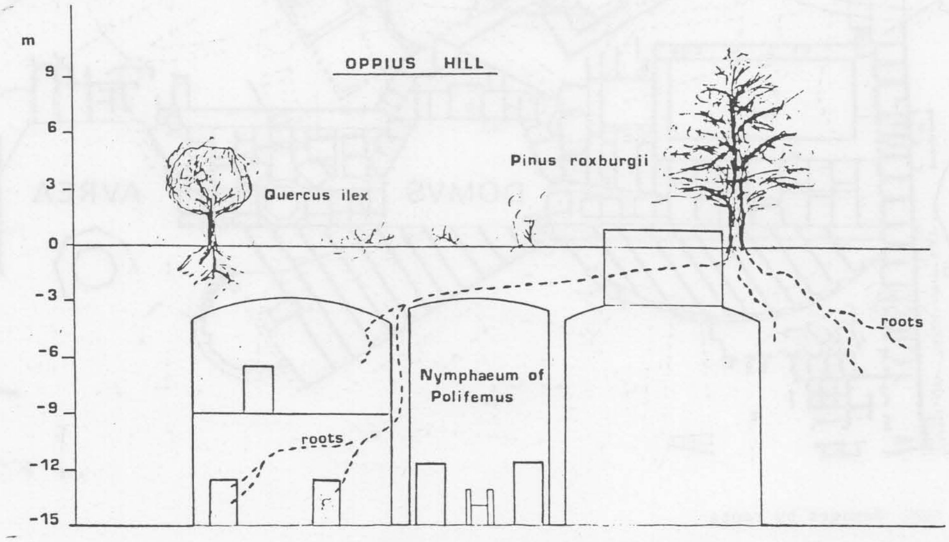


Fig. 3 - Domus Aurea

Dolocoenum in S. Domenico Street

These spaces represent the remains of a place of worship dating to the 2nd-3rd centuries A.D. All that exists today is the central space with two lateral rooms. Unfortunately the frescos present on the walls, have a decidedly poor state of conservation. In many areas the frescoed mortars show signs of bulging and detachment caused by the penetration of numerous tree roots.

Most of these roots are now decomposing, and hence their presence relates to the trees which lined the streets previously, namely *Robinia pseudoacacia*. They were replaced by the Garden Services with small specimens of *Quercus ilex*. As concerns the roots still in life, thin sections show that they are roots of *Pinus pinea*. Notwithstanding the small distance separating to street level from the ceiling of the *Dolocoenum* (1.6 m), the roots of the very young *Quercus ilex* trees have not yet penetrated through the wall structure.

A comparison between epi- and hypogeous situations shows that the trees lining the street are situated directly above the lateral spaces of the *Dolocoenum*. Moreover, within the contiguous school, various trees are present along the perimeter wall (*Pinus pinea, Laurus nobilis, Cupressus sempervirens, Cercis siliquastrum*). The occurrence if these tree species obviously is of less concern that of those lining the street, owing to the greater distance the roots would have to travel, not only in length but also in depth, considering that the base level within the perimeter wall is about 2.5 m higher as compared to that of the street.

For the future it is easy to foresee new damage from *Quercus ilex,* and to a lesser extent from *Pinus pinea*.

This case points out the lack of connection between the various administrative bodies which act on the territory with little knowledge of their reciprocal problems. It also documents the need to pay greater attention to the growth potential of roots.

Conclusion

This paper has aimed to show how the problem of root growth must be carefully evaluated whenever hypogeous structures are present in the area.

Unfortunately the literature on the topic is not yet sufficient to indicate which tree species are suited to correct botanical planning in this context. Very few publications deal with the problem of the root mass of tree species with exact data on the extension of root systems (GIORDANO E., 1968; LYR, HOFFMAN, 1967; PADULA M., 1968; ROBERTS, 1977). More detailed documentation only exists for plants of agricultural interest (e.g. MORETTINI, 1942; SPINA, 1966; STRABBIOLI, MANZO, 1981; BALDINI, 1986).

The presence of vegetation, obviously important from the landscaping and aesthetic standpoint, if properly selected, could have even a positive function for both outcropping and underground structures. This is because the roots can reduce the percolation of water in the subsoil, and restrict the formation of saline efflorescences. Generally this is achieved through the construction of waterproof barriers whose efficiency and duration in time often do not provide desired results.

The knowledge in this field is, however, incomplete, and it is hoped that our work can contribute to filling the gap. All the data these studies can constitute a kind of data bank to be integrated with specific studies on single species.

To that end, the existence of a study procedure will be an aid in creating uniformity in data collection.

The need for correct identification of roots must also be borne in mind, and not simply indications suggested by what seems logical on an empirical basis.

Unfortunately today nondestructive systems are lacking for the control of root expansion, with the exception of young plants which can be removed.

The isolation of the roots of a tree species from the rest of the soil, in order to limit excessive growth would first require excavation and then the construction of mechanical barriers which would be costly and have far from certain results. Nor is it conceivable in these cases to employ locally chemical products to inhibit growth, that was proposed in some cases (NAZER, CLARK, 1982), owing to obvious technical reasons. Pruning seems to be able to reduce root expansion, but does not ensure perfect containment.

The felling of trees responsible for damage is conditioned by an evaluation of the effective growth and penetration capacity of the roots (at times penetration can be accidental owing to interruption of wall structures or channels), and by the naturalistic importance of the species involved. Both of these factors – historic and naturalistic heritage – must be taken into account in deciding which of the two should take precedence in not easily reconciled cases.

Riassunto

Viene analizzato il problema della crescita delle radici degli alberi nelle aree archeologiche in relazione alla conservazione dei monumenti ipogei. Viene fornita una raccolta di dati sulla frequenza della penetrazione delle radici in monumenti romani sotterranei e sulla loro capacità di sviluppo in profondità.

Viene menzionato questo fenomeno relativamente al caso di tombe (es. le necropoli etrusche di Tarquinia e Chiusi) e di catacombe.

Alcune specie, quali *Pinus pinea, Pinus roxburgii, Quercus ilex,* etc. si sono mostrate dannose per le costruzioni sotterranee, a causa dello sviluppo della biomassa radicale.

Sulla base di questo studio e di un'analisi critica della letteratura, viene proposta una metodologia per studiare questo tipo di alterazione.

Vengono infine fornite alcune indicazioni per evitare questi problemi, soprattutto attraverso una corretta pianificazione della vegetazione nelle aree archeologiche.

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La phytotoponymie des Nuraghes en Sardaigne

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Keywords: Phytonims, Nuraghes, Sardinia.

Abstract

Sardinian nuraghes phytotoponimy. Plant-related names of nuraghes, about 7.000 prehistorical towers of Sardinia, are considered. Local phytonims occur in 345 cases and, among 93 different species identified, *Ficus carica, Olea sylvestris, Myrtus communis, Ulmus minor, Prunus domestica, Quercus suber, Ruscus aculeatus* are the most common.

Introduction

La toponomastique d'un territoire donne plusières d'informations sur l'histoire, la langue, les rapports de l'homme avec son milieu (PAULIS, 1988). Les études les plus valides a cet ègard sont realisés, sans doute, par les linguistes. Dans ce cas, l'intéret d'un botaniste pour cette discipline derive du grand nombre de phytotoponimes, environ 20.000, de la Sardaigne (CAMARDA, inédit) et encore, surtout, de la remarquable variabilité de noms des plantes attribués à la meme espèce, selon les différentes localités (COSSU, 1968; CAMARDA et VALSECCHI, 1983; CAMARDA 1986). L'étude des toponymes, liés au châtaigner et aux chenes, donne de motift de réflexion sur la repartition de ces espéces dans l'Iles dans le passé (ASOLE, 1950). J'ai trouvé interessante l'analyse de phytotoponimes dans la chaine calcaire du Monte Albo (CAMARDA, 1984) et dans le territoire de Dorgali, une ville de la Sardaigne centre-orientale (CAMARDA, inédit). Cette note, qui traite des toponymes des nuraghes, veut donner une contribution dans le domaine de la toponomastique sarde et, moi, j'espère, solleciter l'intéret des glottologues vers les plants qui donnent leur nom aux lieux, mais surtout souligner l'importance des plants dans ce domaine.

Discussion

Les Nuraghes sont des particulierès tours préhistoriques exclusives de l'ile de Sardaigne. Ils sont plus que 7.000 et sont répartis chez toutes les zones, du niveau de la mer jusqu'à 1.400 m l'altitude, et ils constituent une note special du paysage. La toponymie de l'Ile est trés riche en phytonimes et aussi parmi les nuraghes qui donnent le nom aux lieux on trouve souvent des noms de plants qui le désignent. L'analyse de tous les noms des nuraghes, en suivant PAULIS (1988), a permis de mettre en evidence les nombreux phytonymes (345) liés à ces tours et les résultats obténus on été syntétiquement résumés ici.

Tout d'abord on a verifié les villes et villages dont le territoire presente des nuraghes avec de noms de plantes, en les numérautant selon l'ordre alphabétique:

1 - Abbasanta
2 - Aidomaggiore
3 - Alghero
4 - Allai
5 - Anela
6 - Ardara
7 - Arzana
8 - Assolo
9 - Atzara
10 - Austis
11 - Baressa
12 - Barisardo
13 - Bauladu
14 - Baunei
15 - Benetutti
16 - Bessude
17 - Bolotana
18 - Bonarcado
19 - Bono
20 - Borone
21 - Bortigali
22 - Buddusò
23 - Burgos
24 - Busachi
25 - Cabras
26 - Castelsardo
27 - Chiaramonti
28 - Codrongianus
29 - Collinas
30 - Cuglieri
31 - Domus de Maria
32 - Dorgali
33 - Dualchi
34 - Escalaplano
35 - Escolca
36 - Esporlato
37 - Esterzili
38 - Florinas
39 - Fonni
40 - Gairo
41 - Galtellì
42 - Gavoi
43 - Genoni
44 - Genuri
45 - Gergei
46 - Gesico
47 - Gesturi
48 - Ghilarza
49 - Giave
50 - Giba
51 - Goni
52 - Gonnesa
53 - Gonnosnò
54 - Guasila
55 - Guspini
56 - Ilboro
57 - Illorai
58 - Irgoli
59 - Isili
60 - Ittiri
61 - Jerzu
62 - Laconi
63 - Laerru
64 - Lanusei
65 - Macomer
66 - Mamoiada
67 - Mandas
68 - Mara
69 - Maracalagonis
70 - Martis
71 - Masullas
72 - Meana sardo
73 - Milis
74 - Mogorella
75 - Mogoro
76 - Mores
77 - Morgongiori
78 - Muravera
79 - Noragugumene
80 - Norbello

81 - Nulvi
82 - Nuragus
83 - Nurallao
84 - Nureci
85 - Nurri
86 - Nuxis
87 - Olmedo
88 - Oniferi
89 - Orani
90 - Orgosolo
91 - Oristano
92 - Orosei
93 - Orroli
94 - Ortacesus
95 - Ortueri
96 - Oschiri
97 - Osidda
98 - Osilo
99 - Osini
100 - Ossi
101 - Ottana
102 - Pzieri
103 - Pabillonis
104 - Padria
105 - Pattada
106 - Paulilatino
107 - Perfugas
108 - Ploaghe
109 - Pozzomaggiore
110 - Quartu S. Elena
111 - Samugheo
112 - San Basilio
113 - San Nicolò Arcidano
114 - San Vero Milis
116 - San Vito
117 - Sanluri
117 - Sant'Andrea Priu
118 - Sant'Antioco
119 - Santadi
120 - Santulussurgiu
121 - Sardara
122 - Sarroch
123 - Sassari
124 - Scano Montiferro
125 - Sedilo
126 - Sedini
127 - Semestene
128 - Seneghe
129 - Senorbì
130 - Serbariu
131 - Seui
132 - Siamanna-Siapiccia
133 - Siddi
134 - Silanus
135 - Siligo
136 - Sindia
137 - Sinnai
138 - Solarussa
139 - Sorgono
140 - Sorradile
141 - Suni
142 - Tadasuni
143 - Talana
144 - Tempio
145 - Tertenia
146 - Teti
147 - Teulada
148 - Thiesi
149 - Torpé
150 - Tortolì
151 - Tresnuraghes
152 - Triei
153 - Tula
154 - Ula Tirso
155 - Uras
156 - Uri
157 - Usellus
158 - Usini
159 - Ussaramanna
160 - Villagrande Strisaili
161 - Villamar
162 - Villanova Monteleone
163 - Villanovaforru
164 - Vilaputzu
165 - Villaurbana

Il y a donc plus que la moitié des centres de la Sardaigne, qui dans leur territoire includent des nuraghes nommés par un'espèce végétale.

Voilà maintenant l'énumération des espèces suivies par les phytonimes (c'est à dire le nom vernaculair des espèces) des nuraghes et par le numéro de la ville ou du village. Tous les noms sardes des plantes son précédés par le terme «*Nuraghe, Nurake* ou *Nuraxi*».

Allium ampeloprasum: *Porru - 30;*
Allium triquetrum: *Appara - 30;*
Alnus glutinosa: *S'Alinu - 38, Alinoe - 58, Funtana Alinus - 80, Alinedu - 146;*
Amygdalus communis: *Pranu e Mendula - 47, Mendula - 76, Mendula - 164, Bau Mendula - 164;*
Anagyris foetida: *Silimba - 14, Della Giorba - 3, Siliqua - 67, Tilibbas - 149, Mori Siliqua - 163;*
Arbutus unedo: *Genna Olidone - 14, Tuppa Lidone - 88;*
Artemisia arborescens: *Su Sensu - 11, Su Senzu - 53, Su Sensu - 71, Attetu - 89, Attentu - 108, Senzu - 119, Attentu - 156, Su Senzu - 159;*
Arundo donax: *De Cannas - 17, Cannas - 45, Cannas - 62, Sa Canna - 64, Cannalza - 81, Cannas - 94, Cannedu - 108, Cannarza - 108, Cannalza - 126, Utturos de Canna - 135, Sa Cannera - 145, Dessa Canna - 147;*
Asphodelus microcarpus: *Arbutzu - 61, Arbuzzo - 71, Arbutzu - 145, Corru e Trebuzzu - 150;*
Calycotone villosa: *De sa Tiria - 145;*
Carduus sp.: *Corruardu - 29, Su Gardu - 41, Baldosa 81, Pardu - 83, Carducca 106, Corruardu - 133, Cardaxiu - 115;*
Carlina corymbosa: *Spinalva - 70, Spinalva - 96, Spinarba - 114;*
Celtis australis: *Suarzeda - 48, Surzagas - 106, Mura Surzagas - 106, Mura Surzagos - 120, Mura Surzagas - 125, Surzase - 160;*
Ceratonia siliqua: *Silimba - 14, Siliqua - 110;*
Chamaerops humilis: *Palmavera - 3, Sa Pramma - 32;*
Clematis cirrhosa: *Esterzu 64, Bintirissos 85, Bidichinzos - 104, Su Idichinzu - 106, Sterzu - 154;*
Clematis vitalba: *Atzara - 106, Baccu Arzula - 150;*
Cistus sp.: *Mudegu/Murdegu - 75;*
Crataegus monogyna: *Calavrichedu - 125, Calavrigus - 145;*
Crocus minimus: *Zafferano - 147;*
Cynara cardunculus: *Su Reu - 69, Cuili Gureu - 164;*
Daphne gnidium: *Truiscedu - 80, Truiscu 80, Ziu Truiscu - 82;*
Daucus carota: *Aiga - 1;*
Erica scoparia: *Scovera - 18, S'Iscopa - 88, Tuvurunaghe - 60, Tuvaru - 133, Iscobalzu - 97, Iscova - 140;*
Eryngium campestre: *Peicani - 122;*
Euphorbia characias: *Sa Mandra de sa Lua - 3, Lua - 7, Luas - 74, De Lua - 145, Lua - 162, Perda su Luaxiu - 164, Uluedu - 164;*
Euphorbia cupanii: *Su Luargiu - 32, Launessi - 54;*
Euonymus europaeus: *Boladigas - 125;*
Ferula communis: *Ferula - 5, Ferulas 19, Ferulaghe - 65, Feruledu - 49, Erulas - 101, Erula - 107, Feurredu - 132, Feurra - 161;*
Ficus carica: *Fighera - 3, Figughia/Figuchia - 6, Monte Figu - 8, Crabia - 13, Mura Figus - 13, Figu - 17, Mura e Figu - 18, Sa Mura sa Figu - 18, Su Fogu - 20, Sa Mura sa Figu - 20, Figu Niedda - 23, Figu de Cara - 25, Sa Figu - 38, Figu - 49, Figus - 52, Crabione - 60, Sa Figu -*

60, Figados - 65, Figu Niedda - 65, Figu Ranchida 65, Figu Niedda - 78, Figu Pinta - 81, Figu - 91, Figu Chia - 107, Su Crabione - 107, Figaru - 108, Figosu - 108, Figurassa - 113, Sa vigu - 115, Figu Ranchida - 124, Figu - 152;
***Foeniculum vulgare:** Fenugu - 2, Frenugarzu - 21, Fenugu - 74, Badu Fenuju - 127, Banghienuargiu - 128, Fenuga - 129, Fenuju - 157;*
***Fraxinus ornus:** Frassina 107;*
***Fraxinus oxycarpa:** Sa Pala de su Frassu - 108, Frassu - 119;*
***Genista sp.:** Sa sorighina - 18, Sorighina - 153;*
***Hedera helix:** Giada Edra - 21, Edra - 23, Era - 72, S'Ederosu - 88, Pranu Edere - 106;*
***Helminthia echioides:** Isteccori - 10;*
***Holoschoenus romanus:** Sussuni - 43, Li Sessini - 81, Sessini - 106, Sessini - 119;*
***Ilex aquifolium:** Olostru - 57;*
***Juglans regia:** Scala Nughes - 104, Nughe - 126;*
***Juniperus sp.;** Sinipei - 84, Sinibridaxiu - 86;*
***Laurus nobilis:** Lavredu - 65, Savruezzu - 107, Cantaru de Laros - 108, Mura Lavros - 120;*
***Lavatera olbia:** Norba - 51, Sa Narba - 59, Monte Narbeddu - 115;*
***Lycium europaeum:** Pruna Cristi - 122;*
***Lilium sp.:** Frontelizzos - 2, Ligios - 9, Liggiu - 24, Su Lizzu 27, Truncu Lillu 35, Mura e Lizzos - 109, De su Lillu 110, Lilloi 114;*
***Linum usitatissimum:** Scala e Linus - 24, Su Linu - 46;*
***Myrtus communis:** Murtas nieddas - 46, Murtas - 67, Pedra e Multa - 69, Murtas 84, Murtas - 88, Sa Murta - 115, Sa Murta - 128, Murta arba - 145;*
***Malus domestica:** Sa Mela - 7, Melas 55, De sas Melas - 66, Badu e mela - 109, Melas - 114, Melas 125, Melas 165;*

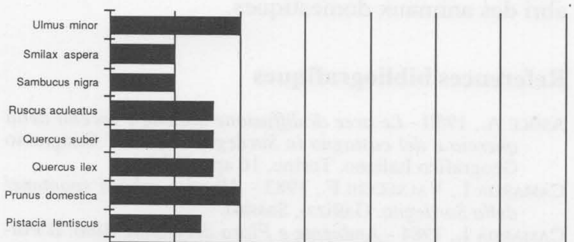

Fig. 1 - Espèces les plus réprésentées (en valeur absolue) parmi les phytonimens des Nuraghes.

***Mentha sp.:** Sa Menta - 134;*
***Nasturtium officinale:** Giuspiu - 28, Mantuzzu - 72;*
***Nerium oleander:** Leonai - 95, Lionagi - 145;*
***Olea sativa:** S'Ulivera - 33, Olia - 83, Mura Olia - 106, S'Ulia - 109, Uliana - 149;*
***Olea sylvestris:** Ozastru - 6, Ozastru - 16, Oddastra - 22, Ollastu - 25, Ozzastru - 28, Solastu - 64, Pranu Ollastus 75, Pranu d'Ollastu - 84, Corti Oliastu - 85, Serra s'Ozzastru - 101, Sos Olieddos - 106, Concas de Ozzastru - 108, Ozzastru - 128, S'Ollastu ventosu - 131, Ozzastru - 162;*
***Papaver (roheas?):** Oratanda - 30;*
***Phillyrea latifolia:** Arrideli - 77, Aladerru - 109, S'aridelauiu - 115, S'Arrideli - 137;*
***Phragmites australis:** Cannisones - 16, Cannixeddu - 64;*
***Pistacia terebinthus:** Soperis - 37;*
***Pistacia lentiscus:** Lestincos 48, Stincoddi - 51, Arzola e Chessa - 57, Modditzi - 78, Sa Chessa - 114, Iscala Chessa - 135, Sa Chessa - 141;*
***Pisum elatius:** Cixiri - 119;*
***Populus alba:** Arbiarbu - 48, Pibilìa - 15, Arburi/Arbari - 128;*
***Prunus armeniaca:** Piricoccu - 115;*
***Prunus avium:** Cilixia - 43, Sas Cariasas - 65;*
***Prunus domestica:** Prunas 4, Sa Pruna - 5, Pruna - 18, Prunu - 18, Prunas - 24, Prunas - 58, Prunas - 65, Sa Pruna - 106, Ena e sa Pruna - 108, Pruna 118;*
***Prunus spinosa:** Annaju - 108, Su Annaju - 136;*
***Pteridium aquilinum:** Sa Coa Filigosa - 17, Filighe - 65, santo Filighe - 134, E Filighe 158;*
***Pyrus amygdaliformis:** Su Piru - 33, Pirasta - 69;*
***Pyrus communis:** Is Piras - 50, Piranseri - 56, Piremau - 61, Piradolta - 97, Piredu - 101, Pira 105, Mulinu e Pera - 106, Piraferta - 106,*

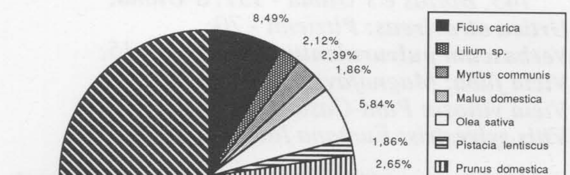

Fig. 2 - Valeur en pourcentage des espèces les plus réprésentées parmi les phytonimes des Nuraghes.

Pierdu - 108, Pirarba - 111, Piras - 115, Pireddas - 119, Pirosu - 130, Genna Pira - 145;
Quercus ilex: *Genna illighi - 4, Mura elighe - 21, Elighìa - 27, S'Elighe - 87, Elighe Onna - 120, Eligosu - 134, Elighe - 136, Ilixi - 157;*
Quercus congesta: *Chercu - 6, Crechu - 18;*
Quercus pubescens: *Funtana Crecu - 18, Orrolo - 97, Crecu - 139, Crecos - 139;*
Quercus suber: *Suerzu - 20, Suergiu - 25, De su Urtija - 23, Suergiu - 46, Gherdone - 58, S'Ortigosu - 65, Badde Suergiu - 101, Suelzu - 102;*
Rhamnus alaternus: *Tasarus - 82, Su Tasaru - 115;*
Rosa canina: *de Rosa - 27, Badde Olostru - 108;*
Rosmarinus officinalis: *Zippiri - 31, Su Zippiri - 147;*
Rubus ulmifolius: *Pranu e ruos - 21, Orrui - 42;*
Ruscus aculeatus: *Vrusciu - 6, Vruscu - 8, Vruschiosu - 23, Vruschiosu - 36, Vruscu - 43, Su Vrusciu - 135, Fruscos - 106, Fruscittu - 123;*
Ruta chalepensis: *Sa Ruda - 25;*
Salicornia sp.: *Sassoini - 8;*
Salix alba: *Salighes - 30, Salighentosa - 68, Tanca salighes - 136;*
Salix atrocinerea: *Sa Toa - 23, Sa Toa - 27, Sa Toa - 57;*
Sambucus nigra: *Samuccu - 99, Su Saucce - 105, Sauccos - 108, Mura sauccu - 65, De su Sauccu;*
Senecio vulgaris: *Predufeghe - 20*
Smilax aspera: *Tetti - 27, Su Tione - 36, Tetti - 102, Tettinosa - 107, Tetti - 108;*
Smyrnium olusatrum: *Livandru/Livrandu - 18, Lisandru - 62;*
Solanum nigrum: *Margarida - 109;*
Tamarix sp.: *Tomarittu - 98;*
Taxus baccata (?): *L'Eni - 26*
Typha latifolia: *Genna Uda - 8, De Tutturu - 58, Ispadula - 89, Monte Uda - 94;*
Ulmus minor: *Ulmos - 2, S'Ulumu - 32, Is Ulmus - 50, Sa Mura e s'Ulimu - 134, Ulumedu - 141, S'Ena de sos Ilimos - 141, S'Ulimu/Ulumu - 145, Binzas e s'Ulimu - 151, S'Ulimu;*
Urtica atrovirens: *Pitzienti - 70;*
Verbascum pulvurulentum: *Torodda - 15;*
Vicia faba: *Magnafave;*
Vicia villosa: *Pani-Casu - 50;*
Vitis sylvestris: *Funtana Ide - 65, Bidde - 97;*

On a considéré encore les mots bois-foret, qui rappellent, naturellement, des aspects liés au monde des plantes.

Bois: *Sirbonica - 2, Boschinu - 12, Silbanis - 30, Sirboniga - 32, Antepadente - 61, Sirbas - 101, Silvanis - 120, Littu Ertikes - 105, Littu Pedrosu - 105, Linnarta - 92, Su Linnari - 95, Ena e Littu, Su Linnamini, 115, Matta - 82;*

On trouve interessant de marquer les mots (Ruiu, Ruggiu, Arrubiu etc.) qui signalent la presence dominante du lichène ***Xanthoria ochroleuca***, lequel donne la couler rougeatre au monument.

Lichenes: *Ruiu - 18, Ruggiu - 21, Rubiu - 50, Ruggiu - 65, Muros Rujos - 79, Ruju - 91, Arrubiu - 93, Ruju - 96, Ruggiu - 109, Arrubiu - 121, Ruju - 125, Ruju - 128, Scala Ruja - 134, Orrubiu - 139, Ruju - 143, Arrubiu - 145, Orrubiu/Arrubiu - 145, Ruju - 153, Arrubiu - 155, Orrubiu-Arrubiu - 160;*

Enfin on signalise d'autres noms: *Des Follas - 40, (des feuilles) Pranu de Follas - 82 (plan des feuilles), Fenu - 103 (fien), Fenu - 116 (Fien), Fiorosu - 108 (fleury), Fioriosu - 136 (Fleury, Florissa - 165 (fleury?).*

Conclusion

Les phytotoponimes sont 345 tandis que les espèces qui donnent des noms aux nuraghes sont 93 (on a exclus le noms génériques tels que *littu*, mais aussi *Ruju-Arrubiu*) et les espèces les plus representées sont résumé dans les figures 1 et 2.

Seulement 13 espéces donnent le 36,9% des phytonimes et ce sont ***Ficus carica*** (incl. var. ***caprificus*** et ***Olea sativa*** (incl. var. ***sylvestris***), ***Pyrus communis***, les chênes (***Quercus suber, Q. ilex, Q. pubescens***) les espèces les plus fréquentes. On peut dire, en général, que les espèces les plus réprésentées ont un écologie qui permet leur vie dans les murs, dans les ruines e dans les lieux pierreux, mais aussi des espéces nitrophiles (***Sambucus nigra, Senecio vulgaris, Smyrnium olusatrum, Lavatera olbia, Artemisia arborescens***), qui trouvent un ambience favorable dans ces lieux, à cause de l'utilization des nuraghes pour abri des animaux domestiques.

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Besiedlung eines mauretanischen pyramidenförmigen Grabmals bei Tipasa in Nordalgerien durch Pflanzen in den letzten 120 Jahren

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Keywords: Archaeology, Plant succession, Mediterranean Vegetation.

Abstract

Plant succession on an archaeologic monument (tomb) in Northern Algeria has been studied during several years by the authors and compared with the results of different botanists in the past 120 years.

Auf dem Gipfel der Hügelkette des Sahels, die sich entlang der Mittelmeerküste zwischen Algier im Osten und Tipasa im Westen zieht, erhebt sich, etwa 50 km westlich von der Hauptstadt Algeriens, ein riesiges, pyramidenförmiges Grabmal (Abb. 1 A-B). Dieses Monument, das heute als ein mauretanisches, königliches Grabmal betrachtet wird+/ und vermutlich aus der Periode zwischen dem III. und I. Jahrhundert v. Chr. stammt, ist 32 m hoch. Sein Durchmesser beträgt 60 m.

Die Felsblöcke, die zum Bau des Grabmals benutzt wurden, sind lose, ohne jedes Bindemittel aufeinandergelegt worden (Abb. 2). Der Sand von der Meeresküste und der feine Staub aus den benachbarten Feldern, jahrhundertelang angeweht von starken Winden, haben die Felsspalten ausgefüllt und gute Bedingungen zur Besiedlung dieses Denkmals durch Pflanzen geschaffen.

Das Grabmal ist heute, trotz periodischen Rückschnittes der Sträucher in den letzten Jahren, schön begrünt. Seine Flora hat seit langem das Interesse der Botaniker geweckt.

Die erste Beschreibung der Flora dieses Grabmals, die vor 120 Jahren erschienen ist (P. JOURDAN 1867), enthält 78 Pflanzenarten. Jourdan hat das Denkmal Stufe nach Stufe floristisch

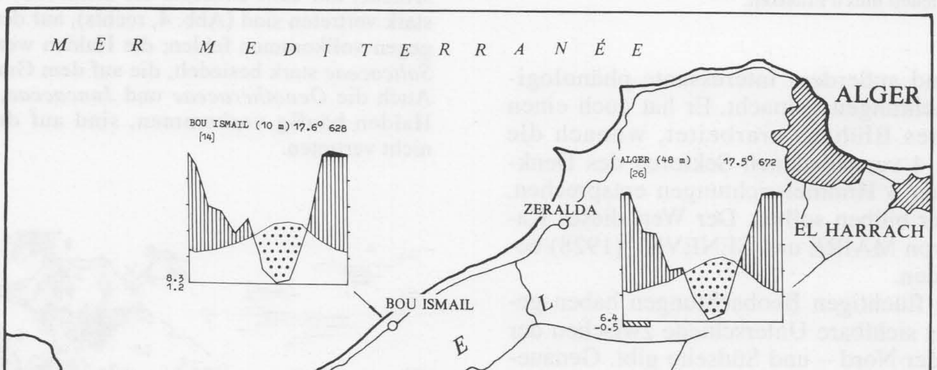

Abb. 1/A - Das mauretanische königliche Grabmal in der Sahel bei Tipasa und Klimadiagramm, charakteristisch fur diese Gegend.

Abb. 1/B - Nordwestliche Seite des mauretanischen Grabmals bei Tipasa besiedelt durch Pflanzen.

erforscht und außerdem interessante phänologische Beobachtungen gemacht. Er hat auch einen Kalender des Blühens erarbeitet, wonach die Pflanzen in 4 verschiedenen Sektoren des Denkmals, die den 4 Himmelsrichtungen entsprechen, nacheinander blüben sollten. Der Wert dieses Kalenders ist von MAIRE und SENEVET (1928) bestritten worden.

Unsere flüchtigen Beobachtungen haben gezeigt, daß es sichtbare Unterschiede zwischen der Vegetation der Nord – und Südseite gibt. Genauere Schlüsse sind erst nach weiteren Untersuchungen möglich.

Die floristischen Beobachtungen wurden nach 60 Jahren von R. Maire und G. Senevet (1928) wiederholt. Unter den 79, von diesen Autoren genannten Arten (bei einmaliger Untersuchung im Dezember) gibt es 30, die Jourdan nicht gefunden hat.

Die Adventivflora des Grabmals ist letztens auffälling reicher geworden und beträgt heute nach unseren Untersuchungen (8 Beobachtungen) 176 Pflanernarten, darunter 102, die neu entdeckt worden sind. Die gesamte Flora des Grabmals, zusammen mit den Arten, die wir nicht gefunden haben, zählt damit 216 Arten.

Die Mehrzahl dieser Flora besteht aus anemo- und zoochoren Arten, die ihre Standorte in der nächsten Nähe des Grabmals haben.

Ein Aspekt der Flora des Grabmals – der Anteil der Familien – ist mit Hilfe eines Kreisdiagramms (Abb. 3) gezeigt worden. Am meisten vertreten sind die Familien: *Compositae* (29 Arten), *Liliaceae* (16 Arten), *Gramineae* (16 Arten), *Papilionaceae* (13 Arten) und *Umbelliferae* (10 Arten).

Wir haben auch versucht, diese Ergebnisse mit jenen zu vergleichen, die einen anderen, aber auch von Menschen geschaffenen Standort, der durch die Pflanzen besiedel wurde, betreffen. Es handelt sich um die Halden (Oberfläche 360 ha, Höhe bis 70 m), die im Zusammenhang mit Braunkohlegewinnung (Tagebau) in Zentralpolen bei Konin entstanden sind. Das zweite Diagramm (Abb. 4) zeigt die Unterschiede, die trotz:

des anderen Klimas: in Algerien – mediterran, in Polen – temperiert;

des anderem Substrats: in Algerien – mit Sand und Ton gefüllte Spalten zwischen den Sandsteinblöcken, in Polen – Geschiebemergel, Pleistozäner sand und Ton, Tertiärer Ton;

der verschiedenen Feuchtigkeitsverhältnisse: in Algerien – wind – und sonnenexponiertes Grabmal, in Polen – feuchtes, teilweise sogar sehr nasses, reliefreiches, undurchlässiges Plateau verhältnismäßig klein sind. Nur einige Familien zeigen deutlichere Unterschiede: auf dem Grabmal die *Liliaceae*, die mit 8,6% stark vertreten sind (Abb. 4, rechts), auf den Halden dagegen vollkommen fehlen; die Halden werden von den *Salicaceae* stark besiedelt, die auf dem Grabmal fehlen. Auch die *Oenotheraceae* und *Juncaceae*, die auf den Halden häufig vorkommen, sind auf dem Grabmal nicht vertreten.

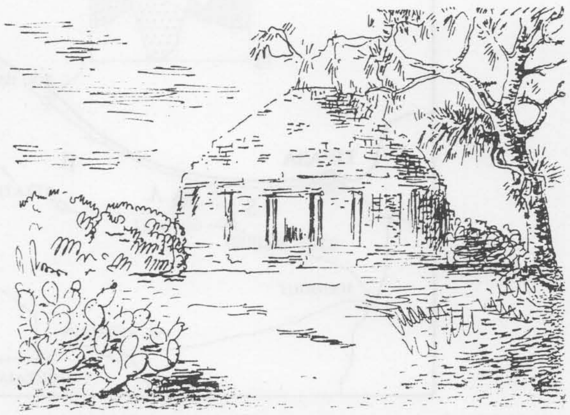

Abb. 2 - Mauretanisches königliches Grabmal bei Tipasa.

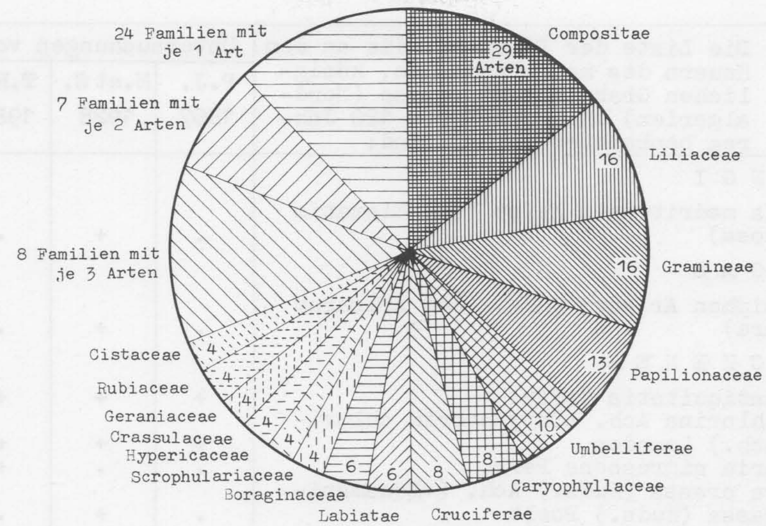

Abb. 3 - Die Flora des Grabmals besteht aus 54 Familien. Anteil der Familien.

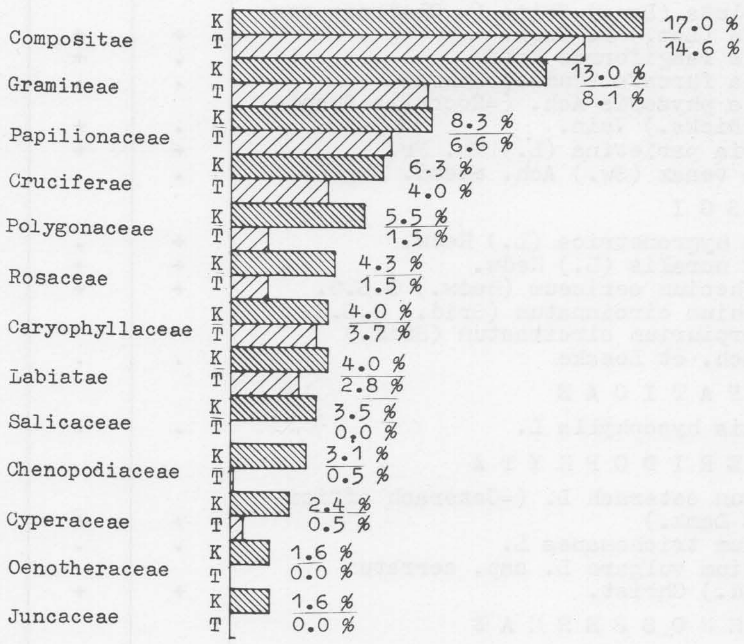

Abb. 4 - Anteil der Familien in der Flora der Flanken bei Konin (Polen) ind in der Flora des Grabmals bei Tipasa (Algerien).

Tab. 1

Tabelle 1. Die Liste der Pflanzen, die an den Mauern des mauretanischen, königlichen Grabmals bei Tipasa (Nordalgerien) in den letzten 120 Jahren beobachtet worden sind:	Untersuchungen von			Auftreten
	P.J. 1867	M.et S. 1928	T.H.W. 1986	
F U N G I				
1. Puccinia madritensis Maire (auf Clematis cirrhosa)	.	+	.	.
A L G A E				
2. Phyllosiphon Arisari Kuhn. (auf Arisarum vulgare)	.	+	.	.
L I C H E N E S				
3. Lepra antiquitatis Hoffm.	+	+	+	CCC
4. Lepra chlorina Ach. (Chrysothrix chlorina (Ach.) Laundon	+	+	+	CC
5. Verrucaria nigrescens Pers.	.	.	+	C
6. Lecanora crassa (Huds.) Ach. (=Squamarina crassa (Huds.) Poelt	.	+	.	.
7. Caloplaca murorum (Hoffm.) Th.Fr. (=Caloplaca saxicola (Huds.) Nordin	.	+	.	.
8. Cladonia foliacea (Huds.) Schaer. var. convoluta (Lam.) Vain. (= Cladonia convoluta (Lam.) P. Cout.	+	+	+	C
9. Cladonia rangiformis Hoffm.	.	+	.	.
10. Cladonia furcata (Huds.) Schrad.	.	.	+	R
11. Roccella physopis Ach. (=Roccella fucoides (Dicks.) Vain.	.	+	.	.
12. Xanthoria parietina (L.) Th. Fr.	+	+	+	C
13. Collema tenax (Sw.) Ach. emend. Degel.	.	.	+	R
M U S C I				
14. Funaria hygrometrica (L.) Hedw.	+	.	.	.
15. Tortula muralis (L.) Hedw.	+	+	+	C
16. Homalothecium sericeum (Hedw.) B.S.G.	+	+	+	CC
17. Eurhynchium circinnatum (Brid.) B.S.G. (=Scorpiurium circinnatum (Brid.) Fleisch. et Loeske	.	.	+	C
H E P A T I C A E				
18. Targionia hypophylla L.	.	+	.	.
P T E R I D O P H Y T A				
19. Asplenium ceterach L. (=Ceterach officinarum Lamk.)	+	+	+	AR
20. Asplenium trichomanes L.	.	.	+	AC
21. Polypodium vulgare L. ssp. serratum (Willd.) Christ.	+	+	+	CC
G Y M N O S P E R M A E				
P i n a c e a e				
22. Pinus halepensis Mill.	.	.	+	AC
C u p r e s s a c e a e				
23. Callitris articulata (Vahl.) Link. (=Tetraclinis articulata (Vahl.) Masters	+	+	+	AR

Die letzte Spalte zeigt die Häufigkeit des Auftretens der Pflanzenarten. Die Abkürzungen entsprechen denen von Quézel und Santa (1962): AC - ziemlich verbreitet, C - verbreitet, CC - sehr verbreitet, CCC - außerordentlich verbreitet, AR - ziemlich selten, R - selten, RR - sehr selten.

Tabelle 1. (Fortsetzung)	Untersuchungen von P.J. 1867	M.et S. 1928	T.H.W. 1986	Auftreten
ANGIOSPERMAE				
MONOCOTYLEDONES				
Gramineae				
24. Oryzopsis miliacea (L.) Asch. et Schw.	+	+	+	CC
25. Oryzopsis coerulescens (Desf.) Richt.	•	•	•	AR
26. Polypogon monspeliensis (L.) Desf.	•	•	+	R
27. Lagurus ovatus L.	•	+	+	C
28. Cynodon dactylon (L.) Pers.	•	•	+	R
29. Ampelodesma mauritanicum (Poir.) Dur. et Schinz.	+	+	+	C
30. Avena alba Vahl.	•	•	+	C
31. Avena sterilis L.	•	•	+	AC
32. Koeleria phleoides (Vill.) Pers.	•	•	+	AR
33. Melica ciliata L.	+	+	+	C
34. Scleropoa rigida (L.) Gris.	•	•	+	AR
35. Cynosurus echinatus L.	•	+	•	•
36. Catapodium loliaceum (Huds.) Link.	•	•	+	AR
37. Bromus madritensis L.	•	•	+	C
38. Dactylis glomerata L.	•	+	+	CCC
39. Brachypodium distachyum (L.) P.B.	•	•	+	C
Cyperaceae				
40. Carex halleriana Asso	•	•	+	AR
Palmae				
41. Phoenix canariensis Chabaud	•	•	+	RR
42. Chamaerops humilis L.	+	+	+	C
Araceae				
43. Arisarum vulgare Targ.- Tozz.	+	+	+	CCC
Liliaceae				
44. Asphodelus microcarpus Salzm. et Viv.	+	+	+	CC
45. Scilla autumnalis L.	+	•	+	CC
46. Scilla obtusifolia Poiret	•	+	+	CC
47. Scilla numidica Poiret	•	+	+	C
48. Urginea maritima (L.) Baker	+	+	+	R
49. Urginea undulata (Desf.) Steinh.	+	•	•	•
50. Urginea fugax (Moris) Steinh.	•	+	•	•
51. Ruscus hypophyllum L.	+	+	+	C
52. Asparagus albus L.	+	+	+	C
53. Asparagus acutifolius L.	+	+	+	AC
54. Smilax aspera L.	+	+	+	CC
55. Allium subhirsutum L. ssp. album (San i) M. et W.	+	+	•	•
56. Allium roseum L.	+	+	+	AR
57. Allium paniculatum L.	•	•	+	AC
58. Allium sphaerocephalum L.	•	•	+	C
59. Allium ampeloprasum L.	•	+	•	•
Iridaceae				
60. Gladiolus byzantinus Mill.	•	+	•	•
Orchidaceae				
61. Ophrys tenthredinifera Willd.	+	+	•	•
62. Orchis coriophora L.	+	•	•	•
63. Aceras anthropophorum (L.) Ait.	•	+	•	•

Tabelle 1. (Fortsetzung)	Untersuchungen von			Auftreten
	P.J. 1867	M.et S. 1928	T.H.W. 1986	
DICOTYLEDONES				
F a g a c e a e				
64. Quercus coccifera L.	+	+	+	CC
P o l y g o n a c e a e				
65. Rumex bucephalophorus L.	+	.	+	AR
66. Rumex thyrsoides Desf.	.	.	+	R
67. Polygonum aviculare L.	.	.	+	AC
U r t i c a c e a e				
68. Parietaria officinalis L.	.	+	+	CCC
S a n t a l a c e a e				
69. Osyris alba L.	+	.	.	.
C h e n o p o d i a c e a e				
70. Chenopodium album L. ssp. opulifolium (Schrad.) Batt.	.	.	+	R
T h e l i g o n a c e a e				
71. Theligonum cynocrambe L.	.	+	.	.
C a r y o p h y l l a c e a e				
72. Polycarpon tetraphyllum L.	.	.	+	R
73. Paronychia argentea (Pourr.) Lamb.	.	.	+	R
74. Arenaria serpyllifolia L.	.	.	+	R
75. Cerastium glomeratum Thuill.	.	.	+	R
76. Silene cucubalus Wibel (=Silene inflata (Salisb.) Sm.)	+	.	+	R
77. Silene secundiflora Otth. (=Silene glauca (Spreng.) Pourret)	+	+	+	CC
78. Silene nocturna L.	.	.	+	R
R a n u n c u l a c e a e				
79. Clematis cirrhosa L.	.	+	+	R
80. Clematis flammula L.	.	+	+	AR
81. Ranunculus bullatus L.	+	+	+	AC
P a p a v e r a c e a e				
82. Papaver rhoeas L.	+	.	+	AC
83. Papaver pinnatifidum Moris	.	.	+	AR
F u m a r i a c e a e				
84. Fumaria capreolata L.	+	.	+	C
85. Fumaria parviflora Lamk.	.	.	+	AR
C r u c i f e r a e				
86. Coronopus didymus (L.) Smith.	.	.	+	R
87. Lobularia maritima)L.) Desf. (=Alyssum maritimum (L.) Lamk.)	+	+	+	CCC
88. Draba verna L. (=Erophila verna (L.) Chevallier	+	.	.	.
89. Diplotaxis tenuifolia (L.) DC	.	.	+	R
90. Sinapis arvensis L.	.	.	+	R
91. Hirschfeldia incana (L.) Lagrese	.	.	+	AC
92. Erucastrum varium Dur.	+	.	.	.
93. Brassica fruticulosa Cyrillo	.	+	+	CC
R e s e d a c e a e				
94. Reseda alba L.	+	+	+	CC

Tabelle 1. (Fortsetzung)	Untersuchungen von P.J. 1867	M.et S. 1928	T.H.W. 1986	Auftreten
Crassulaceae				
95. Cotyledon Umbilicus-Veneris L.	+	+	+	CC
96. Sedum sediforme (Jacq.) Pau. (=Sedum altissimum Poiret)	+	.	+	C
97. Sedum album L. var. micranthum DC	.	+	.	.
98. Sedum coeruleum L.	+	.	+	CCC
Rosaceae				
99. Sanguisorba minor Scop.	.	.	+	CC
100. Rubus ulmifolius Schott.	.	.	+	AC
101. Crataegus oxyacantha L. ssp. monogyna (Jacq.) Rony et Camus	.	.	+	AC
Papilionaceae				
102. Lotus ornithopodioides L.	.	.	+	R
103. Lotus creticus L. ssp. cytisoides (L.)Asch.	+	+	+	CCC
104. Medicago hispida Gaertn.	.	.	+	AR
105. Trifolium campestre Schreb.	.	.	+	AR
106. Trifolium resupinatum L.	.	.	+	R
107. Trifolium angustifolium L.	.	.	+	AC
108. Trifolium scabrum L.	.	.	+	R
109. Trifolium pallidum Waldst. et Kit.	.	.	+	R
110. Trifolium stellatum L.	.	.	+	AR
111. Anthyllis vulneraria L.	+	.	+	AR
112. Ononis sicula L.	+	.	.	.
113. Ononis hispida Desf.	.	.	+	R
114. Hippocrepis multisiliquosa L.	.	.	+	R
Geraniaceae				
115. Geranium Robertianum L. ssp. purpureum Willd.	+	+	+	AR
116. Geranium molle L.	.	.	+	AR
117. Geranium dissectum L.	.	.	+	R
118. Erodium malachoides (L.) Willd.	.	.	+	CC
119. Erodium chium (Burm.) Willd.	.	+	.	.
Linaceae				
120. Linum strictum L.	.	.	+	AC
Rutaceae				
121. Ruta chalepensis L. ssp. bracteosa (DC)Butt.	+	+	.	
Euphorbiaceae				
122. Euphorbia peplus L.	+	.	+	R
123. Mercurialis annua L. (=Mercurialis ambigua L.)	+	+	+	CCC
Anacardiaceae				
124. Pistacia lentiscus L.	+	.	+	CCC
Rhamnaceae				
125. Rhamnus alaternus L.	+	.	+	AC
Malvaceae				
126. Lavatera cretica L.	.	.	+	R
Thymelaeaceae				
127. Daphne gnidium L.	.	.	+	AR

Tabelle 1. (Fortsetzung)	Untersuchungen von			Auftreten
	P.J. 1867	M.et S. 1928	T.H.W. 1986	
U m b e l l i f e r a e				
128. Eryngium dichotomum Desf.	+	.	.	.
129. Thapsia garganica L.	.	.	+	R
130. Elaeoselinum thapsioides (Desf.) Maire (=Laserpitium gummiferum Desf.)	+	+	+	CC
131. Daucus muricatus L.	.	.	+	R
132. Daucus carota L. ssp. hispanicus (Gouan) Thell.	.	+	+	C
133. Torilis arvensis (Huds.) Link. ssp. neglecta (Roem. et Schultz) Thell.	.	+	+	R
134. Ferula communis L.	+	+	+	R
135. Foeniculum vulgare (Miller) Gaertn.	.	.	+	R
136. Kundmannia sicula DC	.	.	+	AC
137. Magydaris pastinacea (Lamk.) Paol.	+	.	.	.
H y p e r i c a c e a e				
138. Hypericum tomentosum L. ssp. pubescens (Boiss.) Ball.	.	.	+	AC
139. Hypericum perforatum L.	.	.	+	R
140. Hypericum humifusum L. ssp. australe (Ten.) R. et F.	.	.	+	AR
141. Hypericum perfoliatum L.	.	.	+	R
C i s t a c e a e				
142. Cistus heterophyllus Desf.	.	+	+	AC
143. Cistus salvifolius L.	.	.	+	R
144. Cistus monspeliensis L.	+	.	+	C
145. Fumana laevipes (L.) Spach. (=Helianthemum laevipes Pers.)	+	+	+	C
E r i c a c e a e				
146. Arbutus unedo L.	+	+	+	C
147. Erica multiflora L.	+	+	+	C
148. Erica arborea L.	.	.	+	AR
P r i m u l a c e a e				
149. Anagallis arvensis L. ssp. parviflora (Hoff. et Link.) Batt.	.	.	+	AC
O l e a c e a e				
150. Jasminum fruticans L.	+	+	+	AR
151. Olea europaea L.	+	+	+	CC
152. Phillyrea angustifolia L. ssp. media (L.) Rouy	.	+	+	C
G e n t i a n a c e a e				
153. Blackstonia perfoliata L.	.	.	+	AC
154. Erythraea maior Link.	+	.	.	.
C o n v o l v u l a c e a e				
155. Convolvulus althaeoides L.	.	.	+	AC
156. Convolvulus arvensis L.	.	.	+	C
B o r a g i n a c e a e				
157. Echium vulgare L.	+	.	.	.
158. Echium plantagineum L.	.	.	+	AR
159. Solenanthus tubiflorus Murb. (=Anchusa lanata L.)	+	.	.	.

