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Lichens and Air Pollution

A study of cryptogamic epiphytes and environment in the Stockholm region

By

Erik Skye

UPPSALA 1968
ALMQVIST & WIKSELLS BOKTRYCKERI AB

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Erik Skye
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PREFACE

According to the information I have received, the idea that gave rise to this investigation came from Professor John Axel Nannfeldt in 1962. In his capacity as a member of the State Scientific Research Council, he took up the question within the Council's Natural Resources Committee (the Committee for Research on the Conservation and Utilization of Swedish Natural Resources). The secretary of this Committee, Bengt Lundholm, Ph.D., first approached Docent Rolf Santesson on the subject, and the latter in his turn communicated with me.

My original task was to draw up guiding principles for a synoptic investigation in Stockholm and Gothenburg. In the summer of 1962, the first fieldwork season began in Stockholm, and it was followed by five more. In the summer of 1963 I worked in Gothenburg also. A first report on the investigations in Stockholm was published in the Research Council's yearbook for 1964.

The first investigation-plan had to be abandoned because the area to be investigated in Stockholm proved to be considerably larger than we had had reason to suppose from the beginning. The Gothenburg portion, therefore, has not been concluded.

The investigation was carried out in close consultation with the Natural Resources Committee, later the Natural Resources Inquiry of 1964, whose secretary Dr. Lundholm showed encouragingly great interest in my work. Funds for the investigation were made available throughout its duration by the State Scientific Research Council. It was also possible for me to employ an assistant for laboratory work. Without this help it would have been impossible to produce the quite extensive material concerning the pH of substrates and epiphytes, etc., which has been published in this report on the investigation. I also found it possible to employ a helper who worked mainly as a secretary for a few hours every day on the task of labelling and arranging the large quantities of botanical materials, on typing reports, manuscripts, etc., and on the statistical processing of collected data, etc.

During the course of the investigations several students, under my guidance, carried out minor investigations of the effect of different kinds of air pollution on lichen flora. Thus Lars Westman, B.A., worked in the Örnsköldsvik district and Roland Moberg, M.A., in the Köpmanholmen district. Both these places are in the province of Ångermanland. Hans Lundström, B.A., worked in my own investigation area (see p. 98). Georg Schuisky studied the effect of air pollution on vegetation and soil in the Borlänge district. Kjell Ericson is studying lichen flora at Köping, Ingemar Hallberg is editing my own investigation at Kvarntorp, which has now been proceeding for almost 15 years. Marianne Gelting is studying lichen flora at Karlshamn, and Björn Magnusson is at work on the effect of dust on epiphytic lichens around a cement works in the island of Gotland. All these investigations are carried out with financial grants from the Research Council. The Swedish Aluminium Company at Sundsvall financed a fairly comprehensive investigation of damage caused to vegetation in consequence of the immission of substances containing fluorine. The work was carried out by Olov Eriksson. The materials obtained through all these investigations are processed at the Institute of Ecological Botany.

Industrial enterprises and private landowners showed their interest, in various ways, in the methods of investigation I employed. In Stockholm I had the benefit of very satisfactory collaboration with the Public Health Committee. I also enjoyed fruitful cooperation with the National Institute of Public Health, the National Institute for Plant Protection, and the National Air Purification Committee, now the Air Purification Bureau of the Nature Conservation Department.

The Press showed benevolent and stimulating interest in my investigations.

Rena öknen

Luftföroreningarna gör Stockholms innerstad till en biologisk öken där lavar och mossor inte kan klara sig

Det spirar ingen mossa här i stan.
På Norr och Söder gror det inga lavar.
I biologiskt ökenland vi travar.
Det växer ingenting på Odenplan.

Nej, vår miljö är omöjlig för renar.
Dess atmosfär tar kål på varje lav.
Ty vi har grumlat luftens fria hav.
Blott dammet täcker våra träd och stenar.

Visst verkar luften ren i solens sken,
som över Strömmen emot kvällen brinner.
Men du har faktiskt tur ifall du finner
en gnutta skorplav på en poppels gren.

Kajenn
Sv. Dagbladet 18/3 1964

I. INTRODUCTION

Statement of the Problem

As far as is known, attention was first drawn to the question of the effect of the urban environment on lichen flora in Paris, in the middle of the 19th century (Nylander 1866). Since then, a considerable quantity of more or less lengthy dissertations have been published on the subject (see the bibliography in for example Barkman 1958, Skye 1958, and Natho 1964 *c*).

Various opinions have been expressed as to the reasons why lichens disappear from cities and urban areas. Nylander himself declared that the absence of lichens in the outskirts of the Jardins du Luxembourg in Paris was due to air pollution originating in the surrounding buildings. Several scientists have associated themselves with this view in a more or less modified form, including Arnold (1891–1901), Sernander (1912, 1926), Vaarna (1934), Høeg (1934), Vareschi (1936, 1953), Sauberer (1951), Barbalić (1953), Beschel (1958), Skye (1958, 1964, 1965), Villwock (1959, 1962), Le Blanc (1961), Pišút (1962), Gilbert (1965), Pearson and Skye (1965), Domrös (1966), Rao and Le Blanc (1966) and Laundon (1967).

The sharpest criticism of this opinion was expressed by Rydzak (1953). His opposing view is that it is a question of a desiccation phenomenon. One of the points he employs to support his opinion is the fact that the epigeic lichens generally thrive better in an urban environment than do the corticolous lichens. In this connection, he severely criticizes the use of the distribution of epiphytic lichens as an indication of air pollution. The second phenomenon upon which Rydzak bases his opinion is that even small towns without industry in some cases are without lichens in their centre (Rydzak 1957, 1958, 1959). Rydzak is supported in his views by Steiner and Schulze–Horn (1955), Klement (1956, 1958, 1966), Natho (1964 *a*, *b* and *c*) and others. Klement (1966) even goes so far as to express the belief that the death of lichens in the rural areas of northern Germany is due to a far-reaching but never recorded change in microclimate. (Cf. Barkman 1961.)

A third group of scientists considers that the question is not one of "either/or" but of "both/and". Among these may be mentioned Haugsjå (1930), Felföldy (1942), Barkman (1958), Bortenschlager and Schmidt (1963), Brodo (1966). Domrös (1966, p. 13) writes: "Kristallisiert hat sich aber die Erkenntnis, dass die Flechten ein empfindlicher Indikator der stadtbedingten Umweltfaktoren sind."

However, investigations of the composition of lichen flora on roadside and park trees in agricultural country surrounding the shale oil works at Kvarntorp during the 1950s (Skye 1958) show that air pollution—and primarily sulphur dioxide—kills lichens in the surroundings of industrial establishments, and that a zoning such as that outlined by Sernander (1912 and 1926) is also formed around a point source. In the vicinity of the factory, coniferous forest was also killed, other vegetation showed damage of seemingly the same appearance as that caused by the attack of sulphur dioxide, and corrosion greatly increased. Under such circumstances it was difficult to explain the disappearance of lichens by desiccation, which would have affected only ten square kilometres or so of the arable land around the factory and not areas situated farther away.