Tabelle 1. (Fortsetzung)	Untersuchungen von			Auf-tre-ten
	P.J. 1867	M.et S. 1928	T.H.W. 1986	
160. Cynoglossum creticum Miller (=Cynoglossum pictum Ait.)	+	.	+	R
161. Borago officinalis L.	+	.	+	R
162. Lithospermum arvense L.	+	.	.	.
Verbenaceae				
163. Verbena officinalis L.	.	.	+	C
Labiatae				
164. Ajuga iva (L.) Schreber	.	.	+	AC
165. Salvia verbenaca (L.) Briq.	.	.	+	AC
166. Marrubium vulgare L.	+	+	.	.
167. Prasium majus L.	+	+	+	CC
168. Satureja graeca L.	.	.	+	AR
169. Stachys ocymastrum (L.) Briq.	.	.	+	R
Solanaceae				
170. Solanum nigrum L.	.	.	+	C
Scrophulariaceae				
171. Verbascum sinuatum L.	.	.	+	AR
172. Anarrhinum pedatum Desf.	.	.	+	AC
173. Antirrhinum majus L.	+	+	+	AC
174. Veronica polita Fries	.	.	+	R
Orobanchaceae				
175. Orobanche crenata Forsk.	.	.	+	AC
Plantaginaceae				
176. Plantago serraria L.	.	.	+	R
177. Plantago lagopus L.	.	.	+	AC
Rubiaceae				
178. Rubia peregrina L.	+	+	+	C
179. Galium murale All.	.	.	+	AR
180. Galium tunetanum Poiret	.	.	+	R
181. Sherardia arvensis L.	+	.	+	C
Caprifoliaceae				
182. Lonicera implexa L.	+	+	+	CC
Valerianaceae				
183. Kentranthus calcitrapa (L.) Dufr.	+	+	+	CC
184. Fedia cornucopiae (L.) Gaertn.	+	.	.	.
185. Valerianella Morissonii DC ssp. microcarpa (Lois.) P. Four.	+	.	.	.
Dipsacaceae				
186. Scabiosa atropurpurea L. ssp. maritima (L.) Fiori et Paol.	.	.	+	C
Campanulaceae				
187. Campanula erinus L.	.	.	+	C
Compositae				
188. Bellis silvestris L.	.	+	.	.
189. Phagnalon saxatile (L.) Cass.	.	.	.	CC
190. Pallenis spinosa (L.) Cass.	.	.	+	C
191. Senecio vulgaris L.	+	.	.	.

Tab. 2

"MAQUIS" AN DEN MAUERN UND AUF DER KUPPEL DES GRABMALS

	Nr. der Aufnahme		1	2	3
	Exposition		N	W	–
	Höhe am Grabmal		10 m	16 m	32 m
	Neigung		30^{o}	30^{o}	0^{o}
	Bedeckung	b/c	70 %	70 %	80 %
	"	d	20 %	–	5 %
	Aufnahmefläche		$16\ m^2$	$10\ m^2$	$10\ m^2$
	Zahl der Arten		26	27	32
	Assoziation		Lonicero implexae-Quercetum cocciferae		Oleo-Pistacietum lentisci
	Ch. Ass.$^{+}$, O. und Kl.$^{++}$				
+	Quercus coccifera	b	4.3	3.3	.
+	Lonicera implexa		1.2	2.2	+
++	Arbutus unedo	b	2.2	1.2	.
++	Ruscus hypophyllum	c	2.2	1.1	+
++	Smilax aspera	b	2.2	.	+
	Carex halleriana	c	+	1.2	.
	Erica multiflora	b	1.2	1.2	.
	Cistus heterophyllus		+.2	+.2	.
	Dactylis glomerata	c	2.2	2.2	.
	Ampelodesma mauretanicum		1.2	.	.
	Pinus halepensis		+	.	.
	Callitris articulata	b	.	2.3	.
	Fumana laevipes	c	.	1.2	.
	Hyoseris radiata		.	1.2	.
	Orobanche crenata		.	+	.
	Prasium majus	b	.	2.2	3.3
	Elaeoselinum thapsioides	c	.	1.1	3.2
	Phillyrea angustifolia	b	.	1.2	2.2
	Allium paniculatum	c	.	1.1	+
	Ch. Ass.^{o}/				
o	Pistacia lentiscus	b	1.1	1.2	4.3
o	Olea europaea		.	.	2.3
++	Rubia peregrina	b	2.1	+	2.1
	Lotus creticus	c	1.2	+.2	+.2
	Silene glauca		+	1.1	1.1
	Brachypodium distachyum		+	+	+
	Linum strictum		+	+	+
	Kentranthus calcitrapa		+	+	+
	Allium sphaerocephalum		+	+	+
	Sonchus oleraceus		+	+	+
++	Asparagus acutifolius		1.1	.	+
	Reichardia picroides		+	.	+
	Trifolium stellatum		+	.	.
	Brassica fruticulosa		.	+	+.2
	Asphodelus microcarpus		.	+	+.2
	Daucus hispanicus		.	.	1.2
	Antirrhinum majus		.	.	+.2
	Oryzopsis coerulescens		.	.	+.2
	Avena alba		.	.	+
	Bromus madritensis		.	.	+
	Mercurialis annua		.	.	+
	Oryzopsis miliacea		.	.	+
	Sedum coeruleum		.	.	+
	Sedum sediforme		.	.	+
	Homalothecium sericeum	d	2.3	.	.
	Eurhynchium circinnatum		2.2	.	.
	Tortula muralis		1.2	.	.
	Cladonia foliacea		.	.	+.2
	Cladonia furcata		.	.	+.2

Tab. 3

Tabelle 3. Vegetation de Felsspalten in den, dem Norden zu, exponierten Mauern des Grabmals

										Constance
Aufnahme-Nummer	1	2	1	2	3	4	5	6	7	
Gelände-Nummer	297	301	298	304	300	299	303	302	305	
Exposition	NNE	NNW	NNE	NNE	NNW	NNE	NNE	NWW	SWW	
Deckung in %	10	10	60	70	50	50	60	60	60	
Aufnahmefläche	10	16	10	12	16	12	16	16	20	
Artenzahl	4	15	33	40	45	34	53	35	38	
Kennarten										
Parietaria officinalis	1.1	+.2	2.2	2.2	2.2	2.3	2.2	2.2	1.2	V
Hyoseris radiata	.	.	1.2	2.2	2.1	1.1	2.1	1.2	2.2	V
Reichardia picroides	.	.	.	+.2	1.1	+.2	2.2	1.2	2.2	V
Antirrhinum majus	.	+.2	r	r	+	+	.	+	+	V
Felsspaltenarten										
Phagnalon saxatile	+	+	+	+.2	+.2	+.2	1.2	+.2	+.2	V
Sedum coeruleum	.	.	.	1.1	+	.	+.2	+	+.2	IV
Cotyledon Umbilicus-Veneris	.	+	.	+	.	+	1.1	+	.	III
Asplenium ceterach	.	1.2	.	.	+	.	+.2	+.2	.	III
Polypodium vulgare	.	+.2	.	+.2	.	.	+	.	.	II
Asplenium trichomanes	.	.	.	.	r	.	.	.	.	I
Quercetea ilicis-Arten										
Rubia peregrina	2.3	2.3	1.2	+.2	+.2	+.2	+.2	2.2	1.2	V
Asparagus acutifolius	.	.	+.2	+	.	.	+	.	.	III
Smilax aspera	.	.	.	1.2	+	.	+	.	.	III
Pistacia lentiscus	.	.	.	.	+.2	.	.	+	+	III
Ruscus hypophyllum	.	.	.	+.2	.	+	.	.	.	II
Quercus coccifera	.	.	.	+.2	.	.	+	.	.	II
Tamus communis	.	.	.	.	.	.	+	.	.	I
Lonicera implexa	.	.	.	.	.	.	.	+	.	I
Begleiter										
Daucus hispanicus	.	r	1.2	2.2	3.3	2.2	1.2	1.2	+.2	V
Kundmannia sicula	.	.	+	2.2	1.2	3.3	3.2	+.2	+.2	V
Lotus creticus	.	.	1.2	1.2	2.3	1.2	2.2	3.3	2.2	V
Elaeoselinum thapsioides	.	.	+	+.2	+.2	+	+	+	3.2	V
Dactylis glomerata	.	+.2	1.2	1.2	2.2	2.2	1.2	2.2	+.2	V
Oryzopsis miliacea	.	+.2	1.2	1.2	2.2	+.2	1.2	2.2	+.2	V
Silene secundiflora	.	.	1.1	1.2	1.1	1.1	2.2	2.2	+.2	V
Lagurus ovatus	.	.	+.2	+	+.2	1.2	1.1	1.1	+	V
Avena alba	.	+	+	+	+.2	1.2	1.1	+.2	+	V
Picris Duriaei	.	.	+	+.2	+	+	+.2	+	+	V
Sanguisorba minor	.	.	+	1.2	+.2	1.2	1.1	.	+.2	V
Convolvulus althaeoides	.	.	2.1	1.2	+	2.2	1.2	.	.	IV
Melica ciliata	.	.	+	.	+.2	.	+	1.2	+	IV
Pallenis spinosa	.	.	+	.	.	+	+.2	+.2	1.2	IV
Mercurialis annua	+	.	.	.	+	+	1.1	+	1.1	IV
Geranium molle	.	.	+	+	.	+	1.1	.	.	III
Trifolium campestre	.	.	r	+	+	.	1.1	.	.	III
Bromus madritensis	.	.	+	+	+	.	+	.	.	III
Orobanche crenata	.	.	r	+	+	.	.	r	.	III
Sonchus oleraceus	.	+	+	.	.	+	1.1	.	+.2	III
Asphodelus microcarpus	.	.	.	+	+	+.2	+.2	.	.	III
Scilla obtusifolia	.	.	.	+	+	.	.	+	+	III
Lobularia maritima	.	.	.	+	.	.	1.1	+	1.1	III
Brachypodium distachyum	.	.	.	+	.	.	+	+	+	III
Brassica fruticulosa	.	+	.	.	+	+	.	+.2	1.2	III
Prasium majus	.	1.2	.	.	+	.	1.1	+	2.2	III
Reseda alba	.	+	.	.	+	.	+	+.2	1.2	III
Cichorium intybus	.	.	+	+	+	.	.	.	.	III
Campanula erinus	.	.	+	+	.	.	+	.	.	III
Scabiosa maritima	.	.	+	.	.	.	+	.	+	III
Sinapis arvensis	.	.	.	+	+	.	+	.	.	III
Rumex bucephalophorus	.	.	.	+	.	1.2	+	.	.	III
Hypericum tomentosum	.	.	.	.	+.2	2.2	2.2	.	.	III
Sonchus tenerrimus	.	.	.	.	.	+	+	+	.	III

Sporadische Arten

Allium roseum 299(+),305(+); Allium sphaerocephalum 305(+ 2); Ampelodesma mauritanicum 300(+); Anagallis arvensis ssp. parviflora 305(+); Arenaria serpyllifolia 303(+),304(+); Blackstonia perfoliata 300(+); Convolvulus arvensis 299(+),303(+); Coronopus didymus 299(+); Crataegus [illegible] ssp. monogyna 305(+); Crepis vesicaria 298(+); Cynoglossum creticum 300 (+); Echium plantagineum 298(+),305(1.2); Filago spathulata 302(+),303(+); Fumana laevipes 305(+); Galactites tomentosa 298(+); Hirschfeldia incana 298(+),299(+); Hypericum perforatum 300(+); Kentranthus calcitrapa 299(+), 300(r); Leontodon hispidulus 298(+),303(+.2); Linum strictum 303(+),305 (+); Plantago lagopus 299(+),302(+); Plantago serraria 303(+); Polycarpon tetraphyllum 304(+); Rubus ulmifolius 302(+); Satureja graeca 300(+); Scleropoa rigida 300(+),304(+); Scolymus grandiflorus 300(1.1),303(+); Silene nocturna 298(+),305(+); Trifolium angustifolium 300(+),303(+); Trifolium resupinatum 303(+), Trifolium stellatum 303(+); Urospermum picroides 300(+).

The effect of earlier settlements on contemporary distribution of *Adonis aestivalis* L. along lower Vistula banks (Northern Poland)

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Keywords: Adonis aestivalis, Lathyro-Melandrietum Oberd. 57, *Caucalidion daucoides*, archaeological sites, mediaeval settlements, lower Vistula, northern Poland, black earths, rendzinas, archaeophyte, edge of geographical range, local refuges.

Abstract

Historical and contemporary localities of *Adonis aestivalis* along the lower Vistula banks (northern Poland) have been investigated. It was found that this species permanently exists almost only within the limits of Mediaeval settlements and cementeries. The soils in these places differ from heavy black soils of the neighbourhood and become similar to rendzina.

Introduction

The physiognomical individuality of vegetation on archaeological sites is a phenomenon commonly known to archaeologists. It is manifested, among other things, in a different intensity of verdure, vitality and size of plants, e.g. higher in the regions of filled-in ditches, moats, etc., and lower on walls levelled down to the ground. These phenomena are so typical as to serve, among other things, as a basis in archaeological aerial investigations to find structures invisible at ground level (DUEL 1969 and others).

Another characteristic of former settlement is the fact that certain plants formerly cultivated, e.g. those of the genus *Allium* and *Malva,* can survive on the site of, or in the neighbourhood of former settlements for a long period of time and thus constitute indications of such (BAUCH 1937, 1951/52, HOLLNAGEL 1953, cit. after GARCZYNSKI 1959, GARCZYNSKI 1959, BULINSKI 1986 and others). In the opinion of specialists, certain of today's weeds could have, at one time, been cultivated, such as, e.g., *Chenopodium* sp. div., *Camelina* sp. div. (HELBAEK 1960 and other papers by the same author, GIZBERT 1971 and literature quoted there, and others). Theoretically, it can be assumed that in some cases they could have survived on sites of former cultivation, on condition that suitable habitats were available, but they are at present too common plants for their contemporary existence to be defined as being spatially related with sites of former settlement.

Relationships of native plants which appeared spontaneosuly on sites of former settlements, may be highly complex. For instance, the contemporary distribution of settlements from the younger stone age and bronze age, in central and southern Germany, as also in southern Poland, corresponds with the present-day range of the remains of steppe vegetation (FIRBAS 1962, 1967 et al.). In the opinion of this author, the people of those times preferred to settle in open country with its xerophilous and thermophilous vegetation. The present author's observations of xerothermal vegetation along the lower Vistula indicates the possibility of the later reversal of this relation. Proof of this is the occurrence of species and even well-formed communities on artificially built ramparts of Mediaeval fortified settlement ruins. The relationship of certain thermofilous species, including those characteristic of the order *Festucetalia valesiacae,* with the ramparts of fortified settlement ruins lying along the Wierzyca (tributary of the lower Vistula) is also stressed by BULINSKI (1986), who considers these secondary habitats to be contemporary refuges of the plants mentioned.

The distinct local floristic feauters of former settlement sites may take on still other forms, which is shown by the investigations of the author, as well as SZMEJA (1989) and BULINSKI (op. cit.). The present paper is concerned with one of the rarest species of weeds in northern Poland.

In Poland, *Adonis aestivalis* occurs mainly on the rendzinas in the southern part of the country (Fig. 1A), whereas there are only sparce localities in the central and northern parts of the country, in different types of soil, although this also rich in $CaCO_3$. Here it grows in what are locally, the most favourable habitat conditions (KORNAS 1966). It is so strongly connected with rendzinas that in the opinion of some authors, e.g., TYMRAKIEWICZ (1959), it is only found transitional-

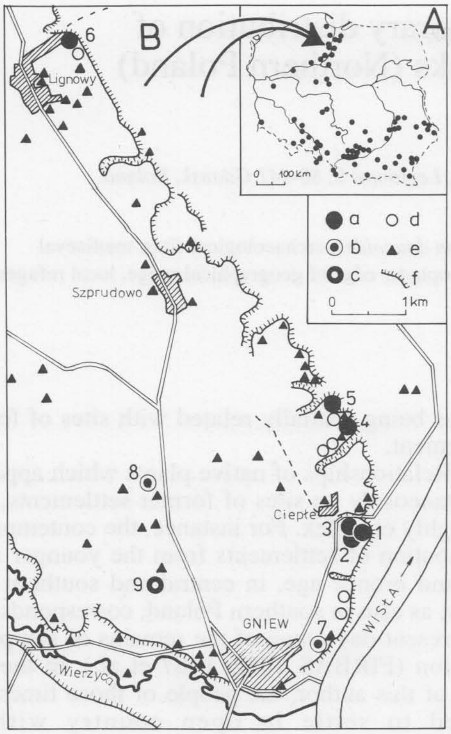

Fig. 1 - Distribution of *Adonis aestivalis* in Poland /A/ and the investigated are /B/
a - permanent localities investigated on archeological sites, b - permanent localities investigated in close neighbourhood of archaeological sites, c - ephemeral locality investigated outside archaeological sites, d - ephemeral localities observed, e - archaeological sites, mostly Mediaeval, f - edge of an upland, 1 - Mediaeval fortified settlements, 2 - Mediaeval surrounds, 3 - Roman period cementery with cave, skeleton and urn graves, 4 - unidentified late Mediaeval archaeological site, 5 - unidentified Mediaeval archaeological site, 6 - early and late Mediaeval settlement, also remains of Bronze Age and Roman period settlements, 7 - top of hill in neighbourhood of Mediaeval fortified settlement, 8 - top of hill in neighbourhood of Mediaeval settlements and remains of neolithic encampment, Roman period and modern settlements, 9 - top of probably man-made hill close to excavation of clay.
Numbers 1-9 refer to remaining figures and phytosociological table.
/A: acc. to Abromeit 1898-1940 and Kornas 1966, B: acc. to Abromeit op. cit. and partly original. Archaeological data after unpublished and partly published materials from Archaeological Museum in Gdansk/.

ly in other types of soil, having brought there together with seeds and later dying off. In the light this, what is an even more interesting phenomenon is the density of localities of *A. aestivalis* along the lower Vistula, situated on the extreme boundary of the species geographical range (MEUSEL, JÄGER, WEINERT 1965), and mostly considered by ABROMEIT (1898-1940) to be permanent. The historical and contemporary occurrence of *Adonis aestivalis* along the lower Vistula quite distinctly conforms with the areas in which former settlements were concentrated, mainly in the Early Middle Ages. The author's preliminary observations already suggested distinct relations between the present-day occurrence of the species with the surface of archaeological relics. It was from this that the aims of the present paper arose:

1. An analysis of the regional and local occurrence of Adonis aestivalis along the lower Vistula.
2. Determination of the relationship of its contemporary occurrence with sites of former settlement, i.e., fortified settlements, open settlements and necropoli.
3. Determination of the habitat conditions affecting the present-day preservation of the species.

1. Material and basic methodical assumptions

Field work was conducted during the period 1979-1985, when almost all the localities of *Adonis aestivalis* given by ABROMEIT (1898-1940) were verified. The localities were observed for several year, to determine their permanency. Only those in which *A. aestivalis* occurred in fields of cultivated vegetation were examined in detail; there were 9, 8 permanent and 1 ephemeral. The remaining ephemeral localities situated on the edges of cultivated fields, boundaries, etc., were observed, and the results were utilized as supplementary material in the discussions and conclusions. Phytosociological records were kept using the Braun-Blanquet method and samples of the superficial horizon of soil taken on all *A. aestivalis* localities investigated. A control area was chosen from each site, assuming as basic criteria an identical contemporary method of cultivation with the same plant cultivated, in as proximate a vicinity as possible, with similar topographic features. The same kind of documentary material was taken from both kinds of surface area at the same time.

The values of ecological indices were calculated by the ELLENBERG (1979) method. The calcium carbonate content was determined by Scheibler's volume method. Data as to the distribution, classification and dating of the ruins of fortified settlements, settlements and necropolii were obtained from the Gdansk Archaeological Museum; this was mainly unpublished material. Other material utilized included published results of archaeological soundings from the region of Cieple (NIWINSKI 1973, SZYMANSKA 1973 a, b, WAPINSKA 1973).

2. Discussion of Results

2.1 *Local features of Adonis aestivalis habitats*

All the localities of *Adonis aestivalis* found and analyzed, along the lower Vistula, were in areas of occurrence of Gniew black earths. On the other hand, none of the localities known from the literature (Cf. ABROMEIT 1898-1940, Fig. 1A; JELINOWSKI, SCHWARZ, TOKARZ 1981) from other types of habitats, were found during investigations. Gniew black earths were formed from very heavy and compact loams with a high $CaCO_3$ content and low permeability, unfriable and gleyey in the lower and frequently the middle horizons of the profile (WITEK, BYCZKOWSKI, CHALECKI 1974). They are thus formations unfavourable to the permanent survival of *Adonis aestivalis*.

In most parts of the *Adonis aestivalis* localities were found pieces of daub (unlashed, rarely lashed), and frequently also stones, slag, fragments of bones, pottery and even bricks. Such remains were either absent or fewer in number in the immediate vicinity of *Adonis aestivalis* localities. An analysis of archaeological material showed that 6 localities of *A. aestivalis* were located in areas in which archaeological relics had been recorded; these constituted the riuns of a Mediaeval fortified settlement, surrounds and settlement, necropolis from the Roman period and two indefinable objects of Mediaeval origin (Fig. 1B: Nos. 1-6). The following two localities are situated on the tops of hills, in the immediate vicinits (150-200 m) of recognized Mediaeval settlements (Fig. 1B: 6-7). The surface material collected does not indicate its monumental character, although its location and neighbourhood do not exclude this; these areas would thus require final professional confirmation in the field. The only ephemeral habitat investigated (Fig. 1B: N. 9) is located close to excavations of clay for the brick works, most probably on a base artificially covered over with soil taken from the surface layer of the excavation, the *Adonis aestivalis* mainly concentrating in places where there is a distinctly lower concentration of wheat and in the unsown gaps. In the remaining ephemeral localities observed, *A. aestivalis* mainly occurred in the ecotons on the boundary of the field, along the boundary of upland and sides of the Vistula valley (Fig. 1B).

2.2 *Soil conditions*

The soil on the archaeological sites investigated, differed distinctly from that where there was black earth (Figs. 2, 3). The differences consist in, among other things, the morphology of soil profiles, the presence of foreign substrata influencing

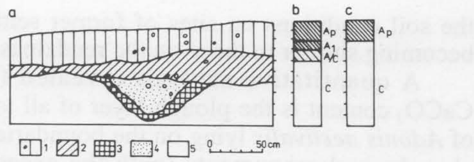

Fig. 2 - Vertical profile of culture layer /with cave/ in fortified settlement: a - in locality 1A /see Fig. 1/ and black earth soil profiles: - on stable and flat area, c - on denuded area. 1 - dark-grey clayey soil with daub and pottery, 2 - dark brown clayey soil, small amount of daub, 3 - dark clayey soil well saturated with charcoal, 4 - yellow clayey sand, 5 - virgin soil = natural layer, 3+4 - cave, A_p - plough layer, A_1 - humus horizon, C - parent rock /a: after Szymanska 1973b/.

the change of mechanical structure, chemical composition and colour of the superficial horizons. Soil samples taken from archaeological sites are mainly less compact than in the control areas, which means that aeration is more favourable for the *Adonis aestivalis* and other components of the *Caucalidion* alliance. All the pieces of daub, pottery, bones, clinker and coal, as well as stones (particularly numerous on site 7), fulfil the function of the soil skeleton which does not occur at all in black earths. The may thus be the reason for

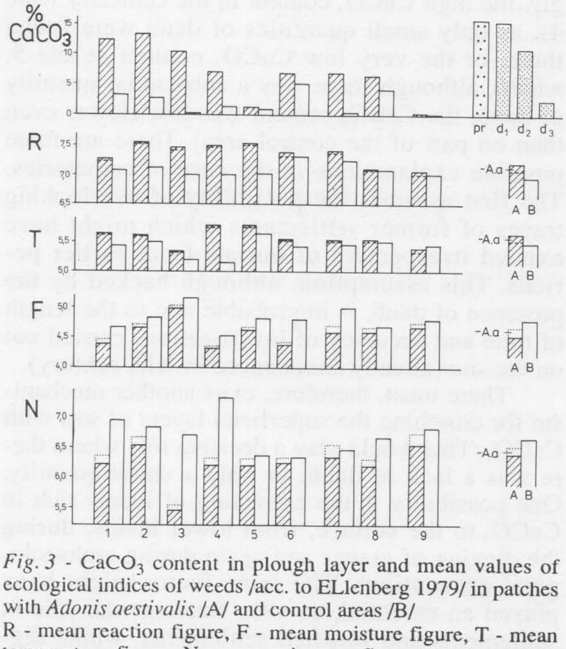

Fig. 3 - $CaCO_3$ content in plough layer and mean values of ecological indices of weeds /acc. to ELlenberg 1979/ in patches with *Adonis aestivalis* /A/ and control areas /B/
R - mean reaction figure, F - mean moisture figure, T - mean temperature figure, N - mean nitrogen figure, 1 - 9 numbers of localities, see Fig. 1.
pr - parent rock, d_1 - large pieces of daub, d_2 - small and decaying pieces of daub, d_3 - fired daub, A.a. - values of figures indices of *A. aestivalis* omitted.

the soil conditions on sites of former settlements becoming similar to those on the rendzinas.

A quantitative analysis revealed that the $CaCO_3$ content is the plough layer of all localities of *Adonis aestivalis* lying on the boundaries of archaeological monuments (with the exception of area 5), is much higher as compared with the control area (Fig. 3). As previously mentioned, all soil samples from these sites contain fragments of daub, sometimes quite substantial, of varying degrees of degradation and weathering. The highest $CaCO_3$ content (about 15%) was noted in the largest, non-weathered pieces of daub with diameters of up to 10 cm, found on the surface of the soil. This is a quantity similar to that found in the parent rock of the soils examined, and distinctly greater than in the plough layer; this difference is particularly striking as compared with the control areas. Field observations indicate that the daub undergoes gradual granulation, weathering and degradation, the results of analyses also suggesting a drop in the $CaCO_3$ content with the natural disintegration of particles (Fig. 3). These facts lead to the conclusion that in part, at least, daub constitutes a secondary source of $CaCO_3$ in the superficial layer of soil on the sites of archaeological monuments.

This does not, however, explain convincingly, the high $CaCO_3$ content in the cemetery (Site 4), as only small quantities of daub were found there, or the very low $CaCO_3$ content at site 5, where, although there was a substantial quantity of daub, the $CaCO_3$ content was low (lower even than on part of the control area). There are three possible explanations in the case of cemeteries. The first assumes the possibility of overlooking traces of former settlements which might have existed irrespective of burials from earlier periods. This assumption, although backed by the presence of daub, is improbable due to the length of time and accuracy of investigations carried out on the site (already commenced in XIX century).

There must, therefore, exist another mechanism for enriching the superficial layers of soil with $CaCO_3$. This would play a decisive rôle where there was a lack of daub, or only a small quantity. One possibility is the extracting of loams rich in $CaCO_3$ to the surface, from lower levels, during the digging of graves and again during archaeological excavations. The same factor might have played an essential, or even fundamental rôle in settlements and fortified settlements, whilst digging moats, pits (i.e. parts of the dwellings which were immersed in the ground, see Fig. 2), and others, also during the building of ramparts. Another possible factor is denudation. This consists, among other things, in the uncovering of deeper levels of soil as the result of degradation and the removal of the surface layers, particularly in sloping and upland areas. This appears in a distinct lessening of the thickness of the humus horizon which is relatively poor in $CaCO_3$. This means the slow diminishing of the occurrence of parent rock rich in $CaCO_3$, its being ploughed up to the surface, resulting in an essential increase in $CaCO_3$ concentrations in the plough layer. As opposed to the previously discussed local extraction of loams, all localities of *Adonis aestivalis,* both permanent and ephemeral, as well as the control area, undergo denudation, as well the sites are located along the edges of uplands and the tops of hills. Although substantially stimulated by human activity, this natural factor may thus also explain the high $CaCO_3$ content in control samples and the ease with which the *A. aestivalis* is temporarily propagated along the boundaries of fields on hill tops and sides of the Vistula valley (Cf. Fig. 1).

It is much more difficult to explain the permanent presence of *A. aestivalis* on site 5, i.e. on a less clearly defined settlement site where the surface soil is noticeably poorer in $CaCO_3$ as compared with the other permanent localities of the species. This locality is on the edge of an upland, in a poorly outlined depression, where there may be an accumulation of material with a low $CaCO_3$ content, denuded from the parts of the field situated somewhat higher. The surface soil sample might thus have contained allochthonous material. This difference may not, however, be essential for the *A. aestivalis* taking root much deeper (acc.to HEGI, 1974, to 80 cm). Another explanation is similar, with the one difference that surface material and *A. aestivalis* seeds were carried down and then settle, the greatest accumulation of *A. aestivalis* suggesting this point as the optimum sampling site. The third explanation is based on the assumption that the site and sampling method were good and the presence of *A. aestivalis* was influenced by some other, unknown factor which compensating for the lower quantity of $CaCO_3$ in the substratum. In accordance with this assumption, this factor does not occur outside the settlement areas, hence *Adonis aesivalis* does not appear there permanently, despite the much higher concentration of $CaCO_3$ in the surface layer.

2.3 Phytocoenotic relationship

The vegetation on sites of the permanent occurrence of *Adonis aestivalis* also differs noticeably from the control areas (Table 1); at the same time, it should be remembered that the latter are representative of fields in the region investigated. These differences concern both cultivated plants

Tab. 1 - Comparison of phytocoenoses with *Adonis aestivalis* (A) with control patches (B)

	A									B								
Number of locality	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Date	5	5	8	19	19	19	8	28	12	5	5	8	19	19	19	8	28	12
	8	8	6	7	7	7	6	6	7	8	8	6	7	7	7	6	6	7
	79	79	83	80	80	80	83	85	83	79	79	83	80	80	80	83	85	83
Cover	30	70	100	80	80	70	40	60	70	50	60	100	70	70	70	90	90	70
Exposure	S	SSW	SE	NE	E	-	E	-	-	S	S	-	-	NEE	NEE	NE	-	NW
Slope °	5	10	5	5	5	-	10	-	-	5	5	-	-	5	5	10	-	5
Area of record	150	150	100	150	100	100	100	150	100	150	150	100	150	100	100	100	150	100
Number of weed species	30	30	34	34	40	30	19	24	22	20	27	16	13	33	22	18	19	18
Cultivated:																		
Triticum vulgare	2	2	+	r	.	.	2	4	4	3°	3	.	.	.	.	3	5	4
Hordeum vulgare	+	.	.	4	4	4	.	.	.	.	.	.	4	3	4	.	1	+
Avena sativa	+	.	.	.	+	1	1	.	.	.	.	.	.	.	1	2	+	.
Lolium perenne	.	.	.	1°	1°	.	+	.	.	.	.	.	.	1°	.	.	.	.
Hordeum distichum	1	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+
Brassica napus	+	+	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Brassica napus napobrassica	.	.	5	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.
Secale cereale	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	1
Sporadic species: A: 8 - Dactylis glomerata +, Festuca pratensis +, Phleum pratense +, Poa pratensis																		
Ch. Caucalidion lappulae:																		
Adonis aestivalis	1	+	1	+	+	+	1	1	1	.	.	.	.	.	.	.	.	.
Consolida regalis	+	1	1	2	2	+	.	+	.	+	+	.	.	2	+	.	.	.
Aethusa cynapium	.	.	+	.	1	+	+	.	.	.	.	.	.	+	.	.	.	+
Euphorbia exigua	+	+	.	.	.	+	.	+	.	.	+	.	.	.	.	+	.	.
Lathyrus tuberosus	.	.	.	+	+	.	1	.	.	.	.	.	.	+	1	+	.	1
Ranunculus arvensis	r	.	.	+	+	.	.	.	.	.	.	.	.	1	.	.	.	.
Avena fatua	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	+
Silene noctiflora	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	+	.
Ch. Centauretalia cyani:																		
Veronica hederifolia	.	.	+	+	+	+	.	2	.	.	+	.	.	+	+	.	1	+
Papaver rhoeas	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	+	.
Lithospermum arvense	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Apera spica-venti	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Papaver argemone	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Centaurea cyanus	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Vicia tetrasperma	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Ch. Stellarietea mediae:																		
Stellaria media	+	1	+	1	+	1	+	+	1	+	1	1	1	+	+	.	1	.
Fallopia convolvulus	+	+	+	+	2	+	+	+	1	1	+	.	+	1	+	.	+	.
Thlaspi arvense	+	+	+	+	+	+	+	+	1	+	+	+	+	+	.	.	.	+
Tripleurospermum maritimum	+	+	+	1	1	+	.	1	+	.	1	+	+	1	+	.	+	+
Lamium amplexicaule	+	2	1	+	+	+	+	.	+	1	2	+	+	+	.	+	.	.
Chenopodium album	1	+	+	+	+	+	+	1°	+	.	1	.	.	+	.	.	.	.
Geranium pusillum	+	+	+	+	+	+	.	.	.	.	+	+	+	+	+	+	.	.
Sonchus asper	+	+	+	+	+	.	.	+	+	+	+	.	.	+	.	.	+	.
Polygonum heterophyllum	1	2	+	+	+	+	.	.	.	.	+	+	.	+	.	.	+	.
Viola arvensis	+	.	+	+	+	2	.	+	.	+	+	.	.	.	+	.	.	.
Euphorbia helioscopia	+	.	+	.	.	+	.	+	+	+	+	.	.	.	.	+	.	+
Myosotis arvensis	.	+	+	.	+	+	.	.	.	.	.	+	+	+	+	+	+	+
Veronica polita	+	+	.	.	.	.	+	+	.	+	+	.	.	.	.	.	+	.
Tussilago farfara	.	.	.	.	+	.	+	.	+	.	.	.	.	1	+	2	.	.
Sinapis arvensis	.	.	.	+	+	.	.	+	.	.	.	.	.	+	r	.	+	.
Atriplex patulum	+	+	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Capsella bursa-pastoris	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Sonchus arvensis	.	.	.	.	.	+	2	.	.	.	.	.	.	.	+	1	.	+
Veronica persica	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	+	+
Galeopsis tetrahit	.	+	.	.	.	.	.	.	1	+	.	.	.	+	.	.	.	+
Descurainia sophia	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	+	.
Anagallis arvensis	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Polygonum tomentosum	.	.	.	.	r	.	.	.	.	.	+	.	.	.	.	.	.	.
Veronica opaca	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	.	.	.
Fumaria officinalis	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.
Erodium cicutarium	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sonchus oleraceus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Accompanying species:																		
Galium aparine	+	1	1	1	1	.	+	1	2	2	2	1	2	1	+	3	1	.
Agropyron repens	.	3	+	+	+	1	2	1	2	+	1	.	2	2	2	+	+	2
Convolvulus arvensis	+	+	+	.	2	1	1	+	+	+	.	+	.	2	1	+	.	2
Taraxacum officinale	+	+	r	+	.	+	.	2	+	+	+	.	+	+	1	.	.	.
Cirsium arvense	+	1	.	+	+	+	+	.	+	.	.	.	.	+	1	+	+	+
Campanula rapunculoides	+	1	.	.	+	+	+	.	+	.	+	.	.	.	+	+	.	.
Lapsana communis	+	1	.	+	+	.	.	.	.	1	+	+	+	+	.	+	.	+
Melandrium album	.	+	.	+	+	+	.	.	.	+	+	.	.	.	.	.	.	.
Arctium tomentosum	+°	+	+°	+°	+°	.	.	.	.	.	.	.	+°	.	.	.	.	.
Trifolium repens	.	.	+	+	1	+	.	.	.	.	.	.	.	2	1	.	.	.
Galium spurium	.	.	+	.	.	+	+	.	1	.	.	.	.	.	.	.	.	.
Rumex crispus	.	+	+	.	+	.	.	r	.	+	+	.	.	.	+	.	.	.
Falcaria vulgaris	.	+	.	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.
Chaerophyllum bulbosum	.	+	+	.	+	.	.	.	.	.	.	+	.	+	.	.	.	.
Veronica arvensis	.	.	.	1	1	.	.	.	1	.	.	.	.	+	.	.	.	.
Carduus personata	.	+	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.
Medicago lupulina	+	.	.	2	2	.	.	.	.	+	.	.	1	.	.	.	.	.
Camelina microcarpa	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria serpyllifolia	.	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum amphibium	.	.	+	.	.	.	.	.	.	.	.	+	.	.	+	+	.	.
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.
Stachys palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+
Galeopsis bifida	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Rubus sp.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.
Galeopsis pubescens	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Trifolium pratense	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Sherardia arvensis	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.

Sporadic species: A: 1 - Plantago intermedia +; 3 - Polygonum monspelliense +, Trifolium dubium +, Cirsium lanceolatum r; 5 - Ranunculus repens +, Rumex acetosa r°; 6 - Plantago major +; 7 - Vicia cracca +; B: 2 - Senecio sp. +; 5 - Lathyrus pratensis +; 7 - Symphytum officinale r°; 9 - Artemisia vulgaris +, Poa trivialis +.

and weeds. In the area of archaeological monuments, wheat has a lower vitality – it is about 1/3 less in height, yellowish and grows in less compact groups. These facts conform with those generally known in archaeology. The phytocoenoses of field weeds in the terrain of confirmed archaeological monuments have richer flora than the control areas – there are, on overage, 11 more species of weeds (Fig. 4). In the remaining three locations of *Adonis aestivalis,* these differences are much less significant, but the general conformity is the same. Almost all phytocoenoses in which *Adonis aestivalis* is present are also richer in other species characteristic of *Caucalidion* alliance.

Considering the combination of species containing a large proportion of calciphilous plants

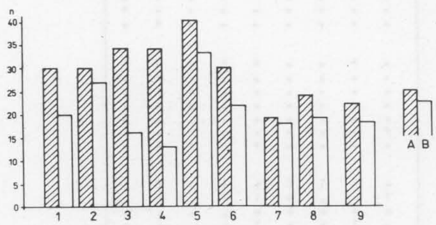

Fig. 4 - Number of weed species in the records compared.
1 - 9 - numbers of localities, see Fig. 1.
A - patch with *Adonis aestivalis,* B - control patch without *A. aestivalis.*

they have been included in the association of *Lathyro-Melandrietum* Oberd. 1957; this is one of the most northerly situated locations of this association and the *Caucalidion alliance* in Poland (SZMEJA 1987, HERBICH in print).

Comparison of all the phytocoenoses containing *Adonis aestivalis* applying the Jackard and Steinhaus formula with Romaniszyn's modification (P1, 2 = $\frac{c \times 100\%}{a + b - c}$), quite distinctly confirm the relationship of areas containing confirmed archaeological monuments and separates them from the remainder (Fig. 5: 1-6 and 7-9).

An analysis of the mean values of ecological indices calculated for weeds in the areas, indicates the recurrence of floristic-habitat conditions on archaeological sites (Fig. 3: 1A - 6) and their difference from the control areas (Fig. 3: 1B - 6B), namely a greater calciphility (R) and thermophility (T), with a simultaneously lower humidity (F) and fertility (N). Although some differences are statistically unimportant, they illustrate concordance with the general tendency. After rejecting the index numbers characterizing *Adonis aestivalis* from the calculations, very similar results were obtained. This would indicate that not only the presence or lack of *A. aestivalis* influences the floristic-ecological similarity or differences in the areas analyzed.

3. The problem of the appearance and disappearance of *Adonis aestivalis* localities along the lower Vistula

The results given are related to two questions, namely, that of the time and way in which *Adonis aestivalis* appeared along the lower Vistula and the reasons for the disappearance of the majority of localities over the past several score years (Cf. ABROMEIT 1898-1940 and Fig. 1). They did not constitute the subject of detailed studies, as this would exceed the aims set, hence they are only mentioned preliminarily; this concerns, in particular, the first problem.

The determining of the time at which *Adonis aestivalis* appeared is impossible in view of the lack of palinological and archaeological source material. The fact that *A. aestivalis* is an archaeophyte and found on Bronze Age excavations in Czechoslovakia (GIZBERT 1971), comparison with the age of settlement and agriculture along the lower Vistula might suggest that it appeared here a long time ago. On the other hand, the spatial relationship of all the localities with the trade routes in the whole of Poland's lowland, particularly grain trade along the lower Vistula in XV-XVII centuries (Fig. 6, Cf. KORNAS 1966, CZAPLINSKI, LADOGORSKI 1979), might suggest a much younger origin of the plant along the lower Vistula. The acceptance of the first possibility does not, of course, exclude the second, as a secondary appearance of the species. It should,

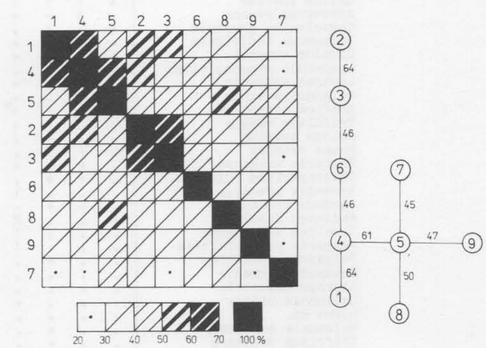

Fig. 5 - Diagram and dendrite constructed on the base of floristical similarity of patches with *Adonis aestivalis* / cultivated plants excluded/.
1 - 9 - numbers of localities, see Fig. 1.

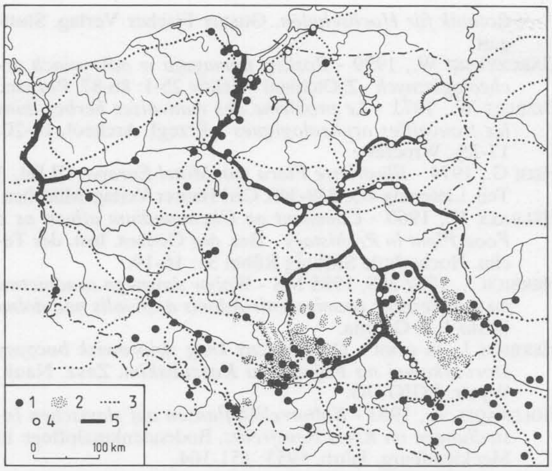

Fig. 6 - Localities of *Adonis aestivalis* in Poland against the background of the occurence of rendzinas and the trade routs in XVI century.
1 - localities of *A. aestivalis*, 2 - main areas of occurence of rendzinas - the centre of distribution of *A. aestivalis* in Poland, 3 - main overland routes, 4 - corn ports, 5 - corn trade water routes (1, 2 after Kornas 1966, 3-5 after Czaplinski, Ladogórski 1979).

however, be emphasized that considering the material available, this is purely speculation.

It would seem much simpler to explain the shrinking of the local range, as basing on material from both historical and contemporary localities, the following reasons for the disappearance of *A. aestivalis* can be formulated: 1) abundant fertilizing of fields with fresh manure; 2) the universal introduction of new plants (*Papilionaceous,* maize), which with their specific periods and types of agrotechnical operations, effectively eliminate almost all grain weeds; 3) continous or periodic changing of fields for the long-term cultivation of grass or pasture; such a change in the utilization is also one of the forms of protecting archaeological monuments. Together with the universal intensification of agriculture, these effects might considerably restrict both the regional and local range of *Adonis aestivalis* to habitats most unfavourable to the plant, and usually related to the loams rich in carbonates from the region of Gniew.

4. Conclusions

1. In the area investigated, such archaeological monuments as ruins of fortified settlements, settlements and cemeteries constitute local refuges of *Adonis aestivalis,* hence the plant has temporarily spread to other habitats abudant in calcium carbonate.

2. The basis factor influencing the permanent survival of *Adonis aestivalis* on the localities investigated today, is the mechanical raising to the surface of soil abundant in calcium carbonate from the lower horizons of the profile. This may be in the processed form (daub) or in its natural state; in the second case this takes place during the digging of pits, graves, moats and excavation investigations – the latter playing the least rôle.

3. Fragments of daub together with pieces of bone, clinker etc., constitute the soil skeleton which, together with the loosening of the soil during digging, improves the porosity of the heavy, compact Gniew black earths. As a result, the conditions become partially similar to those existing in rendzinas, which constitute the optimum habitat for *Adonis aestivalis* in Poland.

4. Denudation, causing the uncovering of deeper layers of soil abundant in $CaCO_3$, would appear to play the basic rule in the local shifting of ephemeral localities of *Adonis aestivalis.*

5. Factors favouring the survival of *Adonis aestivalis* localities also favour the development of the *Lathyro-Melandrietum* Oberd. 1957 association, which forms island locality in the area studies, far beyond the boundary of the continuous range of associations of the *Caucalidion* alliance in Poland.

6. In two cases, the presence of *Adonis aestivalis* helped in the finding of a former settlement site previously unknown to archaeologists. This fact would apepar to emphasize the relationship between the contemporary vegetation and former settlements.

7. The results obtained indicate that former settlement sites, at present fields, may constitute local refuges of segetal archaeophytes outside the boundaries of their continuous range.

8. The relationship between the historical and contemporary distribution of *Adonis aestivalis* localities along the banks of the lower Vistula and other parts of lowland Poland, and the early trade (particularly that of grain) routes, would seem to suggest the path along which this species was propagated in the past.

Zusammenfasung

Einfluss früherer Ansiedlungen auf die gegenwärtige Verteilung von *Adonis aestivalis* L. an der unteren Weichsel (Nordpolen).

Adonis aestivalis tritt in Polen hauptsächlich auf den Kreidemergelerden in südlichem Teil des Landes hervor, dagegen in Mittel und Nordpolen hat sie nur seltene Fundorte auf anderen Bodenarten, die auch reich an $CaCO_3$ sind. In Nordpolen konzentrieren sich die Fundorte an der unteren Weichsel. Das sind die Bereiche der früheren, hauptsächlich mittelalterlichen Ansiedlungen. Man erforschte fast alle bekannten Fundorte von *Adonis aestivalis* in dieser Region und stellte fest, dass zur Zeit ein dauerhaftes Hervortreten dieser Gattung auf den Feldern sich fast ausuchliesslich nur auf der Oberfläche des

archeologischen Denkamals berschränkt. Agrophytocoenose mi *A. aestivalis,* im Vergleich mit der Nachbarschaft, hat auch eine grössere Zahl von Arten, darunter besonders charakteristish für den *Caucalidion* - Verband. Die Oberflächenschicht des Bodens, auf den archeologischen Fundorten, enthält zahlreiche Fragmente von Lehmestrich, Keramik, Knochen usw., sowie auch eine grössere Menge von $CaCO_3$. Das verursacht, dass sich der Boden von der Typischen Schwarzerde unterscheidet, die in der Umgebung archeologischer Fundorte hervortritt und sich den Kreidemergelerden angleicht. Es scheint, dass die spezifischen, lokalen Eigenschaften des Standortes eine gegenwärtige, dauerhafte Anwesenheit von *A. aestivalis* auf dem erforschten Gebiet ermöglichen. Die Gebiete ehemaliger Ansiedlungen und Gräberfelder erfüllen jetzt die Funktion lokaler Refugien von *A. aestivalis* an ihrer Verbreitungsgrenze.

Summary

Adonis aestivalis occurs in Poland mostly on rendzinas in the southern part of the country, whereas in its central and northern parts there are only a few localities on the other kinds of soils, but also rich in $CaCO_3$. In northern Poland the localities are concentrated along the lower Vistula banks. This is an area also rich in earlier settlements. Almost all known historical and all contemporary localities of A. aestivalis in this region have been investigated. It was found that this species permanently exists only within the limits of archaeological sites. The greater number of species, particularly those characteristic of the *Caucalidion* alliance, distinguishes these agrophytocoenoses from the surrounding ones. The upper layer of soil on the sites of earlier settlements etc. contains numerous pieces of daub, pottery, bones and the like and also a much higher $CaCO_3$ content. The soil thus becomes similar to rendzina and differs from the heavy black soils of the neighbourhood. It seems that these specific local features of present-day habitats on archaeological sites render possible the contemporary permanent occurrence of *A. aestivalis* in he investigated area. Earlier settlements and graveyards function now here as local refuges of *A. aestivalis* at the edge of its geographical range.

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Spontane Vegetation auf den Böschungen des Elbe-Seitenkanals im Bereich der Samtgemeinde Bodenteich

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Keywords: Plant communities, embankment, channel.

Abstract

Ten years after the opening of the ESK (Elbe-Seitenkanal) plant communities are studied on a one meter strip of the embankment.

1. Vorbemerkungen

Der Anfang der 70er Jahre in Betrieb genommene Elbe-Seitenkanal verbindet mit einer Länge von 115 km die Elbe mit dem Mittellandkanal zwischen Braunschweig und Wolfsburg. Neben der Schiffahrt wird er auch in größerem Umfang für die Feldberegnung genutzt (Abb. 2, NIETFEID 1986 und SCHWERDTFEGER 1987).