Tallis (1964, pp. 250 ff.) draws attention to the poverty of lichens in Lancashire. He discusses the reasons for this and writes: "Undoubtedly the lichen flora is affected to some extent by this dryness of the atmosphere; but the scarcity of lichens in wide belts around urban areas, and particularly in the moorland areas of south Lancashire, where atmospheric humidity is fairly high, suggest that climatic dryness is only a subsidiary cause."

Verona M. Conway (1949, pp. 161 ff.) discussed the effect of air pollution on the vegetation at Ringinglow bog near Sheffield. She summarized this part of the discussion as follows: "While the evidence does not exclude the possibility that the degradation of Ringinglow bog might have been caused by atmospheric smoke pollution, it is also possible to explain it in terms of improved drainage conditions" (l.c., p. 169). There are thus indications that other vegetation too which is highly dependent on a supply of nutrients from the air can show damage caused by air pollution. The problem, however, is by no means so simple, as other factors can also play a part in this connection.

isolated branch occurs here and there at a considerably lower level than that of other branches in the crown, it is disregarded. (See also Sjögren 1961, p. 8.) The "height" of the crown means the distance from the crown's lowest branches to the top of the tree. A low tree may have a fairly high crown, a high tree may have a low crown (usual in *Pinus silvestris*).

The lowest 2 $^1/_2$ metres were examined for the occurrence of epiphytes, the abundance (Braun-Blanquet 1964, p. 32) of lichens and mosses having been estimated with the aid of a three-grade scale, more closely described on p. 9. Examples of lichens without fruiting bodies are described as "sterile", while if they occur the examples in question are called "fertile".

As regards terms expressing the epiphytes' requirements or the like, the present author has been extremely cautious. I have avoided such terms as "nitrophilous", "ammoniophilous", etc., as I consider that they originate in theory rather than in knowledge. In fact there are extremely few laboratory experiments which lend support to classifications of this kind. So-called "sciophilous" species, for example, often prove to be at least phototolerant if only the atmospheric humidity is sufficiently great.

Sernander's terms "coniophilous" and "coniophobous", taken by him from Almborn (1948) are considerably better. In connection with the discussion on the significance of dust impregnation, Almborn (1955, p. 13, etc.) writes of "eutrophic" barks. In such contexts, I have made use of a term, "auxotrophified", employed—although rarely—in limnology, in order to emphasize that the supply of nutrients is from an extraneous source. On the whole I may say that I share Barkman's (l.c., p. 12) feelings about terms with the suffixes "-philous" and "-phobous".

Barkman (1946) introduces the terms "toxiphobous" and "toxitolerant". "Toxisensitive", however, would be a much better expression than "toxiphobous". On the other hand I agree with his view that *Lecanora conizaeoides,* for example, may be described as "toxitolerant".

The fact that I have not used the terminology described by Sjögren, for example (1961, pp. 93 ff.) with respect to pH tolerance in epiphytes does not mean, however, that I dissociate myself from it; merely that I have not been conscious of any need for it.

Other terms are defined in the sections in which they occur.

With regard to the nomenclature used for lichens I have benefited from the work of Almborn (1952), Poelt (1965) and others, and I have also enjoyed the assistance of Docent Rolf Santesson, Uppsala. If there are any errors in nomenclature, this is due to my not having used the latter source to its full extent. As far as the nomenclature for mosses is concerned, the reader is referred to Sjögren (1961, p. 9).

Analysis of Sources of Error with Regard to the Botanical Material

IN THE FIELD

No reliable, objective method of selecting the station trees was available, and the final choice was made subjectively. It is difficult to judge whether any species or combination of species has throughout been favoured or disregarded as a result of this. The bulk of the material, however, seems to form a representative collection.

Although the station trees were investigated very carefully in the field, in certain cases some species were not discovered until the material was processed in the workroom. Abundant materials were brought from every station, but there is nevertheless reason to fear that species have been occasionally overlooked in the work of collection. It is impossible to estimate their number or which species might have been overlooked. However, it seems more likely that this has happened to lichens of the *Bacidia* and *Arthopyrenia* type rather than to species of, say, *Parmelia.* It also seems certain that such species were rare on the stations. The risk that any species may have been overlooked is probably rather smaller in the case of stations with few species than it is for stations with an abundance of different species. This source of error, although a minor one, affects the number of species as an indication of, for instance, regions of air pollution. This fact is one of the reasons why the number of species per station is not directly used for mapping (p. 27).

A comparison between the stock of species now reported and the epiphytic species in the card index of the Swedish Museum of Natural History for the same area shows that the species dealt with here constitute approximately 50% of the latter. If an examination is made of the species that are missing, it will be found that in many cases they represent old discoveries that have not been found again. Moreover, the total material is not narrowly restricted to occurrences on selected trees, mainly roadside trees and park trees, as is that of the present investigation, which has not had the purpose of searching for rarer species. Discoveries within forested areas and the like often appear in the material of the Museum of Natural History, where moreover other phorophytes are to be found, e.g. *Corylus avellana, Prunus spinosa, Juniperus communis. Populus tremula,* which usually supports a rich and varied epiphyte vegetation, is also considerably commoner as a phorophyte than in the present material. There are thus grounds for supposing that the great difference in the number of species is only partly due to the fact that some species are no longer found in the area. On the other hand, about ten species that are new to the area have been noted (see pp. 31 ff.).

At the analysed lichen-stations, not only the lichen flora has been noted but also the occurrence of mosses, algae and fungi. The stations have been chosen with respect to the lichen flora, not to the whole of the epiphyte flora, and this means that occurrences of mosses and algae have perhaps been rarer on the station trees than on neighbouring trees. As far as the occurrence of algae is concerned, the aerophytic algae show according to Lehtsaar (1963) a maximum in the autumn and spring, while they are at a minimum in the summer. The field work for this investigation was mainly carried out in the summer.

The 3-grade scale for the abundance of the species on the stations is subjective and rough. It can hardly be doubted that some species, especially usually rare crustose lichens, may have been wrongly classified, but the scale is usable nevertheless, provided that no excessively far-reaching conclusions are drawn when the information is used.

AT THE WORK-TABLE

The abundant material obtained included some species represented by extremely few specimens. Some of them even had empty fruiting bodies or were sterile. There are thus grounds for fearing that the collected material also includes species that were overlooked, despite the fact that the work of determination was carried on with the greatest possible care and took up a great deal of time. It is also realistic to expect that a few species may have been wrongly determined because some individuals were deformed or untypical, or for other reasons. This would probably have happened mainly in the case of rarely-found species. The extent of such cases is difficult to estimate, but it is certainly limited.

Although I have endeavoured to name as many as possible of the species present in the samples collected, there was a residue of sterile or stunted individuals which have been classified as indeterminable.

Table 2. *Epiphyte lichen species noted in the card index of the Museum of Natural History but not found by the present author.*

Alectoria nidulifera
Alectoria sarmentosa
Allarthonia patellulata
Arthonia didyma
Arthonia dispersa
Arthonia impolita
Arthonia punctiformis
Arthonia radiata
Bacidia albescens
Bacidia arceutina
Bacidia circumspecta
Bacidia incompta
Bacidia intermissa
Bacidia inundata
Bacidia melaena
Bacidia Nitschkeana
Bacidia populorum
Bacidia subincompta
Bacidia vermifera
Biatorella campestris
Buellia Schaereri
Buellia Zahlbruckneri
Calicium abietinum
Calicium adspersum
Calicium lenticulare
Calicium quercinum
Calicium salicinum
Caloplaca cerinella
Caloplaca ferruginea
Caloplaca phlogina
Caloplaca pyracea
Candelariella reflexa
Catillaria atropurpurea
Catillaria elachista
Cetraria juniperina
Cetraria sepincola
Chaenotheca aeruginosa
Chaenotheca chlorella
Chaenotheca chrysocephala
Chaenotheca trichialis
Coniocybe furfuracea
Coniocybe nivea
Coniocybe inquinans
Didymella fallax
Didymella Persoonii
Didymella punctiformis
Evernia divaricata
Graphis scripta
Gyalecta ulmi
Lecanactis abietina
Lecanactis Dilleniana
Lecania cyrtella
Lecania dimera
Lecania syringea
Lecanora cadubriae
Lecanora distans
Lecanora intumescens
Lecanora leptyrodes
Lecanora obscurella
Lecanora pallida
Lecanora pinastri
Lecanora rugosella
Lecanora subintricata
Lecanora varia
Lecidea anthracophila
Lecidea botryosa
Lecidea flexuosa
Lecidea Nylanderi
Lecidea pullata
Lecidea symmictella
Lecidea turgidula
Lecidea vernalis
Lepraria latebrarum
Leptogium saturninum
Leptogium teretiusculum
Leptorhaphis epidermidis
Lobaria pulmonaria
Lobaria scrobiculata
Mycoblastus sanguinarius
Mycocalicium subtile
Nephroma resupinatum
Opegrapha abscondita
Opegrapha diaphora
Opegrapha herpetica
Opegrapha pulicaris
Opegrapha rimalis
Opegrapha vulgata
Opegrapha zonata
Parmelia olivacea
Parmelia tiliacea
Parmeliella corallinoides
Phlyctis agalaea
Physcia ciliata
Porina carpinea
Pyrenula farrea
Ramalina obtusata
Rinodina archaea
Rinodina colobina
Rinodina laevigata
Rinodina milvina
Rinodina pyrina
Rinodina sophodes
Usnea comosa
Usnea dasypoga
Usnea hirtella
Usnea plicata
Usnea scabrata

In some cases it has been possible to state the genus or group only. This is true for example of sparsely occurring species belonging to the *Lecanora subfusca* group. The *Usnea* genus shows in the investigated area such an extensive change in morphology that no determination of species has been made. However, in certain cases *Usnea hirta* was so well developed that it could be determined. It has been impossible in certain cases to determine the species of *Cladonia* phyllocladia, and this is equally true of small thalli of *Ramalina,* mainly on *Quercus robur*. A few sterile species have had to be laid aside as unknown.

The Investigated Area and Its Limits

SITUATION AND LIMITS

Stockholm, the capital of Sweden, is built on both sides of the outlet of Lake Mälaren into the Baltic Sea. The city's centre may be said to be at approximately 59°20′ north latitude and 18°4′ east longitude. It also forms the central point for the area actually concerned in the present investigation. This is an almost square area bearing north and south and with a side of rather more than 30 km (see Fig. 1).

The city boundaries of Stockholm comprise a very irregular area. The following suburban towns are included wholly or partly in the district of investigation: Nacka, Lidingö, Solna, Sundbyberg, Djursholm and Vaxholm. Several boroughs (*köpingar*) are also concerned: Stocksund, Sollentuna, Danderyd, Täby and Saltsjöbaden. There are also a number of larger or smaller communities including Handen, Huddinge, Jakobsberg, Kallhäll, Tullinge, Tyresö and Vendelsö. The distribution and extent of the built-up areas can be ascertained from Fig. 1.

When the investigation was first planned, no delimitation of the investigation area was made. It was decided instead that the central parts of the built-up area in the Greater Stockholm region would be the centre of the investigation area and that this would extend so far out that it would not be possible to trace any influence from the urban environment in the most outlying parts as far as the composition and vitality of the lichen vegetation were concerned. The area thus finally became considerably larger than had been originally expected, and it is still somewhat on the small side to meet the requirements aimed at.

PHYSICAL CONDITIONS

The physical conditions of the Stockholm region have been studied by a large number of researchers, and there is a voluminous literature on the subject. It would, however, exceed the object of the present study to discuss them more extensively. The geology of the area is dealt with by De Geer (1932), Sundius (1948), and by Möller and Stålhös (1964, 1965). The investigated area falls entirely within the geological maps included in de Geer's and Sundius' works. The bedrock of the Stockholm region consists overwhelmingly of gneiss rocks and granites. It is largely covered by loose earth strata in the form of moraine, eskers, glacial and post-glacial clays, and rarely sand. The Stockholm esker extends in a north-north-western to south-south-eastern direction through the central parts of the area. Observatoriekullen ("Observatory Hill") is at the highest point, 42 metres above sea level, of the Stockholm esker (Sernander 1926, p. 49). The Stockholm meteorological station is there. The investigated area is characterized topographically by a peneplain broken by fissures and faults. (See Sundius 1948, p. 12.) Along some of the fault lines, a not inconsiderable vertical movement has resulted in an obliquity of the different bedrock blocks. South Mälarstrand ascends noticeably above the area north of it, and south of Södermalm the ground rises markedly again. It then rises again still farther south.

The highest sections of the investigated area are in the southern part. Masmoberget at Huddinge, for example, has a height of 93.77 m. In the General Plan for Stockholm (1952) Fromm points out the difference in topography between the area north of the Mälaren–Saltsjön waterway and south of it (Södertörn). While Södertörn is typified by narrow, deep depressions and large coherent rock plateaux, approaching a height of 80–90 metres, south Uppland and the Mälaren islands are characterized by large open plains covered by loose earth strata. At their highest, the rock knobs rise to 70 metres. This is also clearly shown by the geological maps. The General Plan (p. 67) also shows two north-south profiles through central Stockholm.

The topography of the Stockholm region has been studied by Laurell and Hedenstierna (1938) among others. The map referred to covers a considerable part of the central and western parts of the investigated area.

Stockholm's climate has been studied by, among others, Bergsten (1930), Ångström (1952, 1958) and Modén and Nyberg (1965). A treatment of certain parts of the climate of Stockholm follows on pp. 64 ff.