Zur Beobachtung der Vegetation an den Böschungen des Kanals ist die Strecke vom km 41 bis zum km 53,3 - Südgrenze der Samtgemeinde Bodenteich bis zu deren Nordgrenze am Sperrtor Wieren gut geignet. Hier verläuft der Kanal sowohl im Einschnitt als auch auf einem Damm (Abb. 1, BELLIN 1975). Der Böschungsbereich bis 1 m über dem Kanalwasserspiegel ist durch eine mit Asphalt vergossene Steinlage befestigt.

Während die über dieser Steinlage befindlichen Böschungsbereiche angesät und teilweise bepflanzt worden sind, soll die Steinlage durch den Asphaltverguß weitgehend vegetationsfrei bleiben. Hier hat sich jedoch in einem Jahrwehnt eine spontane Vegetation eingestellt, die während der Vegetationsperiode 1987 und im Frühjahr 1988 untersucht wurde.

Wasserspiegelbreite	= 53 m
Fahrwasserbreite	= 35 m
Sohlbreite	= 26 bis 29 m
Wasserseitige Böschungen	= 1 : 3
Wassertiefe	= 4,15 bis 4,65 m
Benetzter Querschnitt	= 166 m^2
$n = \frac{F\ Kanal}{f\ Schiff}$	= 7.

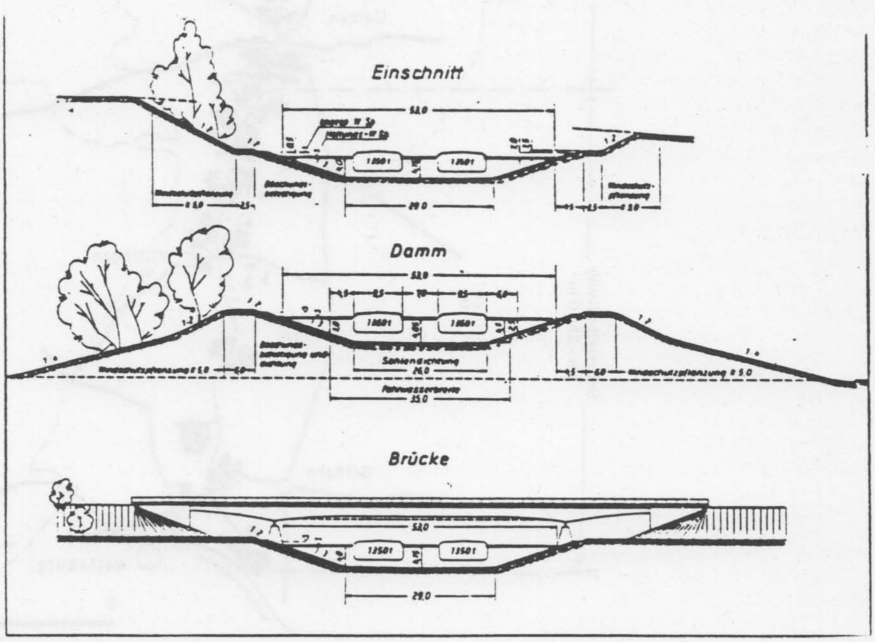

Abb. 1 Kanalquerschnitte.

2. Der untersuchte Streckenabschnitt

Der Kanalkilometer 41 liegt an der Südostecke des Lüberbruchs im Bereich des Staatsforstes Knesebeck. Daran schließen in nördlicher Richtung bis zum km 46 Ackerflächen der Gemarkung Lüder an. In der Ortslage dieses Dorfes wird der Kanal von drei Straßenbrücken gekreuzt. Anschließend unterquert die Aue, Quellfluß der Ilmenau, in einem Düker den Kanal. Hierzu wird dieser auf einer ersten Dammstrecke im Untersuchungsabschnitt geführt.

In der Ortslage Bodenteich ist am Ostufer eine durch eine gerammte Spundwand gesicherte Schiffsanlegestelle von etwa 300 m Länge vorhanden. Nördlich davon kreuzen zwei Straßenbrücken und eine Fußgängerbrücke den Kanal. Letztere verbindet zwei Neubaugebiete über den hier im Einschnitt verlaufenden Kanal. Nördlich des Fleckens Bodenteich durchschneidet der Kanal ein Waldgebiet, das ein Ausläufer der westlich gelegenen Wierener Berge ist (ab km 49,5).

Der restliche Untersuchungsabschnitt des Kanals bis zum Sperrtor Wieren bleibt am

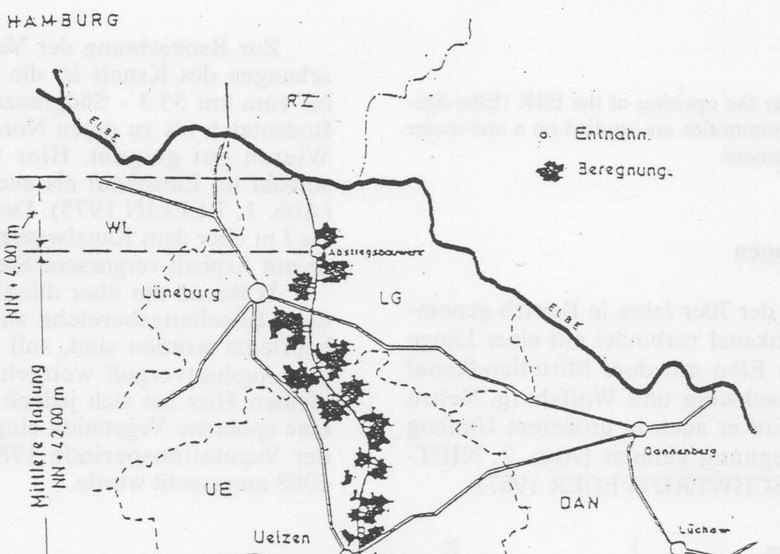

Abb. 2 - Beregnungsverbände am Elbe-Seitenkanal.

Tab. 1 - Spontane Vegetation am Elbe-Seitenkanal in der Steinböschung 1987/88 im Bereich der Samtgemeinde Bodenteich

	1	2	3	4	5
Acer campestre		r	?		
Achillea millefolium	+	1	+	2	
Aegopodium podagraria		1		+	
Agrostis tenuis	1	1	1	2	1
Alchemilla vulgaris				2	
Alnus glutinosa		2		1	
Anthriscus sylvestris	1	2	+	1	+
Apera spica-venti	+	1	+	1	
Artemisia vulgaris	1	3	1	2	+
Bellis perennis		+		1	
Betula pendula	1	2	1	2	+
Capsella bursa-pastoris				+	
Cerastium holosteoides				1	
Cerastium arvense	+			+	
Chrysanthemum vulgare	1	2	1	3	+
Cirsium arvense		1		1	
Cirsium vulgare	+	1		+	
Conyza canadensis		2		1	
Corylus avellana		+		+	
Corynephorus canescens	1	+	+	1	+
Dactylis glomerata				+	
Echium vulgare		+			
Epilobium angustifolium	1	2	1	3	+
Equisetum arvense	+				
Erodium cicutarium	+		+		
Erophila verna		2			
Festuca arundinacea				3	
Festuca ovina	+	1	+	2	1
Festuca rubra				+	
Frangula alnus	1	1	+	1	+
Fraxinus excelsior		+			

1 km 41 - 46 freie Landschaft mit Wald (Staatsforst Lüderbruch)

2 km 46 - 47 Ortslage Lüder

3 km 47 - 48 freie Landschaft

4 km 48 - 49,5 Ortslage Bodenteich

5 km 49,5-53,3 freie Landschaft- Waldrandlage am Wierener Berg

Tab. 2 - Spontane Vegetation (Fortsetzung)

	1	2	3	4	5
Fumaria officinalis		+		r	
Gnaphalium uliginosum	+		1		
Heracleum sphondylium	1	2	2	3	1
Hieracium pilosella	+				
Holcus lanatus		1			
Hypericum perforatum	1	2	1	3	+
Juncus effusus	+	1			
Mentha aquatica	+ ?				
Molinia caerulea			r		
Myosotis palustris	+				
Oenanthe aquatica		1	+	1	
Origanum vulgare		+ ?			
Peucedanum palustre	+	1			
Pinus sylvestris	r				
Plantago lanceolata		+		1	
Poa annua	+	1	+	1	
Poa pratensis				+	
Poa trivialis	+	1		+	
Potentilla anserina	1	2	+	1	+
Ranunculus repens	2	3	1	2	+
Rubus fructicosus		+		1	
Rumex crispus		+			
Sagina procumbens				+	
Salix aurita		1	+	2	r
Salix caprea	+	1		r	
Salix cinerea ?				+	
Salix purpurea	+	2	+	1	1
Sambucus nigra		+			
Sarothamnus scoparius		1		r	
Scleranthus annuus		+			
Senecio vulgaris	1	2		1	+
Sisymbrium officinale	1	3	1	2	+
Solidago gigantea		+ ?			
Sorbus aucuparia	+	1	r	2	r
Taraxacum officinale	1	3	1	2	1
Trifolium repens		1		+	
Tussilago farfara	2				
68 Zahl der beobachteten Arten	35	49	25	47	19

Ostrand des Waldgebietes der Wierener Berge. Die Forsten bestehen an Stelle des dort heimischen *Querco roboris-Betuletum* überwiegend aus angepflanzten, artenarmen *Pinus sylvestris*- Beständen.

Aus dieser Beschreibung ergibt sich die Aufteilung der untersuchten trecke in die fünf Abschnitte, die in Tabelle 1 aufgeführt sind.

3. Die pflanzensoziologische Einordnung

In Tabelle 1 sind 68 Species aufgeführt, die in den fünf vorstehend beschriebenen Untersuchungsräumen beobachtet worden sind. In den beiden Orstlagen Lüder und Bodenteich sind mit 49 und 47 Species mehr als doppelt so viel wie im nördlichen Abschnitt an denWierener Bergen beobachtet worden.

Mit dieser geringen Artenzahl könne die Pflanzenbestände nur als spontane Vegetation angesprochen werden. Bei der großen Lückigkeit der Bestände können Assoziationen allenfalls nach mehrjährigen Beobachtungen erfaßt werden. Dabei besteht die Gefahr, daß bei der geringen Artenzahl Fragmente zu wenig aussagekräftigen Tabellen führen.

Eine pflanzensoziologische Kartierung ist auch in der weiteren Umgebung nicht erfolgt. Die nächste Lokalflora mit ausführlichen Angaben der fundorte ist in etwa 100 km Entfernung für den Landkreis Harburg veröffentlicht worden (MÜLLER/HORST 1983).

Im Rahmen der «Mitteleuropakartierung» liegen beim Niedersächsischen Landesverwaltungsamt, Dezernat Naturschutz, Landespflege, Vogelschutz in Hannover Pflanzenlisten vor. Diese hat der damalige Naturschultz-beauftragte des Landkreises Uelzen nach eigenen Feststellungen bei vielen Begehungen in den Jahren 1947-1972 aufgestellt (WILDFEUER 1972). Für die TK 25 3129 Wieren sind 752 Sippen und für die TK 25 Bodernteich 654 Sippen verzeichnet. Die in den Steinböschungen 1987 beobachteten 68 Artenhaben danach an der gesamten Gebietsflora einen anteil von etwa 10%.

Dies entspricht einer angabe von BRANDES (1988): «Von insgesamt 238 Ruderalpflanzenarten des Braunschweiger Umgebung sind nur 10,9% der Sippen in mehr als 90% der untersuchten TK 25-Quadranten vertreten. Die Hälfte der Arten ist jeweils in weniger als 30% der Quadranten vorhanden».

4. Ruderalpflanzen

Die spontane Vegetation auf den mit Steinlagen befestigten und mit Asphalt vergossenen Böschungen des Elbe-Seitenkanals kann bei der bisherigen Entwicklung nicht als Ruderalvegetation angesporchen werden.

«In der Definition werden Ruderalgesellschaften charakterisiert als vom Menschen "stark geprägt". Der Begriff "Störung" wurde absichtlich vermieden, da er eine "Unterbrechung des Normalzustandes" impliziert. Derartige Eingriffe sind aber essentieller Bestandteil des "Ökosystems Ruderalgesellschaft"». (FISCHER 1988).

In der Naturlandschaft Mitteleuropas gab es immer wieder offene, konkurrenzarme Wuchsorte durch Wind- und Gewässeranrisse, um Tierbauten und an frühen Siedlungsplätzen. Schon in der Jungsteinzeit führte der beginnende Ackerbau mit zunehmender Besiedlungsdichte zur Einwanderung von Arten aus dem Mittelmeergebiet und aus Vorderasien. Erst zu Beginn der Neuzeit kamen auch Arten aus Übersee vor allem aus Nordamerika nach Mitteleuropa, die das heimische Arteninventar deutlich vermehrten. Sie alle fanden an diesen, in unserer modernen Kulturlandschaft zunehmenden, vorhandenen Wuchsplätzen einen geeigneten Standort. Die Ruderalvegetation im weiteren Sinne bedeckt daher in der Bundesrepublik Deutschland einen höheren Flächenanteil als alle Naturschutzgebiete des Festlandes zusammen (BRANDES 1988).

Der untersuchte Böschungsstreifen am Elbe-Seitenkanal ist durch den Asphaltverguß der Steinlage schwer zu besiedeln. Asphalt ist aber ein Naturprodukt, das nicht so besiedlungsfeindlich ist wie Beton, der für die Befestigung von Verkehrsflächen eingebaut wird. Für letztere trifft BRANDES (1988) die Feststellung: «Auf versiegelten bzw. überbauten Flächen können sich nur noch Fragmentgesellschaften aus trivialen Arten entwickeln».

Bei der Besiedlung auf der untersuchten Böschung sind mehrjährige Arten den einjährigen deutlich überlegen. Dies findet in der Zusammensetzung der Vegetation seien Ausdruck. Von 68 gefundenen Arten sind nur 11 Therophyten.

Ob auf diesem Standort eine Sukzession zu einer annähernd stabilen Klimax-Gesellschaft möglich ist, kann aus den kurzfristigen Beobachtungen noch nicht abgeleitet werden. An Stelle der oft uferbegleitenden Hochstaudengesellschaften der *Phragmitetea* kann es an diesem Standort wahrscheinlicher zu einer Gehölzvegetation aus der Klasse der *Alnetea* und *Salicetea* kommen.

Zusammenfassung

Am Elbe-Seitenkanal sind die durch Steinpackungen gesicherten Böschungen bis etwa ein Meter overhalb der Wasserlinie mit Asphalt vergossen und sollen dadurch vegetationsfrei bleiben. Im Laufe eines Jahrzehnts sind jedoch zahlreiche Pflanzenarten durch natürlichen Anflug zum Keimen und Durchwachsen der Asphaltdecke gekommen. Dieser Anflug ist nach Artenzahl und Wuchskraft in den beiden Ortslagen Bodernteich und Lüder deutlich größer als außerhalb. Die pflanzensoziologische Einordnung wird auch im Hinblick auf benachbarte Ruderalgesellschaften diskutiert.

Summary

The stone-embankment of the new channel «Elbe-Seitenkanal» was filled with asphalt upto one meter above the water-line to keep it vegetation-free. But in one decade numerous plants, that got there by deposit of airtransported seeds, have germinated or grown from the under-layer through the asphalt.

In the surrounding locality of the two villages Bodenteich and Lüder is the number of species and their growth higher and stronger as in the other parts of the enbankment. The future possibility of the succession of plantcommunities is discussed also in regard to the neighbouring ruderal-societies.

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Toleranz eines fragmentarischen *Bryo-Saginetum procumbentis* auf einem städtischen Parkplatz gegenüber Schwermetallanreicherung

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Keywords: Bryo-Saginetum procumbentis, soil seed bank, contamination, chemical elements.

1. Einleitung

Urbane Trittrasen werden insbesodere im innerstädtischen Bereich als Parkplatz genutzt. Hierbei sind sie aufgrund des ständigen Befahrens nicht nur einer stärkeren Verdichtung ausgesetzt, sondern aufgrund der Kfz-Frequentierung auch einer starken Schwermetallbelastung.

Achon zu Beginn der siebziger Jahre wurden die Auswirkungen dieses Streßfaktors auf einzelne Pflanzenarten untersucht (z.B. LAGERWERFF & SPECHT 1970, SOMMER et al. 1971, KLOKE 1972). Neben dem ökologischen Aspekt ist aber auch die synökologische Betrachtung von großem Interesse.

Wie wirkt sich die Verkehrsbelastung auf die floristische Zusammensetzung einer Sonderform eines Trittrasens, der Pflasterritzenvegetation aus. Diese Pflanzengemeinschaften siedeln in den Fugen zwischen Pflastersteinen, Betonplatten etc. Kommt es auf diesen Flächen zu einer Verarmung der Pflanzengesellschaften? Spielen weitere chemische Elemente des Bodes eine Rolle, bei der Zusammensetzung? Das sind Fragen, die in vorliegender Untersuchung aufgrund von Vegetations-, Samenspeicher- und Multielement- analysen bearbeitet werden sollten (vhl. MARKERT & BERNHARDT, in Druck).

2. Die Untersuchungsflächen

Im zentralen Bereich Osnabrücks (Norddeutschland) wurden in einem Wohnbereich (Jahnstraße) stark und weniger gestörte «Trittflächen» untersucht.

Sämtliche Probeflächen sind Pflasterritzengesellschaften. Bei den Aufnahmen 1-5 handelt es sich um Parkplätze, die intensiv befahren und betreten werden. Die Pflasterung besteht aus Naturstein. Vergleichsweise wurde ein naheliegender, wenig begangener Weg mit einer Pflasterung aus Betonplatten und sehr breiten Fugen ausgewählt (Probeflächen 6-9). Die direkte Einwirkung durch Tritt und Verkehr ist im Vergleich zu den Probeflächen 1-5 wesentlich geringer. Im Nachfolgenden werden die ersten 5, stark gestörten Flächen als P (Parkplatz) und die Aufn. 6-9 als G (Gehweg) bezeichnet.

3. Methoden

3.1 Vegetationsanalysen

Die Aufnahme der pflanzensoziologischen Einheiten richtet sich nach BRAUN-BLANQUET (1964), die Nomenklatur der Artnahmen nach EHRENDORFER (1973).

3.2 Diasporenbank

Auf jeder Probefläche (1 m²) wurde der in den Ritzen vorhandene Boden entnommen und als Mischprobe in Plastikbeutel gefüllt, dabei entsprach die Bodentiefe der Tiefe der Pflastersteine (ca. 3 cm). Die Probenahme erfolgte nach Beendigung der Vegetationsperiode (Anfang November).

Zur Extraktion der Samen wurde ein Spülverfahren verwendet. Nach zahlreichen Literaturangaben sind die Arten- und Individuenzahlen bei dem Spülverfahren wesentlich höher als beim Ausstreichen von Bodenproben (BRENCHLEY & WARINGTON 1930, KROPAC 1966, BERNHARDT & HURKA 1988 u.a.), da hierbei einige Samen nicht auflaufen. Der Nachteil aber ist, daß nicht alle ausgespülten Diasporen keimfähig sind (FISCHER 1987). Unter fließendem Wasser wurde die Bodenmenge nacheinander durch 6 Bodensiebe (2; 1; 0,8; 0,5; 0,2; 0,1 mm) gespült (vgl. STANDIFER 1980). Die Fraktion jedes Siebes wurde unter einem Binokular nach Samen durchsucht.

3.3. Multielementanalysen

Um einen ersten Einblick in den Elementhaushalt von Pflasterritzengesellschaften zu erhalten, wurden vom Standort «Parkplatz» mehrere Bodenproben entnommen (1 cm Tiefe) und zu einer repräsentativen Mischprobe (200 g) vereinigt. Die Bodenprode wurde im Vakuumtrockenschrank unter vermindertem Druck (20 Torr) 48 Stunden bei 50°C getrocknet und anschließend durch ein Nylonsieb (Maschenweite 2 mm) geschickt, vakuumverpackt, und an die Universität London, Imperial College, Applied Geochemistry Research Group, versand.

Das folgende Aufschluß- und Meßprogramm konnte jeweils an zwei Teilen der Gesamtprobe durchgeführt werden. Je 0.200 g (+/- 0.001 g) des Bodens wurden in gereinigte Glas-Aufschlußgefäße eingewogen, 4 ml Salpetersäure (P.A., 70%) hinzugefügt, und in einem aufheizbaren Aluminiumblock bei 50°C über Nacht stehengelassen. Nach dem Abkühlen wurde 1 ml Perchlorsäure (P.A., 60%) hinzugefügt und folgendes automatisches Temperaturprogramm aktiviert (THOMPSON & WOOD 1982):

Aufheizsauer	*Temperatur*
12 h	100°C
3 h	150°C
18 h	190°C
0.1 h	195°C

Der trockene Rückstand wurde mit 2 ml Salzsäure (P.A., 5 M) aufgenommen, 1 h auf 60°C erhitzt und anschließen mit 8 ml destilliertem Wasser versetzt. Nach kräftigem Schütteln der Proben mit einem Vertex-Mixer und Überführung in Plastikgefäße wurden die Proben mit Hilfe eines ABS/ICP der Firma ARL (34000C) vermessen. Die verwardten Geräteparameter sind bei THOMPSON er al., 1987, beschrieben. Die Qualitätskontrolle des gesamten Analysengangs wurde nach THOMPSON & WALSH (1983) mit Hilfe von Blanks, Doppelbestimmungen und Referenzmaterialien durchgeführt.

4. Ergebnisse

4.1. Vegetationsverhältnisse

Bei den untersuchten Vegetationseinheiten handelt es sich um Trittpflanzen-Gesellschaften, die an extreme Standortbedingungen wie etwa ständigen Tritt, angepaßt sind (LIETH 1953, OBERDORFER 1983). Sie gehören zur Klasse der *Plantaginetea majoris* Tx. et Prsg. in TX 50 em. Oberd; et al., zur Ordnung: *Plantaginetalia majoris* TX 50 em Oberd. et al. 67, und zum Verband *Polygonion avicularis* Br.-Bl. 31 ex Aich.

Tab. 1 - Soziologie der untersuchten Pflasterritzen (Bedeckungsskala nach Braun-Blanquet): *Bryo-Saginetum procumbentis*

	Lfde. Nr.	1	2	3	4	5	6	7	8	9
	Flächengröße (m^2)	1	1	1	1	1	1	1	1	1
	Ritzenbreite (cm)	5	5	3	4	7	5	3	5	6
	Bedeckung (%)	100	90	90	90	100	100	90	90	100
	Artenzahl	8	6	7	7	7	11	13	10	14
AC:	Bryo-Saginetum procumbentis									
	Sagina procumbens	+	1	3	1	2	+	-	-	-
DA:	Bryum argenteum	4	2	2	3	2	+	+	-	-
VC:	Polygonion avicularis									
	Polygnonum arenastrum	-	-	-	-	+	1	+	1	-
O, K:	Plantaginetea majoris, Plantaginetalia majoris									
	Poa annua	2	2	2	2	2	3	4	4	5
	Plantago major	+	1	2	+	1	3	2	3	1
	Matricaria discoidea	+	-	-	+	-	-	+	+	+
Begleiter:										
	Taraxacum officinale	+	-	+	-	+	-	-	-	1
	Ceratodon purpureus	1	-	-	-	-	-	-	-	-
	Fumaria hygrometria	-	-	+	-	-	-	-	-	-
	Agrostis tenuis	+	3	-	+	-	-	+	-	-
	Conyza canadensis	-	+	+	+	+	-	+	-	-
	Capsella bursa-pastoris	-	-	-	-	-	1	1	2	1
	Stellaria media	-	-	-	-	-	1	1	+	+
	Chenopodium album	-	-	-	-	-	+	1	-	+
	Achillea millefoliatum	-	-	-	-	-	+	-	1	-
	Veronica serpyllifolia	-	-	-	-	-	-	-	+	1
	Trifolium repens	-	-	-	-	-	-	+	-	+
	Arenaria serpyllifolia	-	-	-	-	-	+	-	-	+
	Senecio vulgaris	-	-	-	-	-	-	+	-	+
	Sedum acre	-	-	-	-	-	+	-	-	+
	Cerastium holosteoides	-	-	-	-	-	-	-	+	+
	Poa pratensis	-	-	-	-	-	-	-	+	+
	Rumex acetosella	-	-	-	-	-	-	+	-	-

33. Aufgrund der Assoziationscharakterart *Sagina procumbens* und der Differentialart *Bryum argenteum* können die Aufnahmen 1-6 (Tab. 1) zum *Bryo-Saginetum procumbentis* Diem, Siss. et West. 40 n-inv. Oberd. gezählt verden. Es handelt sich dabei um eine artenarme Pioniergesellschaft in Pflasterritzen auf verdichteten, stark betretenen oder befahrenen Böden. Auffälling ist der große Moosreichtum dieser Gesellschaft (*Bryum argenteum, Ceratodon purpureus, Fumaria hygrometrica*). Die Aufnahmen 6-8 sind nur durch die Verbandscharakterart *Polygonum arenastrum*, die Aufn. 9 nur durch Ordnungs- und Klassencharakterarten gekennzeichnet. Sie zeigen fragmentarischen Charakter. Auffällig sind die hohen Bedekkungsgrade von *Poa annua* in den Aufs. 6-9. Diese Aufnahmen zeigen Ähnlichkeiten zu der von OBERDORFER (1983) angebenen *Poa annua*-Gesellschaft.

Die durchschnittliche Artenzahl dieser Aufnahmen (6) liegen mit 12 wesentlich höher als die der Aufn. 1-5 (P) (Abb. 1). Hier machen sich die extremen Standortbedingungen bemerkbar. Zum einen sind es die extreme Verdichtung und das ständige Befahren. Dadurch werden die Arten gefördert, die Ihre Wuchshöhe so einschränken können daß sie dei Maximalhöhe der Pflastersteine nicht überragen. Hierzu gehören die charakteristischen «Pflasterritzenarten».

Dieser Streßfaktor «Befahren» ist auf der Fläche G nicht vorhanden. Dazu tritt die große Fugenbreite von z.T. 10 cm. Hier können sich auch höherwüchsige ruderale Pionierarten ansiedeln wie z.B. *Capsella bursa-pastoris* und *Veronica serpyllifolia*. Dadurch erhöhen sich die artenzahlen (Abb. 1).

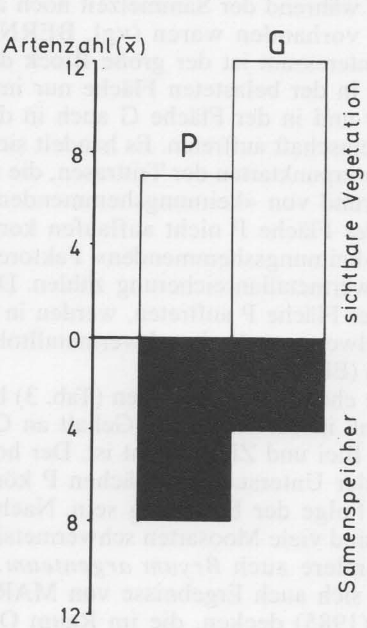

Abb. 1 - Vergleich der mittleren Artenzahl der Flächen (sichtbare Vegetation und Samenspeicher).

4.2. *Diasporenbank*

Als Samenspeicher wird der Vorrat der keimfähigen Diasporen in Boden bezeichnet (vgl. ROBERTS 1981, BERNHARDT 1987, FISCHER 1987). Dieser Samenvorrat beinhaltet nicht nur die Arten der sichtbaren Vegetation, sondern auch weitere Pflanzen, die aufgrund fehlender Keimbedingungen nicht auflaufen (BERNHARDT, in Druck).

Der Samenspeicher der untersuchten Probeflächen enthält im wesentlichen die charakteristischen Arten der beschriebenen Pflanzengesellschaften (Tab. 2). Die Moossporen wurden allerdings nicht bestimmt.

Auffälling ist die Verschieburg der höheren Artenzahlen zugunsten der Fläche P (Abb. 1). Sie liegen hier höher als auf der ungestörten Fläche. Es treten im Samenspeicher einige Arten auf, die nur in der aktuellen Vegetation der Fläche G vorhanden waren (Tab. 2). Dieses Phänomen könnte dadurch erklärt werden, daß in der Fläche G sämtliche Pionierarten aufgelaufen sind und der Vorrat im Boden aufgebraucht ist. Pionierarten müssen u.a. in der Lage sein, möglichst schnell zu

Tab. 2 - Samengehalt der untersuchten Aufnahmeflächen (Angabe der absoluten Anzahl).

Lfde. Nr.		1	2	3	4	7	9
Flächengröße (m^2)		1	1	1	1	1	1
Ritzenbreite (cm)		5	5	3	4	3	6
Bodenmenge (cm^3)		200	150	180	200	200	200
Artenzahl		10	9	5	6	3	5
AC:	Bryo-Saginetum procumbentis						
	Sagina procumbens	2	-	1	-	1	6
DA:	Moose	/	-	-	/	-	/
VC:	Polygonion avicularis						
	Polygonum arenastrum	2	1	-	2	-	-
OC, KC:	Plantaginetea majoris, Plantagenetalia majoris						
	Poa annua	1	-	-	1	-	-
	Matricaria discoidea	-	1	2	-	-	1
Begleiter:							
	Conyza canadensis	-	1	-	-	1	-
	Capsella bursa-pastoris	5	3	1	8	-	1
	Stellaria media	1	6	-	1	1	-
	Chenopodium album	1	-	-	-	-	-
	Veronica cf. serpyllifolia	-	1	1	-	-	-
	Arenaria serpyllifolia	1	-	-	1	-	-
	Senecio vulgaris	-	2	-	-	-	-
	Rumex acetosella	1	-	-	-	-	-
	Potentilla anserina	-	2	1	-	-	-
	Lepidium ruderale	3	1	-	-	-	1

/ Moossporen konnten nicht determiniert werden keimen, um der Konkurrenz, z.B. mehrjähriger oder rasenbildender Arten auszuweichen (BAKER 1964, FISCHER 1987, BERNHARDT 1987 u. in Druck). Das Vorhandensein dieser Arten, die in Fläche G in der sichtbaren Vegetation vorhanden sind, im Samenspeicher der Fläche P deutet daraufhin, daß sie hier keine optimalen Keimbedingungen vorfinden. Das kann einmal an dem dichten Abschluß der Moosschicht liegen, aber auch an der Schwermetallanreicherung im Boden.

Interessant ist das Vorkommen von *Potentilla anserina* und *Lepidium ruderale* im Samenspeicher. Beide traten in keiner der untersuchten Flächen auf. *Lepidium ruderale* konnte in beiden Probeflächen festgestellt werden, *Potentilla anserina* nur in P. Beide Arten treten im bebauten Bereich des Osnabrücker Stadtgebiets häufig auf (HARD 1983), besonders an offenen Standorten wie Baumscheiben etc. Das läßt den Schluß zu, daß beide Arten in den Ritzengesellschaften kaum optimale Lebens- und Keimbedingungen finden. Die Samenproduktion, besonders von *Lepidium ruderale* ist groß, so daß das Auftreten dieser Diasporen im Samenspeicher erklärt werden kann. Generell ist die Anzahl der im Boden festgestellten Diasporen sehr gering (Tab. 2).

4.3. Schwermetallanreicherung

Als ein weiterer Streßfaktor, der zur Reduzierung der Artenzhal höherer Pflanzen führen könnte, muß die Schwermetallbelastung des Bodens angeführt werden (LAGERWERFF & SPECHT 1970; SOMMER er al. 1971; MARKERT & JAYASEKERA 1987). Wie aus der chemischen Multielementalyse hervorgeht, sind insbesondere die Blei-, Cadmium-, Kupfer- und Zinkwerte erhöht (Abb. 2). Dies wird besonders dann deutlich, wenn wir die ermittelten Elementkonzentrationen mit den «Normalwerten» für Böden vergleichen, wie dies in Tab. 3 getan wurde.

5. Diskussion

Neben den für «Pflasterritzengesellschaften» typischen Streßfaktoren Verdichtung und mechanische Beeinflussung durch Tritt und Befahren liegt für die untersuchte Parkplatzfläche ein weiterer vor. Die auffällige Schwermetallbelastung des Standortes könnte zu einer Reduzierung der Artenzahl führen (cgl. LAGERWERFF & SPECHT 1970, SOMMER et al. 1971, MARKERT & JAYASEKERA 1987).

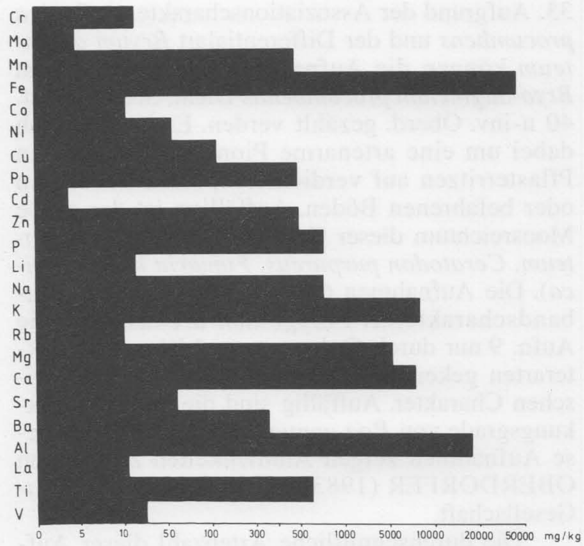

Abb. 2 - Ergebnis der Multielementanalyse.

Neben den Pflanzen, die in Fläche P und G im Samenspeicher sowie auch in der Pflanzengemeinschaft auftreten (Tab. 4), wie *Sagina procumbens, Matricaria discoidea, Agrostis tenuis* un *Conyza canadensis*, konnten zahlreiche Arten in der sichtbaren Pflanzengemeinschaft festhestellt werden. Es handelt sich hierbei im wesentlichen um Pflanzen, die kaum einen Samenspeicher anlegen und während der Sammelzeit noch als adulte Pflanze vorhanden waren (vgl. BERNHARDT 1987). Interessant ist der große Block der Pflanzen, die in der belasteten Fläche nur im Samenspeicher und in der Fläche G auch in der Pflanzengemeinschaft auftreten. Es handelt sich hierbei um Schwerpunktarten der Trittrasen, die vermutlich aufgrund von «keimungshemmenden» Faktoren in der Fläche P nicht auflaufen konnten. Zu diesen «keimungsshemmenden» Faktoren könnte die Schwermetallanreicherung zählen. Die Arten, die in der Fläche P auftreten, werden in der Literatur teilweise auch als schwermetalltolerant angegeben (ERNST 1974).

Die chemischen Analysen (Tab. 3) haben gezeigt, daß insbesondere der Gehalt an Cadmium, Kupfer, Blei und Zink erhöht ist. Der hohe Moosanteil der Untersuchungsflächen P könnte eine direkte Folge der Belastung sein. Nach ERNST (1974) sind viele Moosarten schwermetalltolerant, insbesondere auch *Bryum argenteum*. Hiermit würden sich auch Ergebnisse von MARKERT & MEER (1985) decken, die im Raum Osnabrück im Rahmen einer Biomonitoruntersuchung eine Anreicherung von Blei, Cadmium, Kupfer und

Tab. 3 - Vergleich der Ergebnisse der Multielementanalyse der Probefläche sowie einer «normal belasteten» Fläche (Daten aus Bowen 1979) (Angabe in mg/kg)

Element	Probefläche (x aus 2 Messungen)	Vergleichsfläche (n. BOWEN 1979)
Cr	24	70
Mo	4	1
Mn	480	1000
Fe	36000	40000
Co	13	8
Ni	60	50
Cu	120	30
Pb	350	35
Cd	3.1	0.4
Zn	420	90
P	550	800
Li	22	25
Na	600	5000
K	3400	14000
Rb	12	150
Mg	4300	5000
Ca	16000	15000
Sr	65	250
Ba	320	500
Al	15500	71000
La	13	40
Ti	570	5000
U	34	90
Be	1.1	0.3

Tab. 4 - Das Auftreten der einzelnen Arten in den verschiedenen Untersuchungsflächen

Art	P	G
Sagina procumbens	/	/
Matricaria discoidea	/	/
Agrostis tenuis	/	/
Conyza canadensis	/	/
Plantago major	o	o
Taraxacum officinale	o	o
Achillea millefoliatum	o	o
Sedum acre	o	o
Cerastium holostoides	o	o
Poa pratensis	o	o
Trifolium repens	o	o
Poa annua	/	o
Capsella bursa-pastoris	x	/
Stellaria media	x	/
Polygonum arenastrum	x	o
Chenopodium album	x	o
Veronica serpyllifolia	x	o
Senecio vulgaris	x	o
Rumex acetosella	x	o
Arenaria serpyllifolia	x	o
Lepidium ruderale	x	x
Potentilla anserina	x	–

/ Samenspeicher und sichtbare Vegetation
x nur Samenspeicher
o nur sichtbare Vegetation
– kein Vorkommen

Zink (also der gleichen Elemente wie in dieser Untersuchung) in dem Moos *Hypnum cupressiforme* (Hedw.) feststellten.

Sagina procumbens, die neben dem Silbermoos eine Charakterart der Fläche P ist, soll ebenfalls eine Toleranz gegenüber Schwermetallbelastrungen aufzeigen. So tritt sie auch als steting Begleiter in *Sileno-Armerietum metallicolae* (Schwermetallrasen) auf (ERNST 1974).

Zusammenfassung

Auf einem innerstädtischen Parkplatz Osnabrücks wird ein fragmentarischen *Bryo-Saginatum procumbentis* pflanzensoziologisch und mit Hilfe des Samenspeichers beschrieben. 24 chemische Elemente wurden quantitativ ermittelt. Dabei stellte sich heraus, daß der Boden mit verschiedenen toxischen Elementen wie Pb und Cd angereichert ist. Die Konzentration von wichtigen Elementen wie P wurde mit anderen Böden verglichen. Aufgrund dieser Untersuchungen sowie Vergleiche des Samenspeichers und der Pflanzengemeinschaft mit anderen Flächen kann angenommen werden, daß die Verarmung der vorliegenden Pflasterritzengesellschaft hierdurch bedingt ist.

Summary

A description of a fragmental *Bryo-Saginetum procumbentis* is given by the seed bank in soil and the physiological characterization. 24 chemical elements were quantitatively determined in the soil substrate. It was found that the soil substrate is entiched with different toxic elements like Pb and Cd. The concentration of essential elemente like P were decreased compared with other soilds. It could be assumed that the impoverishment of the investigated plant association should be related to the unnatural element concentration.

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Vegetation recovery at the Braun-Blanquet class level after several types of human disturbance at the Fish Creek Test Well 1, arctic Alaska

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Keywords: vegetation recovery, arctic Alaska, solid waste, trails, surface human disturbance, hydrocarbon spills, resistance, resilience, multiple disturbance, disturbance intensity

Abstract

The Fish Creek Test Well 1 was drilled on the Alaskan Arctic Slope in 1949, abandoned the same year, and little disturbed since. The original or newly developing Braun-Blanquet classes/landform units, rather than the type or intensity of disturbance, determined the direction of recovery. Both the colonization rate and the rate of recovery of community composition were lower on disturbances that produced greater departures from the original state. The resistance elasticity of ecosystems to disturbance are specific for different types of disturbance and for different Braun-Blanquet classes/landform units. The elasticity component may dominate the recovery after more intense disturbances and the resistance component after less intense disturbances. Vegetational recovery lagged behind the environmental one, especially after more intense disturbances. Post-disturbance base saturation, nutrients, and depth of thaw were usually higher, and organic matter, available water, silt, clay, and CEC were usually lower than in undisturbed control ecosystems. The rate of recovery of multiple disturbances by spills and blading appeared to be determined by the dominant disturbance, i.e. the one that produced the greatest departure from the original state.

Introduction

Along with other test well sites drilled on the Alaskan Arctic Slope during the 1944-1953 exploration period (REED 1958, GRYC 1985), the Fish Creek Test Well 1 represents a one-time, time-controlled, long-term experiment in the natural recovery of arctic ecosystems from human disturbance. The site has not been artificially revegetated and it has been disturbed very little between the 1949 drilling (BROWN 1978) and the cleanup of solid wastes in 1979 and 1980 (SCHINDLER 1983). The disturbance and the subsequent changes on the site have been documented by LAWSON et al. (1978 a). The pre-disturbance landforms and vegetation have been reconstructed and correlated to the present ones on the basis of air photography (KOMÁRKOVÁ & WEBBER 1978), and the vegetational changes on bladed surfaces have been analyzed by KOMÁRKOVÁ (1983).

The present paper includes one of the studies (KOMÁRKOVÁ 1985 a) following the original investigation in 1977. It focuses on the rate of recovery of several vegetation/landform types after several disturbance types, after single and multiple disturbances, and after several disturbance intensities. The following hypotheses were tested: 1. The rate of plant community recovery differs with the type and intensity of disturbance and with the vegetation/landform type. 2. The degree of plant community recovery is closely related to the degree of recovery of the physical environment. 3. In sites of multiple impacts, the rate of recovery is slower than in sites of component single impacts. 4. The direction of plant community recovery differs with the vegetation/landform type but not with the type and intensity of disturbance.

Vegetation type hierarchies based on floristic composition such as the Braun-Blanquet hierarchy (WESTHOFF & VAN DER MAAREL 1978) correspond to the hierarchies of landform units supporting them and are good measures for the ecosystem recovery after disturbance. Different vegetation hierarchy levels resolve the landscape pattern at different scales. For example, class, the highest level of the Braun-Blanquet hierarchy, corresponds to the level of landform type hierarchy which includes units such as marshes, snowpatches, and ridges. Disturbance is defined as a matter-removing activity (GRIME 1979, ODUM et al. 1979, VAN DER MAAREL 1980, WESTMAN & O'LEARY 1986).

The Site

Location and environment

The Fish Creek Test Well 1 (70° 18'36"N, 151° 52'40"W; Fig. 1 in LAWSON et al. 1978 a) is located on the Arctic Coastal Plain

(WAHRHAFTIG 1965) in the region of consolidated sand dunes which were a part of a Pleistocene sand sea (CARTER 1981). Vegetation and landforms at the test well site belong to the same types as those near Atkasook (KOMÁRKOVÁ & WEBBER 1980, KOMÁRKOVÁ & MCKENDRICK 1988) which is located within the same sand region. The ground contains a high amount of ice and moisture; the surface peat layer insulates permafrost which thaws from 0.2 to 1.5 m-depth during the summer. In the flat, sandy landscape, the rivers, wind, thaw-lake cycle (BRITTON 1967), and cryoturbation produce patches most of which are only several thousand years old (EVERETT 1979, 1980). Therefore, the individual landforms and their vegetation types are distinct but less well differentiated than the corresponding vegetation/landform types in less dynamic landscapes. Although the test well site is near the Arctic Ocean, the area surrounding it is not under the direct influence of ocean climate.

The test well site was placed on a uniform, primary, zonal surface, probably a wide, stabilized, and partly eroded sand dune ridge, elevated above the surrounding oriented lake basins. Some of these lake basins are drained, with low-centered polygons. The extent of natural thermokarst suggested that the primary surface on which the site was drilled was in transition from a low-centered to a high-centered polygon terrain (LAWSON et al. 1978 b).

1949 disturbance

The Fish Creek Test Well 1 was drilled near an oil seep as a stratigraphic test (REED 1958, LAWSON et al. 1978 b). The disturbance was limited to a relatively short period in 1949. The equipment and materials for camp construction and drilling were transported from Barrow between January and April 1949, the drilling took place between May and August, and a production test, which yielded 444 barrels of crude oil, took place in September and October. The well was abandoned shortly thereafter (LAWSON et al. 1978 b).

The buildings were set on short pilings and connected by boardwalks; these and adjacent areas were usually bladed clear of snow and vegetation along with the top of the surface soil layer. Part of the vegetation/soil mat was thawed and used for insulation and part was piled into berms around the site margin. Only a few such mats were rolled up in 1977. Water was hauled on bladed and other trails from a nearby lake and stream. Trails and tracks and a winter runway are the disturbances with the greatest areal extent. The construction of winter snow or ice roads and runway may have involved compaction of snow or spraying of water on the surface. Solid waste left on the site until 1979 included steel drums, pilings, boardwalks, remains of camp buildings and equipment, and a concrete well head drilling pad. Drilling mud was spilled in a small area around the pad. Hydrocarbon spills were common (cover photo, Figs. 3 to 5 and 9 to 20 in LAWSON et al. 1978 a).

Disturbance effects

The most lasting effects have been produced by surface blading or bulldozing, excavations, and diesel fuel spills (LAWSON & BROWN 1978 a). Vegetation, part of the organic surface layer, and soil morphology have been completely destroyed in many places by surface blading or bulldozing and excavations. Hydrocarbon spills killed or damaged vegetation and increased the active layer to twice it's normal depth. All investigated spills penetrated the soil; 28-year-old diesel spills still showed significant depression of permafrost and a toxic component in the soil (EVERETT 1978). Berms piled around the site buried the original vegetation and soil, and solid waste killed the original vegetation and buried the soil.

Initially, surface blading or bulldozing produced a new, relatively homogeneous surface that was later differentiated by new disturbance processes such as permafrost thaw, ground subsidence, thermokarst, and thermal erosion, triggered by reduced albedo and insulation of permafrost (e.g. BROWN et al. 1969, RADFORTH 1972, BLISS & WEIN 1972 a, LAWSON 1986). These processes produced a hummocky topography, thaw ponds, and troughs (Fig. 1) on the bladed site and in bladed trails and some multiple vehicle passes. In 1977 thaw was positively correlated with the intensity of disturbance (range 32 to 53 cm). In less intensely disturbed areas the thaw depths have returned to near their predisturbance depths, suggesting that part of the physical recovery is near completion. Because the test well site has a relatively small amount of ground ice and sandy material, the amount of subsidence after 30 yr was only 0.4 to 2 m. In the flat landscape, thermal and hydraulic erosion were active mainly in drainage ditches and sloping bulldozed trails (Lawson in WALKER et al. 1987). Hydraulic and eolian erosion, thaw, and ground subsidence may still continue in some places (LAWSON et al. 1978 a).

Outside the test well site, a winter runway, trails, trampling, and single and multiple passes

Fig. 1 - Thermokarsting triggered by the 1949 disturbance at the Fish Creek Test Well 1 site. Melting of ice wedges and ground subsidence may be still continuing (LAWSON & BROWN 1978a, b). Except for a few habitats such as both extremes of the moisture gradient, solid waste, intensive hydrocarbon spills, and severely eroded surfaces, vegetation cover was complete after 30 years.

by vehicles compacted or crushed vegetation and the surface soil layer. Usually, vehicle cause much less damage during winter than summer (e.g. HERNANDEZ 1973). Depending on the type of vehicle and vegetation/landform type, summer multiple passes and even single passes may kill or remove vegetation. Such vehicle tracks may persist for decades in the Alaskan arctic tundra (e.g. HOK 1969, ABELE et al. 1984). Some of the tracks still apparent near the Fish Creek Test Well predate the drilling.

Methods

Visually homogeneous 339 vegetation samples were collected on both disturbed and undisturbed surfaces according to the Braun-Blanquet method (WESTHOFF & VAN DER MAAREL 1978) at the Fish Creek Test Well and in its vicinity between 1977 and 1980, the majority (256) in 1978 (Figs. 2 & 3). Homogeneity was favored over plot size on small-sized landforms and disturbances. In each plot, the percentage cover of all taxa of vascular plants, bryophytes, and lichens was recorded. The intensity of disturbance and some other environmental factors were evaluated on subjective environmental gradient scales (e.g. KOMÁRKOVÁ 1979, KOMÁRKOVÁ & MCKENDRICK 1988).

The plants were identified like at Atkasook (KOMÁRKOVÁ & MCKENDRICK 1968). Only vascular plants were used in the present analysis. Relevés were classified according to the Braun-Blanquet method of vegetation analysis by tablework (WESTHOFF & VAN DER MAAREL 1978). Classes and most other units of the undisturbed vegetation were the same as those at Atkasook (KOMÁRKOVÁ & MCKENDRICK 1988, KOMÁRKOVÁ in prep.). The physical analysis of surface soil horizons was carried out at the Institute of Arctic and Alpine Research, Uni-

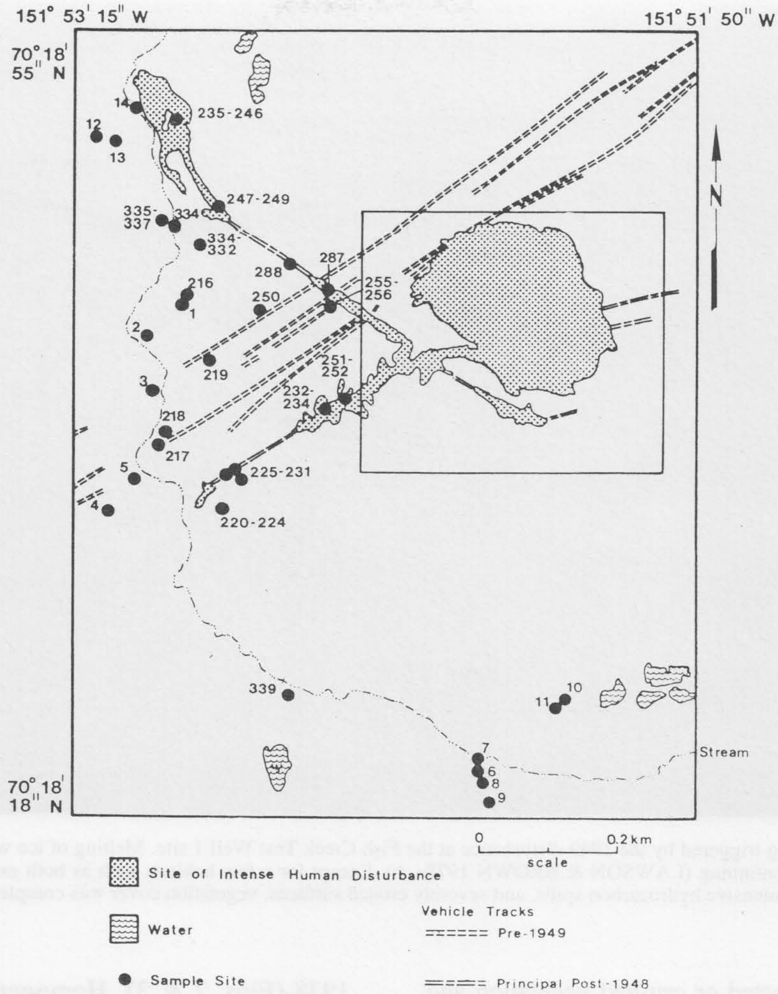

Fig. 2 - Relevé locations in the vicinity of the Fish Creek Test Well 1 site. Rectangle indicates the intensely disturbed test well area (Fig. 3).

versity of Colorado, and the chemical analysis at the Ohio State University. 30 environmental variables were selected for partial analysis of the recovery of the abiotic part of the disturbed ecosystems. Most of these variables were physical and chemical surface soil properties; also included were the depth of thaw and estimates of moisture, erosion, duration of snow cover, and cryoturbation.

Disturbances were classified according to LAWSON et al. (1978 b). The investigated primary disturbances which occurred in 1949 included surface removal and subsurface compression during blading or bulldozing, surface compression or removal on trails, new surfaces created by solid waste, and toxic chemical damage by hydrocarbon spills. In each plot, all disturbances were ranked in importance according to their intensity. Omitted were plots bare of vegetation due to disturbance.

Pre-disturbance ecosystems on the test well site were assumed to be similar to undisturbed, mature ecosystems in its vicinity. These undisturbed ecosystems were used as the controls of the disturbed ones that have been recovering or newly developing for about 30 yr. Control and disturbed plots belonging to the same Braun-Blanquet classes were numerically related. The degree of recovery of community composition was inversely related to the distance between disturbed and control samples in ordinations (KOMÁRKOVÁ 1983). The methods included numerical classification, ordination (DECORANA; HILL 1979), and multivariate statistics (SPSS, SYSTAT, and

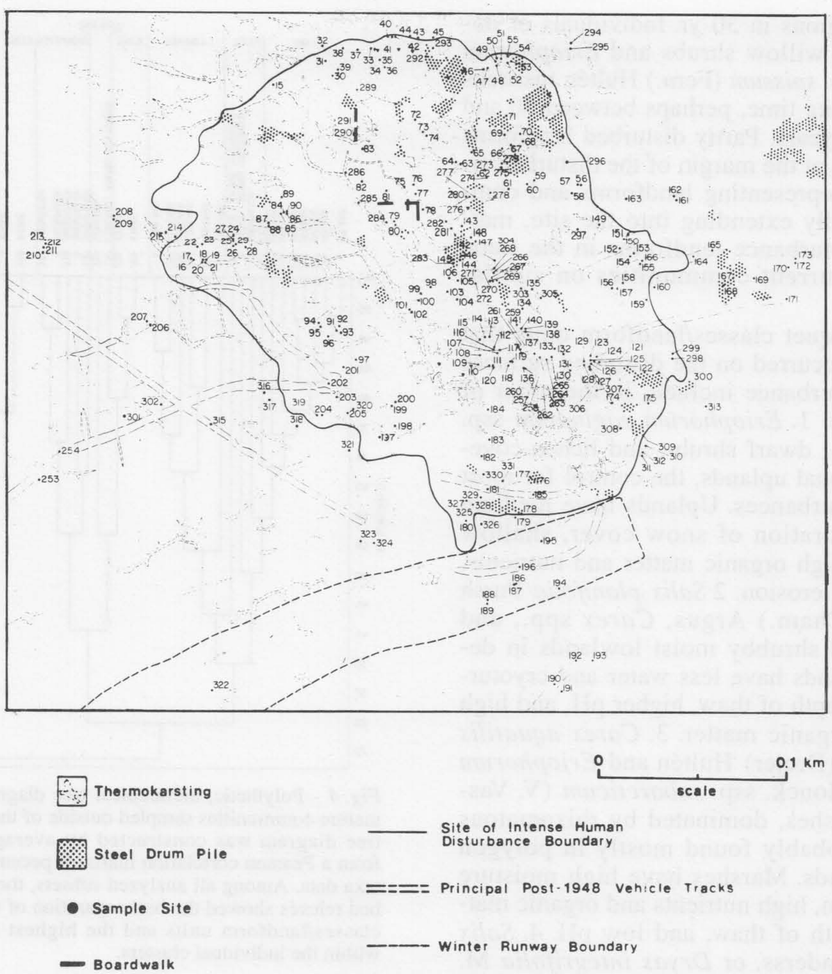

Fig. 3 - Relevé locations in the intensely disturbed test well area. Parts of the site which are little thermokarsted today probably indicate pre-disturbance sand ridges with few ice wedges (KOMÁRKOVÁ & WEBBER 1978). Relevés 107 to 111 were collected on the concrete pad of the well head. Steel drum piles and other solid waste also apparent in Fig. 1 have been removed after sampling.

STATVIEW), carried out on the University of Colorado Cyber mainframe and on a Macintosh personal computer.

Results

Undisturbed and pre-disturbance vegetation and landforms

Over 20 mature, undisturbed plant associations were sampled near the Fish Creek Test Well. These associations were classified into 7 Braun-Blanquet classes/landform units; they all occur at Atkasook and most of them are common on the Arctic Coastal Plain, particularly within the sand region. In the description of KOMÁRKOVÁ & WEBBER (1978), Appendix G lists the vascular taxa composition in representative relevés and Appendix F the mean values of some environmental variables for Braun-Blanquet classes/landform units. Table 3 in KOMÁRKOVÁ & MCKENDRICK (1988) gives means and standard errors of chemical and physical properties of surface soil horizons for the same classes/landform units in the Atkasook area.

A map of the Fish Creek Test Well based on pre-disturbance air photography (KOMÁRKOVÁ & WEBBER 1978) identified the pre-disturbance landforms and indicated the pre-disturbance vegetation units. This vegetation was probably very similar to the vegetation currently surrounding the site; in the absence of disturbance, only small changes can be observed in mature plant communities in cold regions in 30 yr. Individuals of dominants such as willow shrubs and *Eriophorum vaginatum* L. ssp. *spissum* (Fern.) Hultén tussocks may live for a long time, perhaps between 50 and several hundred years. Partly disturbed landforms and communities at the margin of the disturbed site, presumably representing landforms and communities originally extending into the site, matched the pre-disturbance landforms in the same areas and the current communities on similar landforms.

Braun-Blanquet classes/landform units that most probably occurred on the disturbed surfaces prior to the disturbance include, in the order of their importance: 1. *Eriophorum vaginatum* ssp. *spissum* tussock-, dwarf shrub-, and lichen-covered flat mesic zonal uplands, the control for most of test well disturbances. Uplands have medium moisture and duration of snow cover, shallow depth of thaw, high organic matter and nutrients, and low pH and erosion. 2 *Salix planifolia* Pursh ssp. *pulchra* (Cham.) Argus, *Carex* spp., and moss-dominated shrubby moist lowlands in depressions. Lowlands have less water and cryoturbation, deeper depth of thaw, higher pH, and high nutrients and organic matter. 3. *Carex aquatilis* WG. ssp. *stans* (Drejer) Hultén and *Eriophorum angustifolium* Honck. ssp. *subarcticum* (V. Vassil.) Hultén marshes, dominated by rhizomatous Cyperaceae, probably found mostly in polygon troughs and ponds. Marshes have high moisture and cryoturbation, high nutrients and organic matter, shallow depth of thaw, and low pH. 4. *Salix phlebophylla* Anderss. or *Dryas integrifolia* M. Vahl ssp. *integrifolia* dwarf shrub-, lichen-, and cushion- dominated elevated, ancient sand dune ridges. Ridges are older, drier, and sandier than other landforms, may be snow-free in winter, have deep depth of thaw, and are windy, eroded, and poor in nutrients. 5. *Cassiope tetragona* (L.) D. Don ssp. *tetragona* or *Salix rotundifolia* Trautv. dwarf shrub-dominated snowpatches, with most stands on outlying disturbances and only very few, poorly developed stands on the test well site. Snowpatches have long duration of snow cover, low pH, low nutrients, and relatively high erosion.

Undisturbed relevés were clearly sorted into several clusters representing Braun-Blanquet classes/landform units (Fig. 4). Uplands and marshes, the most common and best developed units with fewest associations, clustered at the highest similarity (Tab. 1). In the ordination space, classes/landform units were arranged according to moisture, the duration of snow cover, and the intensity of natural disturbances determining, in combination with the age of the surface, the proportion of the ground covered by vegetation (Fig. 5).

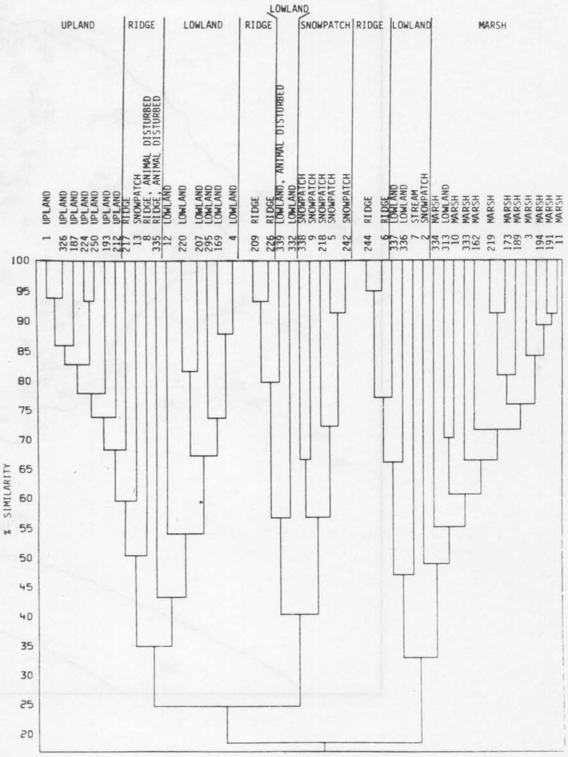

Fig. 4 - Polythetic, hierarchical tree diagram of undisturbed, mature communities sampled outside of the test well site. The tree diagram was constructed by average linkage method from a Pearson correlation marix of pecentage cover vascular taxa data. Among all analyzed subsets, the group of undisturbed relevés showed the best separation of the Braun-Blanquet classes/landform units and the highest average similarity within the individual clusters.

Based on environmental variables, the grouping of the same samples was less clear; wetter lowlands and marshes were separated from drier uplands and ridges (Fig. 6). The average similarity was close for all units, with uplands having the highest and marshes and ridges the lowest (Tab. 1). All classes/landform units were better defined based on vegetation than on environment; the difference was greatest in marshes and uplands.

Vegetation/landform type disturbance and recovery

Ecosystem resistance (ability to remain unaffected by disturbance) determines the type and degree of damage a disturbance will cause, and eco-

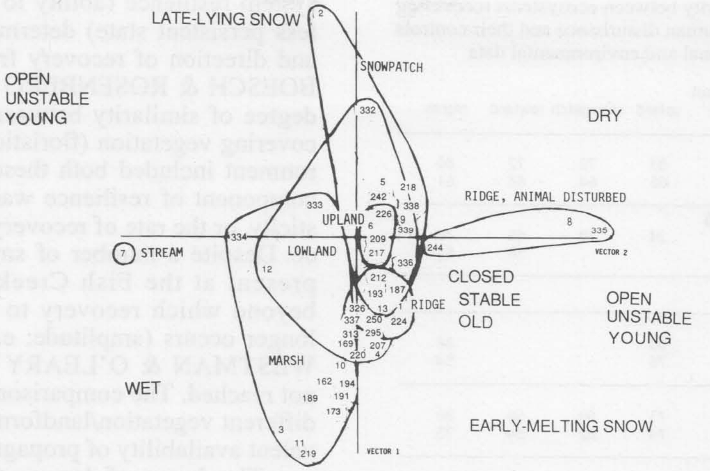

Fig. 5 - Detrended correspondence analysis (DECORANA) ordination of percentage cover vascular taxa data for undisturbed, mature communities sampled outside the test well site. The groups of relevés are similar to clusters in Fig. 4 and are outlined. Relevés and Braun-Blanquet classes are primarily ordered by moisture and the duration of snow cover. Closed vegetation on older and stable surfaces surrounds the center of the diagram while open vegetation on younger and unstable surfaces is placed at the ends of the ordination axes.

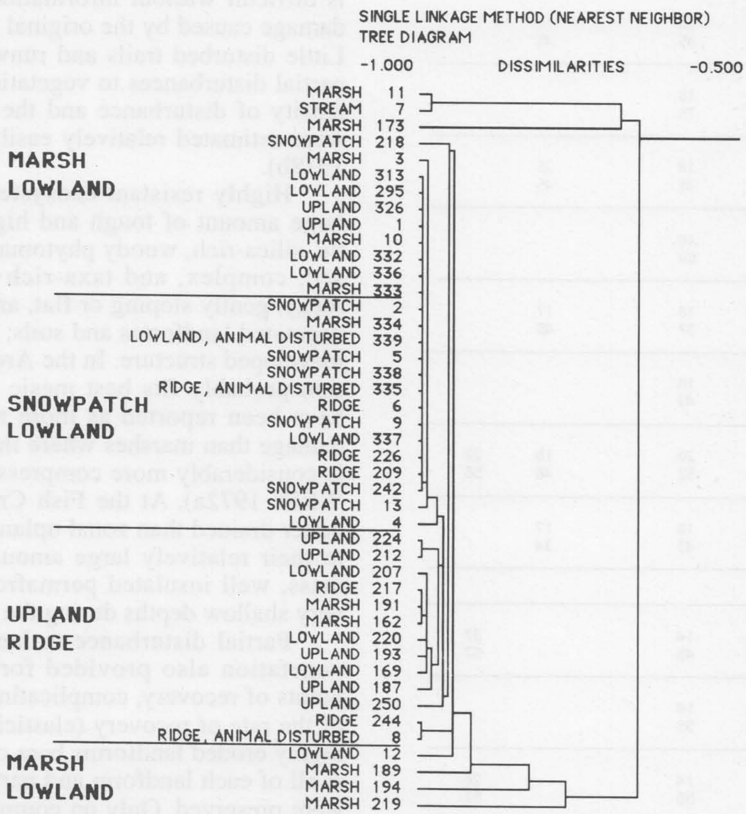

Fig. 6 - Single linkage (nearest neighbor) hierarchical tree diagram from a Pearson correlation matrix showing groups of undisturbed relevés based on environmental variables. The sorting of relevés into groups corresponding to the five investigated classes/landform units is considerably poorer than in Fig. 4. Somewhat better groups of relevés appeared in a configuration produced by monotonic multidimensional scaling using Kruskal's coefficient of alienation from Pearson correlation matrix (not presented).

Tab. 1 - Average % similarity between ecosystems recovering or newly forming after a human disturbance and their controls based on vegetational and environmental data

Disturbance type - Class/landform unit	ridge	upland	snowpatch	lowland	marsh
UNDISTURBED					
vegetation	70	83	72	72	80
environment	61	66	64	63	61
BLADED OR BULLDOZED SURFACES					
vegetation recovering	31	28	30	65	75
vegetation new				38	52
TRAILS					
Winter trails					
vegetation		60			86
environment		75			54
Single pass trails					
vegetation	66	73	60	58	80
environment	75	74	62	54	75
Multiple pass trails					
vegetation	61	25		73	88
environment	72	62		39	75
Bladed trails					
vegetation		36		58	73
environment		68		54	75
SOLID WASTE					
Concrete pad					
vegetation	27	18		18	
environment	75	45		45	
Pebble fill					
vegetation	22	18			
environment	75	75			
Landing mat					
vegetation		18		25	
environment		45		45	
Rope					
vegetation		18			
environment		60			
Steel drum					
vegetation	22	18		17	
environment	75	37		45	
Tarp					
vegetation	32	18			
environment	75	49			
Wood					
vegetation	30	20		18	22
environment	73	52		48	58
Wood stack					
vegetation	32	18		17	
environment	73	43		34	
SPILLS					
Crude oil					
vegetation	14	14			37
environment	80	45			57
Crankcase					
vegetation	14	14			
environment	45	55			
Diesel fuel					
vegetation		14			26
environment		50			51
Drilling mud					
vegetation					38
environment					45

system resilience (ability to recover to a more or less persistent state) determines the rate, degree, and direction of recovery from this damage (e.g. BOESCH & ROSENBERG 1981). The measured degree of similarity between undisturbed and recovering vegetation (floristic similarity) and environment included both these attributes. Only one component of resilience was represented: its elasticity, or the rate of recovery following disturbance. Despite a number of small bare patches still present at the Fish Creek site, the threshold beyond which recovery to the original state no longer occurs (amplitude; e.g. WESTMAN 1986, WESTMAN & O'LEARY 1986) probably was not reached. The comparison of elasticity between different vegetation/landform types assumed equivalent availability of propagules.

The degree of damage to an ecosystem at the time of disturbance indicates the resistance of that ecosystem to that type and intensity of disturbance. Because some types of vegetation and landforms are more resistant to disturbance than others, the interpretation of the degree of recovery is difficult without information on the degree of damage caused by the original partial disturbance. Little disturbed trails and runways were the only partial disturbances to vegetation in which the intensity of disturbance and the degree of damage were estimated relatively easily (LAWSON et al. 1978b).

Highly resistant ecosystems usually have a large amount of tough and highly sclerenchymatic, silica-rich, woody phytomass that forms a closed, complex, and taxa-rich vegetation cover; rocky, gently sloping or flat, and well drained and vegetated landforms and soils; and soils with welldeveloped structure. In the Arctic, such a description probably fits best mesic zonal uplands that have been reported as more resistant to vehicle damage than marshes where the surface soil layer is considerably more compressible (e.g. BLISS & WEIN 1972a). At the Fish Creek site ridges are better drained than zonal uplands which have, due to their relatively large amount of dense phytomass, well insulated permafrost which thaws to very shallow depths during the summer.

Partial disturbance to landforms, soils, and vegetation also provided for different starting points of recovery, complicating the interpretation of the rate of recovery (elasticity). Except for two highly eroded landforms bare of vegetation, almost all of each landform and part of the surface soil were preserved. Only on completely new surfaces such as solid wastes, the elasticity of landforms, soils, and whole ecosystems was being measured. The rate of soil recovery is also important; for example, the recovery of vegetation on a hydrocarbon spill cannot start until toxic chemicals are removed from the soil.

Highly elastic ecosystems usually have a small amount of weak phytomass that can be rapidly replaced, forms an open, simple, and taxa-poor vegetation cover, and consists of colonizers which are also dominants of mature communities or which are rapidly replaced by the dominants. The colonizers are characterized by rapid, often vegetative reproduction and rapid dispersal, establishment, and growth. Landforms and soils are poorly developed and vegetated, flat or gently sloping, little stabilized, and easy to colonize. In the Arctic, this description probably fits best simple azonal ecosystems with high degree of material movement and enough moisture to ensure rapid growth, such as riverbars, wet sand dunes and, to a lesser degree, marshes. Particularly high elasticity will result when the type and intensity of human disturbance match those of the natural disturbance controlling the ecosystem such as when a riverbar is bladed.

Bladed or bulldozed surfaces

On most of the Fish Creek site, vegetation was totally destroyed by blading or bulldozing. On current ridges, in parts of uplands and lowlands, snowpatches, and in a small proportion of current marshes, this disturbance did not change landforms significantly, did not trigger any further landform changes, and partially destroyed soils, leaving a part of the compacted soil profile with some plant propagules in place. In such areas the measured degree of recovery indicates the elasticity of the original vegetation, combined with the partial elasticity of the soil. Most resistant to blading or bulldozing were probably flat mesic uplands and elevated dry ridges. The although soils on uplands are moist in summer and soils on ridges are sandy and loose, while soils on most other landforms are usually wet and little resistant to surface disturbance. However, the differences in resistance to such an intense disturbance probably did not produce large differences in disturbance effects.

The new, relatively homogeneous, predominantly upland bladed surface became topographically differentiated during the 30 yr following the disturbance through newly triggered disturbance processes. New marshes formed in thermokarsts in places of thawed ice wedges and, along with new lowlands, in areas of surface subsidence due to the lowering of the permafrost table.

Recovering and newly forming marshes and, to some degree, lowlands are covered by the dominants of undisturbed communities already during colonization and cluster with their respective controls at higher levels of similarity than in other classes/landform units (Fig. 7, Tab. 1; in KOMÁRKOVÁ 1983, the similarity levels showed the same trends). Marshes developed more rapidly than other classes/landform units recovered even when a new marsh landform was being differentiated with the contribution of partly bladed upland organic surface soils. Newly forming marshes had lower similarity levels than recovering marshes (Tab. 1). Marsh formation may be even more rapid on surfaces newly bared by wind or rivers on nutrient-rich riverbars. The spread of dominant sedges into places covered by old organic soil layers may be slowed down during drought when the connection to wet subsurface soil layers is interrupted by dry organic matter. This occurs in shallow polygon ponds during exceptionally dry summers.

Bladed uplands, ridges, and partly snowpatches, all probably located in places of their respective pre-disturbance landforms, were covered by succesional communities of otherwise infrequent rhizomatous graminoids or, more rarely, prostrate herbs. These successional communities are relatively homogeneous and well separated in the treediagram. Their replacement by the dominants of the undisturbed vegetation is starting; some disturbed upland, ridge, and snowpatch relevés clustered with their controls.

In the ordination of composite data for bladed surfaces presented earlier (KOMÁRKOVÁ 1983), the principal ordering factor was disturbance along with moisture, the duration of snow cover, and the depth of thaw. Clusters based on environmental data, were much less clear than those based on vegetation; wetter lowlands and marshes were only slightly separated from drier uplands and ridges. Snowpatches and lowlands showed the highest similarity and marshes and ridges the lowest.

Moisture, the duration of snow cover, and erosion were higher and thaw was deeper by up to 40 cm (on ridges) in most disturbed plots than in their controls. Disturbance decreased organic matter, available water, silt, clay, CEC, and exchangeable H^+; it usually increased NO_3, P, pH, sand, base saturation, and exchangeable Ca^{++} and Mg^{++}. Shrubs and soil lichens had considerably lower percentage in disturbed plots. Total vegetation cover, herbs, and bryophytes usually decreased, but sometimes (e.g. in marshes, uplands) increased after disturbance. Some of these trends were rever-

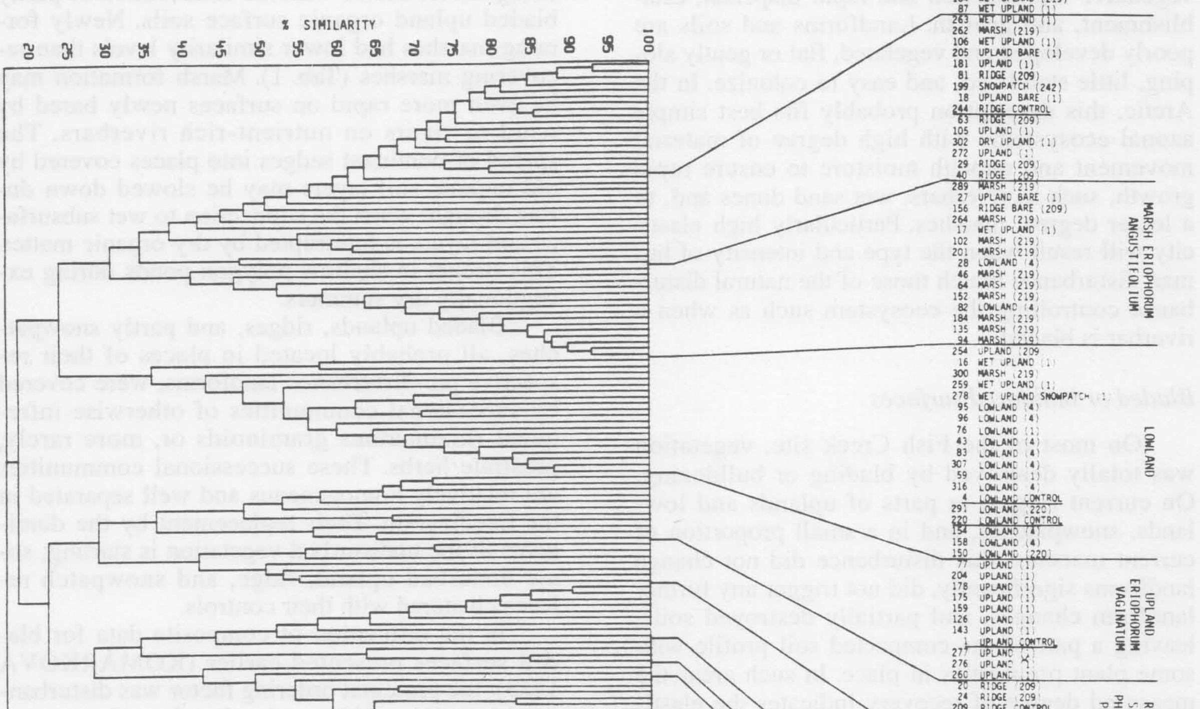

Fig. 7 - Polythetic, hierarchical tree diagram of recovering or newly developing communities on bladed surfaces of the test well site and their controls. The tree diagram was constructed by average linkage method from a Pearson correlation matrix of percentage cover vascular taxa data. Bladed surfaces show better separation of the Braun-Blanquet classes/landform units and higher average similarity within the individual clusters than solid waste (Fig. 11) and hydrocarbon spill (Fig. 14) surfaces, and poorer separation than undisturbed surfaces (Fig. 4).

sed in ridges that disturbance brought closer to uplands.

Trails and runways

The composition of undisturbed communities is usually only impoverished or slightly altered in less disturbed trails. However, compression of the moss layer and subsidence due to the melting of the permafrost occurred even on heavily used lowland winter vehicle trails (FELIX & RAYNOLDS 1989). A single vehicle pass in summer can change the original class/landform unit due to the thaw of ground ice followed by subsidence or thermokarsting. The recovery and development of newly forming landforms in such trails and in severely disturbed multiple vehicle passes and bladed or bulldozed trails follows, on a smaller scale, the patterns on bladed or bulldozed surfaces.

Some time after partial disturbance to vegetation, the contributions of the resistance and elasticity of the original communities to the measured degree of similarity between disturbed and undisturbed relevés cannot be separated. In the absence of ground ice melting, the same intensity of vehicle disturbance will produce less damage in more resistant uplands with a larger amount of tougher phytomass than in marshes where there is a greater compression of the water-saturated surface organic soil layer (e.g. BLISS & WEIN 1972a). Once damaged, uplands will recover more slowly than more elastic marshes in which saturated compressed fibrous organic material regains its original structure rapidly (ABELE et al. 1984). Equal similarities between two pairs of undisturbed and recovering communities thus could be produced by either high resistance (uplands) or high elasticity (marshes).

Braun-Blanquet classes/landform units were relatively well separated in trails (Fig. 8). Again, marshes clustered at the highest similarity levels and lowlands at the next highest, followed by snowpatches, uplands, and ridges. New marshes in original uplands and lowlands were less similar to marsh controls than recovering marshes, but were still highly elastic. The similarity between undisturbed and recovering relevés also decreased with the increasing intensity of disturbance from

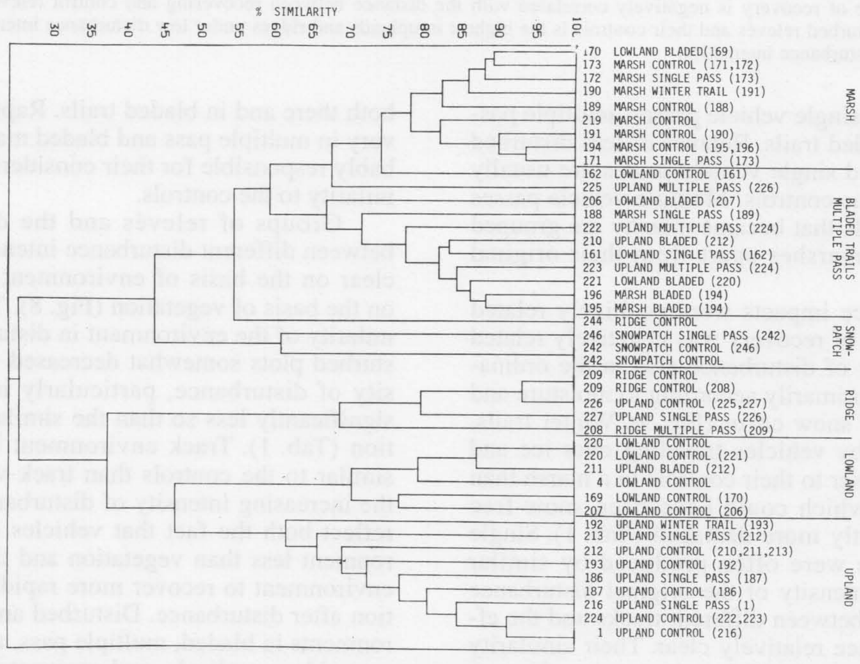

Fig. 8 - Polythetic, hierarchical tree diagram of recovering or newly developing communities in trails and their individual controls. The tree diagram was constructed by average linkage method from a Pearson correlation matrix of percentage cover vascular taxa data. The individual Braun-Blanquet classes/landform units are well separated. The similarity within clusters of less disturbed relevés approaches that of the undisturbed controls (Fig. 4). At low disturbance intensities in winter trails and single vehicle passes, the recovering relevés cluster with their undisturbed controls. At high disturbance intensities in multiple vehicle passes and in bladed trails, marshes may develop even in originally other vegetation/landform types, and there is little similarity between the recovering relevés and their controls (cluster «bladed trails/multiple pass»).

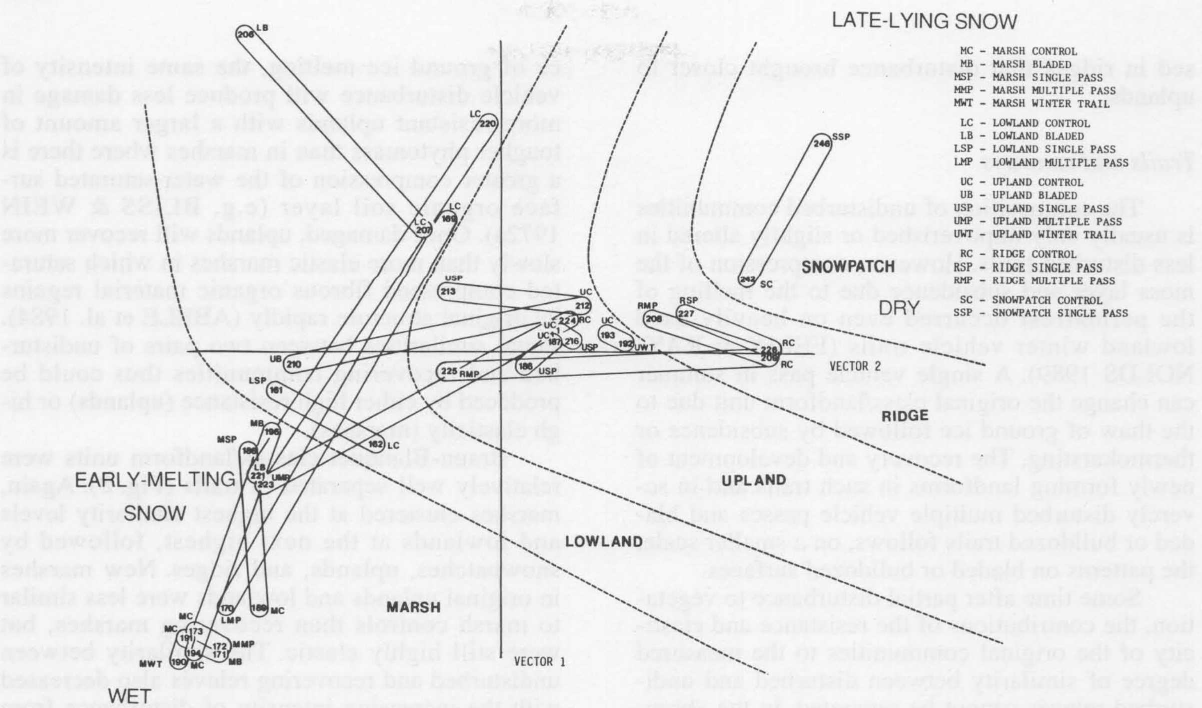

Fig. 9 - Detrended correspondence analysis (DECORANA) ordination of percentage cover vascular taxa data for trails and their controls sampled outside the test well site. The pairs of disturbed relevés and their controls are outlined. Relevés and Braun-Blanquet classes are primarily ordered according to moisture and duration of snow cover. The degree of disturbance impact is positively related and the degree of recovery is negatively correlated with the distance between recovering and control relevés. The similarity within pairs of disturbed relevés and their controls is the highest in uplands and ridges under low disturbance intensities and in marshes under high disturbance intensities.

winter trails to single vehicle passes, multiple passes, and to bladed trails. Relevés of less disturbed winter trails and single vehicle passes are usually near their unique controls. Multiple vehicle passes and bladed trails that became marshy are grouped together with marshes apart from their original controls.

Disturbance impacts were positively related and the degree of recovery was negatively related to the intensity of disturbance also in the ordination, arranged primarily according to moisture and the duration of snow cover (Fig. 9). Winter trails, little affected by vehicles traveling over ice and snow, were closer to their controls in a marsh than in an upland which could have been snow-free and consequently more damaged (Tab. 1). Single vehicle passes were often produced by similar vehicles; the intensity of the original disturbance is comparable between different tracks and the effect of resistance relatively clear. Their similarity to the controls was the highest in marshes (low resistance, high elasticity), followed by uplands (high resistance, low elasticity). The damage to vegetation was often total in multiple pass tracks and, due to their successional communities, upland tracks showed very little similarity to the controls both there and in bladed trails. Rapid rate of recovery in multiple pass and bladed marshes was probably responsible for their considerably greater similarity to the controls.

Groups of relevés and the differentiation between different disturbance intensities were less clear on the basis of environment (Fig. 10) than on the basis of vegetation (Fig. 8). The average similarity of the environment in disturbed and undisturbed plots somewhat decreased with the intensity of disturbance, particularly in uplands, but significantly less so than the similarity of vegetation (Tab. 1). Track environment becomes more similar to the controls than track vegetation with the increasing intensity of disturbance. This could reflect both the fact that vehicles damaged environment less than vegetation and the tendency of environment to recover more rapidly than vegetation after disturbance. Disturbed and control environments in bladed, multiple pass, and even single pass ridges, uplands, and snowpatches were more similar than disturbed and control vegetations, in uplands up to twice as much. Upland landforms and soils are probably relatively resistant to severe disturbance even after the vegetation is destroyed. Disturbed and control marsh landforms

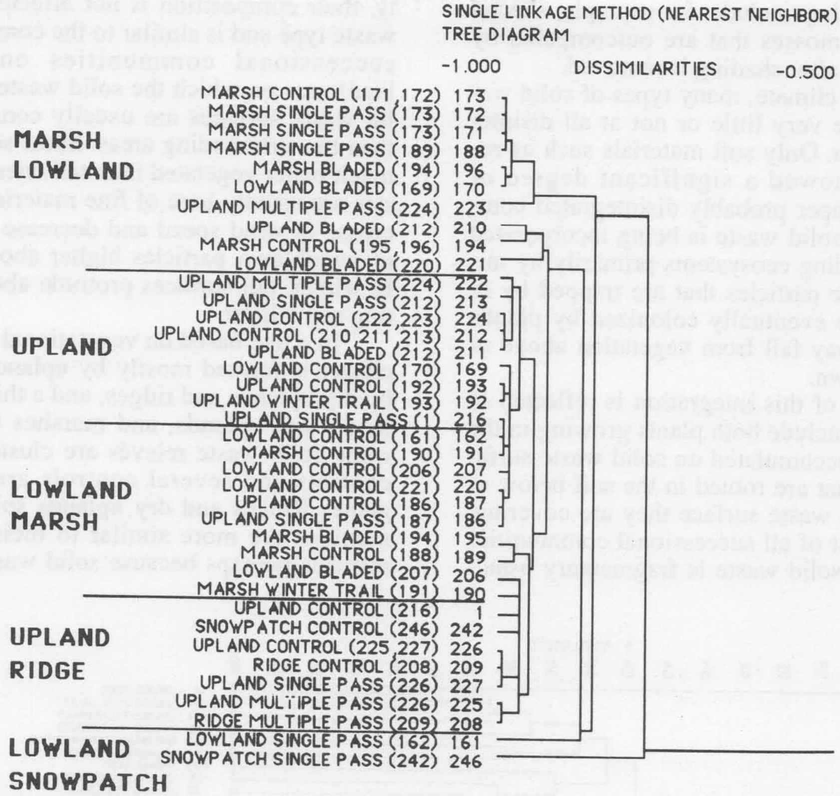

Fig. 10 -Single linkage (nearest neighbor) hierarchical tree diagram from a Pearson correlation matrix showing groups of trail relevés and their controls based on environmental variables. The sorting of relevés into groups corresponding to the five investigated classes/landform units is poorer than in Fig. 8. Control, winter trail, and single pass relevés are usually grouped in separate clusters, while multiple passes and bladed trails are not. A configuration produced by monotonic multidimensional scaling using Kruskal's coefficient of alienation from Pearson correlation matrix (not presented) showed results similar to Fig. 9, wih less clear groups. Recovering samples and controls were again closest in little disturbed uplands and ridges and in heavily disturbed marshes and lowlands.

and soils showed the highest similarity, probably due to their relatively high elasticity; lowland landforms and soils, which may be neither resistant nor resilient, showed the lowest.

After 30 yr, the effects of disturbance were apparent even in winter trails. Moisture, the duration of snow cover, erosion, the percentage cover of surfaces bare of vegetation were higher and thaw was deeper by 3 to 5 cm in almost all tracks than in their controls. Disturbance decreased organic matter, available water, silt, clay, CEC, and some exchangeable bases; it often increased NO_3 and P. Shrubs and soil lichens had considerably lower percentage in the tracks and often disappeared after disturbance. In winter trails, vegetation cover and the cover of herbs and bryophytes were lower in disturbed than undisturbed marshes and uplands. In single pass tracks, herb and bryophyte covers were higher in uplands but lower in all other units, and pH was slightly lower than in the controls. In multiple passes and in bladed trails, herb and bryophyte covers were lower except for uplands and marshes where bryophyte cover was higher, thaw was deeper, and pH was higher after disturbance.

Solid waste

On top of bladed surfaces and undisturbed vegetation, solid wastes created small-scale landforms with dry, solid surfaces and no soil. Such habitats are not available in the surrounding tundra, and pieces of wood may support the only adventive community of lichens (JOHNSON et al. 1978). Solid waste caused secondary disturbances such as shading, reduced wind, reflected infrared radiation, and prolonged duration of snow cover in its immediate vicinity (also JOHNSON et al. 1978). Communities controlled by these factors occur near certain landforms or shrubs even in undisturbed areas; they include, for example, shaded communities of mosses that are outcompeted by graminoids soon after shading is removed.

Due to cold climate, many types of solid waste surfaces were very little or not at all disintegrated after 30 yr. Only soft materials such as rope and tarps showed a significant degree of disintegration; paper probably disintegrated completely. Most of solid waste is being incorporated into the surrounding ecosystems primarily by mineral and organic particles that are trapped by it, cover it, and are eventually colonized by plants. Such particles may fall from vegetation above or may be windblown.

The degree of this integration is reflected in the relevés that include both plants growing in the material newly accumulated on solid waste surfaces and plants that are rooted in the soil below or next to the solid waste surface they are covering. The development of all successional communities associated with solid waste is fragmentary usually, their composition is not affected by the solid waste type and is similar to the composition of the successional communities on the bladed landforms on which the solid waste is resting. Solid waste surfaces are usually considerably drier than the surrounding areas. Short solid wastes are much better vegetated than tall ones; tall solid wastes are usually bare of fine material due to an increase in wind speed and decrease in the number of windblown particles higher above the ground. In winter, tall surfaces protrude above the protecting snow layer.

In a tree based on vegetational data, one large cluster is formed mostly by uplands, another one by dry uplands and ridges, and a third one by lowlands, wet uplands, and marshes (Fig. 11). Only some solid waste relevés are clustered with their controls and several controls are clustered together. Ridges and dry uplands solid waste communities are more similar to their controls than marshes perhaps because solid waste surfaces are

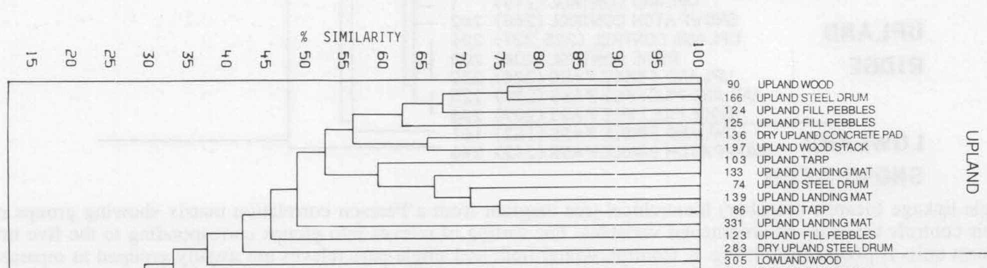

Fig. 11 - Polythetic, hierarchical tree diagram of newly developing communities on solid waste and their controls. The tree diagram was constructed by average linkage method from a Pearson correlation matrix of percentage cover vascular taxa data. Individual Braun-Blanquet classes/landform units are relatively poorly separated although some relevés cluster with their undisturbed controls.

usually dry (except for tarps and rope; Tab. 1). Uplands and lowlands had the lowest similarity values.

Wood stacks with fine material filling the space between pieces of wood had almost complete cover of herbs; landing mats and rope were also covered more than 50%. A high cover of bryophytes occurred on moist places on the concrete drill pad, on wood stacks, and on wood. Lichens were generally rare but could have relatively high cover on wood. Shrubs did not grow on solid waste.

The differentiation of classes/landform unit groups in the ordination was much poorer, the overlap of the groups was greater, and the environmental axes were less clear on solid waste than on other disturbance types (Fig. 12). Disturbance, moisture, and the duration of snow cover were the principal ordering factors. The tree based on environmental data shows a poor sorting into classes/landform units that reflects the poor development of soils on solid waste (Fig. 13).

Soils developing on solid waste were more similar to their controls than vegetation (Tab. 1). The average similarity of the environment in disturbed and undisturbed plots was more related to the vegetation/landform type than to the degree of solid waste disintegration or even the degree to which solid waste conducts moisture (tarps, rope). Like vegetation, environment of solid waste surfaces is most similar to the controls on ridges and least similar to the controls in lowlands and uplands. The difference between the vegetational and environmental similarities is also highest in ridges, followed by marshes, uplands, and lowlands.

Solid waste surfaces are always drier and have less snow for a shorter period of time than the surrounding landforms. The material accumulated on solid waste is considerably lower in organic matter, CEC, exchangeable cations, available water, silt, clay, NO_3, and P, and considerably higher in pH, sand, and base saturation than the control soil.

Spills

Intense hydrocarbon spills prevented vegetation establishment for at least 30 yr. Both in undi-

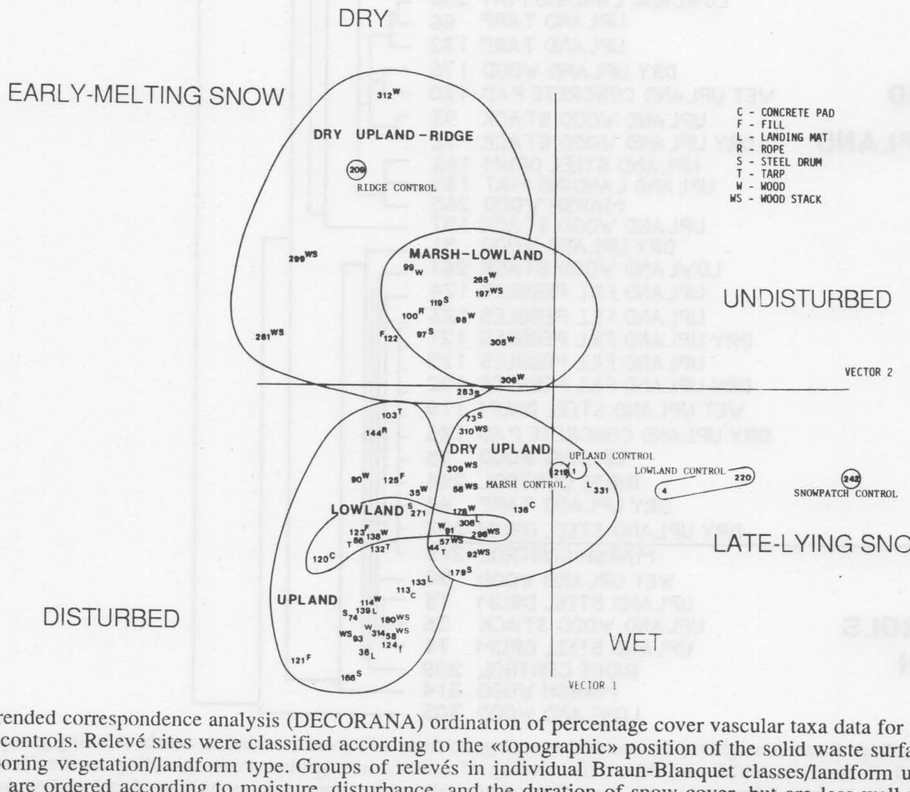

Fig. 12 - Detrended correspondence analysis (DECORANA) ordination of percentage cover vascular taxa data for solid waste surfaces and their controls. Relevé sites were classified according to the «topographic» position of the solid waste surface and according to the neighboring vegetation/landform type. Groups of relevés in individual Braun-Blanquet classes/landform units are outlined. These groups are ordered according to moisture, disturbance, and the duration of snow cover, but are less well formed than such groups from other disturbance types.

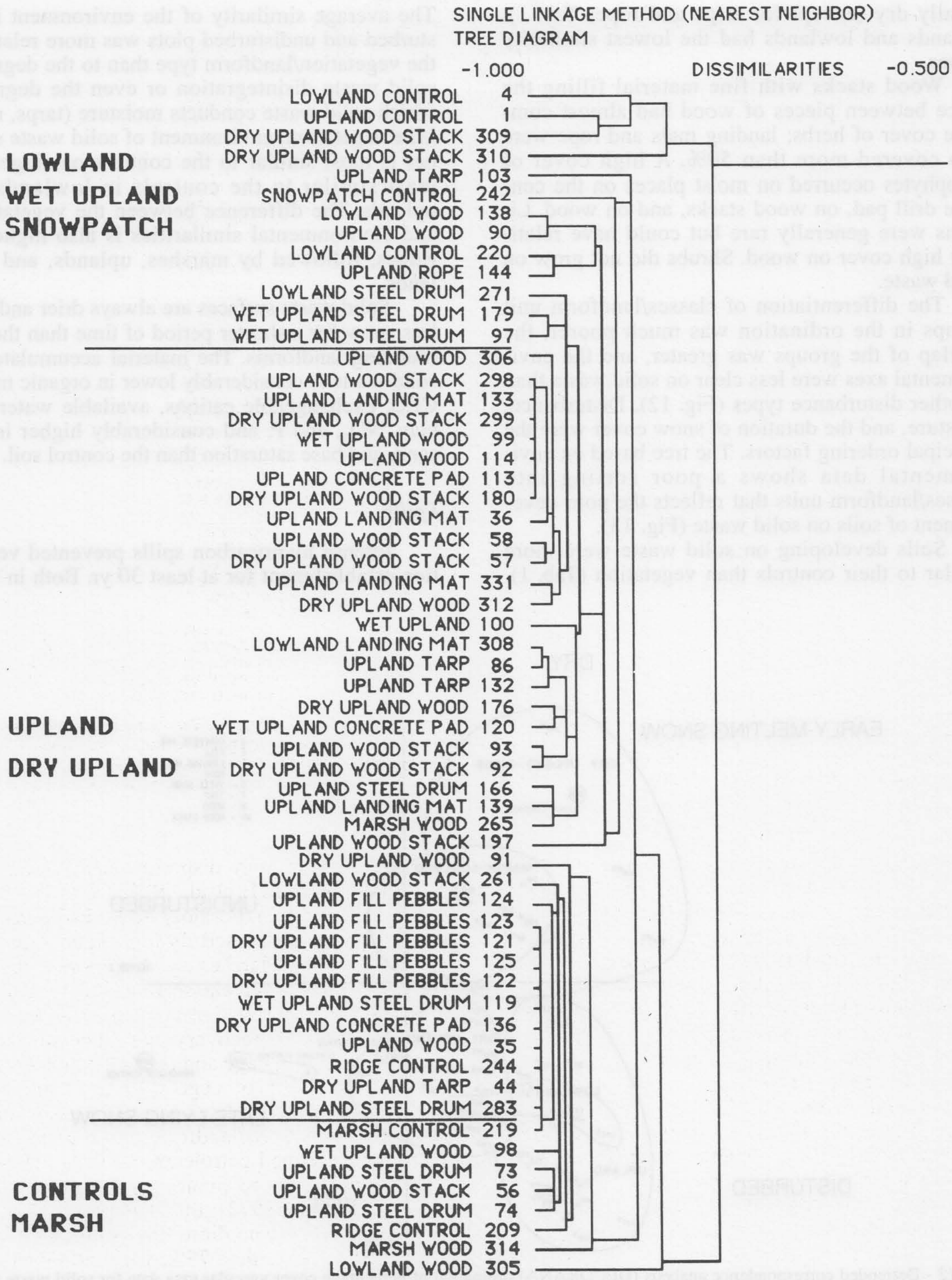

Fig. 13 - Single linkage (nearest neighbor) hierarchical tree diagram from a Pearson correlation matrix showing groups of solid waste relevés based on environmental variables. The sorting of relevés into groups corresponding to the five investigated classes/landform units is poorer than in Fig. 11. A configuration produced by monotonic multidimensional scaling using Kruskal's coefficient of alienation from Pearson correlation matrix (not presented) showed similar results.