As regards flora and fauna in general, only parts of the former will be dealt with here. Sernander (1926, pp. 25 ff.) has given a description of Stockholm's phytogeographical and botanical natural features. (See also Sernander *et al.* 1935.) The Stockholm Botanical Society has published two works on the plant life of the Stockholm region: "Stockholmstraktens växter" (1914 and 1937) and "Stockholms-

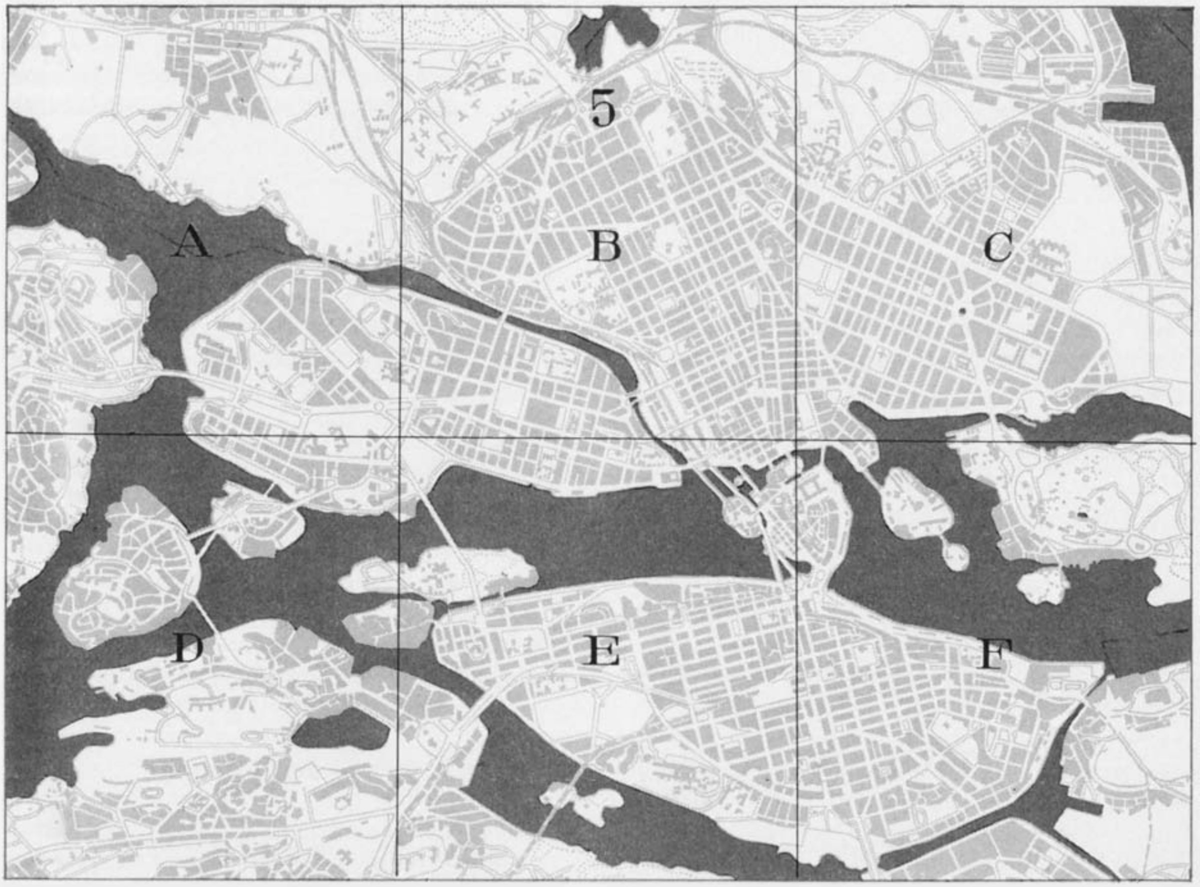


Fig. 1 b. Boundaries and partitioning of the investigated area.

traktens bladmossor" (von Krusenstjerna 1964). Apart from the floras included in these works there is a copious botanical literature dating from later years. Only the kinds of trees concerned with the present work will be dealt with here. On p. 9 there is a list of the kinds of trees whose bark forms a substrate for the lichens mentioned below.

Acer platanoides (Fig. 80) appears sparsely to fairly commonly throughout the area (Almquist and Asplund 1937).

Acer pseudoplatanus (Fig. 80) has run wild in the area but occurs as planted mainly in the inner city area (same work).

Aesculus hippocastanum (Fig. 85) occurs in the same way. According to Sernander (1926, p. 115) none of Stockholm's horse-chestnut trees is older than from the 18th century.

Alnus glutinosa (Fig. 87) is common to very common throughout the area (Almquist and Asplund 1937).

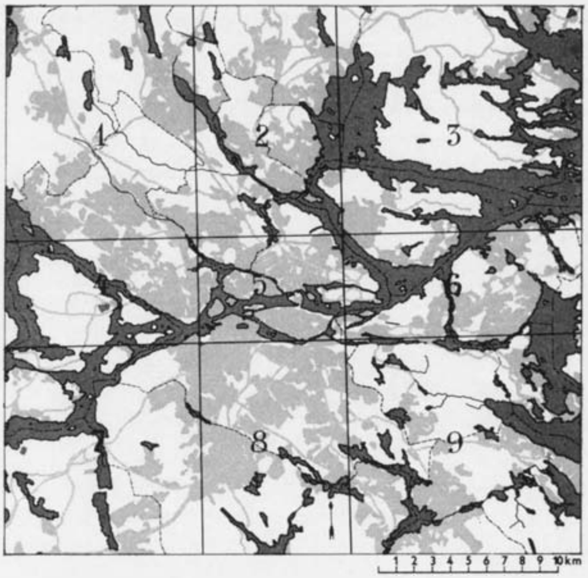


Fig. 1 a. Boundaries and partitioning of the investigated area.

Betula pubescens (Fig. 86) is described as rare in the investigated area, i.e. the Stockholm area and the adjacent parts of the other areas. (Same work.)

Betula verrucosa (Fig. 86), on the other hand, is very common in the wild, but less so as a park tree in the city. Of the 8 birches investigated, all except one (station 127 Grimsta) are *B. verrucosa.*

Trägårdh (1925, p. 190) considers it not improbable that the birch in Stockholm is more susceptible to attack by the scolytid sapwood borers than in the natural landscape as its powers of resistance are lowered because of "coal smoke".

Sernander (1926, p. 114) believes that the ash was one of the 17th century's most popular avenue-trees. *Fraxinus excelsior* (Fig. 84) is described in "Stockholmstraktens växter" as scarce and in certain cases rare in the investigated area. In some cases it has run wild. In the more central parts of the investigated area, however, it is more seldom encountered than in the periphery. The reason for this is not known, but it hardly seems probable that *F. excelsior* would find it more difficult to thrive in an urban environment than other park trees.

Picea abies (Fig. 86) is common, except inside the built-up urban areas. Sernander (1926, p. 123) regards the spruce as the problem child of the Stockholm plantations. According to him, sulphurous acid and soot will sooner or later destroy all the city's spruces. He goes so far (p. 161) as to speak of a zone lethal to the spruce, a "kampzon" and a normal zone, analogously to his previously suggested division for the lichens into a lichen desert, a "kampzon" and a normal zone. The spruces of the Stockholm region also suffer greatly from rot, says Sernander. He says nothing, however, about the extent to which this may be a consequence of the formerly mentioned causes.

Pinus silvestris (Fig. 86) is also common in the investigated area. Sernander (1926, p. 121) points out that the pine as a roadside tree was formerly much commoner. He also mentions (p. 161) that the pine was surprisingly resistant to smoke damage, especially as compared with the spruce. Trägårdh (1925) draws attention to the fact that the pine is often attacked by the lesser pine-shoot beetle (*Myelophilus minor*). According to Trägårdh, the latter accompanied the consignments of wood which formerly arrived in the city. Similar phenomena can be observed around the wood-pulp mills along the coast of Norrland (see for example Moberg 1966, p. 56). Whether air pollution has an effect by reducing vitality has not been investigated, but seems not unlikely. Lundström (1966, p. 85) has observed that pine bark of the type which forms large shields flakes off more easily from pines in the central parts of the investigated area than in its periphery. Beschel (1958, p. 83) draws attention to the significance of bark desquamation, and notes that trees whose bark flakes off easily soon lose the whole of their bark epiphytes, the more the nearer they are to the centre of the city. The limit of distribution will then be reached when the growth of the lichens is insufficient in relation to the bark desquamation.

The sensitivity of conifers—especially of the spruce—to air pollution should be borne in mind when the location of major heating-plants is to be decided. On the subject of the reactions of alien conifers to smoke gases, see Wille (1917, pp. 161–174).

The following *Populus* species (Fig. 87) are included in the investigation: *P. alba, P. nigra* v. *italica, P. tremula* and *P. balsamifera.* Of these, only *P. tremula* is included in the floras of the Stockholm region, and is described as common in the area dealt with by the investigation (except in densely built-up areas). Other *Populus* species are planted. Sernander (p. 117) points out that poplars have always been favourite park trees and avenue trees because of their rapid growth and their robustness. Poplars also seem to tolerate air pollution better than many other deciduous trees, and their large crowns may help to separate dust and other solid particles from the air.

Quercus robur (Fig. 83) is described by Almquist and Asplund (1937, p. 268) as common to fairly common, most frequent in the neighbourhood of the coast and of Lake Mälaren. In Täby, etc., it is said to be few in numbers. It is confirmed by my observations that the oak is considerably more common south of Lake Mälaren and on the Mälaren islands than it is north of the city. Sernander (p. 75) believes that most of the oaks in the Stockholm region are wild, exceptions being the so-called "king's oaks".

The species in the *Salix* genus are in many cases impure in the investigation area, and I have therefore not differentiated at all between species. The trees and shrubs in the Stockholm region include 15 different species and hybrids, among them *S. caprea, S. aurita, S. cinerea* and *S. repens.* However, they are not included in the present material, but only species of the type represented by *S. fragilis, S. alba* and *S. pentandra.* Among the cultivated forms occur *S. alba* × *fragilis, S. alba* × *pentandra,* and *S. alba* × *fragilis* × *pentandra.* Sernander (p. 115) draws attention to the prevalence of *S. fragilis* in Långholmsviken and Pålsundet. The weeping willow, *S. babylonica,* is also found in churchyards and in Kungsträdgården Park (stations 1 and 2).

Tilia (Fig. 81) is represented as a wild tree by *T.*

cordata, which according to "Stockholmstraktens växter" occurs here and there in the investigated area. Sernander (p. 94) points out that limes have been planted on a large scale as avenue and park trees ever since the 17th century, but that almost all of them have been park limes, *T. vulgaris* (= *T. cordata* × *platyphylla*). The first park limes were imported according to Sernander (p. 96) from Holland. He also mentions that a tree or two in Kungsträdgården Park, several avenue-trees at Drottningholm Palace—whose baroque gardens began to be laid out in 1681 (Wollin 1926–1927)—and at Ulriksdal date from the 17th century. Several of the limes around Karlberg and Ulriksdal, however, were originally grown at the Krusenberg estate south of Uppsala in the early 1700s. The *Tilia* included in the present investigation are probably mostly *T. vulgaris*.

Ulmus (Fig. 82) is a common tree in Stockholm's parks. Most of the elms in this investigation are probably *Ulmus glabra*. *Ulmus glabra* is mentioned in "Stockholmstraktens växter" as a sparsely spontaneously occurring tree, growing wild in the Stockholm area, at least near Lake Mälaren and Saltsjön. As a tree that has run wild, however, its occurrence is fairly common. Sernander (p. 109) points out that the elm preceded the lime as an avenue and garden tree, and that it played an important part in Stockholm's parks during the 17th century and the beginning of the 18th. See also Lindquist 1932, pp. 32–33, and Claeson 1923.

URBANIZATION

Stockholm was founded in the first half of the 13th century and soon became the most important trading city in central Sweden. It did not receive the formal status of a capital city until 1634, though in reality it had been the capital of Sweden for centuries. For a long time, the "city between the bridges" (the present "Old Town" of Stockholm) was the actual heart of the city. Building on the "malmer", the suburbs adjoining the Old Town, was disorderly and scattered. Not until the 17th century did Stockholm lose its fortress-like appearance (Söderlund 1930). Hedenstierna (1938) studied old maps of Stockholm which show the great changes in the city scene after the year 1640. During the about eighty years of Sweden's epoch as a great power, the population of the city was quadrupled. After this rapid development Stockholm grew comparatively slowly. The population in 1750 was 53,500. It did not reach 100,000 until a hundred years later. At that time large areas in the "malmer" had still not been built on (Fig. 2). Building development in the outskirts of the city was of a suburban character until the middle of the 1870s, and it was still permitted to build low wooden houses there. The development was still nearly exclusively inside the old "toll-gates" (Norrtull, etc.) marking the outward extension of the "malmer".

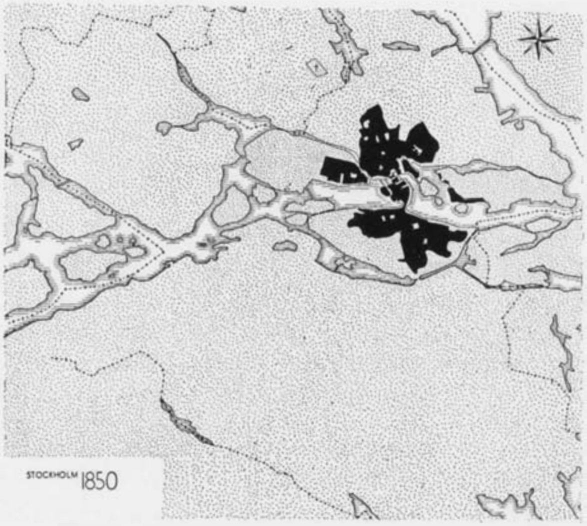


Fig. 2. Stockholm in 1850.

The South Station was opened for railway traffic in 1860. The North Station began to be used six years later. The Central Station was opened in 1871, and in 1877 the first horse-drawn tramcars began to run. They were electrified in 1904.