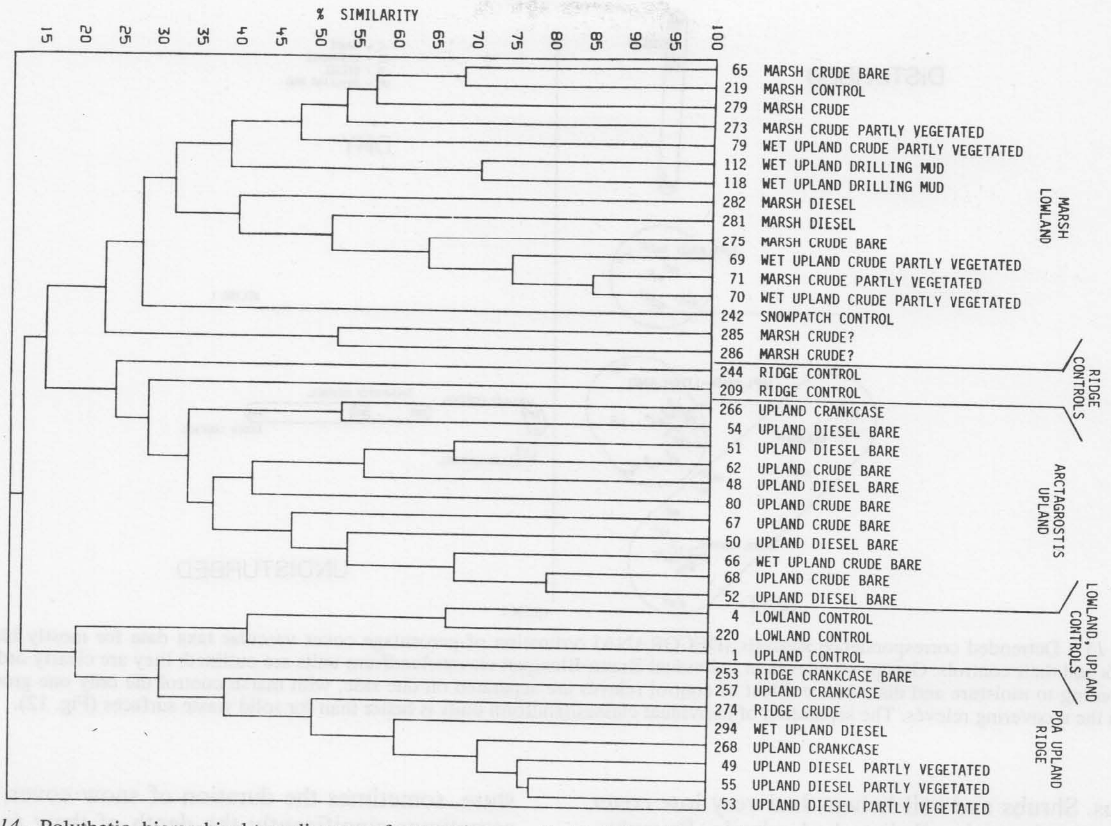

Fig. 14 - Polythetic, hierarchical tree diagram of recovering, mostly bladed, spills and their controls. The tree diagram was constructed by average linkage method from a Pearson correlation matrix of percentage cover vascular taxa data. Individual Braun-Blanquet classes/landform units are relatively well separated although controls, except for marshes, cluster together. The similarity between recovering and control samples was the highest in marshes and the lowest in uplands, where spill sites often remained bare after 30 years.

sturbed and successional vegetation, the recovery on less intense spills proceeded, as on other types of disturbance, without a specific successional pathway. The number of hydrocarbon spills in otherwise undisturbed vegetation was small. To estimate the original intensity of a spill and the damage caused by it is difficult. The measured degree of recovery on non-bladed surfaces thus reflected both the resistance of the original ecosystems and their elasticity. On top of bladed surfaces, spills were additional, multiple disturbances. There, the measured degree of recovery reflected mainly the resistance to spills and the elasticity after both blading and spills.

Based on vegetation, the groups of classes/landform units were relatively good (Fig. 14). The cluster of disturbed marshes included the control plot and was formed at the highest similarity level (Tab. 1); none of the other controls were grouped with the recovering relevés. Spills are usually more damaging in dry sites than in wet ones where they may disperse quickly (e.g. PLICE 1948, DENEKE et al. 1975, LINKINS et al. 1984, HOLT 1987). Possibly at the Fish Creek site, spills were dispersed during marsh formation in thermokarsts. Marshes are thus more elastic after spills than other classes/landform units also due to lower initial damage. In other classes/landform units the recovery was much slower due to both greater damage and lower elasticity.

The recovery of vegetation appeared to be considerably more related to the intensity of the spill and to the class/landform unit than to the type of spill. Refined petroleum products are considered more toxic to plants than crude oil (e.g. MCCOWN et al. 1973); this was probably reflected in the fact that no diesel fuel spill had a vegetation cover higher than 75%, while all other spills (crude oil, crankcase, drilling mud) were almost fully covered by vegetation in at least some relevés. All types of spills except for drilling mud had very low or no vegetation cover in some

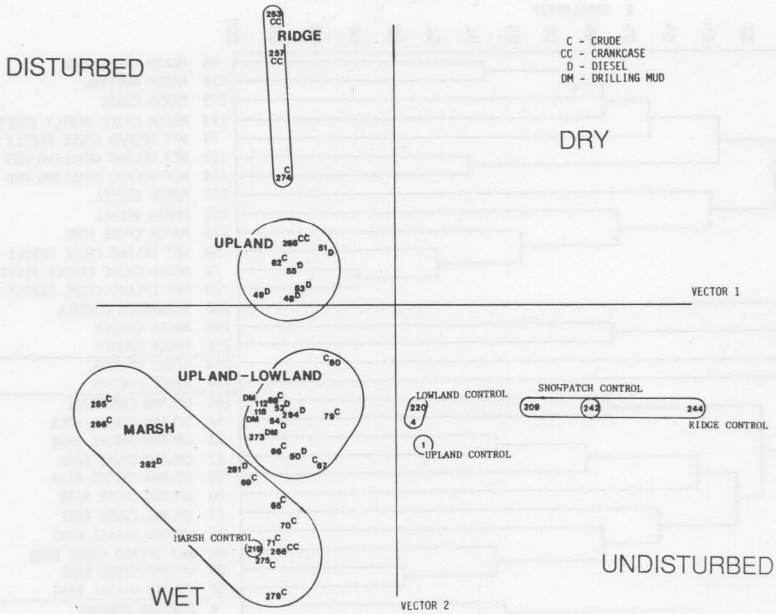

Fig. 15 - Detrended correspondence analysis (DECORANA) ordination of percentage cover vascular taxa data for mostly bladed spills and their controls. Groups of relevés in individual Braun-Blanquet classes/landform units are outlined; they are clearly ordered according to moisture and disturbance. Most of control relevés are separated on one side, with marsh control the only one grouped with the recovering relevés. The separation of individual classes/landform units is better than for solid waste surfaces (Fig. 12).

areas. Shrubs and soil lichens had very low cover or were absent in all disturbed relevés. Bryophytes reached up to 60% cover on crude oil or crankcase spills in most classes/landform units; their highest cover on diesel fuel spills was 33%. This response probably also depends on the individual taxa in question, because different growth recovery has been reported in different studies.

The groups of classes/landform units were also so well apparent in the ordination, ordered primarily by disturbance and moisture (Fig. 15). On the basis of environmental variables, the main classes/landform units were separated (Fig. 16) less clearly than on the basis of vegetation data (Fig. 14). Except for marshes, all controls were again clustered together and with some less disturbed relevés. Similarities between undisturbed and recovering plots were considerably higher based on environment than based on vegetation (Tab. 1); they did not differ much with the spill type. The smallest difference between vegetational and environmental similarities was in marshes and the greatest one on ridges.

Spills caused some subsidence and changed soil chemistry and perhaps other soil properties; the recovery of vegetation probably proceeds along with the removal of toxic chemicals from the soil. Disturbance usually increased site moisture, sometimes the duration of snow cover, and sometimes significantly the depth of thaw (up to three times the original), particularly in marshes and on ridges. NO_3 and P sometimes decreased and pH usually increased after the disturbance. On bladed surfaces, it was impossible to separate the effects of blading and spills.

Discussion

Direction of recovery

The test well disturbance increased spatial and temporal heterogeneity (e.g. LEVIN & PAINE 1974, RAUP 1981, BOESCH & ROSENBERG 1981), breaking larger uniform landforms into smaller ones that are undergoing secondary (most of the disturbed surfaces) or primary (solid waste) succession and may persist until the next thaw lake development. The test well disturbance did not permanently increase organismic, community, or ecosystem diversity. No landforms that do not exist near the site were created, except for solid waste that will eventually disintegrate or be overgrown. The floristic diversity did not increase except for one lichen that will probably also disappear when solid waste wood, most of which

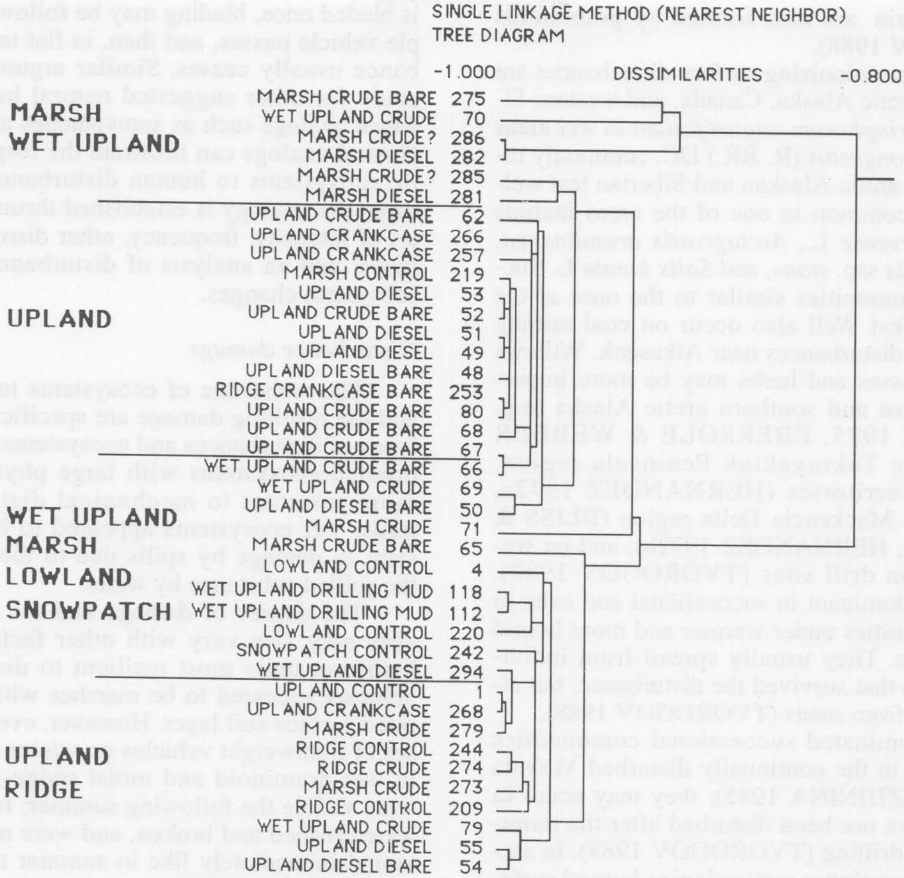

Fig. 16 - Single linkage (nearest neighbor) hierarchical tree diagram from a Pearson correlation matrix showing groups of mostly bladed spill relevés and their controls, based on environmental variables. The sorting of relevés into groups corresponding to the five investigated classes/landform units is apparent but less clear than in Fig. 14. Except for marshes, controls for various classes are again grouped into a cluster which also includes less disturbed relevés. A configuration produced by monotonic multidimensional scaling using Kruskal's coefficient of alienation from Pearson correlation matrix (not presented) showed that the intensity of disturbance and moisture are again important ordering variables. The sorting of individual classes/landform units is relatively good although much poorer than in the ordination based on vegetational data.

was removed from the site during the cleanup, disintegrates. In drier habitats, successional communities of mosses, herbs, and shrubs increased the current diversity of vegetation types.

The direction of plant community recovery was strongly related to the different environments associated with different landforms but usually not to the intensity and type of disturbance. The successional pathways are similar on most types of disturbance and the current undisturbed communities seem to be the last step in the succession on each particular landform.

Disturbed moist and wet habitats were colonized directly by the dominants of undisturbed marshes (more common *Carex aquatilis* ssp. *stans* and less common *Eriophorum angustifolium* ssp. *subarcticum)* and lowlands. Disturbed uplands, ridges, and partly snowpatches were colonized by rhizomatous graminoids (primarily *Arctagrostis arundinacea* [TRINO BEAL and *Poa arctica* R. BR.) which can disperse, grow, and reproduce rapidly (colonizers; GRIME 1979) and which are relatively rare in the surrounding tundra (e.g. HERNANDEZ 1972a,b, 1973, YOUNKIN 1973, KOMÁRKOVÁ 1983). Successional communities in drier sites may also be dominated by prostrate herbs (e.g. *Stellaria edwardsii* R. BR.). Dry elevated berms of bladed material surrounding the site were covered by rhizomatous *Poa arctica* and bladed ridges outside the main site by caespitose *Poa glauca* M. VAHL. Long-lasting succession stages in arctic western Siberia are also formed by graminoids (TVOROGOV 1988).

Some taxa colonizing surface disturbances are the same in arctic Alaska, Canada, and western Siberia. Only *Eriophorum angustifolium* in wet areas and *Senecio congestus* (R. BR.) DC. commonly revegetate both arctic Alaskan and Siberian test wells; taxa less common in one of the areas include *Equisetum arvense* L., *Arctagrostis arundinacea, Carex aquatilis* ssp. *stans,* and *Salix lanata* L. Successional communities similar to the ones at the Fish Creek Test Well also occur on coal mining and dwelling disturbances near Atkasook. Willows and other grasses and herbs may be more important in western and southern arctic Alaska (e.g. EBERSOLE 1985, EBERSOLE & WEBBER 1983), in the Tuktoyaktuk Peninsula region, Northwest Territories (HERNANDEZ 1972a, 1973), in the Mackenzie Delta region (BLISS & WEIN 1972b, HERNANDEZ 1972b), and on western Siberian drill sites (TVOROGOV 1988). Willows are dominant in successional and even in zonal communities under warmer and more humid arctic climate. They usually spread from individuals or parts that survived the disturbance, but also germinate from seeds (TVOROGOV 1988).

Moss-dominated successional communities do not occur in the continually disturbed Vorkuta region (DRUZHININA 1985); they may occur in areas that have not been disturbed after the termination of the drilling (TVOROGOV 1988). In arctic Alaska, bryophytes may colonize burned surfaces and persist for decades (e.g. JOHNSON & VIERECK 1983) or reach maximum cover 5 to 6 yr after fire and then decline as the vascular overstory develops (RACINE et al. 1987). At the Fish Creek Test Well in places shaded by solid waste and on moist solid waste surfaces, bryophyte-dominated communities are still persisting.

In well-drained habitats, successional pathways following human disturbances were different from those following natural disturbances. For example, *Arctagrostis arundinacea,* which often dominates successional communities on human surface disturbances, dominated only one several- m²-large site on a floodplain near Atkasook. Possibly, it dominates only one-time surface disturbances that enrich soil in nutrients. Webber & Walker (in WALKER et al. 1987) suggested slope failures, river and lake banks, and frost scars as natural analogs to bladed trails. Repeated surface disturbance and material movement in these natural habitats produce and maintain persistent communities with unique composition that is very different from the composition of successional communities colonizing trails in which surface is bladed once, blading may be followed by multiple vehicle passes, and then, in flat terrain, disturbance usually ceases. Similar arguments can be made for other suggested natural human disturbance analogs such as snowpatches and riverbars. Natural analogs can illustrate the response of arctic ecosystems to human disturbances, but only when the analogy is established through an analysis of intensity, frequency, other disturbance attributes, and an analysis of disturbance-associated ecosystem changes.

Disturbance damage

The resistance of ecosystems to disturbance and the resulting damage are specific for different types of disturbances and ecosystems. While well-drained ecosystems with large phytomass were more resistant to mechanical disturbances in trails, wet ecosystems appeared to be most resistant to damage by spills due to the dispersal of the spilled substance by water.

The degree of damage and the rate of recovery may also vary with other factors. Classes/landform units most resilient to disturbance by vehicles appeared to be marshes with water-saturated surface soil layer. However, even single passes of lightweight vehicles on winter seismic trails in wet graminoid and moist sedge-shrub tundra were visible the following summer; frozen mosses were crushed and broken, and were not able to rebound immediately like in summer trails (FELIX & RAYNOLDS 1989).

Rate of recovery

The rate of ecosystem recovery (elasticity) differs with the type and intensity of disturbance and with the Braun-Blanquet class/landform unit. Like resistance, elasticity is specific for each disturbance and vegetation/landform unit. The elasticity component may dominate the recovery after more intense disturbances and the resistance component after less intense disturbances.

Very early stages of colonization of bladed or bulldozed surfaces have been observed, in much smaller plots than the original test well disturbance, after the removal of solid waste in 1979 and 1980. More of this colonization was accomplished by rhizomes and other vegetative means by plants growing at the edges of the disturbed patches than from seeds, especially in dry or wet places where seedlings were rare (KOMÁRKOVÁ 1985b). This was also true in small recovering sites at the Oumalik Test Well to the south of Fish Creek where seeds did not survive long-term burial under solid waste (EBERSOLE 1987).

The size of the disturbed area has an important relation to the speed and, in some cases, the direction of the recovery. When the area is too large to be rapidly colonized vegetatively from the edges, plants may colonize the central area more slowly by seeds and dominate the successional communities. This was observed by EBERSOLE (1987) at the Oumalik Test Well. It is unlikely that early colonizers originated from the seed bank at the Fish Creek Test Well. Seeds of early colonizers that are rare in undisturbed vegetation will be considerably less numerous in the seed bank than seeds of upland dominants that do not participate in successional communities.

A remnant of an old organic mat may serve as a source of seeds for revegetation (e.g. MCGRAW 1980) in places where successional dominants are common in undisturbed vegetation or where dominants are also colonizers. This is possible only in the presence of ample moisture, usually on mineral substrate. Old organic matter layers may become dry even in originally mesic upland habitats where there is moisture near the surface on top of the permafrost table. Once dry, organic matter does not conduct enough moisture for successful germination and establishment of seeds that it may contain or for colonization by other taxa (ZASADA & GREGORY 1969, DENEKE et al. 1975, VAN CLEVE 1977, JOHNSON et al. 1978, KOMÁRKOVÁ 1983, 1985b, EBERSOLE 1985, 1987). For this reason and because old organic mats, particularly in northern upland sites, may lack the seeds of early colonizers, it is doubtful that all such mats in disturbed mesic sites will be rapidly revegetated by natural succession from the seeds they contain (CARGILL & CHAPIN 1987).

The period of rapid ecosystem change that follows disturbance (e.g. GUTIERREZ & FEY 1980) has not been observed at the Fish Creek Test Well. Arctic disturbed areas are usually invaded by colonizers in 5 yr (JOHNSON 1969) and the recovery of full vegetation cover may last 10 yr even on bladed surfaces. In arctic western Siberian gas fields on disturbances very similar to the Fish Creek Test Well, natural regrowth after total destruction of vegetation lasted about 10 to 15 yr; it proceeded in zones from the edges of a disturbed area to its center (TVOROGOV 1988). Rapid establishment of vegetation cover is followed by slow community composition change controlled by slow environmental recovery, new landform differentiation, and by newly triggered natural disturbances; during this period, successional communities are being replaced by communities similar to the undisturbed ones.

It has been noted that the recovery of disturbed arctic vegetation may be relatively rapidly accomplished within a few years (e.g. WEBBER & IVES 1978, CARGILL & CHAPIN 1987). At the Fish Creek Test Well, even the composition of vegetation on winter trails was not fully recovered 30 yr after the disturbance. In marsh vehicle trails, the highest average similarity to controls was 88%, but in upland trails it was only 73%. FELIX & RAYNOLDS (1987) reported little recovery on winter trails on the Coastal Plain in the Arctic National Wildlife Range, Alaska, second or third summers after the disturbance.

At the Fish Creek Test Well, both the colonization rate and the rate of recovery of community composition were lower on disturbances that produced greater departures from the original state. Solid waste vegetation composition differed from the original ecosystems most drastically; hydrocarbon spills, bladed surfaces, multiple vehicle passes, single passes, and winter trails and a runway supported vegetation increasingly more similar to the controls. A high degree of community differentiation was indicated by a low degree of similarity between and a high degree of similarity within the groups of samples belonging to each community. This degree was highest in trails and on bladed surfaces, approaching that of undisturbed communities. The recovery was slowed down when disturbance was followed by a newly triggered natural disturbance such as the lack or oversupply of moisture or erosion.

Excluding thermokarsts and ponds in which water is too deep to be vegetated, the measured degree of community composition recovery decreased along with decreasing moisture from marshes to lowlands to snowpatches to uplands and ridges on most disturbance types. The elasticity of newly developing marshes is still greater than the elasticity of other ecosystems recovering from disturbance. The regrowth rate was also highest in wet, depressed areas with longer-lying snow at other disturbed Alaskan (e.g. EBERSOLE 1985, EBERSOLE & WEBBER 1983) and western Siberian (TVOROGOV 1988) tundra sites, and in forest-tundra and northern taiga in western Siberia (MOSKALENKO 1980).

The inhibition of the undisturbed vegetation dominants by the successional dominants (e.g. LAMBERT 1972, JOHNSON & VAN CLEVE 1976) on bladed upland, ridge, and snowpatch surfaces lasts at least for several decades. Pioneer taxa also persist for more than 10 yr on the Siberian wells, particularly in the drilling mud around the well head (TVOROGOV 1988). Some of the original dominants, even *Eriophorum vaginatum* ssp. *spissum* which propagates by seeds (GARTNER 1982, GARTNER et al. 1986), are at least present in successional communities in many places 30 yr after the disturbance.

At the Fish Creek site, both microtopographical and vegetational differentiation will continue more rapidly than in the surrounding landscape for some time. Even recovering plant communities most similar to their controls are still relatively poorly differentiated. Even at low disturbance intensities, full recovery may still take between a hundred and several hundred years, as long as the development of new ecosystems takes on naturally disturbed surfaces (KOMARKOVA 1983). In temperate scrub or grassland, recovery may be much faster. In coastal sage scrub in California, the pre-burn and post-burn community similarity is on the average 85% 5 yr after the fire (WESTMAN & O'LEARY 1986); this is similar to Mediterranean-climate shrublands of southern France where the elasticity is between 3 and 11 yr (WESTMAN 1986).

Recovery of environment

Environment was relatively poorly differentiated in recovering ecosystems. Discriminant analysis showed less clear prediction of group membership in recovering than in undisturbed ecosystems for both vegetational and environmental data. However in most cases, the similarity of disturbed to control vegetation was considerably lower than the similarity of disturbed to control environment; only in marshes and lowlands in less disturbed winter, single pass, and multiple pass trails was the similarity of vegetation in disturbed plots to their controls higher (Tab. 1). The more intense disturbance, the greater the difference. This was again supported by discriminant analysis: environmental, including soil, properties predicted group membership considerably more accurately than plants.

This probably reflects the fact that soils and landforms were less disturbed, especially by more intense disturbance, than vegetation; it could also indicate a greater elasticity of environment than vegetation. Vegetational recovery lags behind environmental one also, for instance, after a fire in a coastal sage scrub in California, where nutrients that increased after the burn more or less returned to pre-burn levels within five years, but the elasticity of vegetation was about 7 yr (WESTMAN & O'LEARY 1986).

Six yr after the disturbance, the soil in a compressed track at Barrow, Alaska, had higher bulk density, reduced moisture content and aeration, lower acidity, higher nutrients, and higher plant productivity than the surrounding tundra (CHALLINOR & GERSPER 1975, GERSPER & CHALLINOR 1975). At the Fish Creek Test Well, most of this was still true for most disturbance types 30 yr after the disturbance. Post-disturbance base saturation, nutrients, and depth of thaw were usually higher, and organic matter, available water, silt, clay, and CEC were usually lower. Similar patterns also appeared elsewhere. For example, the following soil properties increased in the Californian coastal sage ecosystem, after fire: N, PO_4, K, Ca^{++}, NO_3^-, NH_4, salinity, and water holding capacity (WESTMAN & O'LEARY 1986).

Because part of the organic soil layer was not removed and more organic matter was released by deeper thaw, after blading or bulldozing, the Fish Creek Test Well was relatively rich in nutrients that supported high plant production and rapid growth and colonization by invading rhizomatous graminoids; an old organic mat may serve as an all-important source of nutrients (e.g. VAN CLEVE 1977). Higher soil temperatures may also increase decomposition rates and nutrient availability (EBERSOLE & WEBBER 1983). In places where the organic matter layer is removed along with vegetation, most of nutrients may be lost from the ecosystem (VAN CLEVE 1977).

Plant community recovery is parallel and closely related to the recovery of the physical environment. While environmental recovery is usually ahead of vegetational one during the first decades after disturbance, full recovery of insulating and nutrient-cycling vegetation may be necessary for full recovery or development of soil properties and the depth of thaw. LAWSON (1986, in WALKER et al. 1987) proposed a sequence of events, including both physical and biological processes, leading to the restoration of thermal equilibrium in disturbed Alaskan tundra. Three influential factors included the distribution of ice volume, which directly affects the mode and rate of degradation; the physical properties of sediments, which affect their susceptibility to failure once thaw begins; and the local and regional slope which affects moisture conditions, drainage, and thus degradational processes. In some sequences proposed by other authors (e.g. CHAPIN & SHAVER 1981), landforms and environment do not play large enough role.

Multiple disturbances

The recovery of vegetation cover was complete after 30 yr, except for small patches still bare of vegetation that were produced by all investigated human disturbance types, usually in conjunction with a newly triggered natural disturbance. Such patches and their possible causes included, for example, small areas of hydrocarbon spills (high intensity of the spill); bladed, elevated tops of ridges (lack of moisture); piled up mineral material (lack of moisture); overturned organic mats (lack of moisture); deep ponds in new thermokarsts (too much moisture); severely eroding surfaces (gravity); and most solid waste surfaces (high disturbance intensity, lack of moisture). Elsewhere in the Arctic, no or very little of vegetation occurred 20 yr after disturbance in sites with high ice content, thermokarst subsidence, and erosion (HOK 1969), and in trails up to 10 yr old (BLISS & WEIN 1972a).

The only recovering multiple human disturbances were hydrocarbon spills on bladed surfaces. Vegetation was totally removed by both intensive spills and blading. The recovery was equally slow in otherwise undisturbed spills outside the main site as in spills that were also bladed. In both areas on corresponding landforms, several spills were still bare; the vegetation cover in others was very low and consisted of successional dominants. Surfaces that were only bladed were completely vegetated unless some natural disturbance factor intervened. Fish Creek Test Well, it was not true that the rate of vegetation recovery was slower in multiple impacts than in the sites of component single impacts. Rather, this rate appeared to be determined by the dominant toxic disturbance of hydrocarbon spills.

In hydrocarbon spills on bladed surfaces, environment was damaged more than in places of the component single impacts. The measured disturbance effects, such as the release of nutrients and the depth of thaw were greater in bladed sites than in places where hydrocarbon spills were the only disturbance. The recovery of these environmental characteristics appeared again to be dominated by the disturbance that produced the greater effect, i.e. by blading. For example, thaw was deeper only by several centimeters when the only disturbance was a hydrocarbon spill, but it could be deeper by several tens of centimeters in both hydrocarbon spills on bladed surfaces and when the only disturbance was blading.

Summary and conclusions

A common pattern emerged in response to a variety of disturbance factors (e.g. SELYE 1956, WOODWELL 1970, AUERBACK 1981) 30 years after the disturbance at the Fish Creek Test Well. There was a temporary increase in heterogeneity of plant commnities and spatial heterogeneity of landforms and their ecosystems. The successional pathways after various disturbance types were similar, and the degree to which the disturbed ecosystems were different from the original controlled the rate rather than the direction of recovery in almost all cases.

The rate of recovery was highly dependent on the type and other properties of disturbance (e.g. type, intensity, frequency, predictability) and on the properties of the responding unit itself (e.g. VITOUSEK et. al. 1981). Each specific case of ecosystem disturbance involved different resistance and damage characteristics and different elasticity responses.

The Braun-Blanquet class/landform unit was the major factor controlling the direction and rate of recovery. Natural disturbances triggered by the human disturbance often determined the rate of recovery within the individual vegetation/landform types; again, this effect may be very specific for different disturbances and ecosystems. For example, some disturbance may short-circuit or eliminate certain natural pathways, and others may accelerate certain natural processes (e.g. LUGO & SNEDAKER 1974). This disturbance-specificity of ecosystem response is most important where ecosystems are in equilibrium with particular disturbances, especially where the probability of the disturbance increases with time since the disturbance occurred last (HOLLING 1981, VITOUSEK et al. 1981). This may be the case on the Alaskan Arctic Coastal Plain, where natural surface disturbances are relatively frequent.

The rate of recovery in the investigated cold-dominated ecosystems was slow and full recovery may take between a hundred and several hundred years. All changes that the Fish Creek Test Well disturbance produced are temporary; eventually, the site will enter the natural, several-thousand-years-long cycle driven by the thaw lake, river, and wind disturbances and disappear.

Some trends in response to disturbance are the same in different geographical regions; for example, marshes appear to be the most elastic vegetation/landform unit in the whole circumpolar region. However, conclusions reached at one geographical site cannot be transferred to another without a detailed evaluation. Even between the northern and southern reaches of the Alaskan arctic tundra, the response patterns may be quite different. For example the same species may play a different role in the successional process in different parts of it's geographical range. *Eriophorum vaginatum* is not a colonizer in the northern part of the Alaskan Arctic Slope, but it is an important one on surface disturbances in the south and west (Eagle Summit, Toolik Lake, Seward Peninsula; CHAPIN & CHAPIN 1980, CHESTER & SHAVER 1982).

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Vegetationsdynamik in brachgefallenen Parkrasen (*Cynosurion*)

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Einleitung

Parkrasen im Sinne von regelmäßig kurz gehaltenen Grünlandflächen gehören heute in Europa im Bereich des sommergrünen Laubwaldes zu den verbreitetsten Pflanzengesellschaften der Siedlungsräume.

Während der Vegetationsperiode werden sie je nach Biomassenentwicklung 10 - 30 mal gemäht, wobei das Schnittgut liegenbleibt und von Regenwürmern und Mikroben zersetzt wird.

Bei ihrer Anlage werden in der Regel einige regenerationsfreudige Gräser ausgesät (HILLER 1976, HOPE 1983), die allerdings nach einigen Jahren zusammen mit spontan auftretenden Arten ein vielschnittbedingtes Gleichgewicht bilden. Je nach Standort, Vorgeschichte und Alter kommt es zur Ausbildung charakteristischer Pflanzengemeinschaften, wobei die ursprünglich ausgebrachten Gräser nur noch von untergeordneter Bedeutung sind (MÜLLER 1990).

Pflanzensoziologisch werden die Parkrasen zum *Cynosurion* gestellt, wobei die im folgenden behandelten südbayerischen Parkrasen als eigene Gebietsassoziation (*Trifolio repentis - Veronicetum filiformis* N. Müller 88) betrachtet werden können.

Entwicklungsgeschichtlich sind die Parkrasen vorwiegend eine junge Pflanzengesellschaft, deren großflächige Ausbreitung erst Mitte der 60er Jahre dieses Jahrhunderts mit der zunehmenden Verwendung von Motorrasenmähern einsetzte. Zunehmende Rationalisierung bei der Grünflächenpflege und gestalterisch-ästhetische Gesichtspunkte führten dazu, daß Parkrasen in öffentlichen und privaten Grünflächen sowie entlang Straßenbanketten etc. eine weite Verbreitung fanden. Der häufige Schnitt wurde mit dem Ziel betrieben, eine niedrige, dichte, geschlossene und mehr oder minder strapazierfähige Vegetationsdecke zu schaffen. Ökologische Aspekte fanden dabei keine Berücksichtigung. Die neueren Bestrebungen des Naturschutzes, durch abgestufte Pflege in Siedlungsräumen möglichst viele Lebensgemeinschaften nebeneinander zu fördern und so die Arten- und Biotopdiversität zu erhöhen, führten zu der Forderung, auch bei der Rasenpflege differenzierter vorzugehen. Im Herbst 1981 empfahlen darum die Mitglieder der Arbeitsgruppe «Biotopkartierung im besiedelten Bereich der BRD» (SUKOPP u.a. 1979), in verschiedenen Städten Dauerbeobachtungsflächen anzulegen, um die Entwicklung von Parkrasen bei Schnittreduzierung zu verfolgen. Dabei sollten Beobachtungen in Parkrasengesellschaften verschiedener Naturräume nach einem standardisierten Programm (WOLF 1982) über mindestens fünf Jahre durchgeführt werden. Ein Ziel dieser Untersuchungen war es, Erfahrungen zu sammeln, unter welchen Schnittvarianten (1-, 2- oder 3-Schnitt pro Jahr) die Parkrasen in floristisch reichhaltige Wiesen verwandelt werden können.

Desweiteren wurde auch jeweils eine Variante «ungestörte Sukzession» eingerichtet, da aus tierökologischer Sicht das ganzjährige Vorhandensein von Strukturen (Halme, vertrocknete Blütenstände, Samen etc.) als Entwicklungs- und Überwinterungshabitat für Grünlandgesellschaften relevanten Evertebraten (insbesondere Insekten) von Bedeutung ist (DUFFEY u.a. 1974, FEWKES 1961, MORRIS 1971).

Zu vorgenannten Fragestellungen wurden 1982 in Köln (KUNICK 1987), Bonn (WOLF 1982) und Südbayern (Schwerpunkt Augsburg) Dauerflächen eingerichtet.

Aus dem südbayerischen Versuchsprogramm von insgesamt neun Standorten mit jeweils gleichen Pflegevarianten (näheres vgl. MÜLLER 1988), soll im folgenden über die Entwicklung der Bracheparzellen exemplarisch anhand zweier Versuchsstandorte in Augsburg berichtet werden.

Floristisch handelt es sich um sehr ähnlich Bestände, die zur typischen Ausbildung der südbayerischen Parkrasen (*Trifolio repentis - Veronicetum filiformis* N. Müller 1988) gestellt werden können. Mit hohen Anteilen ist die Kennart *Veronica filiformis* vorhanden, die im Frühjahr mit ihren blauen Blüten physiognomisch beherrschend ist.

2. Grundlagen und Methoden

2.1 Allgemeine Beschreibung der Versuchsanlagen

Die beiden Versuchsanlagen liegen im Stadtgebiet von Augsburg, das naturräumlich innerhalb des Bayerischen Alpenvorlandes zu den «Lech-Wertach Ebenen» zählt (Abb. 1).

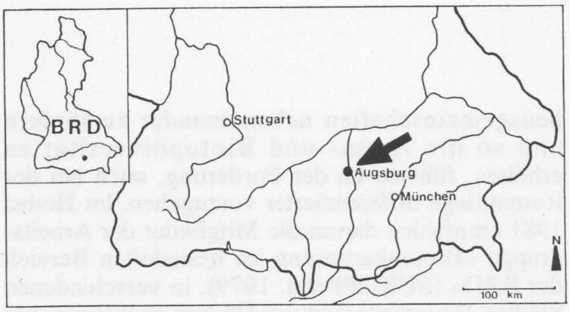

Abb. 1 - Lage der Versuchsflächen.

Das Klima kann als subatlantisch mit kontinentalem Einschlag bezeichnet werden. Für die Interpretation der Vegetationsentwicklung sind neben den Jahresmittelwerten vor allem die jahreszeitlichen Schwankungen während des Untersuchungszeitraumes von Interesse. Sie sind darum in Form eines Klimadiagrammes mit Klimatogramm nach WALTER (1955) in Abb. 2 dargestellt.

Bei der Anlage der Dauerflächen (vgl. Abb. 3) wurde entsprechend dem Minimumareal von Grünlandaufnahmen pro Behandlungsvariante 20 m^2 (4 x 5 m) große Flächen mit versenkten Metallpflöcken dauerhaft markiert.

In der Regel wurde mindestens eine Wiederholung angelegt, um die Ergebnisse statistisch abzusichern. Auf dem Standort Berliner Allee wurden in zwei Wiederholungen umfangreiche Versuchseinsaaten mit dem Ziel durchgeführt, die

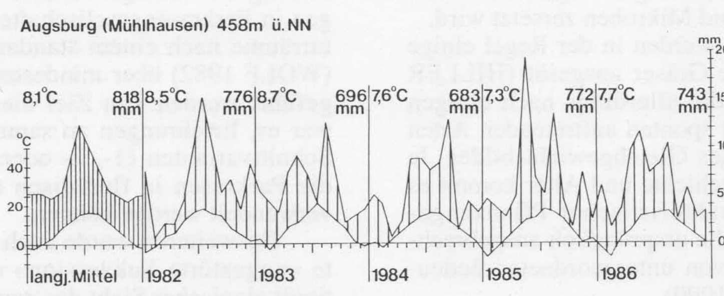

Abb. 2 - Klimadiagramm mit Klimatogramm für Augsburg (nach Grundlagen der Wetterstation des Deutschen Wetterdienstes Augsburg - Mühlhausen).

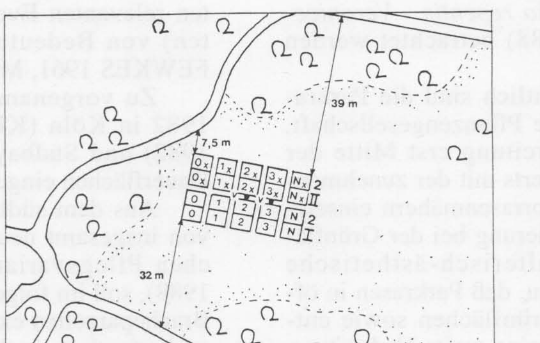

Abb. 3 - Versuchsfläche 2 (Berliner Allee I und II).

Schnittvarianten floristisch anzureichern. Da durch die eingesäten Arten der Sukzessionsverlauf zum Teil stark beeinflußt wurde, erfolgte hier jeweils für zwei Versuchsreihen eine getrennte Auswertung (Berliner Allee I und II).

2. 1. 1 Versuchsfläche 1 (Spickel)

Die Grünanlage, in der diese Versuchsfläche liegt, enstand 1968 auf einer ehemaligen Magerwiese. Nach Umbruch der Flächen im Zuge von Bauarbeiten wurden sie mit einer handelsüblichen Rasenmischung eingesät und in Folge als Parkrasen gepflegt.

Auf die ehemalige Vornutzung als artenreiche Magerwiese ist es zurückzuführen, daß diese Parkrasen zu Versuchsbeginn in geringen Mengenanteilen einige Wiesenarten wie z.B. *Leucanthemum vulgare* und *Ranunculus acris* enthielten.

Die Bodenform stellt eine Auenrendzina mit einer 10 cm mächtigen geröllhaltigen Humusauflage dar. Der C-Horizont besteht aus schwach tonigem Schluff. Das niedrige C/N Verhältnis (8,3) und die ausgeglichenen Phosphat- (9 mg P_2O_5/100 g Boden) und Kaliwerte (6 mg K_2O/100 g) verdeutlichen das gute Nährstoffangebot des Bodens. Gegenüber der Versuchsanlage Berliner Allee hat dieser Standort eine deutlich erhöhte Biomassenproduktion.

2.1.2 Versuchsfläche 2 (Berliner Allee I und II)

Die Versuchsflächen liegen in einer Parkanlage, die 1958 auf Trümmerschuttablagerungen entstand. Nach einer schwachen Humusierung erfolgte, nachdem eine spontane Begrünung einsetzte, regelmäßiger Parkrasenschnitt. Da im Gegensatz zur Versuchsfläche Spickel wahrscheinlich kaum keimfähiger Samenvorrat von Grünlandgesellschaften bei der Neuanlage im Boden ruhte, sind diese Flächen im Vergleich floristisch ärmer.

Trotzdem haben sich – wie in der Versuchsfläche Spickel – innerhalb der über 20 – jährigen Parkrasenpflege alle typischen Arten der Parkrasen eingestellt, so daß zu Versuchsbeginn auf beiden Standorten ähnliche Mengenanteile von *Cynosurion*arten auftraten.

Bei der Bodenprofilbohrung folgte auf eine 7 cm mächtige sandige Humusauflage eine für den Bohrstock undurchdringliche Trümmerschuttlage. Gegenüber der Versuchsfläche Spickel hat der Standort Berliner Allee eine geringere Biomassenproduktion (C/N = 10; 24 mg P_2O_5/100 g Boden, 18 mg K_2O/100 g).

2.2 Methoden

Im Vordergrund der Untersuchungen stand eine möglichst genaue Erfassung der Veränderung der Vegetation.

Mit Hilfe der verfeinerten LONDO-Skala (1975) wurden die Teilflächen jedes Jahr Ende Mai und Anfang August erhoben, daraus ein Mittelwert gebildet und anschließend das arithmethische Mittel aus den zwei Teilflächen errechnet.

Um einen Einblick in den zeitlichen Verlauf der für die Sukzession bezeichnenden Arten zu

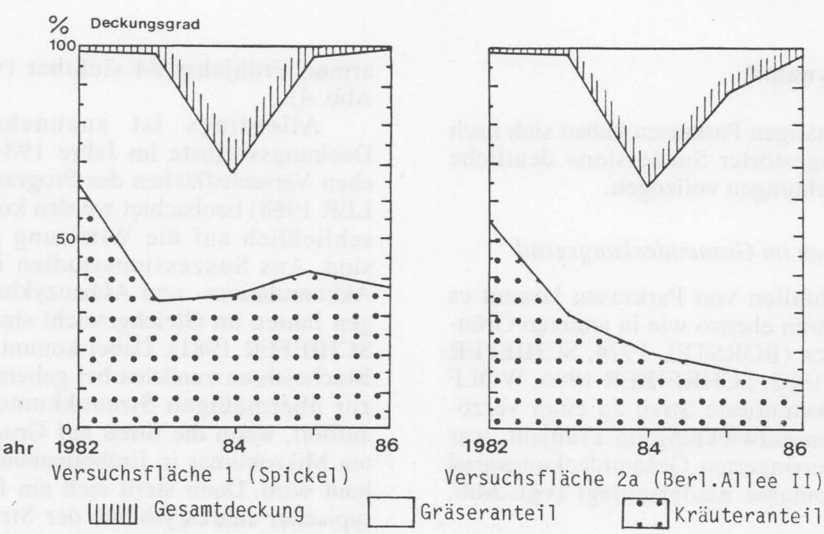

Abb. 4 - Veränderung im Gesamtdeckungsgrad und im Kräuter- u. Gräseranteil in brachgefallenen Parkrasen (*Trifolio repentis - Veronicetum filfiormis)* innerhalb von 5 Jahren.

gewinnen, wurde ihr Deckungsgradverlauf profilartig dargestellt (Abb. 6).

An synthetischen Daten über die Bestandsveränderungen wurden berechnet:

– Veränderung des Gesamtdeckungsgrades und des Kräuter- u. Gräseranteils (Abb. 4).
– Veränderung der Artenzahl und des Gemeinschaftskoeffizienten (SØRENSEN 1948) (Abb. 5).

Weitere Einzelheiten und kritische Bemerkungen zu den Auswertungsmethoden finden sich bei MÜLLER (1988).

dennahen Luftschichten. Verstärkt wird dieser Effekt durch Gräser, die auf Grund eines hohen Gehaltes an langsam abbaubarer Zellulose und Lignin eine verklebte und kompakte Streudecke ausbilden.

Desweiteren führen Trockenperioden im Herbst und darauffolgendem Frühjahr zu einer Verlangsamung der Streumineralisation (GISI u. OERTLI 1981, STÖCKLIN u. GISI 1985). In den brachgefallenen Parkrasen werden am geringeren Gesamtdeckungsgrad 1984 die Auswirkungen des trockenen Herbstes 83 und des niederschlags-

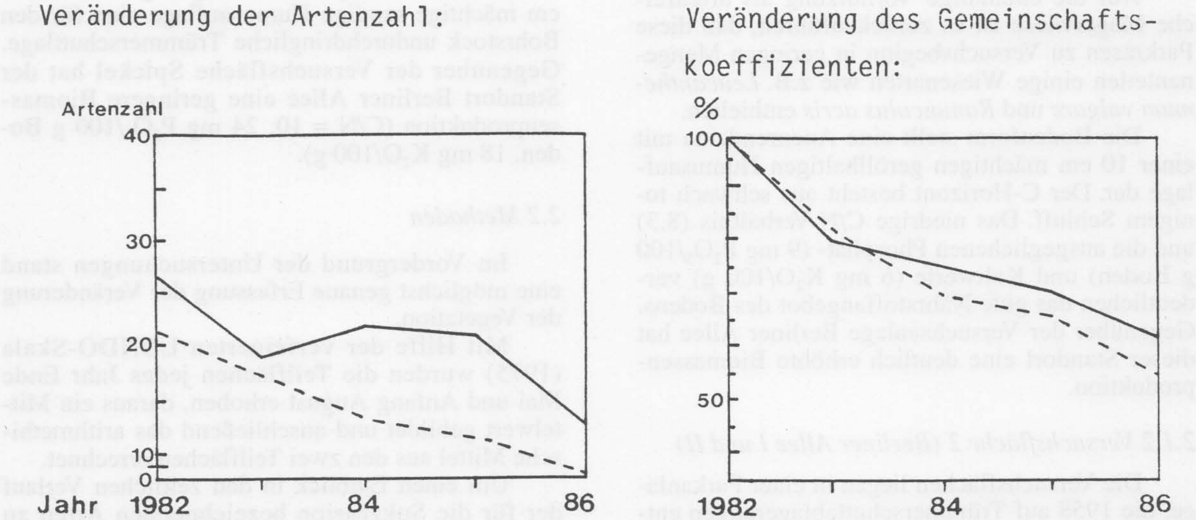

Abb. 5 - Veränderungen der Artenzahl u. des Gemeinschaftskoeffizienten in brachgefallenen Parkrasen (*Trifolio repentis - Veronicetum filiformis)* innerhalb von 5 Jahren.

3. Vegetationsdynamik

In den ehemaligen Parkrasen haben sich nach fünf Jahren «ungestörter Sukzession» deutliche Bestandsumschichtungen vollzogen.

3.1 Veränderungen im Gesamtdeckungsgrad

Beim Brachfallen von Parkrasen kommt es in den ersten Jahren ebenso wie in anderen Grünlandgesellschaften (BORSTEL 1974, SCHIEFER 1981, 1981 a u. 1982, SCHREIBER 1986, WOLF 1979) durch akkumulierte Streu zu einer verzögerten Vegetationsentwicklung im Frühjahr, was sich in einem verringerten Gesamtdeckungsgrad an lebender Biomasse niederschlägt (vgl. Abb. 4).

Die Streuschicht bewirkt eine geringere und langsamere Erwärmung des Bodens und der bo-

armen Frühjahrs 84 sichtbar (vgl. Abb. 2 und Abb. 4).

Allerdings ist anzunehmen, daß die Deckungsverluste im Jahre 1984, die in sämtlichen Versuchsflächen des Programms (vgl. MÜLLER 1988) beobachtet werden konnten, nicht ausschließlich auf die Witterung zurückzuführen sind. Aus Sukzessionsstudien ist bekannt, das Akkumulations- und Abbauzyklus erst nach einigen Jahren im Gleichgewicht sind (ODUM 1960, SCHIEFER 1981). Dabei kommt es in den ersten Brachejahren zunächst bei gehemmter Zersetzung zur übermäßigen Streuakkumulation, die erst aufhört, wenn die Streu auf Grund des veränderten Mikroklimas in Erdbodennähe verstärkt abgebaut wird. Dann stellt sich ein für Brachflächen typischer Jahresrythmus der Streumineralisation ein. Die zu Beginn der Vegetationsperiode recht große Streumasse wird im Frühjahr und Frühsommer besonders schnell zersetzt, so daß im Juni und Juli die geringsten Streumengen anzutreffen sind. Mit dem Vergilben der Pflanzenbestände im Sommer steigt die Streumasse dann schnell an, um im Oktober ein Maximum zu erreichen. Eine kontinuierliche Akkumulation von Streu über Jahre hinweg findet aber nicht statt, da Abbautätigkeit und Streuanfall sich die Waage halten (WOLF 1979, SCHIEFER 1981, STÖCKLIN u. GISI 1985).

Die hohen Deckungsverluste 1984 sind demnach auch damit zu erklären, daß sich der Akkumulations- und Abbauzyklus in Parkrasen erst seit 1985, also nach drei Jahren, eingespielt hat. Das sowohl die Witterung als auch der Abbauzyklus für den geringen Gesamtdeckungsgrad 1984 verantwortlich sind, bestätigen auch Untersuchungen in einer anderen Rasenversuchsanlage innerhalb des Gesamtprogramms, die ein Jahr später als die anderen Standorte eingerichtet wurden (vgl. MÜLLER 1988). Hier war sowohl 1984 bedingt durch die Witterung als auch 1985 bedingt durch den Akkumulationszyklus eine erhöhte Streuauflage zu beobachten.

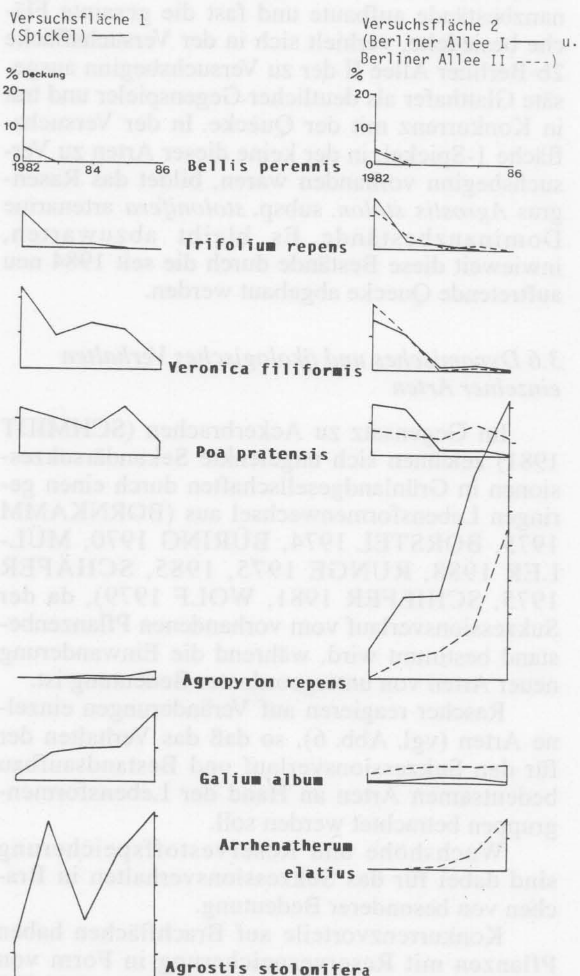

Abb. 6 - Deckungsgradveränderungen einzelner Artne in brachgefallenen Parkrasen (*Trifolio repentis - Veronicetum filiformis*).

Demnach hat sich der Abbauzyklus auf den Rasenbrachen nach drei Jahren eingespielt, was auch Untersuchungen von ODUM (1960) in Ackerbrachen und SCHIEFER (1981) in Grünlandbrachen entspricht.

3.2 Veränderung der Artenzahl

Bedingt durch die erhöhte Streuakkumulation in den ersten Jahren kommt es in den brachgefallenen Parkrasen zu einem deutlichen Artenrückgang (vgl. Abb. 5), wobei vor allem lichtliebende *Cynosurion*-Arten verschwinden (vgl. Tab. 1, Gruppe 1).

Dabei zeigt sich ein Zusammenhang zwischen der Zunahme des Gräseranteils und der Abnahme der Artenzahl. Je höher der Anteil an schwer zersetzbaren Gräsern und der damit verbundenen akkumulierten Streu, um so größer sind auch die Artenverluste, eine Beobachtung die SCHIEFER (1981, 1982) u. SCHREIBER (1986) ebenfalls in *Cynosurion*- und auch in *Arrhenatherion*-Gesellschaften gemacht haben. Auf nährstoffreichen Standorten verläuft dieser Prozess rascher, da schneller einige konkurrenzkräftige Arten zur Vorherrschaft gelangen, als auf mageren Versuchsflächen (vgl. MÜLLER 1988). Die Kurve der Artenzahl verdeutlicht auch, daß die Sukzession in den Parkrasen noch im vollen Gange ist und das auch in den nächsten Jahren mit einem weiteren Artenverlust zu rechnen ist.

3.3 Veränderungen des Gemeinschaftskoeffizienten

Auch die Darstellung des Artenwechsels, bezogen auf den Ausgangsbestand mit Hilfe des Gemeinschaftskoeffizienten (SØRENSEN 1948) zeigt, daß die Sukzession kontinuierlich verläuft und noch nicht abgeschlossen ist (vgl. Abb. 5). Die relativ flachen Kurven machen deutlich, daß sich die Vegetation während der Versuchsdauer qualitativ nicht wesentlich verändert hat.

Zusammenfassend läßt sich an Hand der Veränderungen der Artenzahlen und der Ähnlichkeitsbeziehungen die Vegetationsentwicklung in brachgefallenen Parkrasen nach dem «initial floristic composition model» (EGLER 1954) interpretieren: Der Sukzessionsverlauf wird von dem bei der Pflegeumstellung vorhandenen Pflanzenbestand bestimmt, während neue Arten sich kaum etablieren können.

3.4 Verschiebungen in Kräuter- u. Gräseranteil

In brachgefallenen Parkrasen ist wie in ungemähten *Arrhenatherion*-und *Cynosurion*-Gesellschaften (BORSTEL 1974, SCHIEFER 1981 a) der Artenverlust mit einer mengenmäßigen Zunahme von Gräsern verbunden (vgl. Abb. 4).

Bei allen Ausildungen von Parkrasen innerhalb des Versuchsprogramms (vgl. MÜLLER 1988) konnten deutliche Bestandsumschichtungen zugunsten der Gräser beobachtet werden. Dabei kommen hochwüchsige- bereits im Ausgangsbestand vorhandene Gräser wie z.B. *Agropyron repens, Dactylis glomerata* zur Dominanz, während niederwüchsige Rasengräser wie z.B. Poa trivialis und Poa pratensis verdrängt werden (vgl. Tab. 1 Versuchsfläche 2, Berliner Allee I). Sind allerdings im Ausgangsbestand keine hochwüchsigen Gräser bestandsprägend vorhanden, so erreichen typische Rasengräser wie z.B. *Agrostis stol.* subsp. *stol.* (vgl. Versuchsfläche 1, Spickel) oder *Festuca rubra* und *Poa pratensis* hohe Deckungsgewinne (vgl. MÜLLER 1988) und können artenarme Dominanzbestände ausbilden. Ähnliche Beobachtungen machten auch TRAUTMANN u. LOHMEYER (1975) an wenig oder ungemähten Rasenaussaaten an Autobahnen und KUNICK (1987) in brachgefallenen Parkrasen.

Ob allerdings diese Dominanzbestände aus Untergrässer ähnlich stabil sind wie solche aus Hochgräsern z.B. mit *Arrhenatherum elatius* (FISCHER u.a. 1985) oder mit *Agropyron repens* kann auf Grund der Kürze der Beobachtungszeit nicht beurteilt werden.

3.5 Verschiebungen in der Artenkombination

Faßt man die Veränderungen einzelner Artenkombinationen mit gleicher Tendenz zusammen, so wird deutlich, daß die Sukzession in brachgefallenen Parkrasen in mehreren Etappen verläuft (vgl. Tab. 1).

In den ersten Jahren kommt es durch die erhöhte Streuakkumulation zu einem raschen Verlust der lichtliebenden *Cynosurion*-Arten (Gruppe 1), der durch einen sprunghaften Anstieg einzelner Rasengräser wie z.B. *Agrostis stolonifera* subsp. *stolon.* u. *gigantea* ausgeglichen wird.

Bis sich ein für brachgefallene Parkrasen typischer Streuakkumulationszyklus eingestellt hat, sind weitere verbreitete Arten der Parkrasen (Gruppe 2) verschwunden.

Nach fünf Jahren sind alle lichtliebenden Grünlandarten stark zurückgegangen (Gruppe 3) und es ist mit deren Verlust in den nächsten Jahren zu rechnen.

Der Rückgang der lichtliebenden Rasen- und Wiesenarten wird durch die Zunahme einiger weniger hochwüchsiger Arten mit breiter soziologischer Amplitude ausgeglichen (Gruppe 4). Überwiegend sind dies konkurrenzstarke Obergräser wie *Agropyron repens* und *Arrhenatherum elatius* und Saumarten wie *Galium album* und *Veronica chamaedrys*. Dabei scheint die Durchdringungsgeschwindigkeit einzelner Arten darüber zu entscheiden, welche als erste die Plätze der verschwundenen Arten besetzen und sich durchsetzen können. Während in der Versuchsfläche 2a-Berliner Allee I die Quecke artenarme Dominanzbestände aufbaute und fast die gesamte Fläche besiedelte, verhielt sich in der Versuchsfläche 2b-Berliner Allee II der zu Versuchsbeginn ausgesäte Glatthafer als deutlicher Gegenspieler und trat in Konkurrenz mit der Quecke. In der Versuchsfläche 1-Spickel, in der keine dieser Arten zu Versuchsbeginn vorhanden waren, bildet das Rasengras *Agrostis stolon.* subsp. *stolonifera* artenarme Dominanzbestände. Es bleibt abzuwarten, inwieweit diese Bestände durch die seit 1984 neu auftretende Quecke abgebaut werden.

3.6 Dynamisches und ökologisches Verhalten einzelner Arten

Im Gegensatz zu Ackerbrachen (SCHMIDT 1981) zeichnen sich ungelenkte Sekundärsukzessionen in Grünlandgesellschaften durch einen geringen Lebensformenwechsel aus (BORNKAMM 1975, BORSTEL 1974, BÜRING 1970, MÜLLER 1988, RUNGE 1975, 1985, SCHÄFER 1975, SCHIEFER 1981, WOLF 1979), da der Sukzessionsverlauf vom vorhandenen Pflanzenbestand bestimmt wird, während die Einwanderung neuer Arten von untergeordneter Bedeutung ist.

Rascher reagieren auf Veränderungen einzelne Arten (vgl. Abb. 6), so daß das Verhalten der für den Sukzessionsverlauf und Bestandsaufbau bedeutsamen Arten an Hand der Lebensformengruppen betrachtet werden soll.

Wuchshöhe und Reservestoffspeicherung sind dabei für das Sukzessionsverhalten in Brachen von besonderer Bedeutung.

Konkurrenzvorteile auf Brachflächen haben Pflanzen mit Reservespeicherung in Form von Rhizomen, Pfahlwurzeln, Knollen etc. (OOMES u. MOOI 1985, SCHIEFER 1982, WOLF 1979). Die häufig im Frühjahr vorhandene Streudecke wirkt so stark beschattend, daß eine Assimilation

Tab. 1 - Vegetationsentwicklung in brachgefallenen Parkrasen (*Trifolio repentis - Veronicetum filiformis* N. Müller 88) innerhalb von 5 Jahren (Angaben in Deckungsprozente)

	Versuchsfläche	1-Spickel					2a-Berl.Allee I					2b-Berl.Allee II					
	Jahr	82	83	84	85	86	82	83	84	85	86	82	83	84	85	86	
	Zahl d. Aufnahmen	2	2	2	2	1	2	2	2	2	1	2	2	2	2	1	
	Zahl d. Teilfläch.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	Deckung Gefäßpfl.	99	99	67	97	99	99	99	64	89	99	99	59	58	93	99	
	Kräuter (incl.Leg.)	64	33	35	39	37	55	31	20	16	13	62	38	16	22	19	
	Gräser	36	67	29	58	63	45	69	44	73	87	38	61	42	71	81	
	Gefäßpfl./Teilfl. Ø	26	18	21	20	12	25	21	17	15	12	27	26	21	21	15	Le-
	" absolut	28	22	25	23	17	30	24	22	19	16	32	31	27	26	19	bens-form
G 1	Bellis perennis	4	.	.	.	.	4	.	.	.	.	4	.	.	.	.	Hr
	Capsella bursa-past.	r	.	.	.	.	r	.	.	.	.	r	.	.	.	.	T
	Veronica serpyllifol.	1	.	.	.	.	1	.	.	.	.	r	.	.	.	.	HRr
	Plantago media	r	.	.	.	.	2	r	.	.	.	6	1	r	r	.	Hr
	Prunella vulgaris	1	.	r	.	.	2	r	.	.	.	5	r	.	r	.	HRs
	Cerastium holost.	1	.	.	.	.	1	r	r	.	.	1	r	.	.	.	C
	Lolium perenne	2	1	r	.	.	2	r	.	.	.	1	r	r	.	.	Hc
G 2	Trifolium repens	11	1	1	r	.	15	2	1	.	.	11	3	r	1	.	C
	Taraxacum off.	3	1	1	2	.	7	5	r	r	.	4	5	1	r	.	Hr
	Poa trivialis	6	1	.	.	.	9	1	.	4	r	9	1	r	.	.	HRs
	Leucanthemum vulg.	6	.	r	r	.	.	.	.	.	.	.	.	.	.	.	HRr
	Plantago major	.	.	.	.	.	r	r	r	.	.	1	r	r	r	.	Hr
G 3	Agrost. stol.ssp.gig.	.	.	.	.	.	13	31	7	5	.	23	46	25	28	8	HRr
	Plantago lanceolata	3	r	1	1	r	4	3	r	r	1	5	3	r	r	1	Hr
	Veronica filiformis	23	8	13	12	2	14	10	1	2	r	19	10	.	1	.	C
	Poa pratensis	13	9	7	14	4	15	14	2	2	1	7	6	5	9	6	HRr
	Achillea millefol.	2	1	r	r	r	8	8	13	6	2	5	6	4	5	4	HRr
	Medicago lupulina	.	.	.	.	.	1	1	r	r	r	1	1	1	r	1	T
G 4	Galium album	1	7	9	10	20	r	1	2	2	1	2	4	5	5	6	HRr
	Veronica chamaedrys	4	13	9	10	11	1	3	2	4	7	1	r	1	r	1	HRs
	Dactylis glomerata	1	3	2	4	5	3	5	6	3	6	4	6	8	16	4	HC
	Agropyron repens	.	.	1	1	3	8	23	24	59	82	1	6	8	15	45	G
	Acer pseudoplat.	.	.	.	.	.	.	.	r	r	r	.	.	r	r	r	P
	Fraxinus excelsior	.	.	r	1	1	.	.	.	.	r	.	.	.	.	r	P
	Acer platanoides	.	.	.	.	.	.	.	.	.	r	.	.	.	.	r	P
	Stellaria graminea	.	.	.	.	.	.	r	r	.	1	.	r	1	.	1	HRr
	Populus nigra	.	.	.	.	.	r	r	r	r	r	.	.	.	.	.	P
	Agrost.stol.ssp.stol.	13	48	18	38	50	.	.	.	.	.	.	.	.	.	.	HRs
	Arrhenatherum elat.*	.	.	.	.	.	.	.	.	.	.	.	.	1*	4*	15*	Hc
	Potentilla reptans	.	.	.	.	.	.	.	.	.	.	r	1	1	2	11	HRs
Sonstige:	Ranunculus repens	6	3	1	1	.	r	1	1	1	.	2	4	2	5	2	HRs
	Glechoma hederacea	r	r	r	2	2	1	r	2	2	1	r	1	1	2	r	HRs
	Ranunculus acris	1	1	2	2	1	.	.	.	.	.	1	1	r	1	1	Hs
	Rumex crispus	r	1	1	1	r	.	.	.	.	.	r	r	r	r	.	Hs
	Holcus lanatus	1	1	1	2	1	.	.	.	.	.	.	.	.	.	.	Hc
	Festuca rubra	1	1	2	1	1	.	.	.	.	.	.	.	r	1	.	Hc
	Leontodon hispidus	.	.	.	.	.	.	.	.	.	.	r	1	1	r	r	Hr

* eingesät 1982

Fortsetzung Tab. 1:

Lebensform nach ELLENBERG 1952 und 1979:

Hs = Schaft-Hemikryptophyt
Hc = Horst-Hemikryptophyt
Hr = Rosetten-Hemikryptophyt
HRs = Stolonen-Hemikryptophyt
HRr = Rhizom-Hemikryptophyt
G = Geophyt
T = Therophyt
P = Phanerophyt

Außerdem in
Versuchsfläche 1-Spickel: Sinapis arvensis 1984: r; Acer campestre 1985: 1; Sonchus asper 1984: r; Crataegus monogyna 1985: r; Trifolium prat. 1982: 1; Urtica dioica 1985 u. 86: r;

Versuchsfläche 2a-Berl.Allee I: Veronica arvensis 1982: r; Trisetum flavescens 1984: r; Silene vulg. 1982 u. 83: r; Crepis biennis 1982: r; Poa annua 1982: r;

Versuchsfläche 2b-Berl.Allee II: Veronica arvensis 1982: r; Ajuga reptans 1982: 1, 1983: r; Festuca prat. 1982, 83, 84: r; Trifolium dubium 1982: 3, 1983: r; Cardamine prat. 1982, 84: r, 1983 u. 85: 1; Trifolium prat. 1982 u. 83: r;

erst nach Durchwachsen der Schicht einsetzt (WEAVER u. ROWLAND 1952). Die unterirdische Reservespeicherung von Assimilaten in Knollen und Rhizomen befähigt Geophyten und Rhizom-Hemikryptophyten die Streudecke im Frühjahr gut zu durchwachsen, zumal die Überdauerungsknospen im Winter von den negativen Einflüssen der Streu geschützt sind. Darüber hinaus kommt dieser Lebensformgruppe auch ihre Fähigkeit zur vegetativen Vermehrung bei der Ausbreitung zu Gute, da unter der Streudecke eine generative Vermehrung stark erschwert ist.

Damit ist zu erklären, daß sich der Geophyt *Agropyron repens* in brachgefallenen Parkrasen rasch von Einzelpflanzen aus verbreiten kann.

Von den Rhizom-Hemikryptophyten konnte sich vor allem *Galium album* in den brachgefallenen Parkrasen behaupten und zum Teil ihre Deckungsanteile erhöhen. Auch *Stellaria graminea* zeigt leicht zunehmende Tendenz. Hingegen scheint *Poa pratensis* nicht so konkurrenzkräftig zu sein. Auffallend war, daß bei ihr die Blütentriebe stark vermindert waren und sie sich nur vegetativ ausbreitete, ein Zeichen dafür, daß sie in den brachgefallenen Parkrasen ihre Lichtansprüche nicht decken kann. *Leucanthemum vulgare* zeigt ebenso wie in *Arrhenatherion*-Brachen einen raschen Rückgang. Die Margarite bildet zwar Rhizome aus, aber ein Großteil ihrer Reservestoffe überwintern in den Blattrosetten, die unter der akkumulierenden Streu rasch ersticken.

Hochwüchsige Horst-Hemikryptophyten mit starker Verdrängungstendenz zeigen in brachgefallenen Parkrasen deutliche Deckungsgewinne. Wie aus der Tab. 1 und Abb. 6 deutlich wird, verhält sich der eingesäte Glatthafer als deutlicher Gegenspieler zur Quecke. Verdrängungsstarke Horst-Hemikryptophyten sind innerhalb der Gesamtversuchsreihe vor allem auf kräuterreichen Beständen konkurrenzfähiger, da hier die Streu rascher abgebaut wird und sie sich generativ ausbreiten können. Hingegen erwiesen sie sich in grasreichen Beständen, die zur Ausbildung einer langsamen zersetzbaren Streu neigen, gegenüber den vegetativ sich ausbreitenden Geophyten und Rhizom-Hemikryptophyten unterlegen (vgl. MÜLLER 1988). Niederwüchsige Horst-Hemikryptophyten wie *Lolium perenne* und *Trifolium pratense* werden bereits in den ersten Jahren verdrängt.

Stolonen-Hemikryptophyten sind in der Regel nicht so konkurrenzkräftig wie Rhizom-Hemikryptophyten, da oberirdische Ausläufer der Reservespeicherung dienen und somit zumindest in grasreichen Beständen mit langsam zersetzender Streu keine Konkurrenzvorteile bieten. *Ajuga reptans, Prunella vulgaris* und *Poa trivialis,* Stolenen-Hemikryptophyten mit kurzen Ausläufern, nahmen darum in allen brachgefallenen Parkrasen ab. Die starke Ausbreitung von *Agrostis stol.* subsp. *stol.* in der Versuchsfläche Spickel ist damit zu erkären, daß sich bislang keine konkurrenzkräftigen Geophyten und Horst-Hemikryptophyten ausbreiteten und darum das Straußgras mit seinen langen Ausläufern ungehindert die Streudecke überwachsen konnte.

Rosetten-Hemikryptophyten wie *Bellis perennis, Taraxacum officinale, Plantago media, P. major* und *P. lanceolata* nehmen in Folge der Beschattung durch Pflanzenbestand und Streudecke rasch ab. Dabei konnte beobachtet werden, daß *Taraxacum officinale* und *Plantago media* versuchten, durch Änderung ihres Habitus dem Lichtmangel zu entgehen. Sie strecken ihre Blätter im spitzen Winkel in die Höhe, dabei wurden bei *Plantago media* die Blätter deutlich schmäler und länger.

Auf die hohen Lichtansprüche der meisten Chamaephyten des *Cynosurion* ist es zurückzuführen, daß sie beim Brachfallen nicht mehr konkurrenzfähig sind. *Trifolium repens, Cerastium holosteoides* und *Veronica filiformis* zeigten deutliche Deckungsverluste bzw. verschwanden. *Veronica chamaedrys* hingegen versuchte durch die Bildung von Polykormonen die Streudecke zu überwachsen, wobei sie stets steril blieb und zum Teil ihre Deckungsanteile erhöhte. Die Sterilität stützt die These von JAKUCS (1969) und FÖRSTER (1975), daß die Polykormonbildung ein Zeichen der Grenzlage der Lebensfähigkeit dieser Pflanzen ist.

Für die generative Ausbreitung von Phanerophyten herrschen auf Grund der Streuauflage ungünstige Voraussetzungen. Hin und wieder kommen in offenen Stellen Keimlinge zur Entwicklung, die aber häufig wieder unterdrückt werden und absterben. Erst nachdem sie die Streudecke deutlich überwachsen haben, können sie sich dauerhaft etablieren.

Innerhalb der Versuchsflächen kamen bislang nur einige wenige Gehölze zur Entwicklung. Die in Brachflächen häufig beobachtete vegetative Vermehrung über Wurzelsprosse oder Polykormone kann in den Parkrasen mangels geeigneter Ausgangsgehölze nicht beobachtet werden.

Untersuchungen in brachgefallenen Fettwiesen (SCHIEFER 1981) und Feuchtwiesen (WOLF 1979) zeigten, ebenso wie die brachgefallenen Parkrasen, daß Dominanzbestände von Gräsern und Kräutern über Jahre stabil sein können und nur sehr langsam von Gehölzen durchdrungen und abgebaut werden.

Zusammenfassung

Parkrasen im Sinne von regelmäßig kurz geschnittenen Grünlandflächen sind heute in Europa im Bereich des sommergrünen Laubwaldes eine der verbreitetsten Pflanzengesellschaften der Siedlungsräume.

Auf Grund der neueren Bestrebungen des Naturschutzes in Siedlungsräumen durch abgestufte Pflege möglichst viele Lebensgemeinschaften nebeneinander zu fördern, werden die Rasen nicht mehr so häufig geschnitten oder fallen brach.

Mit Hilfe von geobotanischen Dauerflächen wurde in Südbayern (hauptsächlich Ausburg) seit 1982 auf neun verschiedenen Standorten die Entwicklung der Vegetation bei verschiedenen Pflegevarianten beobachtet. Die Vegetationsdynamik der Bracheparzelle in den ersten fünf Jahren wird an Hand von zwei Versuchsstandorten exemplarisch dargestellt.

Beim Brachfallen von Parkrasen vollziehen sich in den ersten fünf Jahren deutliche Bestandsumschichtungen.

In den ersten Jahren kommt es zu einer erhöhten Streuakkumulation, wodurch ein deutlicher Artenrückgang stattfindet. Betroffen sind dadurch vor allem lichtliebende *Cynosurion*- und *Arrhenatherion*-Arten. Dagegen können einige wenige im Ausgangsbestand bereits vorhandene konkurrenzkräftige Ruderal- und Wiesenarten zur Vorherrschaft gelangen und artenarme Dominanzbestände aufbauen. Diese erweisen sich gegenüber neuen Arten relativ stabil, so daß sich bislang kaum Gehölze etablieren konnten.

Nach drei Jahren hat sich ein für Brachflächen typischer Akkumulations- und Abbauzyklus eingespielt, in dem sich Abbautätigkeit und Streulieferung die Waage halten.

Summary

Lawns, which are regulary cut short, are one of the most widely distributed plant societies in housing-areas within the summergreen deciduous forest region of Europe.

Due to newer activities of nature conservation in urban areas their cutting has been reduced or they lie fallow.

Since 1982 in southern-Bavaria (mainly Augsburg) vegetation dynamics by different treatments has been observed by permanent plots in different formations of laws. The development of vegetation on the succession parcel during the first five years is shown by the example of two experimental plots.

In the abandoned lawns considerable changes have occured. During the first years the accumulation of litter is combined with a frequent decrease of species. These are mainly light prefaring plants of the *Cynosurion* and *Arrheantherion*. On the other hand some highly competitive species from ruderal sites and meadows of the original vegetation can develop and build up species-poor dominance formations. These are relatively stabil against new arriving plants, so that since

today only a few woody species can establish themselves.

After three years a typical cycle of accumulation and mineralization can be observed, in which speed decrease and development of litter are in balance.

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Primary habitats of a few synanthropic plants in Israel

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Keywords: Harvester ants, preadaptation, eutrophic, ruderal plants.

Abstract

Most weeds and synanthropic plant species in many parts of Israel are derived from the local flora. Several species in undisturbed habitats are adapted to live in relations with harvester ants. These old primary adaptations enabled them to develop on human-induced fertile soils (i.e. cattle enclosures, encampments, garbage heaps, ruins, and roadsides). *Silybum marianum,* a common ruderal plant in the Mediterranean region, has pappous achenes that assist wind dispersal. An oily food body (elaiosome) at the achene's top functions as an ant-attractant. The harvester ant *Messor semirufus* efficiently collect achenes and transfer them into their nests. Later, they place intact achenes in the nest's refuse zone together with soil particles, parts of plant diaspores, dead ants, and other organic remains. When wet, the material in the refuse zone disintegrates as a result of microbial activity. Soil near the nests had 2.4 times more nitrates, 4.5 times more phosphorous, and 1.2 times more potassium as compared with the area between the nests. The weight of *S. marianum* plants near the nests was 9 times higher than in the control grassland. The former produced 3-4 times more heads per plant near the nest than in the grassland.

Other ruderal species of the genera *Carduus, Notobasis, Beta, Chrysanthemum, Malva, Calendula,* and *Emex* were also found as important components near nests of the harvester ants.

Introduction

The synanthropic flora of Israel is customarily divided into segetal and ruderal plants (ZOHARY 1973). The intensive human interference with the vegetation and environment of the Mediterranean area during the last millennia is regarded as one of the most important factors that influenced the floristic richness of the area (ZOHARY 1962, 1973; PIGNATTI 1978, 1983). There is no doubt that human interference opened new habitats for plants that are adapted to live in synanthropic habitats. However, the stigma of being an obligatory synanthropic plant has to be tested by studying the primary habitats of species by species. The last comprehensive review of the ruderal flora of the East Mediterranean was that of ZOHARY (1973). He listed the important plants of the ruderal habitats; in his account on the distribution and origin of segetals and ruderals (l.c., pp. 646-650) he did not mention any theory concerning the origin of the ruderals. Nearly non primary habitat is attributed to the ruderal plants in Flora Palaestina (ZOHARY 1966, 1972; FEINBRUN-DOTHAN 1978, 1986).

Nests of harvester ants were found to be a habitat rich in nutrients (COLE 1932, GOLLEY and GENTRY 1964, WIGHT and NICHOLS 1966, KOYUMDJISKY et al. 1967, KING 1977, OFFER 1980, BUCKLEY 1982, BEATTIE 1985, RISSING 1986, DANIN and YOM-TOV 1990, DANIN 1989). In various grasslands in the Mediterranean territories of Israel (DANIN and PLITMANN 1987) we observed circles of tall plants 1-3 m in diameter. These were nests of the harvester ants *Messor semirufus* (E. ANDRE) Santschi subsp. *semirufus* and *Messor semirufus* (E. ANDRE) Santschi subsp. *ebeninus* Eorel (AVIDOV 1968). Most of the plants that were dominants in these circles were regarded as ruderals (ZOHARY 1966, 1972; FEINBRUN-DOTHAN 1978).

The aim of the present paper is to review the supporting facts for the hypothesis that several of the common ruderal plants were preadapted to the new synanthropic habitats through association with harvester ants.

Methods and materials

Ant nests were detected by the appearance of much taller vegetation in the grassland where they developed. After detecting actual activity of harvester ants, the vegetation of the nests was recorded. The plot area was 50 x 50 cm; 10 such plots were recorded for each dominant species on the nest's refuse zone and 10 control plots in the grassland, at least 5 m away from the nest's margin. In the study of two sites (1 and 3 in Tab. 1; DANIN and YOM-TOV 1990, DANIN 1989) all the above-ground phytomass was harvested, and dry weighed. In the rest of the sites (2 and 4-6 in Tab. 1), height of most plants was measured, total vegetation cover and relative contribution of each species was estimated (DANIN and NOY-MEIR, unpublished data). Soil fertility (nitrates, phosphorous and potassium contet) was analyzed in plots of the two species (DANIN and YOM-TOV 1990, DANIN 1989). Plant names and authors are after Flora Palaestina (ZOHARY 1966, 1972; FEINBRUN 1978, 1986).

Environment and vegetation

In all the study sites annual plants cover the entire area. The dominant plants, locations, mean annual rainfall, and soil type for the study sites are summarized in Tab. 1. The dominant species, mean number of species per plot ± SE, height or standing phytomass (expressed as dry weight of the plot) are listed in Tab. 2. The plants near the nest are 2-6 times taller than the plants among the nests. Species composition always differ from the control. The number of species per plot near the nest differs in most cases from the control. In the slightly saline soil of site 3 the number of species near the nest is higher than that of the control. In the sites where *Silybum marianum* was the dominant the number of species in the control area was significantly higher than by the ant nests. *S. marianum* seems to overtop the other species efficiently and decrease the number of its companions. A similar effect takes place in the plots dominated by *Malva parviflora* in the Judean Desert and *Beta vulgaris* in the Jordan Valley. The number of species near the nests dominated by *Chrysanthemum coronarium* and *Echium judaeum* did not differ much. However, the lists of species differ remarkably (DANIN and NOY-MEIR, unpublished data).

Association of several species with harvester ants

The physiognomic appearance of nests of harvester ants is similar for all the species that dominate on the nests (Tab. 2). All the species that dominate near the nests have much more robust individuals there than their individuals away from the nest. They are capable of responding to the rich nutrient situation and aerated soil better than any other species in the local flora. They can be regarded as eutrophic when compared with the oligotrophic (*sensu* DAUBENMIRE 1964) grassland species. Experimental work is needed to ascertain if these species respond to the high nitrate, phosphorous, or potassium content, or to their combinations. The aeration may be of great significance (GLINSKI and STEPNIEWSKI 1985).

Despite of the physiognomic similarity of the sites dominated by various species each of them has its own syndrome of adaptations to arrive and establish in the vicinity of the nest. The most advanced syndrome is that of the myrmecochorous species. Their diaspore is provided with an oily food body (elaiosome) that functions as an ant-attractant (SERNANDER 1906; BERG 1975;

Tab. 1 - Locations and habitats where ant nests and their vegetation were analyzed. Soil types are after Dan et al. (1975); rainfall data are after Dorfman (1981)

Site	Dominant species	Location	Mean annual rainfall (mm)	Soil type
1	Silybum marianum	Lower Galilee	370	Basaltic Protogrumusol
2	Malva parviflora	Judean Desert	300	Brown Lithosol
3	Malva parviflora	Jordan Valley	150	Alluvial Light Brown Soil
4	Beta vulgaris	Jordan Valley	200	Alluvial Brown Soil
5	Chrysanthemum coronarium	Jordan Valley	200	Brown Stony Soil
6	Echium judaeum	Jordan Valley	200	Brown Stony Soil

Tab. 2 - Mean number of species/plot. mean height of most plants in the plot or mean standing phytomass on the vegetation near the nest and on the control grassland

Site	Dominant	Number of species	SE	Height (cm)	SE	Standing phytomass	SE (g)
1 ants	Silybum marianum	7.3	2.0			447.3	64.0
1 control	Avena sterilis + Hordeum spontaneum	24.3	2.9			142.4	19.6
2 ants	Malva parviflora	7.7	2.2	63.3	2.9		
2 control	Erucaria rostrata	13.0	2.1	17.5	1.7		
3 ants	Malva parviflora	12.1	1.1	37.7	3.9		
3 control	Aizoon hispanicum	9.5	1.4	6.8	0.6		
4 ants	Beta vulgaris	13.5	2.0			226.6	8.8
4 control	Aizoon hispanicum	15.5	2.2			48.6	5.1
5 ants	Chrysanthemum coronarium	8.2	1.2	84.5	2.6		
5 control	Stipa capensis	8.3	1.6	49.0	3.6		
6 ants	Echium judaeum	10.2	1.6	82.5	3.7		
6 control	Stipa capensis	9.0	1.6	35.3	3.2		

BUCKLEY 1982; BEATTIE 1983, 1985). This mechanism is not reported much in literature for harvester ants in grasslands but was found to be the syndrome of *Silybum marianum* (DANIN and YOM-TOV 1990). A more generalist syndrome that functions here successfully is synzoochory (RIDLEY 1931; PIJL 1972) of species with hard coated diaspores. The ants collect the diaspores into the nest; unable to obtain all the seeds they deposit diaspores with viable seeds into their refuse zone.

The following is a list of the most common species found near ant nests in Israel with notes on their syndrome of dispersal.

Silybum marianum

The pappous wind-dispersed achenes of this species possess an oily food body that is attractive to ants (DANIN and YOM-TOV 1990). The ants perform secondary movement to the achenes that arrive by wind and collect them into the nest. They efficiently remove the food body, partly scratch the achene coat with their mandibles and do not consume the seed. Soil near the nests had 2.4 times more nitrates, 4.5 times more phosphorous, and 1.2 times more potassium as compared with the area between the nests. The weight of *S. marianum* plants near the nests was more than 9 times higher than in the control grassland. The former produced 3-4 times more heads per plant near the nest than in the grassland.

Carduus argentatus

This species resembles much *S. marianum* in its modes of dispersal. It has achenes with readily caducous pappus and oily food body (cf. FEINBRUN-DOTHAN 1978, Figs. 633, 634). Both *C. argentatus* var. *argentatus* and var. *esdrael esdraelonicus*, *C. australis*, and *C. getulus* Pomel (l.c., Figs. 631, 632) possess this body. From the illustrations of *C. australis* and *C. getulus* Pomel (FEINBRUN-DOTHAN, Figs. 631, 632) it seems that they have a food body as well. *C. argentatus* is occasionally found as a dominant near ant nests.

Notobasis syriaca

This species resembles *Silybum marianum* in its habitus and is often found together with it near ant nests. The pappus of *N. syriaca* is caducous but not as readily as that of *S. marianum*. Experiments should be made to test if there is mimicry of *N. syriaca* and *S. marianum*.

Beta vulgaris

Diaspores of *B. vulgaris* subsp. *maritima* are synaptospermic containing 1-7 seeds. Harvester ants collect such diaspores into the nest and fail to obtain most of the seeds from among the hardened sepals. They dispose the diaspores into the refuse zone (DANIN 1989). They efficiently use the seeds of other synaptosprmic diaspores such as those of *Pteranthus dichotomus.* Soil near the nests had 48.1 times more nitrates, 5.6 times more phosphorous, and 3.3 times more potassium as compared with the area between the nests.

Malva parviflora

The diaspore of this species is a 1-seeded mericarp with a very hard coat. Un-bitten whole diaspores were found in the refuse zone of nests with *M. parviflora* as a dominant or as a companion.

Echium judaeum

The diaspore of this species is a hard coated nutlet. Most nutlets, found in refuse zone of nests in sites 2-6 (Tab. 1), contained seeds and were hardly bitten.

Emex spinosa

The aerial diaspores are trigonous, spiny, 1-seedes fruits with a hard coat. Intact diaspores were found in the refuse zone of many nests in sites 2-6 (Tab. 1). *E. spinosa* was not found as a dominant near nests but was a common companion of nest vegetation where other species dominated.

Chrysanthemum coronarium

There are two types of achenes in this heterocarpous species. There are many that develop from the disc florets; they are obpyramidal with a narrow wing. There is one peripheral circle of achenes that develop from the ray florets; they are triquetrous and 3-winged. Plant debris from the refuse zone of nests from sites 4, 5, and from the coastal plain near Tel Aviv were studied. In most cases intact peripheral achenes of *C. coronarium* were found, whereas from those of the central florets mostly the empty achene coats could be detected.

Calendula arvensis

This is a polymorphic and heterocarpic species (HEYN, DAGAN and NACHMAN 1974). There are nests in sites 2-6 where *C. arvensis* is an important companion. In many of the debris-samples from the refuse zone of sites 2-6, intact diaspores of this species were found. Nearly non achenes of the «rostrate» type were found there, but plenty of the «cymbiform» and «annulate» forms (cf. HEYN et al., 1974, Fig. 5).

Conclusions

All the species that grow as dominants near nests of harvester ants are eutrophic as compared with the oligotrophic species of the grassland in the area between the nests. They have bi-modal or pluri-modal seed dispersal (PLITMANN 1986). Some of them have obvious myrmecochory as indicated by their oily food body; others have hard coated diaspores, or as in heterocarpous species, some hard coated diaspores. These modes of dispersal may be regarded as adaptations to ant dispersal. The worker ants that collect seeds and bring them into the nest do not select diaspores. It is the worker ants inside the nest that obtain seeds wherever they can and dispose the intact hard coated diaspores, together with plant debris, in the refuse zone of the nest.

The adaptations to live with harvester ants may be regarded as preadaptations to many ruderal habitats.

Apart from *Echium judaeum,* the species listed above are of the most important dominants of ruderal habitats in Israel.

Summary

The most common ruderal plants of Israel grow in association with nests of the harvester ant *Messor semirufus.* Responding to the high nutrient situation of the nest's, soil by efficient growth, the plants adapted to live near the nests outcompete most other annuals in the nest area. The true myrmecochorous species among these plants are *Silybum marianum* and the few species of *Carduus* of Israel, all of which have ant-attractant oil body (elaiosome) that has no role in seed germination. At least part of the diaspores produced by the following species are hard for ants to open: *Beta vulgaris, Malva parviflora, Chrysanthemum coronarium, Calendula arvensis,* and *Emex spinosa.* The diaspores of these plants are brought by the worker ants into the nests. When disposing the seeds that are hard to open near the nest, those listed above grow successfully and overtop most other species. Having the ability to grow successfully in nutrient rich soils these plants were preadapted to prosper in the ruderal habitats created by human activity.

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Untersuchungen zur Vegetationsdynamik einer Industriebrache im Stadtgebiet Osnabrücks (Norddeutschland)

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Keywords: soil seed bank, germination, vegetation dynamics.

Abstract

On waste industry land the vegetation dynamics were studied. Therefore the seed bank in soil was observed. The impact of lorries show the influence of soil condensation to vegetation and seed bank in soil. The vegetation is dominated by ruderal plants.

1. Einleitung

Die Inventarisierung der Flora von großen städtischen Ödlandflächen wie Industriebrachen etc. hat gezeit, daß neben den Standortansprüchen Boden, Wasserhaushalt auch der Grad der Habitatsstörung entscheidend für die Ausbildung der Pflanzendecke ist (HARD 1983, GÖDDE 1987, WITTIG et al. 1985, KUNICK 1987 etc.). Bisher wurde die Dynamik dieser Flächen ausschließlich pflanzensoziologisch beschrieben. Dynamische Prozesse in Vegetationseiheiten lassen sich aber auch anhand des Samenspeichers ablesen (BERNHARDT 1987, FISCHER 1987). Die Zusammensetzung des Diasporenlagers im Boden unterscheidet sich gerade bei gestörten Böden von der Zusammensetzung der sichtbaren Vegetation (BERNHARDT & HURKA 1988). Hier spielen populationsdynamische Prozesse wie unterschiedliche Keimoptima, Artenkonkurrenzen etc. eine Rolle.

In vorliegender Untersuchung soll eine große Industriebrache in Hinblick auf die Vegetationsentwicklung und ihre Abhängigkeit von anthropogenen Störungen untersucht werden. Wirkt sich der Streßfaktor «Befahren durch Lkw» auf den Samenvorrat im Boden und auf die sichtbare Vegetation gleich aus? Was sind die Gründe für die unterschiedliche floristische Zusammensetzung des Samenspeichers und der Vegetationsdecke? Das sind die zentralen Fragen dieser Untersuchung.

2. Das Untersuchungsgebiet

Am Piesberg, im Nordwesten Osnabrücks (Norddeutschland), wurde in unmittelbarer Kanalnähe ein Industriegelände untersucht. Dieser Kanalabschnitt stellt die Verlängerung des Hafens dar. Bei dem untersuchten Gebiet handelt es sich um ein ca. 40 ha großes Industriegelände, das als Bedarfsfläche brach liegt. Hier wird teilweise Sand- und Kies gelagert. Ein Teil des Gebietes wird als Abstell- und Wendeplatz für Lkw's genutzt. Insbesondere an den Rändern hat schon eine starke Verbuschung (Birke etc.) stattgefunden. Bei der Probefläche 1 handelt es sich um eine offenen, aufgrund ständigen Befahrens durch Lkw, stark gestörte Fläche. Das Substrat wird aus aufgeschüttenen Fein-, Mittel-, bis Grobsand gebildet. Dieses Sandgemisch ist sehr sauer und weist einen großen Glimmerreichtum auf.

Probefläche 2 wird relativ gering gestört, im wesentlichen nur durch ein zufälliges Befahren. Das Gebiet bildet den Übergang von einer Gebüschreihe zu der offenen Sandaufschüttungsfläche. Der Untergrund wird von einem skelettreichen Kalkboden gebildet, mit einer stärkeren Müllauflage.

Probefläche 3 besteht aus aufgeschüttetem Mutterboden; das Substrat ist sehr tiefgründing. Diese ungestörte Fläche wird im wesentlichen von mehrjährigen Hochstauden (*Solidago gigantea)* eingenommen.

Das Substrat der Probefläche 4 ist skelettreicher Silikatsand. Die Fläche ist durch Befahren stets stärker gestört als Probefläche 2, aber weniger als 1. Es hat sich ein Vegetationsgemisch aus Elementen der «Magerrasen» (*Agrostis tenuis)* und Trittrasen angesiedelt.

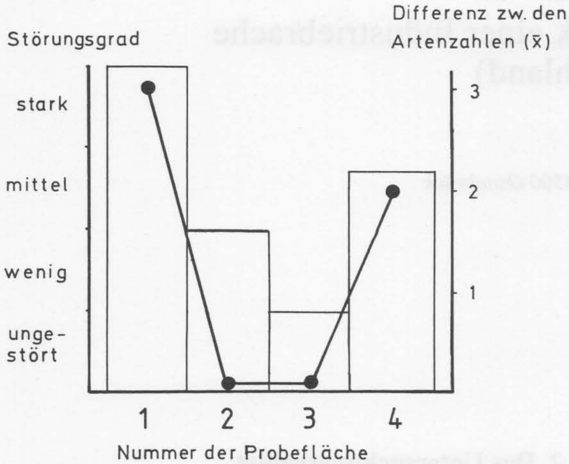

Abb. 1 - Einfluß des Störungsgrades auf die Differenz der Artenzahlen von Samenspeicher und Pflanzengemeinschaft.

3. Methoden

Die Vegetation wurde mit Hilfe des pflanzensoziologischen Methode nach BRAUN-BLANQUET (1964) erfaßt. Pro Probefläche und unterschiedlichem Vegetationstyp wurden 5 Aufnahmen gemacht, die mit Hilfe der Stetigkeit (I ... V) zusammengefaßt wurden. Der Zeitraum der Vegetationsaufnahmen war der August 1986.

Für die Erfassung des Samenvorrats im Boden wurde folgendermaßen verfahren (vgl. BERNHARDT 1987, BERNHARDT & HURKA 1988): Auf jeder Probefläche wurde eine 100 m^2 große Fläche ausgewiesen. Nach dem Zufallsprinzip wurden zwei 1 m^2 große Flächen abgegrenzt. In diesen Quadraten wurden je 2 Proben von 10 cm^2 bis zur Tiefe von 15 cm abgegraben und als Mischprobe in einen Plastikbeutel gefüllt. Diese Mischprobe wurde ausgewaschen und die ausgezählten Samen für 1 m^2 hochgerechnet.

Die Probenahme der Böden erfolgte nach dieser Methode einmal pro Daueruntersuchungsfläche nach dem Fruchten der Mehrzahl der Arten (Anfang September).

Zur Extraktion der Samen wurde ein Spülverfahren verwendet (vgl. BERNHARDT & HURKA 1988). Nach zahlreichen Literaturangaben sind die Arten- und Individuenzahlen bei dem Spülverfahren wesentlich höher als beim Austreichen der Bodenproben(BRENCHLEY & WARINGTON 1930, KROPAC 1966, FAY & OLSON 1978 u.a.), da hierbei die Samen einiger Arten nicht auflaufen. Als Nachteil des Spülverfahrens muß die Tatsache gesehen werden, daß

Tab. 1 - Die Vegetation und der Samengehalt im Boden der Probefläche 1

saurer Sand (fein - grob); hoher Glimmeranteil, ständig befahren (starke Störung)	Vegetation	Samengehalt (x 10 Proben pro 1 m^2)	Verbreitungstyp
Vegetationsbedeckung (x in %)	0		
Artenzahl (x)	0	3	
Arabidopsis thalliana	-	390	o
Poa annua	-	70	o
Betula pendula	-	46	x

z Zoochor
o Windstreuer — Ferntransport
x Flieger
/ Nahtransport

nicht alle ausgespülten Diasporen lebensfähig sind (vgl. FISCHER 1987).

Unter fließendem Wasser wrde die Bodenmenge nacheinander durch 6 Bodensiebe (0; 1; 0.8; 0.5; 0.2; 0.1 mm) gespült (vgl STANDIFER 1980). Die Fraktion jedes Siebes wurde unter einem Binokular nach Samen untersucht. Für die Keimversuche wurden aus den Bodenproben ausgespülte Diasporen verwendet. In Töpfen mit TKS II- Erde wurden jeweils 50 Samen für 21 Tage ausgelegt.

4. Ergebnisse

4.1. Vegetation

Die auf den vier Probeflächen festgestellten Vegetationseinheiten gehören zu folgenden Klassen: *Plantaginetea majoris, Artemisietea vulgaris, Chenopodietea* und *Secalietea*. Das entspricht den Literaturangaben für Osnabrück (HARD 1983) und für das nördliche Mitteleuropa (GÖDDE 1987, KUNICK 1987).

Auf der stark gestörten Probefläche 1 konnte keine Vegetation festgestellt werden. Probefläche 2 (Tab. 2) zeigt ein Gemisch von Arten unterschiedlicher Vegetationseinheiten. Zum Teil handelt es sich um wärmeliebende Arten wie sie häufig im Bahnschotter, Häfen etc. gefunden werden (BRANDES 1983, HARD 1983, BERNHARDT 1986, GÖDDE 1966, SUKOPP et al. 1987 u.a.). Dazu gehören *Berteroa incana, Torilis japonica, Daucus carota, Reseda luteola, Echium vulgare* und *Melilotus albus*. Der Grund hierfür ist der skelettreiche Kalkboden, der aufgrund seiner

Tab. 2 - Die Vegetation und der Samengehalt im Boden der Probefläche 2

skelettreiche Kalk-Rendzina, starke Mullauflage, wenig gestört	Vegetation (Stetigkeit 5 Aufnahmen)	Samengehalt (x 100 Proben pro 1 m^2)	Verbreitungstyp
Vegetationsbedeckung (x in %)	85		
Artenzahl (x)	8	8	
Betula pendula	I	610	x
Betula pubescens	–	35	x
Pinus sylvestris	–	8	x
Chamaecyparis lawsoniana	–	132	x
Poa triviale	V	114	xo
Myosotis arvensis	II	5	/
Solidago canadensis	–	2	xo
Rumex acetosella	IV	12	o
Reseda luteola	III	15	?
Daucus carota	I	4	z
Conyza canadensis	V	22	x
Echium vulgare	III	–	/
Meliolotus albus	II	–	/
Berteroa incana	I	–	o
Torilis japonica	I	–	z
Agrostis tenuis	II	3	xo
Arrhenatherum elatius	III	–	xo
Bromus hordaceus	IV	1	xo

Z Zoocher
O Windstreuer Ferntransport
x Flieger
/ Nahtransport

Tab. 3 - Die Vegetation und der Samengehalt im Boden der Probefläche 3

sandige, tiefgründe Braunerde, ungestört	Vegetation (Stetigkeit 5 Aufnahmen)	Samengehalt (x 100 Proben pro m^2)	Verbreitungstyp
Vegetationsbedeckung (x in %)	95		
Artenzahl (x)	6	6	
KC: Artemisietea vulgaris			
Solidago gigantea	V	788	xo
Poa triviale	V	16	xo
Calystegia sepium	III	12	/
Galium aparine	III	6	z
KC: Chenopodietea			
Chenopodium album	II	12	o
Stellaria media	I	4	o
Urtica urens	I	2	/
Polygonum lapathifolia	I	66	/?
übrige Arten			
Cirsium arvense	II	74	x
Agrostis tenuis	IV	44	xo
Betula pendula	–	280	x
Potentilla anserina	–	2	/
Rhinanthus alectorolophus	I	4	?
Poa annua	III	–	o

Z Zoochor
O Windstreuer Ferntransport
x Flieger
/ Nahtransport

«Wärmespeicherung» diesen wärmeliebenden Arten entgegen kommt.

Die Probefläche 3 wird hauptsächlich von mehrjährigen Stauden besiedelt. Als dominierende Art fällt *Solidago gigantea* auf, die nach OBERDORFER (1983) als Neophyt dichte Bestände mit eigenem syntaxonomischem Rang aufbaut («*Solidago gigantea*-Gesellschaften» (WITTIG 1978). Ihre Vermehrung aufgrund unterirdischer Ausläufer führt zu dichten Beständen und verhindert die Existenz vieler ruderaler Pionierarten (vgl. BERNHARDT 1988). Die Klassen der *Chenopodietea* und der *Artemisietea vulgaris* bilden mit einigen Vertretern die wichtigsten Vegetationseinheiten. Sie deuten auf den Nährstoffreichtum dieser Fläche.

Zu den Pflanzen der Probefläche 4 zählen einige Vertreter der Klasse *Plantaginetea majoris* (*Poa annua, Plantago major, Sagina procumbens* etc.) sowie Arten anderer ruderaler bis halbruderaler Vegetationseinheiten.