The present great development of Stockholm commenced in the 1870s. It was then that the city began to change from an idyllic provincial town into an industrial city with brick-built houses and a closely packed population. Söderlund (1930) points out that suburbs in the proper sense are a comparatively late phenomenon and were made possible only by the improvement in communications. Not long after the arrival of the railway, the first suburb, Sundbyberg on the Stockholm–Västerås railway line, began to be built. This took place at the end of the 1870s. Industrialization and consequent shortage of housing accommodation compelled this development. Sundbyberg became a borough in 1883 and a town in 1927. Djursholm began to be laid out in the final years of the 1880s. In 1890 the community obtained a railway of its own. Djursholm became a borough in 1901 and a town in 1914. Until our time it has retained its character as a "garden city". Saltsjöbaden was founded as a bathing resort in 1891, and the Saltsjö railway was completed in 1893. At that time Nacka was still for the most part undeveloped country.

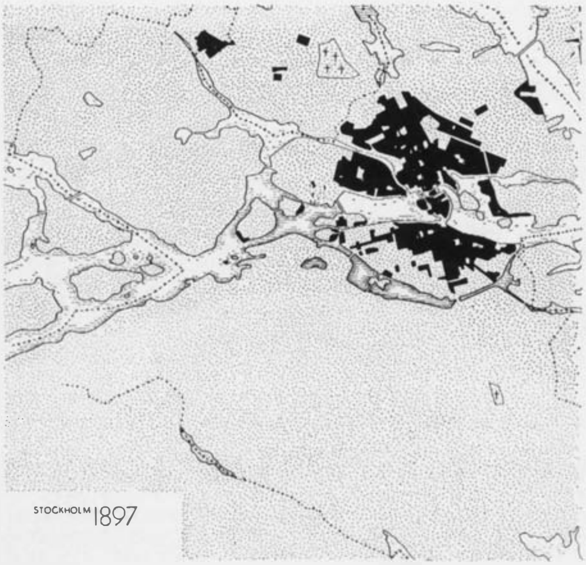


Fig. 3. Stockholm in 1897.

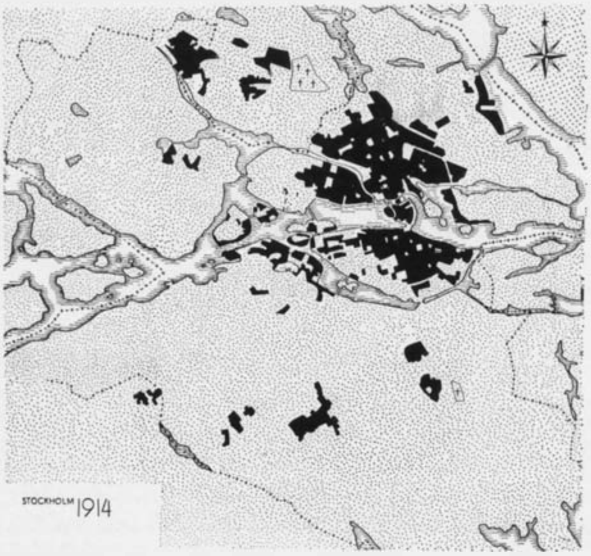


Fig. 4. Stockholm in 1914.

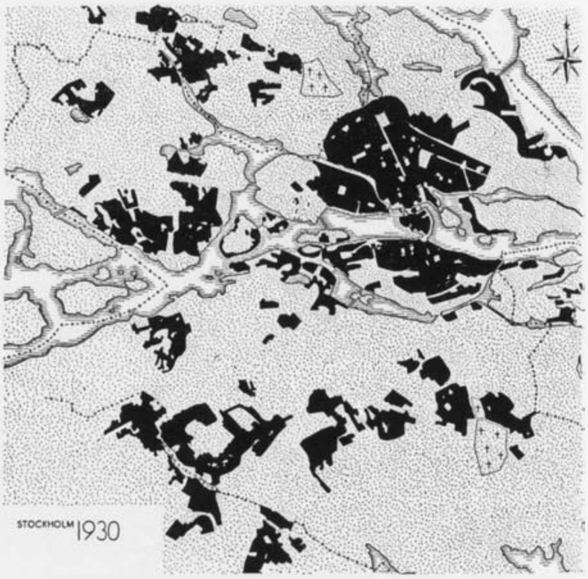


Fig. 5. Stockholm in 1930.

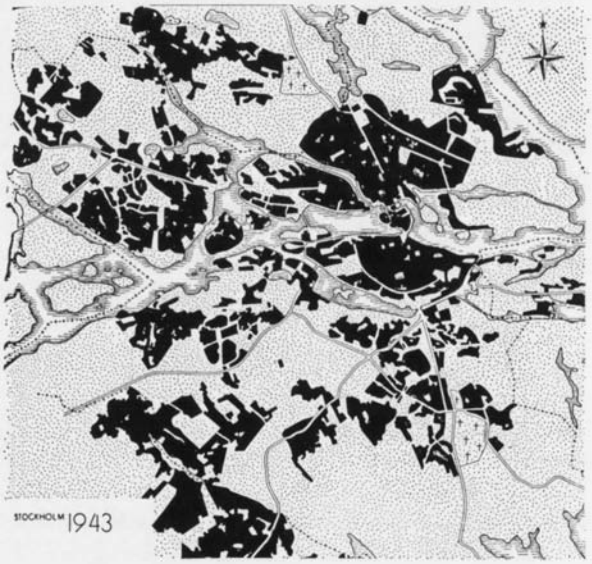


Fig. 6. Stockholm in 1943.

At the end of the 1880s (Fig. 3) Stockholm was still so compact that one had left it as soon as one had passed the toll-gates, and there was still quite a well-defined boundary between the built-up area and the country. At that time, Lidingö was a purely rural area. The community which gradually arose there became a borough in 1910 and a town in 1926. A permanent bridge connection had been opened the year before. Building development beyond the former toll-gates occurred at separate points along the railway lines because of the relatively long distances between the stations. Thus for example a series of communities soon arose along the Saltsjö railway between Stockholm and Saltsjöbaden. Some industrial enterprises also made their way in that direction, but the commune of Nacka did not become a town until 1949.

Along the Västerås railway, which was opened in 1871, other communities began to develop in addition to Sundbyberg. In the parish of Solna, a few suburbs of Stockholm were laid out along the route of this railway (Fig. 3). The railway to Uppsala, which was completed in 1866, was an important factor for the building of new suburbs around 1890.

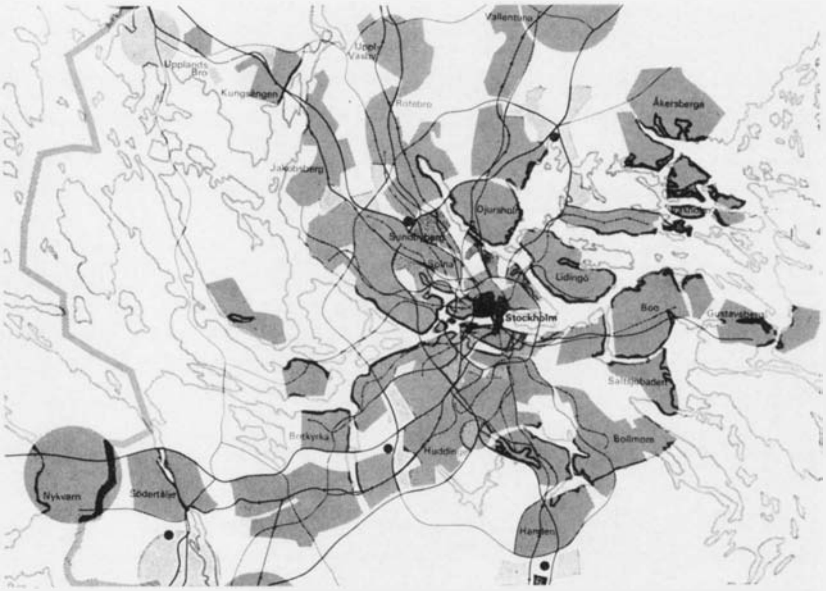


Fig. 7. Stockholm in the year 2000. (The regional plan for the Stockholm area 1966.)

However, development began in real earnest only after the building of the tramway line from Stockholm to Sundbyberg. Solna commune became a town in 1943.

Stockholm has continued to grow throughout the 1900s, mainly as the result of the development of suburbs and neighbouring communities (see Fig. 4). Building began at Äppelviken and Alvik in the parish of Bromma in 1913 (Figs. 4–5). When the supply of available sites began to become exhausted new building began at Brännkyrka and Enskede south of the city (Figs. 5–6). The municipal community of Huddinge was founded in 1923. As the result of its amalgamation with Stuvsta and other districts, Huddinge became in 1947 Sweden's most populous municipal community. Söderlund (1930, p. 306) describes Greater Stockholm as a typical modern city with a central "downtown" area, connected built-up districts and suburbs, with a tendency—originally determined by the railway network—to acquire a star-shaped form, modified by the new communities which, thanks to the tramway lines and new roads, had sprung up between the star's rays. Solna is an example of the latter development.

Since the end of the Second World War, building development has continued at accelerated speed both

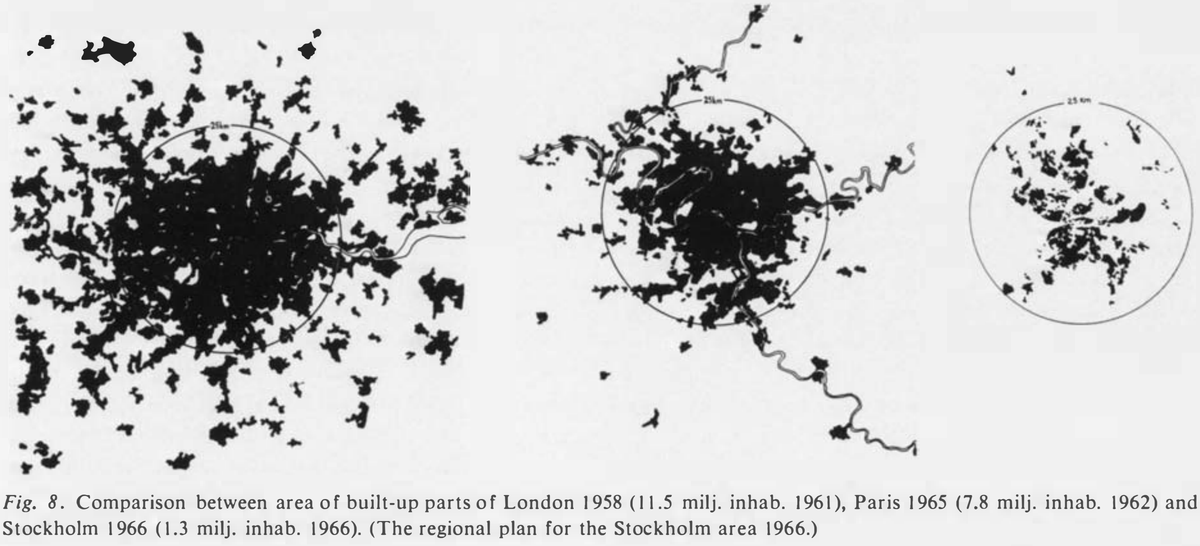


Fig. 8. Comparison between area of built-up parts of London 1958 (11.5 milj. inhab. 1961), Paris 1965 (7.8 milj. inhab. 1962) and Stockholm 1966 (1.3 milj. inhab. 1966). (The regional plan for the Stockholm area 1966.)

Fig. 9. Gustaf O. Malme (1864–1937).

in Stockholm itself and in the neighbouring towns (Fig. 6). By 1940, rather more than 130,000 Stockholmers were living outside the city toll-gates; by 1950 the number had risen to over 300,000. Although at the same time the inner city has been increasingly emptied of apartment houses in favour of office buildings and similar structures, there has been an influx of people to the Greater Stockholm area as a whole. Apart from the housing problems that this has involved, it has led to an enormous increase in traffic. Many of the main roads out of the city are still of proportions that are suitable only for the traffic intensity of the 1920s and 1930s, and this of course brings about traffic queues during rush-hours. It goes without saying that the city planning authorities expect a continued rapid development of the Greater Stockholm area. Fig. 7 shows how Stockholm and its surroundings are envisaged in the year 2000. Three things in particular should be borne in mind when the urbanization of the Stockholm area is under consideration. The first is that the development of the region began as late as at the end of the 1870s. The second is that unusually large and numerous patches of nearly unspoilt rural country and even forests still occur inside the urban area. The third is that Stockholm, considered from an international point of view, is still a small city. A comparison with London and Paris shows this (Fig. 8).

Botanical Examination of the Investigated Area

INTRODUCTION

A brief history of the botanical investigation in the Stockholm region is to be found in Almquist and Asplund (1937, p. xxii ff.). The description appears to be largely based on Andersson and Birger (1914). Von Krusenstjerna (1964, pp. 22 ff.) deals with bryological investigation of the Stockholm region. It is also evident from these works what is meant by "the Stockholm region" in a botanical context.

Nearly all Sweden's lichenologists have worked for longer or shorter periods in the area that is now under consideration. In spite of this, surprisingly little has been published about the lichen flora there. This is probably due primarily to the fact that the more central parts of the Stockholm area have been much less attractive to botanists than for example the Stockholm Archipelago.

As Torsten E. Hasselrot, of the Museum of Natural History in Stockholm, is engaged in the preparation of a work to be called "Stockholmstraktens lavflora" ("The Lichen Flora of the Stockholm Region") and a more detailed presentation of the investigation of the area is naturally appropriate in such a context, it is my intention to describe the investigation of the now examined area's epiphytic lichen flora only in some rough outlines.

THE PERIOD BEFORE 1900

There is little available literature on the lichen flora of the surroundings of Stockholm before the year 1900. The oldest work seems to be Lundequist's flora from Brännkyrka, printed in Uppsala in 1827. In the mid-19th century, Knut Fredrik Thedenius (1814–1894) was the leading collector and author. He published two important works (1852 and 1859) on the lichen vegetation and flora of the Stockholm region. Information regarding occurrences of lichen in the Stockholm region was also published by Nylander (1853) and Björnström (1853) and Theodor Magnus Fries, inter alia in *Lichenographia scandinavica* (1871, 1874). Wittrock and Juel (1891) mention some occurrences of lichens in the Bergian Botanical Gardens.