4.2. Diasporenvorrat im Boden

Der in den Bodenproben der Untersuchungsflächen festgestellte Samenvorrat in ebenfalls in den Tab. 1-4 aufgeführt. Es fällt generell auf, daß in sämtlichen Proben Diasporen enthalten sind, die in der sichtbaren Vegetation nicht festgestellt wurden. Hierzu gehören: *Betula pendula, Betula pubescens, Chamaecyparis lawsoniana* und *Pinus sylvestris*. In Fläche 1 tritt nur *Betula pendula* auf. Bei diesen Pflanzen handelt es sich um Arten, die mit Hilfe des Windes (anemochor) verbreitet werden (MÜLLER-SCHNEIDER 1977). Die Mutterpflanzen sind in der Umgebung des Untersuchungsgeländes zu finden, wie Birkenbüsche und eine *Chamaecyparis*-Hecke. Auffällig bei dem Vorkommen der Diasporen im Boden ist, daß insbesondere diese vier Arten aber auch weitere Pflanzen, die durch den Wind verbreitet werden, in der oberen Bodenschicht oder auf dem Boden zufinden sind (Tab. 5). Sämtliche dieser Arten gelten allgemein als Pionierbesiedler (vgl. BERNHARDT, in Druck). Ihre Diasporen müssen möglichst bald keimen können, da sonst ihr Vorteil gegenüber andere Pflanzen, einen Standort schnell zu besiedeln, hinfällig ist (BAKER 1974, VINCENT 1985, BERNHARDT 1987). Deshalb sind die Samen dieser Arten in der Regel auch nicht in tieferen Bodenschichten zu finden, da nur die Samen in tiefere Bodenschichten gelangen, die längere Zeit im Boden lagern (vgl. HURKA &

Tab. 4 - Die Vegetation und der Samengehalt im Boden der Probefläche 4

humoser, skelettreicher Silikatsand, wenig gestört	Vegetation (Stetigkeit 5 Aufnahmen)	Samengehalt ($\bar{x}$ 100 Proben pro 1 m^2)	Verbreitungstyp
Vegetationsbedeckung (x in %)	95		
Artenzahl (x)	9	7	
KC: Plantaginetea majoris			
Poa annua	V	30	o
Sagina procumbens	IV	170	o
Plantago major	IV	8	/
Potentilla anserina	III	10	/
Polygonum aviculare agg.	II	-	/
übrige Arten			
Betula pendula	IV	2310	x
Chamaecyparis lawsoniana	-	30	/
Pinus sylvestris	-	230	x
Agropyrum repens	-	10	x
Apera spica-venti	IV	6	xo
Agrostis tenuis	V	340	xo
Poa triviale	II	45	xo
Aphanes arvensis	II	24	x
Conyza canadensis	III	-	o
Potentilla norwegica	IV	-	/
Bryum spec.	V	/	xo

Z Zoochor
O Windstreuer — Ferntransport
x Flieger
/ Nahtransport

Tab. 5 - Verteilung der Diasporen in den Bodenschichten (Angabe in %)

Art	Oberfläche	0-1cm Tiefe	1-5cm Tiefe	5-15cm Tiefe
Betula pubescens	100	-	-	-
Pinus sylvestris	100	-	-	-
Chamaecyparis lawsoniana	100	-	-	-
Arabidopsis thalliana	100	-	-	-
Stellaria media	100	-	-	-
Betula pendula	85	15	-	-
Apera spica-venti	-	100	-	-
Urtica urens	-	100	-	-
Rhinanthus alectorolophus	-	100	-	-
Poa annua	75	18	7	-
Sagina procumbens	90	6	4	-
Chenopodium album	80	15	5	-
Conyza canadensis	60	18	22	-
Agrostis tenuis	80	5	15	-
Plantago major	-	-	100	-
Potentilla anserina	-	-	100	-
Agropyrum repens	-	-	100	-
Aphanes arvensis	-	-	100	-
Galium aparine	-	-	100	-
Calystegia sepium	-	-	100	-
Polygonum aviculare	5	15	60	20
Solidago gigantea	10	10	20	60
Poa triviale	-	20	80	-
Cirsium arvense	100	-	-	-

HAASE 1982, BERNHARDT & HURKA 1988). So sind an Pionierstandorten, zu denen auch Ruderalflächen zählen, selten Diasporen tiefer als 5 cm im Boden zu finden.

Von den Arten der Probeflächen konnten nur Samen von *Solidago gigantea* in größerer Menge in tieferen Bodenschichten gefunden werden. Bei diesen Samen wäre zu erwarten, daß eine Anzahl von ihnen nicht mehr keimfähig ist (FISCHER 1987). Eigene Keimungsversuche im Freiland haben gezeigt, daß ca. die Hälfte der getesteten 50 Samen nicht mehr aufliefen. Dagegen gab es bei *Betula pendula* nur einen, bei *Poa annua* nur drei Ausfälle (Tab. 6).

Interessant ist auch, daß je geringer der Störungsgrad der Fläche ist, die Unterschiede zwischen der mittleren Artenzahl im Samenspeicher und der sichtbaren Vegetation wegfallen (Tab. 1). So sind bei den ungestörten bzw. wenig gestörten Flächen 2 und 3 keine Differenzen festzustellen.

Tab. 6 - Keimrate in % (nach 30 Tagen) der getesteten Samen aus dem Samenspeicher im Boden (50 ausgelegte Individuen)

Betula pendula	98
Poa annua	94
Sagina procumbens	72
Agrostis tenuis	64
Solidago gigantea	48

Dagegen weist die stark gestörte Fläche 1 einen Unterschied von 3, und die Fläche 4 eine Differenz von 2 Arten auf. Während aber in der Probefläche 1 nur Arten im Samenspeicher des Bodens auftreten (Tab. 1), weist die sichtbare Vegetation der Fläche 4 mehr Arten als der Samenspeicher auf. Der Grund hierfür ist vermutlich in der dichten Moosschicht dieser Fläche zu sehen. Neue Arten können mit ihren Samen nicht in den Samenspeicher des Bodens eindringen, sie bleiben auf der «Vegetationsdecke» liegen. Dieses Phänomen konnte auch bei einer innerstädtischen Pflasterritzengeselleschaft beobachtet werden (BERNHARDT & MARKERT, in Druck). Bei der Vegetation der Fläche 4 hendelt es sich im wesentlichen auch um eine Trittpflanzengesellschaft.

5. Abschließende Betrachtung

Die Untersuchung des Samenspeichers sowie der aktuellen Vegetation hat gezeigt, daß es deutliche floristische Unterschiede auf unterschiedlich stark gestörten Flächen gibt. Auf der untersuchten Industriefläche konnte ein Mosaik aus starkgestörten bis ungestörten Ruderalflächen vorgefunden werden. Da die Art der Störung sowie die Intensität gleich sind, können sich die vorgefundenen Vegetationstypen längerfristig halten (BRANDES 1987). Das Nebeneinander von therophytenreichen stark gestörten, sowie hemicryptophytenreichen wenig gestörten Bereichen, sowie auch Gebüschstadien wird so erhalten. Das ist nur auf großflächigen, geringen Veränderungen unterworfenen Flächen möglich (KUNICK & SUKOPP 1975, BRANDES 1987). Die Untersuchungen von HARD (1983 u. 1986) bestätigen das für den Osnabrücker Raum. Auf diesen Industriebrachen wird die größte Anzahl an seltenen Adventativ- und Ruderalarten festgestellt (vgl. GÖDDE 1986).

Die Zammensetzung des Samenspeichers zeigt auf diesen Flächen deutlich Einflüsse der weiteren Umgebung an. So deutet das Vorkommen zahlreicher Diasporen von windverbreiteten Pionierarten an, daß auch die mehrjährigen Hochstaudenflächen weiteren Veränderungen ausgesetzt sind. Zwar wird aufgrund einer geschlossenen Vegetationsdecke eine Zeit lang das Eindringen insbesondere der Gehölzpioniere wie *Betula pendula* verhindert, aber durch ständigen Nachschub keimfähiger Samen können diese Arten sich an dem Standort ansiedeln. Das ist aber nur auf ungestärten, der Sukzession belassenen Flächen der Fall. Schon geringe Störungen wie zufälliges Befahren etc. verhindern das Aufkommen der Hochstauden und Gehölzflora. Intensive Störungen wie ständiges Befahren (mehrmals täglich) durch Lastkraftwagen verhindern das Aufkommen einer Vegetationdecke. Der Samenspeicher dieser Flächen beinhaltet nur Pionierarten. Das sind aber nicht nur Therophyten *wie Poa annua* und *Arabidopsis thalliana,* sondern auch Phanerophyten wie *Betula pendula.*

Zusammenfassung

Auf einer ca. ha großen Industriebrache wurden vier verschieden stark gestörte Probeflächen ausgewählt. Es wurde der Samenspeicher sowie die sichtbare Vegetation untersucht. Einflüsse wie das Eindringen von Pioniergehölzen oder die Besiedlung von Therophyten konnten festgesstellt werden. Anemochor verbreite Pionierarten liegen hier in der oberen Bodenschicht oder auf der Bodenoberfläche vor. Die Keimfähigkeit dieser Pflanzen ist noch, während sie bei anderen Arten (z.B. ruderale Hochstauden) mit zunehmender Lagerung und Bodentiefe abnehmen. Eine Abhängigkeit von der Intensität der Störung auf die Vegetationszusammensetzung im Samenspeicher und der Vegetationsdecke wurde sichtbar.

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Wildbienen-Gemeinschaften (Hymenoptera Apoidea) an spontaner Vegetation im Siedlungsbereich der Stadt Freiburg im Breisgau

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Keywords: ruderal plant communities, flower phenology, flower visitors, Hymenoptera Apoidea, community structure.

Abstract

In 1987 the bee community (Hymenoptera, Apoidea) of different ruderal plant communities in and around the city of Freiburg i.Br. (FRG) was studied from the middle of May till the middle of September; e.g.: *Conyzo-Lactucetum, Tanaceto-Artemisietum, Convolvulo-Agropyretum, Ranunculus repens*-community, *Onopordetum acanthii*, ruderal *Arrhenatherion*-fragment community, *Dauco-Melilotion, Vulpia myuros*-community. The 6 study sites, in some cases single plant communities, in other cases vegetation complexes, comprise an area of 100-5000 m². The flower phenology of these different ruderal plant communities was analysed. They are all characterized by a high number of simultaneously flowering entomophilic plant species in July and August. The maximum number of flowering species was reached at the end of July. The flower phenological results are discussed in comparison with other plant communities. We registered 22% (n = 112) of the bee species recorded for the Federal Republic of Germany. The highest diversity of bee species was reached in the ruderal sites which possess a vegetation mosaic built up by plant communities of different phytosociological progression. These ruderal sites offer different nesting habitats for ground nesting bee species as well as for species nesting, e.g., in stems of tall herbs and shrubberies, in old wood, in walls but also in the framework of buildings. 50% of all bee species recorded in this investigation show preferences in their flower visiting behaviour, two thirds of them are stenanthic for the plant families Asteraceae s.l., Fabaceae and Apiaceae. It is remarkable that a high portion of bee species living in the studied ruderal plant communities are species listed in the Red Data Book (18 species Red Data Book for FRG, 31 species for Baden-Württemberg). The results show that the ruderal plant communities and their complexes located in or near settlements do exhibit a flower visitor community rich in endangered species. The importance of these plant communities for nature conservation is thus confirmed.

Einführung

In der BRD sind derzeit 517 Wildbienen-Arten bekannt (WESTRICH 1984). DORN (1983) schließt aus Untersuchungsergebnissen, daß allein 25% der in der ehemaligen DDR nachgewiesenen Arten im urbanen Bereich vorkommen und dort geeignete Lebensbedingungen finden. Ein ähnlich hoher Prozentsatz dürfte auch bei uns anzutreffen sein, so daß mit mindestens 130 Bienenarten im städtischen Bereich zu rechnen ist. Die Tatsache, daß viele Arten nur in kleinen Individuenzahlen vorkommen, ihre z.T. nur kurze Flugzeit von wenigen Wochen im Jahr, die häufig nur auf wenige Tagesstunden begrenzte Aktivitätszeit und auch ihre in vielen Fällen geringe Körpergröße von nur wenigen Millimetern, macht viele Wildbienen-Arten in der Regel zu «unscheinbaren Mitbewohnern» im ländlichen und urbanen Siedlungsbereich. Dennoch sind sie charakteristische Elemente dieses anthropogen so intensiv beeinflußten Lebensraumes. Ein Grund liegt neben den für thermo- und xerophile Insekten dort günstigen mikro- und mesoklimatischen Gegebenheiten vor allem in der im Siedlungs- und besonders im Stadtrandbereich vorhandenen Vielfalt an potentiellen Nistmöglichkeiten (offenen Bodenstellen, Pflanzenstengel, totes Holz, Fachwerk, Mauern u.a.) und in einem oft recht vielseitigen Nahrungspflanzen-Angebot verschiedener Wild- und Gartenpflanzen.

Neben einer Fülle von Einzelbeobachtungen über Wildbienen im Siedlungsbereich, die zum großen Teil weit in der Literatur gestreut sind, liegen nur wenige umfassendere Arbeiten zu diesem Thema vor (z.B. BANASZAK 1982, DORN 1983, JACOB-REMACLE 1984, LECLERCQ 1982, WESTRICH 1985). Aufgrund der Standortsvielfalt urbaner Ökosysteme erscheint es für ökofaunistische Untersuchungen sinnvoll, die unterschiedlichen Lebensräume und Habitattypen differenzierend zu analysieren. Ein Gliederungsschema urbaner Ökosysteme haben KLOTZ, GUTTE und KLAUSNITZER (1984) vorgelegt. In entsprechender Weise wurde eingehender die Wildbienen-Fauna von Stadtgärten (GAUCKLER 1971, HAESELER 1972), von Botanischen Gärten (DORN 1977), von Tierparks (DATHE 1969,

1971) und Bürgersteigen, Parkplätzen und Straßenrändern (HAESELER 1982) vorgestellt.

In einer vorausgegangenen Untersuchung konnte, basierend auf eigenen Beobachtungen und einer umfangreichen Literaturauswertung, durch Zuordnung von 85 Wildbienen-Arten zu bestimmten Vegetationsformationen, in Einzelfällen, wo es möglich war, auch zu bestimmten Pflanzengesellschaften, die große Bedeutung von Ruderal-Pflanzengesellschaften als (Teil-) Lebensräumen von Wildbienen aufgezeigt werden (KRATOCHWIL 1984, Tab. 24, p. 594/595). Aufgrund dieses Ergebnisses erschien es sehr lohnend zu sein, die Wildbienen-Fauna an spontaner Vegetation im Siedlungsbereich näher zu erforschen. Wir haben eine solche Untersuchung in Freiburg im Breisgau durchgeführt (KLATT 1988). Aufgrund der Vielfalt verschiedener Typen von Ruderalgesellschaften und den deshalb auch zu erwartenden Unterschieden in der Tierartenzusammensetzung wurde, wie bei anderen Untersuchungen über Blütenbesucher-Gemeinschaften (KRATOCHWIL 1987), auch hier in definierten pflanzensoziologisch charakterisierten Beständen gearbeitet und ein biozönologischer Ansatz verfolgt, bei welchem pflanzensoziologische und zoozönologische Ergebnisse miteinander verknüpft werden sollten. Einer solchen Vorgehensweise ist bisher (s. z.B. die zusammenfassede Darstellung von KLAUSNITZER 1987) kaum Rechnung getragen worden.

Die Beantwortung der folgenden Fragen war Gegenstand der vorliegenden Untersuchung:

1) Wie lassen sich verschiedene ausgewählte Ruderal-Pflanzengesellschaften blütenökologisch charakterisieren, welche entomophilen Pflanzenarten kommen vor, wie ist das Blumentypen-Spektrum zusammengesetzt?
2) Welche blühphänologische Entwicklung zeigen die Bestände im Jahresverlauf, wie groß ist die Blumendichte?
3) Welche Wildbienen-Arten kommen in den einzelnen Ruderal-Pflanzengesellschaften und Gesellschaftskomplexen vor?
4) Dominieren innerhalb der Zoozönose der Wildbienen an Ruderalstellen besonders angepaßte stenöke Arten, oder eher euryöke?
5) Unterscheiden sich einzelne Ruderal-Pflanzengesellschaften bzw. Gesellschaftskomplexe in

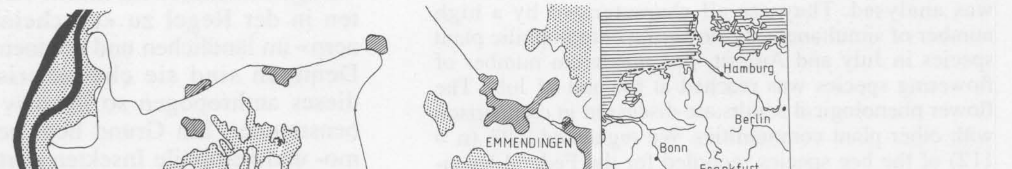

Abb. 1 Untersuchungsgebiet und Lage der 6 Unteruchungs-flächen im Stadtbereich von Freiburg (schraffiert = Siedlungs-bereich, punktiert = Wald).

Tab. 1 - Vergleich einzelner Klimadaten: Freiburg (Wetteramt) und Kaiserstuhl (Oberrotweil)

	FREIBURG WETTERAMT 259 m	KAISERSTUHL OBERROTWEIL 235 m
MITTLERE JÄHRLICHE NIEDERSCHLAGSMENGE (mm) (1931 – 1960)	849	682
JÄHRLICHE SONNEN-SCHEINDAUER IN STUNDEN (h) (1901 – 1950)	1802	1858⁺
JAHRESMITTEL LUFTTEMPERATUR (°C) (1931 – 1960)	10,5	9,9

ANGABEN NACH TRENKLE (1980) ⁺FÜR BLANKENHORNSBERG

ihrem Wildbienen-Inventar, und welches sind mögliche Gründe?

6) Wie ist diese Ruderal-Biozönose bzw. Teilzönose (entomophile Pflanzenarten der Ruderal-Pflanzengesellschaft/Wildbienen) aus Naturschutz-Sicht zu beurteilen?

Einige weiter Gesichtspunkte (z.B. arealgeographische und historische Zusammenhänge) werden in einer eigenen Arbeit behandelt (KRATOCHWIL & KLATT 1989).

2. Untersuchungsgebiet und Untersuchungsflächen

Die Stadt Freiburg liegt in der Südlichen Oberrheinebene am Rande des Schwarzwaldes

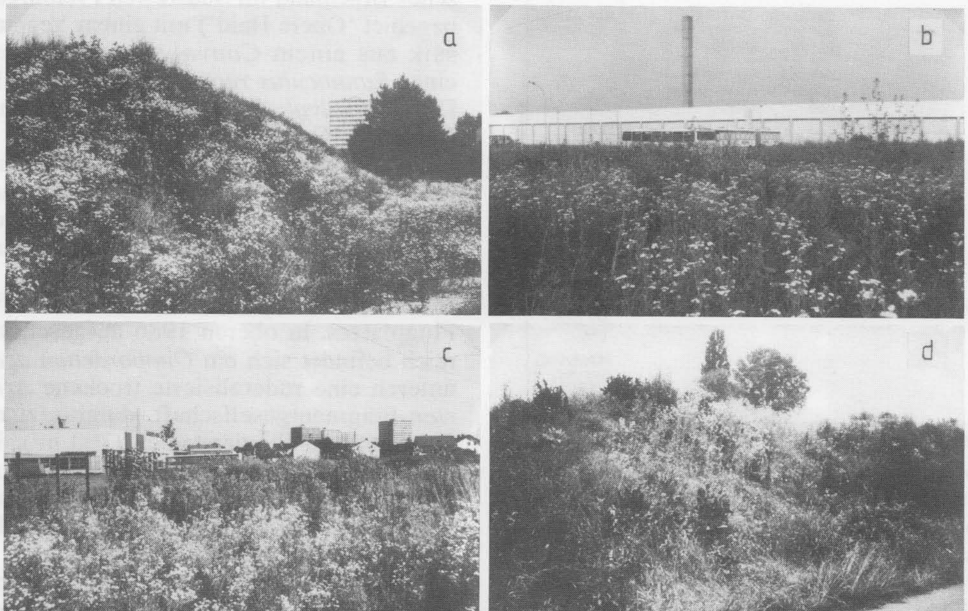

Foto 1 - a) Straßendamm «Weingarten» (I), b) Gewerbegebiet «Haid» (II), c) Gewerbegebiet «Obere Haid» (III), d) Straßendamm «Betzenhausen» (IV), e) Erdwall «Flugplatz» (V), f) Güterbahnhof Freiburg.

Tab. 2 - Die 6 Untersuchungsflächen geordnet nach ihrer Stellung in der soziologischen Progression (nach einem Entwurf von A. SCHWABE und A. KRATOCHWIL)

	STRASSENDAMM 'WEINGARTEN' (I)	GEWERBEGEBIET 'HAID' (II)	GEWERBEGEBIET 'OBERE HAID' (III)	STRASSENDAMM 'BETZENHAUSEN' (IV)	ERDWALL 'FLUGPLATZ' (V)	GÜTERBAHNHOF (VI)
STELLARIETEA MEDIAE SISYMBRION	CONYZO-LACTUCETUM (FRISCH. AUSB.)					CONYZO-LACTUCETUM (TROCK. AUSB.)
ARTEMISIETEA ONOPORDION					ONOPORDETUM ACANTH.	
DAUCO-MELILOTION		TANACETO-ARTEMISIETUM (MIT FRISCHEZEIGERN)				DAUCO-MELILOTION (SUKZ. STAD.) TANACETO-ARTEMISIETUM DAUCO-PICRIDETUM ECHIO-MELILOTETUM
AGROPYRETEA INTERMEDII-REPENTIS			CONVOLVULO-AGROPYRETUM	CONVOLVULO-AGROPYRETUM		CONVOLVULO-AGROPYRION
AGROSTIETEA STOLONIFERAE			*RANUNCULUS REPENS*-GES.	*RANUNCULUS REPENS*-GES.		
MOLINIO-ARRHENATHERETEA					ARRHENATHERION-GES. (RUDERALIS., TROCKEN) MIT SEDO-SCLERANTHETEA-ARTEN	
SEDO-SCLERANTHETEA					SEDO-SCLERANTHETEA-PIONIERSTAD.	
THERO-AIRION						*VULPIA MYUROS*-GES.
OHNE ZUORDNUNG						PIONIERSTAD. AUF SILIKATSCHOTTER, Z.B. MIT *LINARIA REPENS*

→ SUKZESSIONSSTADIUM ↔ STANDÖRTLICH VERMITTELND

(Abb. 1). Wärmeklimatisch zählt Freiburg zu den begünstigsten Städten der Bundesrepublik. Das Klima ähnelt dem des nahegelegenen Kaiserstuhls, dieser submediterran getönten und vielen Botanikern bekannten Gebirgsinsel in der Oberrheinebene, ein Gebiet, das zu den wärmsten und sonnenreichsten der BRD zählt (Tab. 1). Zwar liegt die mittlere jährliche Niederschlags-menge im Falle von Freiburg deutlich höher (um fast 200 mm), dennoch ist die jährliche Sonnenscheindauer fast identisch, das Jahresmittel der Temperatur sogar um 0,6°C höher.

Eine Bestandsaufnahme der Blütenbesucher-Gemeinschaften der Wildbienen setzt eine präzise Biotop-Charakterisierung voraus. Sie erfolgte in einer genauen pflanzensoziologischen Kennzeichnung 6 ausgewählter repräsentativer Untersuchungsflächen im Bereich der städtischen Vegetation (Abb. 1, Foto 1). Diese liegen alle in der Stadtkern-fernen Zone, nur dort waren Ruderalstellen höherer Qualität und größerer Ausdehnung zu finden. Die Charakterisierung der Flächen folgt der zunehmenden soziologischen Progression und Komplexität der Gesellschaften bzw. Komplexität im Gesellschaftsmosaik (Tab. 2).

Fläche 1: Straßendamm in der Nähe eines Wohngebietes im Südwesten Freiburgs (Weingarten) mit einem *Conyzo-Lactucetum* (frische Ausbildung) in Südexposition (300 m²).

Diese Gesellschaft tritt im Gebiet von Freiburg als einzige der einjährigen Ruderalfluren auch in größeren Beständen auf (KOHL 1986).

Fläche 2: Großflächiges *Tanaceto-Artemisietum* (mit Frischezeigern) auf dem Gelände der Freiburger Verkehrsbetriebe (Gewerbegebiet 'Haid') (800 m²).

Diese Gesellschaft ist im Gebiet weit verbreitet.

Fläche 3: Zur Gewerbeansiedlung ausgewiesenes Brachland im Südwesten Freiburgs (Gewerbegebiet 'Obere Haid') mit einem Vegetationsmosaik aus einem *Convolvulo-Agropyretum* und einer *Ranunculus repens*-Gesellschaft (1000 m²). Das *Convolvulo-Agropyretum* kommt häufig auf Baustellen-Gelände der Stadt vor.

Fläche 4: In den Jahren 1980/81 aufgeschütteter Straßendamm bei Freiburg/Betzenhausen mit einem *Convolvulo-Agropyretum* in Südost-Exposition, welches standörtlich zu einer *Ranunculus repens*-Gesellschaft vermittelt (100 m²).

Fläche 5: Erdwall im Gebiet des Freiburger Flugplatzes. In oberen 1986 aufgeschütteten Bereich befindet sich ein *Onopordetum acanthii,* im unteren eine ruderalisierte trockene *Arrhenatherion*-Fragmentgesellschaft, durchsetzt mit *Sedo-Scleranthetea*-Pionierstadien (700 m²). Das *Onopordetum acanthii* ist im Freiburger Raum sehr selten (KOHL 1986), die Bestandsentwicklung, wie in anderen Gebieten auch (BRANDES 1988), muß als rückläufig eingestuft werden.

Fläche 6: Bereich des Güterbahnhofs Freiburg. Innerhalb eines großflächigen Vegetationskomplexes finden sich z.B. in Gleisnähe das *Conyzo-Lactucetum* und ruderalisierte *Dauco-Melilotion*- Fragmentgesellschaften, in Gleisferne, großflächig von *Rosa canina* und *Rubus fruticosus* agg. durchsetzt, Bestände des *Tanaceto-Artemisietum*, *Dauco-Picridetum* und *Echio-Melilotetum* auf dem Silikatschotterband ehemaliger Abstellgleise Pioniergesellschaften mit *Poa compressa, Linaria repens* und *Convolvulus arvensis,* ferner z.B. auch Gesellschaften des *Thero-Airion,* z.B. eine *Vulpia myurus*-Gesellschaft mit *Echium vulgare* und *Hieracium pilosella.* Die Abb. 2 gibt die Lage der 8 Untersuchungsflächen im Güterbahnhofbereich wieder; sie überdecken insgesamt ca. 5000 m².

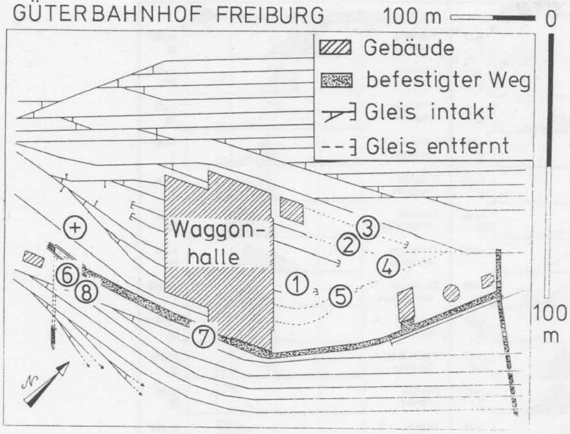

Abb. 2 - Die einzelnen Untersuchungsflächen im Bereich des Güterbahnhofes Freiburg:
1, 2: *Dauco-Picridetum*
3: *Dauco-Melilotion*-Sukzessionsstadien
4: *Convolvulo-Agropyretum / Dauco-Picridetum*-Übergangsgesellschaft
5: *Linaria repens / Convolvulus arvensis*-Bestand
6: *Thero -Airion*-Gesellschaften
7: *Echio- Melilotetum*
8: *Senecio viscosus*-Fragmentgesellschaft
+: *Berteroa incana-/Rhynchosinapis cheiranthos*-Bestand.

3. Methode

Die Untersuchung wurde in einem Zeitraum von Mitte Mai bis Mitte September des Jahres 1987 durchgeführt. Die 6 in Kap. 2 vorgestellten Untersuchungsflächen sind durch mehrere pflanzensoziologische Aufnahmen belegt. In diesen Untersuchungsflächen fand in wöchentlichen Intervallen in markierten homogenen Beständen von 20 - 50 m² Größe eine quantitative blühphänologische Erfassung der entomophilen Pflanzenarten statt (zur Methode s. KRATOCHWIL 1983, 1984). Bezeichnende Arten, die außerhalb der Dauerbeobachtungsflächen vorkamen und die ebenfalls von blütenökologischer Bedeutung sind, wurden zusätzlich gesondert mitaufgenommen.

Die Erfassung der Wildbienen geschah durch Sichtfang an der Blüte (nähere Angaben zur Determination s. KRATOCHWIL 1983). Hummeln (*Bombus*) und die Honigbiene (*Apis mellifica* L.) sind nur durch Sichtbeobachtungen belegt. Insgesamt wurde an 87 Tagen gefangen (105 Stunden), die Fangzeiten lagen für die einzelnen Flächen gestaffelt zwischen 9-18 Uhr bei einer Temperatur von mindestens 20°C (Schatten). Die Indigenität (SCHAEFER & TISCHLER 1983) der in den verschiedenen Untersuchungsflächen erfaßten Wildbienen konnte nur in Einzelfällen nachgewiesen werden (Überprüfung von in verschiedenen Pflanzenstengeln nistenden Tieren, Erfassung einzelner Nistplätze im Boden).

4. Ergebnisse und Diskussion

4.1 Blühphänologie und blütenökologische Charakterisierung ausgewählter Ruderal-Pflanzengesellschaften

Die einzelnen untersuchten Ruderalgesellschaften zeichnen sich alle dadurch aus, daß sie über den Juli and August besonders viele simultan blühende entomophile Pflanzenarten besitzen, in der Regel mit einem Blühmaximum Ende Juli (Abb. 3). Gemeinsam ist ihnen auch die hohe Blumendichte einzelner Pflanzenarten und eine große Farbvielfalt. Im folgenden sei die Blühphänologie 6 verschiedener, repräsentativ ausgewählter Gesellschaften beschrieben (Abb. 3).

Im *Conyzo-Lactucetum* (Fläche I) erreichen unter den für blütenbesuchende Insekten wichtigen Pflanzenarten eine besonders hohe Blumendichte im Untersuchungsgebiet *Barbarea vulgaris, Anthemis arvensis, Erigeron annuus* und *Lactuca serriola.*

Im *Tanaceto-Artemisietum* (Fläche II) sind auf der Untersuchungsfläche blühphänologisch folgende Arten aspektbestimmend: *Cirsium arvense, Melilotus alba, Erigeron annuus,* später im Jahr *Tanacetum vulgare.*

Im *Convolvulo-Agropyretum* (Fläche III) haben unter den entomophilen Pflanzenarten *Erigeron annuus, Crepis capillaris* und *Lactuca serriola* besonders hohe Infloreszenzzahlen.

Im *Convolvulo-Agropyretum* (Fläche IV), das standörtlich zu einer *Ranunculus repens*-Gesellschaft vermittelt, erreichen im Untersuchungsgebiet eine hohe Blumendichte *Ranunculus repens, Vicia villosa, Coronilla varia* und *Erigeron annuus.*

Das *Onopordetum acanthii* (Fläche V) wird im wesentlichen von den hochwüchsigen und hochsteten Distelarten blühphänologisch bestimmt: *Onopordum acanthium, Cirsium arvense, Carduus crispus, Cirsium eriophorum* u.a. Zusammen mit *Echium vulgare* und *Malva sylvestris* bestimmen sie den farbenprächtigen rot-blauvioletten Blühaspekt dieser Gesellschaft, der so ganz von dem weiß- und besonders gelbdominierten Farben der übrigen untersuchten Ruderalgesellschaften abweicht.

Die *Dauco-Melilotion*-Gesellschaft (Fläche VI) zeichnet sich im Untersuchungsgebiet durch die hohe Blumendichte z.B. von *Lotus corniculatus, Trifolium campestre, Campanula rapunculus, Cichorium intybus* und *Crepis capillaris* aus.

Ein Vergleich der Gesellschaften untereinander zeigt, daß das *Echio-Melilotetum,* das *Dauco-*

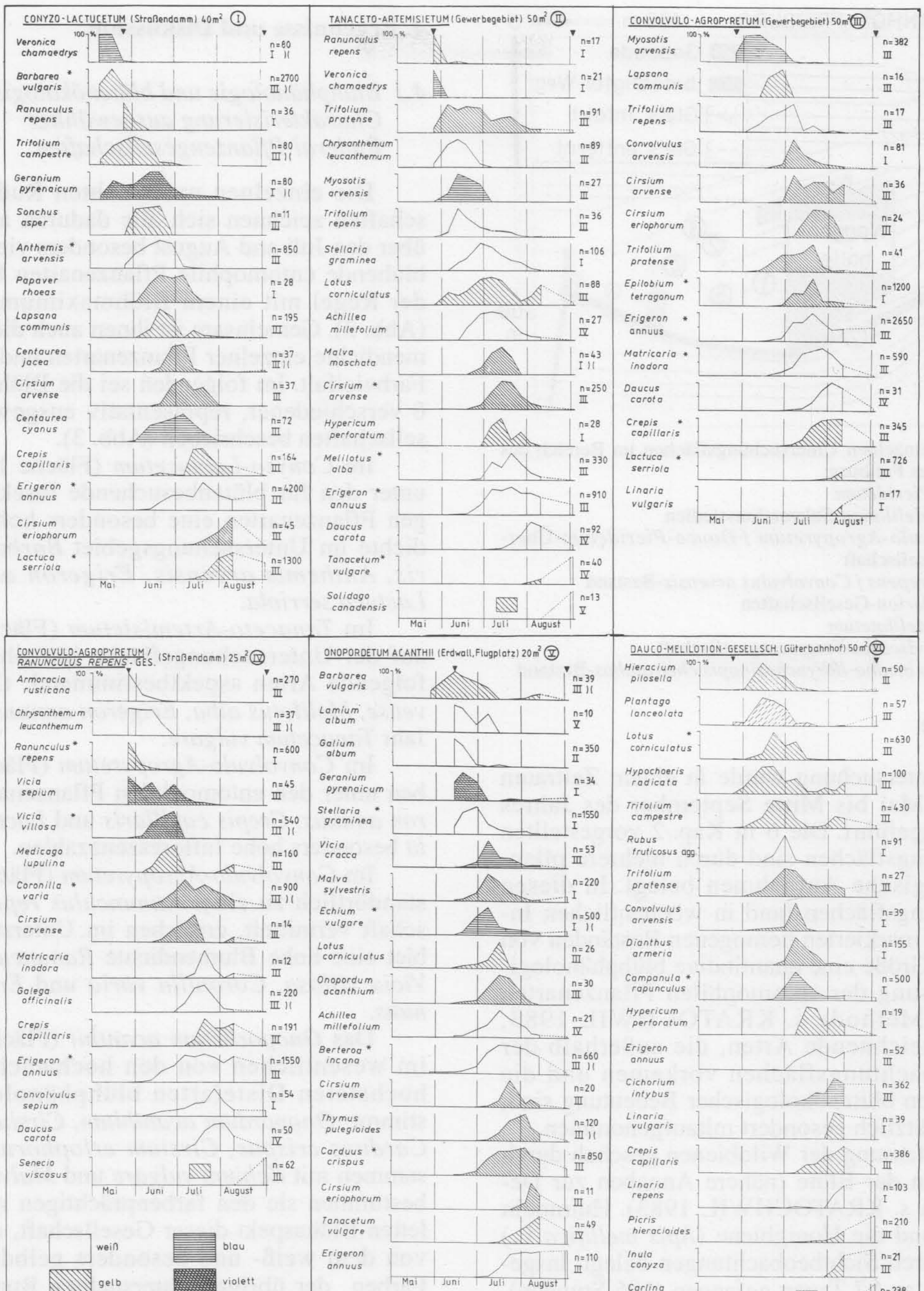

Abb. 3 - Blühphänologie-Diagramme einzelner blütenökologisch wichtiger entomophiler Pflanzenarten ausgewählter Ruderalgesellschaften der einzelnen Untersuchungsflächen.
n = maximal erreichte Zähleinheit pro Art (=100%); Zähl-einheiten: I = Einzelblüte, II = Teilblütenstand, III = Infloreszenz, IV = Synfloreszenz (1. Ordnung), V = blühende Pflanze;
)(= die Art wurde nur außerhalb der Dauerbeobachtungsflächen erfaßt.
Die Beobachtungszeiträume sind durch Pfeile gekennzeichnet; aspektbestsimmende Arten sind mit einem Kreuz gekennzeichnet (weitere Erläuterungen s. Text).

Picridetum und das *Onopordetum acanthii* die farbenprächtigsten Gesellschaften im Untersuchungsgebiet ausbilden. Das *Conyzo-Lactucetum* und das *Convolvulo Agropyretum* sind im Juni blühphänologisch bereits weit fortgeschritten und weisen zahlreiche synchron blühende Arten auf, das *Onopordetum* folgt im Juli, ein Maximum erreichen sie alle Ende Juli. Den spätesten blühphänologischen Höhepunkt unter den vorgestellten Ruderalgesellschaften hat das *Tanaceto-Artemisietum.*

Im folgenden sei ein Vergleich mit der blühphänologischen Entwicklung anderer ebenfalls nicht oder in der Regel nicht gemähter Offenlandgesellschaften gezogen: z.B. dem *Xerobrometum*

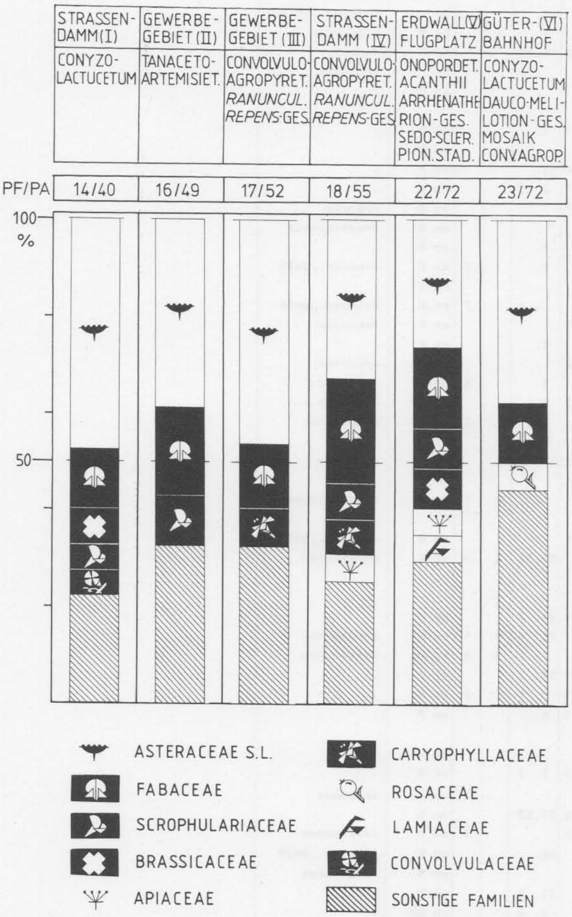

Abb. 4 - Prozentualer Anteil der nach Familienzugehörigkeit zugeordneten entomophilen Pflanzenarten der einzelnen Untersuchungsflächen.
Pflanzenfamilien, die mindestens 5% des Arteninventars einer Fläche stellen, sind durch ein Symbol repräsentiert, alle übrigen durch Schraffur zusammengefaßt.
PF = Anzahl Pflanzenfamilien; PA = Anzahl Pflanzenarten.

und den wärmeliebenden Staudensäumen *(Trifolio-Geranietea*-Gesellschaften).

Blühphänologisch ähneln die untersuchten Ruderalgesellschaften den Saumgesellschaften mit einem späten blühphänologischen Höhepunkt im Jahresverlauf Ende Juli bis Anfang September (KRATOCHWIL 1983, Abb. 22, p. 509); das *Xerobrometum* hingegen erreicht Ende Mai bereits sein Blühmaximum (KRATOCHWIL 1989).

Ein Vergleich der Arealtypen-Spektren verschiedener Pflanzengesellschaften bestätigt die Regel, daß solche mit einem hohen Anteil submediterraner Arten ihr Blühmaximum in der ersten Jahreshälfte ausbilden (z.B. *Xerobrometum, Mesobrometum),* jene hingegen mit einem hohen Anteil (subozeanisch) eurasiatisch verbreiteter Arten ihr Blühmaximum im Juli und viele in der zweiten Jahreshälfte besitzen (z.B. Gesellschaften der *Molinio-Arrhenatheretea,* Saumgesellschaften trockener und frischerer Standorte) (KRATOCHWIL 1988a, b, 1989). Als Grund für dieses spezifische symphänologische Verhalten werden die in den jeweiligen Hauptverbreitungsgebieten der einzelnen Gesellschaften wirkenden phänologisch selektierenden Witterungsbedingungen angesehen (KRATOCHWIL 1988a). Die untersuchten Ruderalgesellschaften entsprechen dieser Regel; sie haben einen höheren Anteil (subozeanisch-) eurasiatisch verbreiteter Arten und ein blühphänologisches Maximum in der zweiten Jahreshälfte.

Die vorherrschenden Pflanzenfamilien, die mit den ihnen zugehörigen Arten die untersuchten Ruderalgesellschaften phänologisch bestimmen, sind die Asteraceae s.l. und die Fabaceae. Sie stellen insgesamt 43-60% aller entomophiler Pflanzenarten (Abb. 4). Da mit der Zugehörigkeit zu einer Pflanzenfamilie gleichzeitig auch ein bestimmter Blumentyp verbunden ist, sei im folgenden kurz auf die blühphänologische Entwicklung im Jahresverlauf auf Familienniveau hingewiesen: Scrophulariaceen erscheinen blühphänologisch gehäuft bereits im Mai, die Fabaceen zeigen einen Schwerpunkt Mitte/ Ende Juni bis Ende Juli, die Asteraceen zeitlich versetzt Anfang Juli bis Mitte/Ende August; die Apiaceen als weitere für blütenbesuchende Insekten wichtige Familie haben wie in anderen Pflanzengesellschaften auch (KRATOCHWIL 1983) den spätesten Blühtermin Ende Juli bis in den September.

4.2 Die Gemeinschaft der Wildbienen an den einzelnen Ruderalstandorten

In dem sehr kurzen Untersuchungszeitraum von nur 4 Monaten konnten insgesamt bereits 112

Tab. 3 - Liste der 1987 auf den Untersuchungsflächen I-VI nachgewiesenen Bienenarten (Hymenoptera Apoidea).
RL1: Rote Liste der Bundesrepublik Deutschland
RL2: Rote Liste Baden-Württemberg
Kategorien: 0 = ausgestorben oder verschollen
1 = vom Aussterben bedroht
2 = stark gefährdet

	N	I ♀♀.♂♂	II ♀♀.♂♂	III ♀♀.♂♂	IV ♀♀.♂♂	V ♀♀.♂♂	VI ♀♀.♂♂	RL1	RL2	NEST	BLÜTENBESUCH
Colletes											
daviesanus SMITH 1846	85	.	6. 3	.	1.	14. 6	34.21			hy en M	*Tanacetum*
similis SCHENCK 1853	28	.	5. 9	1.	1.	5. 2	3. 2		3	en B	*Tanacetum*
Hylaeus											
annularis (KIRBY 1802)	12	.	7.	1.	. 1	1. 2	.			hy PR	*Apiaceae*
brevicornis (NYLANDER 1852)	5	.	.	. 2	1.	2.	.			hy PR	.
communis (NYLANDER 1852)	5	.	.	.	.	.	3. 2			hy HPRM	.
confusus (NYLANDER 1852)	2	.	1.	.	1.	.	.			hy PR	.
cornutus CURTIS 1831	13	.	2. 2	2. 1	2.	. 3	1.		3	hy P	*Asterac.,Apiac.*
difformis (EVERSMANN 1852)	1	.	.	.	.	.	1.	3		hy HLM	.
gracilicornis (MORAWITZ 1867)	3	.	.	.	.	2. 1	.		4	hy P	.
hyalinatus SMITH 1842	20	.	.	.	1.	2.	10. 7			hy HLM	.
leptocephalus (MORAWITZ 1871)	4	.	.	1.	.	.	2. 1	3		hy PR	.
nigritus (FABRICIUS 1798)	92	5.	1.	9. 5	.	48. 7	10. 7			hy	*Asteraceae*
pictipes NYLANDER 1852	5	.	.	.	.	.	1. 4	2		hy HL	*Resed., Apiac.*
punctatus (BRULLÊ 1832)	6	.	2.	.	.	3.	1.			hy	*Asterac.,Apiac.*
punctulatissimus SMITH 1842	1	.	.	.	.	.	1.	3		hy P	*Liliaceae*
signatus (PANZER 1798)	98	.	22.28	.	.	3.12	11.22			hy L	*Reseda*
sinuatus (SCHENCK 1853)	10	.	4. 1	2.	.	2.	. 1			hy	*Apiaceae*
variegatus (FABRICIUS 1798)	1	.	.	.	.	.	. 1			en B	.
Andrena											
bicolor FABRICIUS 1775	2	.	.	.	.	. 1	1.			en B	.
cineraria (LINNAEUS 1758)	1	1.	.	.	.	.	.			en B	.
dorsata (KIRBY 1802) 1)	53	.	14.	4.	.	14. 6	15.			en B	.
flavipes PANZER 1798	94	16.20	7. 1	19. 4	4. 1	18. 1	2. 1			en B	.
florea FABRICIUS 1793	16	.	.	.	4. 2	3. 7	.			en B	*Bryonia*
floricola EVERSMANN 1852	1	.	.	.	.	1.	.			en B	*Brassicaceae*
fulva MÜLLER 1766	1	.	.	.	.	.	1.			en B	.
fulvago (CHRIST 1791)	4	.	.	.	.	.	4.		3	en B	*Asterac.*,gelb
haemorrhoa (FABRICIUS 1781)	1	.	.	.	.	1.	.			en B	.
humilis IMHOFF 1832	1	.	.	.	.	.	. 1		3	en B	*Asterac.*,gelb
labiata FABRICIUS 1781	3	.	.	.	.	2. 1	.			en B	*Veronica*
minutula (KIRBY 1802)	24	11. 1	2.	5.	.	3.	2.			en B	.
minutuloides PERKINS 1914	18	3. 2	.	.	.	11. 2	.			en B	*Apiaceae*
nitidiuscula SCHENCK 1853	4	1.	.	.	1.	1.	1.		3	en B	*Apiaceae*
ovatula (KIRBY 1802)	11	. 2	.	. 1	1.	3. 2	2.			en B	*Fabaceae*
pandellei PÊREZ, 1895	1	.	.	. 1	.	.	.	2	2	en B	*Campanula*
propinqua SCHENCK 1853 1)											
viridescens VIERECK 1916	2	.	.	.	. 1	. 1	.			en B	*Veronica*
Biareolina											
lagopus LATREILLE 1809	7	. 5	.	. 2	.	.	.	0	1	en B	*Brassicaceae*
Panurgus											
calcaratus (SCOPOLI 1763)	2	. 1	.	.	.	. 1	.			en B	*Asterac.*,gelb
dentipes LATREILLE 1811	103	1.	.	.	.	.	69.33	2	3	en B	*Asteraceae*
Halictus											
langobardicus BLÜTHGEN 1944 2)											
maculatus SMITH 1848	56	22. 1	.	8.	1.	10. 1	11. 2			en B	.
scabiosae (ROSSI 1790)	41	3.	. 2	7. 1	2. 2	2.	18. 4	2	1	en B	*Asteraceae*
sexcinctus (FABRICIUS 1793)	1	.	.	.	.	.	1.	3	3	en B	*Asteraceae*
simplex BLÜTHGEN 1923 2)	70	16. 1	4.	12.	9. 3	3. 1	19. 2			en B	.
subauratus (ROSSI 1792)	19	.	1.	1.	3. 3	4. 1	5. 1		3	en B	.
tumulorum (LINNAEUS 1758)	36	8. 2	4.	6.	2. 1	6. 1	6.			en B	.
Lasioglossum											
albipes (FABRICIUS 1781)	16	1.	.	.	12. 2	1.	.			en B	.
calceatum (SCOPOLI 1763)	46	4.	1. 1	9.	1.	12.13	2. 3			en B	.
laevigatum (KIRBY 1802)	1	.	.	.	. 1	.	.		3	en B	*Apiaceae*
laticeps (SCHENCK 1868)	152	1.	3. 1	2.	.	7. 8	77.53			en B	.
lativentre (SCHENCK 1853)	4	. 1	.	1.	1.	. 1	.		2	en B	*Asteraceae*
leucozonium (SCHRANK 1781)	63	5. 1	3.	13. 3	.	12.	26.			en B	*Asterac.*,gelb
minutissimum (KIRBY 1802)	1	.	.	1.	.	.	.			en B	*Asteraceae*
morio (FABRICIUS 1793)	25	2.	.	.	5.	2.	11. 5			en B	.
nitidulum (FABRICIUS 1804)	4	.	.	.	.	.	2. 2			en BM	.
pauxillum (SCHENCK 1853)	142	62. 1	8.	35. 1	10. 5	17. 2	1.			en B	.
quadrinotatum (KIRBY 1802)	2	2.	.	.	.	.	.	3	1	en B	. *(Fabac.?)*
villosulum (KIRBY 1802)	51	3.	.	.	.	32.	15. 1			en BM	*Asterac.*,gelb
Sphecodes											
crassus (THOMSON 1870)	3	.	. 1	.	. 1	. 1	.			( )	.
ephippium (LINNAEUS 1758)	6	2. 2	.	.	.	1.	1.			( )	. *(Asterac.?)*
gibbus (LINNAEUS 1758)	2	.	1.	.	1.	.	.			( )	.
cf. *rufiventris* (PANZER 1798)	1	.	.	.	. 1	.	.			( )	.

Tab. 3 (cont.)

3 = gefährdet
4 = potentiell gefährdet
Nistweise: en = endogäisch (B=Boden)
hy = hypergäisch (H=Holz, Kr=Krautschicht, L= Lehmwand, M=Mauerwerk, P=Pflanzenstengel, R=*Rubus*-Stengel).
1), 2) = systematisch derzeit schwer trennbare und deshalb hier zusammengefaßte Artenpaare.

		I	II	III	IV	V	VI				
	N	♀♀.♂♂	♀♀.♂♂	♀♀.♂♂	♀♀.♂♂	♀♀.♂♂	♀♀.♂♂	RL1	RL2	NEST	BLÜTENBESUCH
Melitta											
nigricans ALFKEN 1905	1	.	.	.	. 1	.	.		3	en B	*Lythrum*
Anthidium											
lituratum (PANZER 1801)	8	1.	2. 1	1.	.	1.	1. 1	1	2	hy HPR	*Asteraceae*
manicatum (LINNAEUS 1758)	24	.	.	.	4. 3	. 3	9. 5			hy HM	.
oblongatum (ILLIGER 1806)	24	.	2. 4	2. 9	.	1.	2. 4	2		en hy BP	*Fabaceae*
punctatum LATREILLE 1809	8	.	. 1	. 1	.	.	3. 3			en B	*Fabaceae*
strigatum (PANZER 1805)	4	.	.	.	.	.	2. 2			hy	*Fabaceae*
Heriades											
crenulatus NYLANDER 1856	5	.	1. 1	.	. 1	.	. 2			hy H	*Asteraceae*
truncorum (LINNAEUS 1758)	15	.	1.	.	7.	3.	3. 1			hy HM	*Asterac.*,gelb
Chelostoma											
campanularum (KIRBY 1802)	2	.	.	.	.	1. 1	.			hy H	*Campanula*
fuliginosum (PANZER 1798)	27	. 2	. 3	.	.	8. 4	3. 7			hy H	*Campanula*
Osmia											
adunca (PANZER 1798)	61	.	.	.	1.	9. 5	15.31			hy HM	*Echium*
coerulescens (LINNAEUS 1758)	9	.	.	.	6.	.	2. 1			hy H	*Fabac.* (*Lamiac.*)
fulviventris (PANZER 1798)	1	.	.	.	.	1.	.			hy H	*Asteraceae*
leucomelana (KIRBY 1802)	3	.	.	.	.	.	3.			hy PR	*Fabaceae*
ravouxi PÊREZ 1902	1	.	.	.	.	.	1.	3	2	hy M	*Fabaceae*
rufa (LINNAEUS 1758)	3	2.	.	.	.	.	1.			hy HM	.
tridentata DUFOUR & PERRIS 1840	13	.	1.	.	.	.	11. 1	3	2	hy P	*Fabaceae*
Dioxys											
tridentata (NYLANDER 1848)	3	.	.	.	.	.	. 3	0	1	( )	.
Megachile											
centuncularis (LINNAEUS 1758)	1	.	.	.	.	.	. 1			hy HP	*Asteraceae*
ericetorum LEPELETIER 1841	29	.	.	1. 5	6.	. 1	11. 5		3	en BM	*Fabaceae*
genalis MORAWITZ 1880	3	.	.	1.	.	1.	1.		1	hy P	*Asteraceae*
pacifica (PANZER 1798)	37	. 1	5. 1	2.	4. 3	7. 3	10. 1		3	en B	.
pilidens ALFKEN 1923	2	.	.	.	.	.	1. 1	3	2	en B	*Fabac.*, *Lamiac.*
versicolor SMITH 1844	2	.	.	. 1	.	. 1	.			hy H	.
willughbiella (KIRBY 1802)	24	.	.	1. 1	3.	.	7.12			hy H	*Fabaceae*
Coelioxys											
aurolimbata FÖRSTER 1853	2	.	.	.	.	.	1. 1		2	( )	*Fabaceae* ?
rufocaudata SMITH 1854	4	.	.	. 1	. 1	. 1	. 1			( )	.
Nomada											
flava PANZER 1798	1	.	.	.	.	1.	.			( )	.
fucata PANZER 1798	1	1.	.	.	.	.	.			( )	.
fulvicornis FABRICIUS 1793	1	1.	.	.	.	.	.			( )	.
goodeniana (KIRBY 1802)	2	2.	.	.	.	.	.			( )	.
lineola PANZER 1798	4	.	.	.	1.	3.	.			( )	.
sexfasciata PANZER 1799	1	.	.	.	.	. 1	.		3	( )	.
striata FABRICIUS 1793	1	.	.	.	.	1.	.			( )	*Hieracium* ?
Epeolus											
variegatus (LINNAEUS 1758)	3	.	.	.	.	.	2. 1		2	( )	*Tanacetum*
Melecta											
punctata (FABRICIUS 1775)	1	.	.	.	. 1	.	.			( )	.
Eucera											
tuberculata (FABRICIUS 1793)	4	.	.	2.	1.	.	1.		3	en B	*Fabac.*, *Lamiac.*
Xylocopa											
violacea (LINNAEUS 1758)	1	.	.	.	1.	.	.	3	2	hy H	.
Ceratina											
chalybea CHEVRIER 1872	4	.	.	.	.	1. 1	2.	3	1	hy PR	*Asteraceae*
cucurbitina (ROSSI 1792)	8	.	.	.	.	2. 3	3.			hy PR	.
cyanea (KIRBY 1802)	13	.	.	.	1.	2. 4	4. 2			hy PR	*Asteraceae*
Bombus											
humilis ILLIGER 1806		.	.	.	+	.	+			en	.
lapidarius (LINNAEUS 1758)		+	+	+	+	+	+			en B	.
lucorum (LINNAEUS 1761)		+	+	+	+	+	+			en B	.
pascuorum (SCOPOLI 1763)		+	+	+	+	+	+			hy Kr	.
pratorum (LINNAEUS 1761)		.	.	.	.	+	.			hy Kr	.
ruderarius (MÜLLER 1776)		.	.	+	.	+	.		3	en B	.
sylvarum (LINNAEUS 1761)		+	+	+	+	+	+			en B	.
terrestris (LINNAEUS 1758)		+	+	+	+	+	+			en B	.
Psithyrus											
bohemicus (SEIDL 1837)		+	.	.	.	.	.			( )	.

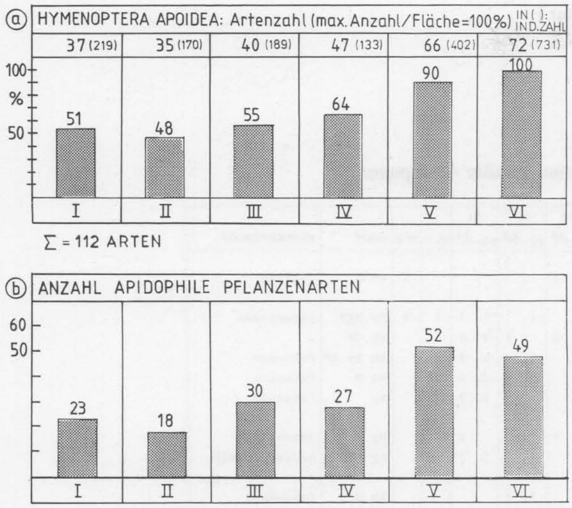

Abb. 5 - a) Anzahl der in den einzelnen Unteruchungsflächen festgestellten Wildbienen-Arten und Individuenzahlen; absolute Zahl und prozentuale Verteilung (Fläche mit der größten Artenzahl = 100%).
b) Anzahl der von Wildbienen besuchten (=apidophilen) Pflanzenarten in den Untersuchungsflächen I-IV; nähere Erläuterungen zu den Untersuchungsflächen s. Tab. 2 und Text.

Wildbienen-Arten an den 6 Untersuchungsflächen festgestellt werden (Tab. 3). Das sind 22% der für die BRD und 27% der für Baden-Württemberg bisher nachgewiesenen Arten.

Je nach Ausbildung des Gesellschaftsinventars, seiner Mosaikbildung, z.T. jedoch aber auch aufgrund der Flächengröße und des Alters der einzelnen Ruderalstellen, ist die Anzahl der hier vorkommenden Bienenarten unterschiedlich groß. Eine geringere Diversität (35 und 37 Arten) ist in den Flächen I und II festzustellen, dem *Conyzo-Lactucetum* und dem *Tanaceto-Artemisietum*, eine hohe (66 und 72) in den Flächen V und VI, den Vegetationskomplexen am Flugplatz und am Güterbahnhof (Abb. 5a). Auch die Anzahl der von Bienen beflogenen Pflanzenarten steigt in analoger Weise (Abb. 5b).

Eine Pflanzenart, *Erigeron annuus* (Abb. 6a, A), kommt in allen Untersuchungsflächen vor und erreicht im Blütenbesuch von allen entomophilen Pflanzenarten der untersuchten Ruderalstellen die höchste Bienenartenzahl (bis 17 Arten). In der Gruppe B (Abb. 6a) sind einzelne Pflanzenarten aufgeführt, die in mehreren Flächen vorkommen und ebenfalls besonders viele Bienenarten anlocken, so z.B. *Tanacetum vulgare* und *Barbarea vulgaris*. Die Gruppe C (Abb. 6a) vereinigt Pflanzenarten mit hoher Blütenbesuchszahl, die nur an wenigen der untersuchten Ruderalstellen vorkommen.

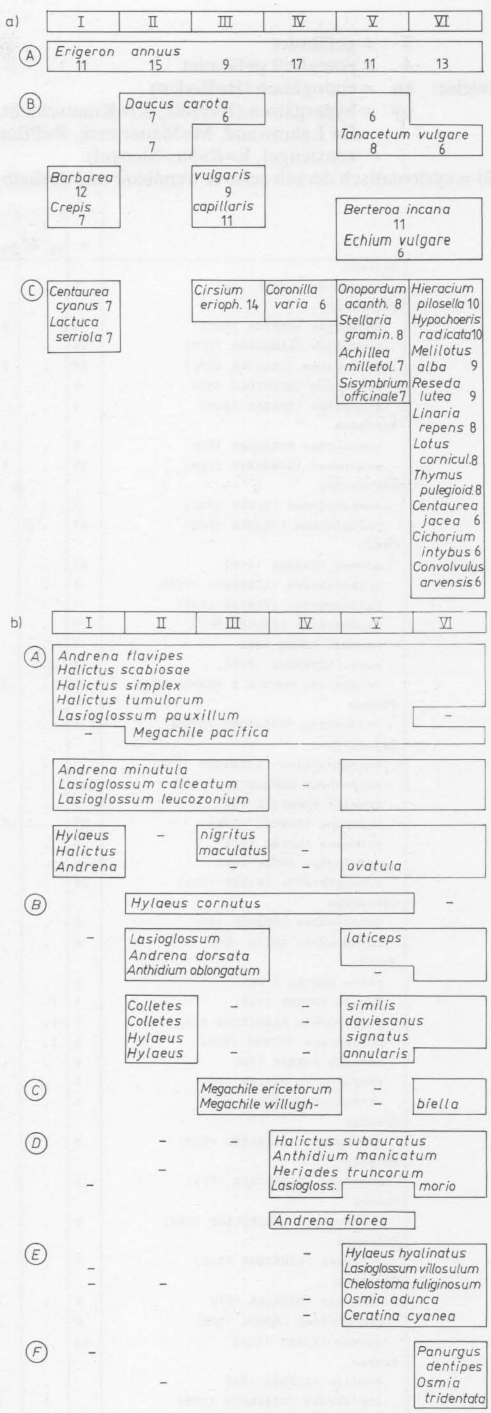

Abb. 6 - a) Die wichtigsten apidophilen Pflanzenarten der untersuchten Ruderalstellen der Stadt Freiburg (I-IV), differenziert nach ihrem Stenotopie-Grad unter Angabe der in den einzelnen Untersuchungsflächen an ihnen festgestellten Wildbienen-Artenzahl.
b) Dominante Wildbiene-Arten der untersuchten Ruderalflächen, geordnet nach ihrem jeweiligen Stenotopie-Grad (A-F).

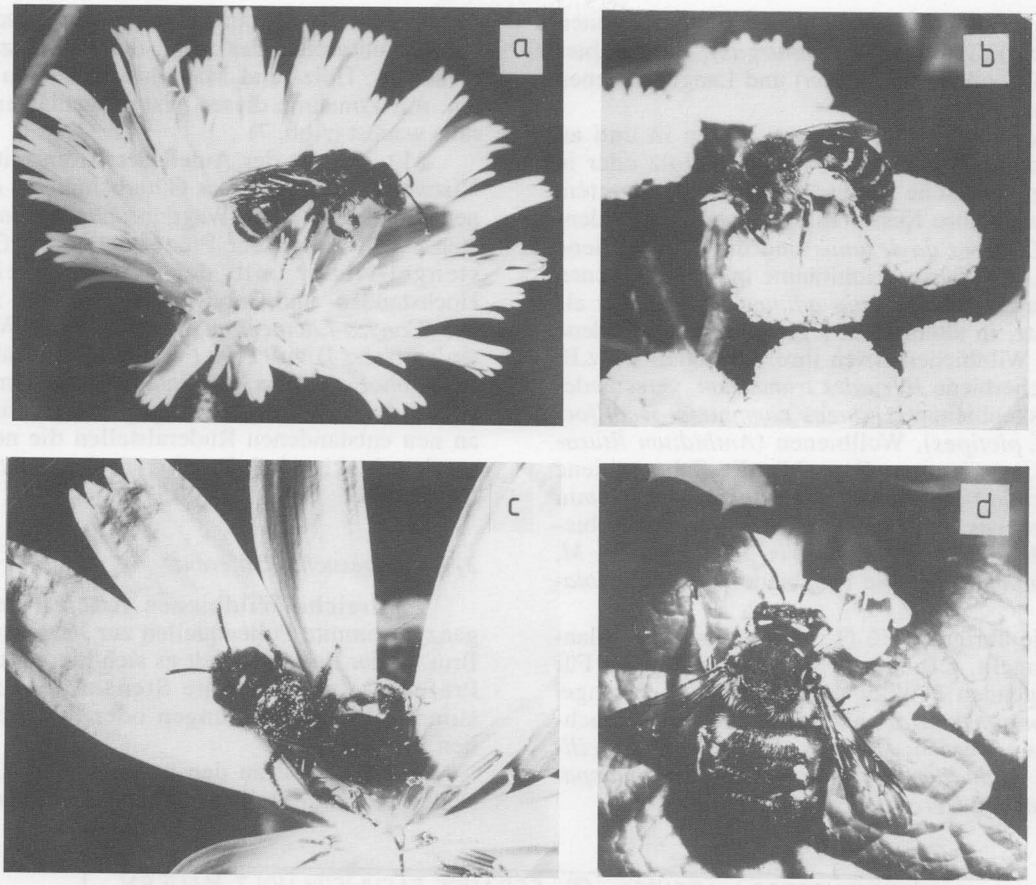

Foto 2 - a) Furchenbiene *Lasioglossum leucozonium* auf *Hieracium pilosella* (Güterbahnhof, 5.6.1987),
b) Seidenbiene *Colletes similis* auf *Tanacetum vulgare* (Gewerbegebiet «Haid», September 1987),
c) Trugbiene *Panurgus dentipes* auf *Cichorium intybus* (Güterbahnhof, 17.7.1987),
d) Wollbiene *Anthidium manicatum* auf adventiv vorkommender *Melissa officinalis* (Straßendamm «Betzenhausen», 20.7.1987.

Eine ähnliche Verteilung wie bei den apidophilen Pflanzenarten läßt sich auch für die Bienenarten nachweisen (Abb. 6b). Unter den dominanten Arten finden sich solche (Abb. 6b, A), die in fast allen Flächen gleichmäßig anzutreffen sind, so z.B. die Furchenbiene *Lasioglossum leucozonium* (Foto 2a). Es handelt sich hierbei im wesentlichen um Arten, die bei uns überall recht häufig auftreten und die in der Regel eine große ökologische Amplitude besitzen. Die übrigen Gruppen (Abb. 6b, B-F) hingegen umfassen Arten, die zunehmend deutlichere Schwerpunkte hinsichtlich ihrer Habitatpräferenzen aufweisen. Ihr Anteil steigt mit der Anwesenheit bestimmter Pflanzengesellschaften, mit dem Grad ihrer Ausbildung, mit der Zunahme der Vielseitigkeit und Komplexität des Vegetationsmosaiks, wobei das Ineinandergreifen möglichst verschiedener Gesellschaften unterschiedlicher Stellung in der soziologischen Progression von besonderer Bedeutung ist (Tab. 2). So kommt die Trugbiene *Panurgus dentipes* (Foto 2c), eine bei uns sehr seltene submediterrane Art, nur im Bereich des Güterbahnhofes vor. Auch spielt in diesem Zusammenhang die Anwesenheit bestimmter abiotischer Strukturelemente (s.u.) ebenfalls eine große Rolle.

Das Schwerpunktvorkommen zahlreicher Wildbienen-Arten beruht immer auf bestimmten Habitatansprüchen, die einerseits die Nistweise (1), andererseits das Blütenbesuchsverhalten (2) dieser Arten betreffen.

1) Nistweise:

Die überwiegende Mehrzahl der an den untersuchten Ruderalstellen festgestellten Wildbienen-Arten sind Bodennister (66%, 59 Arten). Zu diesen gehören im wesentlichen die Sandbienen (*Andrena*), Trugbienen (*Panurgus*), Furchenbienen (*Halictus/Lasioglossum*) und Langhornbienen (*Eucera*).

Weitere 17% (15 Arten) nisten in und an Gebäuden, im Fachwerk, in altem Holz oder in Mauern. Typische Arten, die in lehmverfugtem Mauerwerk ihre Nester anlegen, sind die Seidenbiene *Colletes daviesanus* und die Maskenbiene *Hylaeus hyalinatus.* Hohlräume in Mauern dienen den Mauerbienen *Osmia adunca* und *O. rufa* als Nistplatz; in altem Holz legen viele verschiedene andere Wildbienen-Arten ihre Brutzellen an, z.B. die Löcherbiene *Heriades truncorum,* verschiedene Maskenbienen (*Hylaeus communis, H. difformis, H. pictipes),* Wollbienen (*Anthidium lituratum, A. manicatum:* Foto 2d), die Scherenbiene *Chelostoma fuliginosum,* Mauerbienen (*Osmia coerulescens, O. fulviventris),* Blattschneiderbienen (*Megachile centuncularis, M. versicolor, M. willughbiella)* und die Holzbiene *Xylocopa violacea.*

Die übrigen 17% (15 Arten) nisten in Pflanzenstengeln, z.B. solche von *Rubus*-Sippen. Für die folgenden 5 Wildbienen konnten die Stengel von *Onopordum acanthium* als Nistplatz nachgewiesen werden: *Hylaeus cornutus, H. gracilicornis, Anthidium lituratum, Chelostoma campanularum* und *Ceratina cyanea.*

Ein Vergleuch der einzelnen Untersuchungsflächen untereinander zeigt, daß die Anzahl der Gebäude-, Holz- und Maueraister, wie zu erwarten, mit Zunahme dieser Nistgelegenheiten ebenfalls wächst (Abb. 7)

Mit 28% ist der Anteil der Arten mit dieser Nistweise im Bereich des Güterbahnhofes mit seinen zahlreichen alten Waggonschuppen am höchsten. Auch nimmt der Prozentsatz der Pflanzenstengel-Nister mit der Anwesenheit von Hochstauden- und Gebüschgesellschaften zu, von 3% *(Conyzo-Lactucetum,* Straßendamm 'Weingarten'; Fläche I) auf 16% (Vegetationsmosaik 'Güterbahnhof'; Fläche VI). Entsprechend nimmt der Anteil der Bodernnister hingegen ab; er ist hoch an neu entstandenen Ruderalstellen die noch besonders lückig sind. Im *Conyzo-Lactucetum* betrug er 90%

2) Blütenbesuchs-Präferenz:

Zahlreiche Wildbienen-Arten nutzen nur ganz bestimmte Pollenquellen zur Versorgung der Brut. In der Regel handelt es sich hierbei um eine Präferenz («angeborene Stenanthie») für bestimmte Pflanzengattungen oder Pflanzenfamilien.

Von den 112 an den untersuchten Ruderalstellen der Stadt Freiburg erfaßten Wildbienen-Ar-

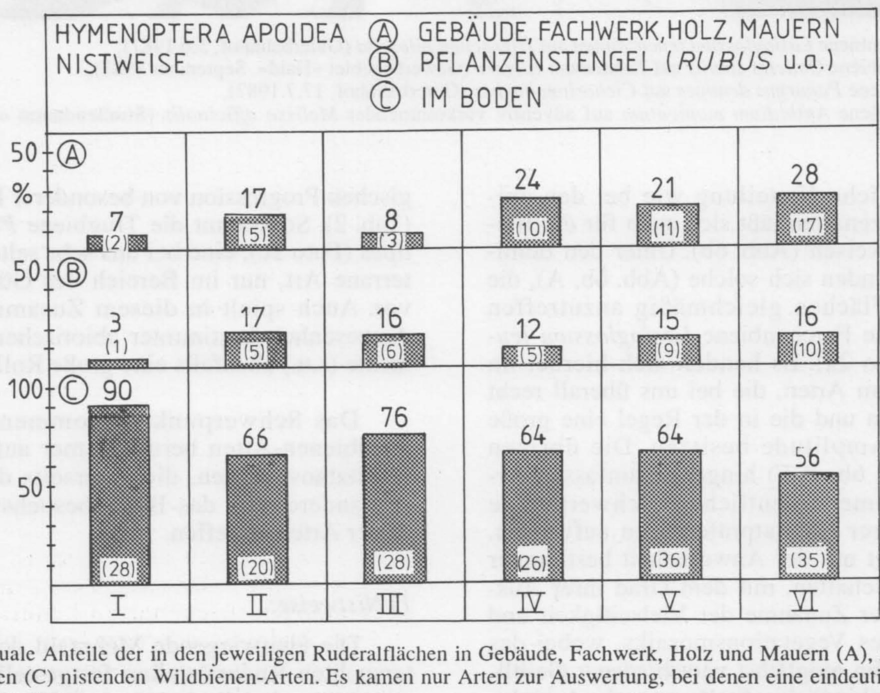

Abb. 7 - Prozentuale Anteile der in den jeweiligen Ruderalflächen in Gebäude, Fachwerk, Holz und Mauern (A), in Pflanzenstengel (B) und im Boden (C) nistenden Wildbienen-Arten. Es kamen nur Arten zur Auswertung, bei denen eine eindeutige Zuordnung getroffen werden konnte.

ten können allein die Hälfte als im Blütenbesuch spezifisch eingestuft werden. Eine hohe Blütenbesuchsspezifität erklärt häufig auch bestimmte Habitatpräferenzen. So besuchen die beiden Seidenbienen-Arten *Colletes daviesanus* und *C. similis* (Foto 2c) fast ausschließlich *Tanacetum vulgare*, ihr Schwerpunktvorkommen liegt deshalb innerhalb der Untersuchungsflächen im *Tanaceto-Artemisietum*, im *Onopordetum acanthii* und im *Dauco-Picridetum*.

Ein weiterer Spezialist ist die Sandbiene *Andrena florea*, die fast ausschließlich an *Bryonia*-Arten (z.B. *Bryonia dioica)* anzutreffen ist. An den untersuchten Ruderalstellen tritt sie deshalb nur an 2 Stellen auf (Straßendamm 'Betzenhausen', Fläche IV, Erdwall 'Flugplatz', Fläche V), wo in Kontakt zu den dort eingehender bearbeiteten Flächen *Alliarion*-Gesellschaften mit *Bryonia dioica* angrenzen.

Eine enge Bindung an *Echium vulgare* zeigt die Mauerbiene *Osmia adunca*. Im Bereich des Güterbahnhofes (Fläche VI) beschränkt sie sich während ihres Pollensammelflugs im wesentlichen auf die *Vulpia myuros*-Gesellschaft, da dort *Echium vulgare* in besonders hoher Blumendichte vorkommt.

Im Pollensammeln spezifisch auf *Reseda*-Arten *(Reseda lutea, R. luteola)* ist die Maskenbiene *Hylaeus signatus*. Ihr Schwerpunktvorkommen liegt deshalb im *Onopordetum acanthii* (Flugplatz, Fläche V) und im *Echio-Melilotetum* (Güterbahnhof, Fläche VI), wo sie *Reseda lutea* besucht, ferner im *Tanaceto-Artemisietum* (Gewerbegebiet 'Haid', Fläche II). Die beiden Scherenbienen-Arten *Chelostoma campanularum* und *Ch. fuliginosum* sind Campanulaceen-Spezialisten. Im Untersuchungsgebiet wurden sie fast ausschließlich an *Campanula rapunculus* in der ruderalisierten *Arrhenatherion*-Fragmentgesellschaft am Flugplatz und im *Dauco-Picridetum* und der *Vulpia myuros*-Gesellschaft am Güterbahnhof angetroffen. Ebenfalls auf *Campanula*-Arten spezifisch ist die Sandbiene *Andrena pandellei*. Während die Weibchen all dieser *Campanula*-Spezialisten die Blüten vorwiegend als Pollenquelle nutzen, dienen sie den Männchen häufig als Übernachtungsquartier und Schlafplatz.

Für die Mehrzahl der im Blütenbesuch spezifischen Bienenarten (73%), die an den untersuchten Ruderalstellen nachgewiesen werden konnten, haben 3 Pflanzenfamilien eine besonders große Bedeutung (Tab. 4).

Tab. 4 - Prozentsatz der Asteraceen (s.l.)-, Fabaceen-, und Apiaceen-Spezialisten unter den an den untersuchten Ruderalstellen festgestellten im Blütenbesuch spezifischen (stenanthen) Wildbienen-Arten; in Klammer: Anzahl der Arten

HYMENOPTERA APOIDEA IM BLÜTENBESUCH SPEZIFISCH AUF:			
ASTERACEAE s.l.	39 %	(22)	73%
FABACEAE	21 %	(12)	
APIACEAE	9 %	(5)	
ASTERACEAE s.l. + APIACEAE	4 %	(2)	

1) Asteraceae

Beispiele für spezifische Bienenarten der Ruderalflächen: *Hylaeus nigritus, Andrena fulvago, A. humilis, Panurgus calcaratus, P. dentipes* (Foto 2c), *Halictus scabiosae, H. sexcinctus, Lasioglossum lativentre, L. leucozonium* (Foto 2a), *L. minutissimum, L. villosulum, Heriades crenulatus, H. truncorum;*

2) Fabaceae

Andrena ovatula, Anthidium oblongatum, A. punctatum, A. strigatum, Osmia coerulescens, O. leucomelana, O. ravouxi, O. tridentata, Megachile ericetorum, M. willughbiella;

3) Apiaceae

Hylaeus annularis, H. punctatus, H. sinuatus, Lasioglossum laevigatum.

Die Dominanz dieser Pflanzenfamilien steht auch in Übereinstimmung mit dem Ergebnis, daß an allen 6 Untersuchungsflächen die Asteraceen, gefolgt von den Fabaceen, die meisten entomophilen Pflanzenarten stellen (Abb. 4).

Ein Vergleich der 6 untersuchten Ruderalstellen untereinander zeigt, daß der Anteil der im Blütenbesuch unspezifischen Arten in der Reihenfolge I-VI abnimmt, der der spezifischen Arten hingegen zunimmt (Abb. 8a). Mit steigender Diversität von Gesellschaften unterschiedlicher soziologischer Progression erhöht sich demnach der Anteil der im Blütenbesuch spezifischeren Arten. Ein Grund liegt einerseits in der steigenden Pflanzenarten-Zahl und dem damit wachsenden Anteil solcher Pflanzenarten, auf die bestimmte Wildbienen-Arten spezifisch sind, andererseits in der längeren Zeitspanne, die viele spezialisierte Bienenarten benötigen, um bestimmte Ruderalstandorte zu besiedeln.

Eine Analyse auf Pflanzenfamilien-Niveau führt zu dem Ergebnis, daß entsprechend der

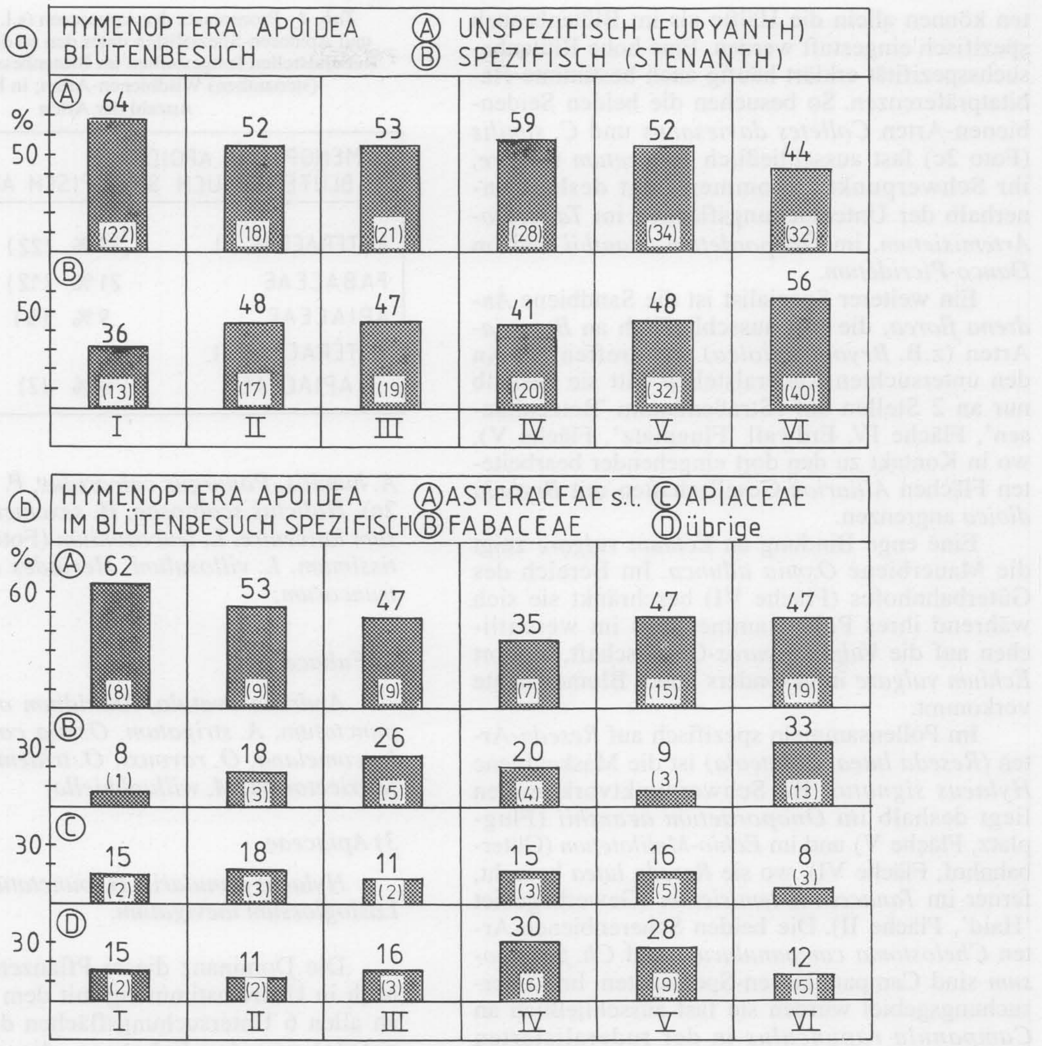

Abb. 8 - a) Prozentuale Anteile der in den jeweiligen Ruderalflächen im Blütenbesuch unspezifischen (euryanthen) und spezifischen (stenanthnen) Wildbienen-Arten.
b) Prozentuale Anteile der in den einzelnen Untersuchungsflächen auf Asteraceen (s.l.) -, Fabaceen-, Apiaceen-Arten, sowie Pflanzenarten anderer Familien spezifischen Wildbienen-Arten.

jeweiligen Ausstattung der einzelnen Ruderalgesellschaften und Gesellschaftsmosaike der Anteil der jeweiligen Spezialisten variiert (Abb. 8b). Ein Zusammenhang zwischen Spezialisierung auf eine bestimmte Pflanzenfamilie und Höhe in der soziologischen Progression der Gesellschaften der Untersuchungsflächen ist z.T. erkennbar. So überwiegen an «jungen» Ruderalstandorten Asteraceen-Spezialisten unter den spezifischen Wildbienen-Arten, an «älteren» Standorten mit Gesellschaften unterschiedlicher Stellung in der soziologischen Progression solche der Fabaceen. Apiaceen-Spezialisten zeigen im Vergleich der Untersuchungsflächen keine Präferenzen.

Zusammenfassend ist festzustellen, daß es sich bei der hier vorgestellten Blütenbesucher-Gemeinschaft der Wildbienen an Ruderalstellen der Stadt Freiburg um eine besonders artenreiche, z.T. hoch angepaßte Zönose handelt. Da dieser Untersuchung nur die Ergebnisse von 4 Monaten zugrundeliegen und der Frühjahrs- und Herbstaspekt nicht oder nur unzureichend erfaßt wurde, ist, gemessen an den tatsächlichen Verhältnissen, die festgestellte Artenzahl noch zu niedrig. Die Erfahrung zeigt, daß bei mehrjährigen Untersuchungen der Wildbienenfauna eines Gebietes der Anteil neuer Arten im 2. Untersuchungsjahr ca. 25-30%, im 3. Jahr ca. 10% beträgt. Es dürfte deshalb an den vorgestellten Ruderalstellen bei der Berücksichtigung der gesamten Vegetationsperiode und einem längeren Untersuchungszeitraum mit ca. 150-180 Wildbienen-Arten zu rechnen sein.

Der Anteil derjenigen Arten, die man als typische Kulturfolger oder synanthrope Arten einstufen kann, ist hier gering (ca. 19%). Auch von der Dominanzstruktur ähnelt die Wildbienen-Gemeinschaft der untersuchten Ruderalstellen eher natürlichen bzw. naturnahen Zönosen (TROJAN et al. 1982).

Die einzelnen Untersuchungsflächen unterscheiden sich in der Zusammensetzung der Artengemeinschaft in Abhängigkeit vom Pflanzengesellschaftsinventar, von seiner Mosaikbildung und Größe, von der Diversität der Pflanzengesellschaften unterschiedlicher soziologischer Progression (und damit auch unterschiedlichen Alters) und von der Anwesenheit bestimmter, über längere Zeit zur Verfügung stehender Nistplatzsubstrate. Die Vergleichsdaten reichen bisher jedoch noch nicht aus, um die Frage beantworten zu können, ob bestimmte Ruderal-Pflanzengesellschaften und Gesellschaftskomplexe eigene Wildbienen-Gemeinschaften besitzen, die sich durch ein charakteristisches Artenspektrum typisieren lassen.

4.3 Naturschutzaspekte

Schon allein die hohe Artenzahl an vorkommenden Wildbienen beweist eine hohe Qualität der untersuchten Ruderalstellen aus Naturschutzsicht. Im Vergleich zu der Wildbienenfauna eines versaumten Kaiserstühler Halbtrockenrasens sind die Ruderalstandorte etwa am Flugplatz oder am Güterbahnhof keinesfalls artenärmer, auch wenn es sich um eine andere Zönose handelt. Dies wird untermauert, berücksichtigt man die Anzahl der Rote-Liste-Arten (Tab. 3, 5).

Tab. 5 - Vergleich: Artenzahl und Anteil Roter-Liste-Arten (Baden-Württemberg) von Wildbienen-Gemeinschaften verschiedener Ruderalstandorte der Stadt Freiburg (1 Untersuchungsjahr) mit einem versaumten *Mesobrometum* im Kaiserstuhl (3 Untersuchungsjahre, s. KRATOCHWIL 1983, 1984)

HYMENOPTERA APOIDEA	RUDERALSTANDORTE STADT FREIBURG 1 UNTERSUCHUNGSJAHR	VERSAUMTER HALBTROCKENRASEN KAISERSTUHL 3 UNTERSUCHUNGSJAHRE
ARTENZAHL	112	130
ANZAHL ARTEN DER ROTEN LISTE BAD.-WÜRTT.	31	29

Unter diesen sind allein 17 Arten der Roten Liste der BRD (nach WARNCKE & WESTRICH 1984) und 28 Arten der Roten Liste von Baden-Württemberg (WESTRICH & SCHMIDT 1984). Die höchste Anzahl von Rote-Liste-Arten bezogen auf Baden-Württemberg beherbergt der Güterbahnhof (N=21), aber auch der nur wenige Jahre alte Straßendamm der Fläche I weist bereits 8 Rote-Liste-Arten auf (Abb. 9). Im folgenden seien 7 «Besonderheiten» vorgestellt:

Biareolina lagopus: Diese submediterrane, den Sandbienen nahestehende Art ist innerhalb der Bundesrepublik nur aus dem südlichen Teil bekannt und bisher nur von wenigen Orten nachgewiesen worden. Die meisten Angaben waren älteren Datums, so daß sie in der Roten Liste der BRD von 1984 als verschollen angegeben wurde. 1983 konnte sie WESTRICH (1984) bei Altlußheim wieder finden. WESTRICH & SCHMIDT (1984) stufen sie in der Roten-Liste Baden-Württemberg in die Kategorie 1 ein: vom Aussterben bedroht.

Bemerkenswert ist, daß sie innerhalb der untersuchten Ruderalstellen an dem nur wenige Jahre alten Straßendamm bei Weingarten (Fläche I) und im Gewerbegebiet «Obere Haid» (Fläche III) auftrat, also keinesfalls an den hinsichtlich der Rote-Liste-Arten dominierenden Flächen. Männchen und Weibchen traten nur an Blüten von *Barbarea vulgaris* auf; wahrscheinlich ist diese Art ein Cruciferen-Spezialist.

Halictus scabiosae: In der Roten-Liste Baden-Württemberg wird diese submediterrane Art in die Kategorie 1 (vom Aussterben bedroht) eingestuft, in der Roten Liste der BRD als stark gefährdet (Kategorie 2). Die Skabiosen-Furchenbiene kommt nur im Süden der BRD vor, wobei es sich zumeist um ältere Funde aus dem Oberrheingebiet handelt (WESTRICH 1984). *H. scabiosae* konnte an allen untersuchten Ruderalstellen nachgewiesen werden. Am Straßendamm «Betzenhausen» waren mehrere Nistplätze (12 Nesteingänge) im *Convolvulo-Agropyretum* an lückigen, vegetationslosen Stellen in südlicher Exposition festgestellt worden.

Lasioglossum quadrinotatum: Auch diese Furchenbiene wird in der Roten Liste von Baden-Württemberg in die Kategorie 1 (vom Aussterben bedroht) gestellt, in der Roten Liste der BRD in die Kategorie 3 (gefährdet). Nach EBMER (1970) kommt sie in ganz Europa vor, jedoch immer nur lokal. Aus Österreich z.B. sind erst 4 Funde bekannt. EBMER (1970) fand diese Art aus-

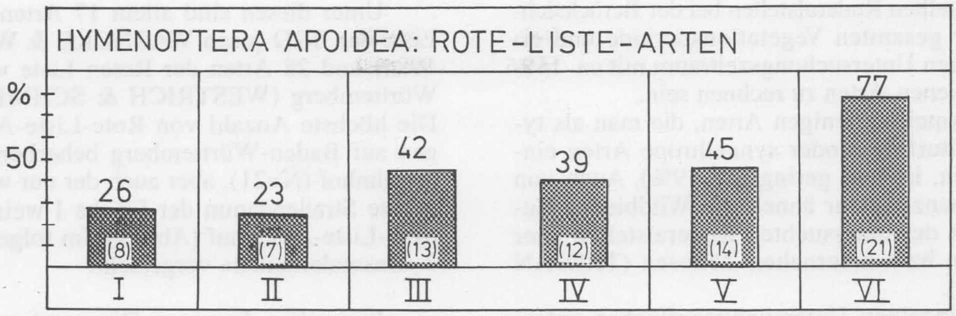

Abb. 9 - Anzahl der Arten der Roten Liste von Baden-Württemberg an den 6 verschiedenen untersuchten Ruderalstellen der Stadt Freiburg in % (100% = 31); in Klammer Anzahl der der Arten.

schließlich auf Sandboden. Innerhalb der untersuchten Ruderalstellen trat sie nur im *Conyzo-Lactucetum* des wenige Jahre alten Straßendammes bei Weingarten (Fläche I) auf.

Anthidium lituratum: Bei dieser Wollbiene handelt es sich um eine submediterrane Art, welche innerhalb der Bundesrepublik nur aus dem Süden bekannt ist (WESTRICH 1984). Sie wird in der Roten Liste von Baden-Württemberg in die Kategorie 2 (stark gefährdet) eingestuft, in der Roten Liste der BRD sogar in die Kategorie 1 (vom Aussterben bedroht). Von dieser Art liegen nur wenige Fundmeldungen aus Baden-Württemberg nach 1960 vor (WESTRICH 1983). Auch für diese Art ist bemerkenswert, daß sie, ähnlich wie *Halictus scabiosae*, mit einer Ausnahme (Fläche IV) in allen untersuchten Ruderalflächen nachgewiesen werden konnte. WESTRICH (1983) erwähnt, daß sie in Baden-Württemberg bisher nur in Lagen bis 500 m auf Flugsanddünen, Trockenhängen und an warmen Waldrändern nachzuweisen war.

Dioxys tridentata: Diese ebenfalls submediterran verbreitete Kuckucksbiene wurde in der Roten Liste der BRD von 1984 noch als ausgestorben bzw. verschollen eingestuft. WESTRICH (1983) nennt für Baden-Württemberg nur einen rezenten Flugplatz: Oberbergen/Kaiserstuhl; entsprechend wird die Zweizahnbiene in der Roten Liste von Baden-Württemberg in der Kategorie 1 geführt. Nach den Angaben von STOECKHERT (1933) war diese Art schon immer selten. Am Güterbahnhof, wo *Dioxys tridentata* vorkommt, flogen *Osmia adunca* und *O. ravouxi*, die beide als Wirtsbienen-Arten angegeben werden (SCHMIEDEKNECHT 1930).

Megachile genalis: Diese subkontinental verbreitete Blattschneiderbiene konnte in Baden-Württemberg bis 1986 erst fünfmal nachgewiesen werden (WESTRICH 1983; WESTRICH, briefl.). Der letzte Fund der Beulen-Blattschneiderbiene geht auf das Jahr 1943 bei Kehl zurück (BALLES 1949). Auf den untersuchten Ruderalstellen war sie auf 3 Untersuchungsflächen angetroffen worden: am Flugplatz, am Güterbahnhof und im Gewerbegebiet «Obere Haid».

In der Roten Liste der BRD fehlt diese Art, in der von Baden-Württemberg wurde sie in die Kategorie 1 eingestuft.

Ceratina chalybea: Von der Großen Keulhornbiene liegen nur vereinzelte ältere Fundmeldungen aus dem Oberrheingebiet vor (LAUTERBORN 1924; LEININGER 1924; STROHM 1924, 1925; BALLES 1925, 1927). Diese submediterran verbreitete Art kommt nur im Süden der BRD vor (WESTRICH & SCHMIDT 1985). In der Roten Liste der BRD wird sie als «gefährdet» (Kategorie 3), in der von Baden-Württemberg als «vom Aussterben bedroht» (Kategorie 1) eingestuft. Innerhalb der untersuchten Ruderalflächen wurde sie am Güterbahnhof und am Flugplatz nachgewiesen.

Ruderalvegetation kann im steten Werden und Vergehen kleinräumig von hoher lokaler Persistenz sein. Gleiches gilt auch für die dort lebende Tierwelt. Bei bestimmten Ruderal-Pflanzenarten (z.B. *Papaver rhoeas)* wird diese Persistenz zusätzlich durch eine 'seed bank' im Boden gewährleistet.

Unsere 6 Untersuchungsflächen liegen alle außerhalb des Stadtkernes. Der heutige Stadtkern ist in seiner Umgrenzung vergleichbar mit der Altstadt des 13. Jahrhunderts. Alle unsere Flächen liegen somit in dem alten Vorstadtbereich um 1300, wo es immer schon solche Ruderalstandorte gegeben haben muß. Um 1300 erreichte die Stadt Freiburg eine Ausdehnung, die sie über das ganze

Mittelalter nicht mehr überschritt. Diese unsere Untersuchungsflächen liegen einerseits auch in einem Bereich, der etwa im 16. Jahrhundert landwirtschaftlich z.T. genutzt, andererseits Ende des 17. Jahrhunderts im Vorfeld der Vaubanschen Festungswerke, wo ebenfalls Standorte für Ruderalbiozönosen sicher in großer Ausdehnung vorhanden waren. Es ist davon auszugehen, daß die untersuchte Ruderalbiozönose etwas über Jahrhunderte Gewachsenes darstellt, nur so ist der hohe Anteil besonders seltener, z.T. wenig ausbreitungsfähiger Standortsspezialisten unter den Wildbienen zu verstehen.

Ihr Schutz muß ein besonders ernstzunehmendes Anliegen sein.

Zusammenfassung

Im Jahre 1987 wurden in einem Zeitraum von Mitte Mai bis Mitte September an Ruderalstellen im Stadtbereich von Freiburg Wildbienen-Gemeinschaften (Hymenoptera Apoidea) in Pflanzengesellschaften u.a. folgender Syntaxa erfaßt: *Conyzo-Lactucetum, Tanaceto-Artemisietum, Convolvulo-Agropyretum, Ranunculus repens*-Gesellschaft, *Onopordetum acanthii*, ruderalisierte *Arrhenatherion*-Fragmentgesellschaft, *Dauco-Melilotion, Dauco-Picridetum, Vulpia myuros*-Gesellschaft. Die untersuchten Flächen, die teilweise Vegetationskomplexe darstellen, hatten eine Größe von etwa 100-5000 m^2. Von den einzelnen Ruderal-Pflanzengesellschaften liegen genaue Daten über ihre Blühphänologie vor; sie zeichnen sich alle durch eine hohe Anzahl simultan blühender entomophiler Pflanzenarten in den Monaten Juli und August aus. Der blühphänologische Höhepunkt der untersuchten Gesellschaften liegt Ende Juli. Insgesamt ließen sich 22% (n=112) der in der BRD bekannten Wildbienen-Arten (n=517) nachweisen. Eine besonders große Artenzahl wurde an solchen Ruderalstellen gefunden, wo Pflanzengesellschaften unterschiedlicher Stellung in der soziologischen Progression das Vegetationsmosaik aufbauen, und sowohl für Bodennister, als auch für Arten, die z.B. im Fachwerk von Gebäuden, in altem Holz, in Mauern oder auch in Pflanzenstengeln von Hochstauden und Sträuchern nisten, ausreichende Nistmöglich-keiten vorhanden sind. 50% aller festgestellten Wildbienen-Arten sind im Blütenbesuch Spezialisten, über zwei Drittel davon auf Asteraceen, Fabaceen und Apiaceen. Bemerkenswert ist auch der hohe Anteil von Arten der Roten Liste (18 Arten der Liste er BRD, 31 der von Baden-Württemberg). So kamen an einem nur wenige Jahre alten Straßendamm mit einem *Conyzo-Lactucetum* bereits 8 Rote-Liste-Arten vor. Hieraus läßt sich ableiten, daß Standorte mit spontaner Vegetation im städtischen Bereich eine artenreiche Blütenbesucher-Gemeinschaft mit z.T. sehr seltenen und bei uns besonders gefährdeten Wildbienen-Arten haben können. Dies belegt auch aus zoologischer Sicht die Schutzwürdigkeit von Ruderal-Gesellschaften im städtischen Siedlungsbereich.

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The paper entitled «Measuring settlement vegetation: structure and function» published on the Part One of this number of Braun-Blanquetia pag. 9-20, because of editorial mistake appeared with the co-author's name missing. Stating that the co-author of this paper is David N. Myers of the Department of Geography, The University of Georgia, USA, the editor apologize for this mistake. Therefore the paper sholud be listed as follows:

Measuring settlement vegetation: structure and function

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Dept. of Geography, The University of Georgia, USA

The editor

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Stampato il 28 dicembre 1993
dalla «Edigrafica Aldina s.r.l.»
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Braun-Blanquetia

Un héritage est enrichissant et curve de nouvelles possibilités créatrices. Mais il en découle en contre partie l'obligation de ne pas gaspiller le patrimoine reçu. Ceux qui, aujourd'hui étudient la végétation grâce à la phytosociologie peuvent utiliser des méthodologies bien au point et tirer profit d'un ensemble cohèrent de connaissances.

C'est le résultat du travail méthodique de nombreux chercheurs de qualité pendant plusieurs décennies. Aujourd'hui, nous nous trouvons face à des problèmes qui ne sont sans doute pas tout à fait nouveaux mais qui paraissent infiniment plus graves que dans le passé: primauté de la technique, spécialisation, pénurie de matières premières, d'énergie et d'espace, crise de l'environnement...

Il se développe ainsi des problèmes spécifiques divers pour lesquels il est nécessaire de trouver des réponses nouvelles. Les chercheurs sont placés devant un véritable défi et il dépend de leur savoir et de leur immagination de montrer si la Science de la végétation est capable d'apporter une contribution appréciable à la solution de ces problèmes.

La tradition phytosociologique dans ce contexte constitue une base essentielle. La conception typologique de la végétation et la clarté du système qui en découle, l'habitude des chercheurs de vivre en contact étroit avec la végétation, les recherches basées sur l'observation condition antithétique de l'expérimentation, sont les traits caractéristiques de la phytosociologie.

Les lignes directrices qui nous ont été transmises par les maîtres de la Science de la végétation, Josias Braun-Blanquet et Reinhold Tüxen avant tout, constituent actuellement une part importante de notre patrimoine d'idées. Notre but est de valoriser cet héritage et d'honorer la mémoire du premier de ces maîtres et fondateur de la phytosociologie moderne par une nouvelle série de publications.

Pourront y trouver place des monographies étudiant concrètement la végétation selon les enseignements de J. Braun-Blanquet et R. Tüxen qui, à travers la créativité des auteurs, produiront de nouveaux fruits.

Disciples nous-mêmes de J. Braun-Blanquet et ayant collaboré à son activité, nous pensons, qu'à travers cette série de publications son héritage restera vivant dans l'esprit originel et avec de nouvelles idées.

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