Among other collectors who have been active in the investigated area that is now under consideration and who have left evidence of their work in this period at the lichen herbarium of the Museum of Natural History or the herbarium at Uppsala, we may mention C. F. Nyman (in the 1830s), G. L. Sjögren (in the 1840s), P. T. Cleve (in the 1850s), S. E. Henschen, E. H. Dahlgren, H. Thedenius (in the 1860s), S. Almquist, E. B. Almquist, K. F. Dusén (in the 1870s), H. Kugelberg (in the 1880s), H. Hamberg, G. Schotte, H. Hesselman, L. Romell, O. Lindblom (in the 1890s).

THE FIRST DECADES OF THE 1900s

The leading personality in the investigation of the Stockholm region's lichen flora in the beginning of the 1900s was Gustav O. Malme (1864–1937). He collected a great deal of material from Boo, but also made botanical excursions in other parts of the area. Malme published some of his discoveries (in 1907, 1909, 1910 *a, b,* 1912, 1916 *a, b,* 1924, 1926, 1927 and 1931, etc.). During the years 1897–1926 he published a large work of exsiccatae entitled "Lichenes suecici exsiccati" which included lichens from the Stockholm region.

During this period, many collectors were at work in the area now investigated, including H. and G. E. Du Rietz, R. Florin, A. Hülphers, G. Lundqvist, F. Ridderstolpe, G. A. Ringselle, G. Täckholm, T. Vesterholm.

The importance of Malme for Swedish lichenology became very great. His exsiccatae were of enduring value, and so was his role as a teacher. One of his pupils was Gustav Einar Du Rietz.

It seems primarily to have been the peripheral parts of the area now in question, as well as the Stockholm Archipelago, which attracted the botanists. Du Rietz for example published (in 1914) a report on lichens collected during an excursion to the Archipelago, and in the following year in article on the lichen flora of Huvudskär. A couple of other works (1921, 1925) also mention lichens from the Stockholm region. However, he never published a report on his collections in his home district, Bromma.

THE 1930s AND 1940s

In 1934, the Norwegian botanist Ove Arbo Høeg published a short article on Stockholm's epiphytic flora. G. Degelius collected during this period a good many samples of lichens in the surroundings of Stockholm. He was particularly interested by the coniferous forest region in the Archipelago, and he published several articles on that subject (1942, 1943, 1948, etc.). A. H. Magnusson mentioned occurrences in the Stockholm region in several articles (1942, 1944, 1947).

Among those who contributed specimens from the investigated area to the lichen herbarium in the Museum of Natural History during this period were S. Ahlner, R. Santesson, Greta Sernander-Du Rietz, A. Silfversparre and M. Östman.

Fig. 10. Torsten E. Hasselrot.

THE 1950s AND 1960s

The most important investigator of the Stockholm region's lichen flora during the last few decades is Torsten E. Hasselrot. No one else has assembled such a comprehensive material. He has apparently visited the whole of the area regarded as the Stockholm region in a botanical context. He has also revised the older herbarium material and carefully examined the existing literature on lichens and sought local information from the Stockholm region.

In 1950 J. W. Håkansson published an article on fruticose and foliose lichens in Lidingö. Without the help of Hasselrot this work would never have come into existence. S. Ahlner (1966) published a species list on lichens found on Sickla Udde. In addition to Ahlner, Degelius, Santesson and Greta Sernander-Du Rietz, S. W. Sundell may also be mentioned among those who during this period contributed with examples and notices from the investigated area. An investigation on conifers by Lundström (1966) is mentioned elsewhere.

II. COMPOSITION AND DISTRIBUTION OF THE EPIPHYTE FLORA

General

The collected data are reported both in tabular form (Tables VI–XIV) and in the form of distribution maps and commentaries. If the number of occurrences of a particular species has been small, the report is given in the form of a list of the stations at which the species has been observed. Conditions at the various stations are reported in Tables I–V.

The data are reported with one table for each kind of tree. In the tables, the stations are arranged primarily according to the number of species, but in some cases the combination of species has been taken into consideration.

To make an attempt at any kind of phytosociological research in an area with such smooth transitions from almost lichen-free stations to those with a normally developed lichen flora, seemed so hazardous that I have refrained from it. However, the two federations *Physodion* and *Xanthorion* (see p. 86). are present although mostly in a fragmentary state. In the strongly affected parts of the investigated area there appears a synanthropic vegetation—admittedly consisting of only a few species but nevertheless clearly discernible—composed of species that are not sensitive to the factors keeping most of the other species away. *Lecanora conizaeoides,* usually strongly sorediose, is a characteristic species in this plant community (cf. for example Barkman 1958, pp. 363 ff.). Laundon (1956, p. 92, 1967, p. 291) distinguishes a *Conizaeoidion* federation.

In Tables I–V, the lichen-free stations are also included. The distribution of these stations is shown on Fig. 11 and Figs. 80–87.

Presentation of the Investigation Stations

EXPLANATION OF AND REMARKS ON THE CODE

In order to be able to present the habitat conditions at the different stations in tabular form (Tables I–V) I have tried to translate the field annotations into a code in which different phenomena are expressed in numbers. This has been possible because the field annotations have been made as a general rule in accordance with a previously determined pattern. It has been possible to analyse the divergences which do occur and to place them in more or less their correct positions in the system.

The following abbreviations for different kinds of trees are used in the table: A = *Acer platanoides,* A.p. = *Acer pseudoplatanus,* Ae = *Aesculus hippocastanum,* Al = *Alnus glutinosa,* B = *Betula verrucosa* and *pubescens,* F = *Fraxinus excelsior,* Pa = *Picea,* Pi = *Pinus,* Po = *Populus,* Q = *Quercus robur,* S = *Salix,* T = *Tilia,* U = *Ulmus.*

The following factors have been noted:

I. *Age of phorophyte*

		%
Very young tree	1	0.15
Young tree	2	0.30
Middle-aged tree	3–4	33.38
Younger middle-aged	3	
Older middle-aged	4	
Fairly advanced age	5	30.06
Advanced age	6	31.42
Very advanced age	7	4.68

Constant efforts were made to obtain, as far as possible, trees of the same age so that stations would be mutually comparable to the greatest possible extent. The percentile distribution with respect to the ages of the stations is shown in the above table, from which it is evident that about 95% are in the age groups 3–6. This may be estimated to mean that the trees are between 40–50 years and 100–130 years.

II. *Appearance of crown*

± high	1	± low	2
± dense	1	± sparse	2
± wide	1	± narrow	2

Obviously this is a very rough evaluation, but it is fully adequate for our purpose. The boundary between "high" and "low" crowns is probably at a crown height of 5–7 metres, depending to some extent on the age of the tree. A trunk that is high, dense

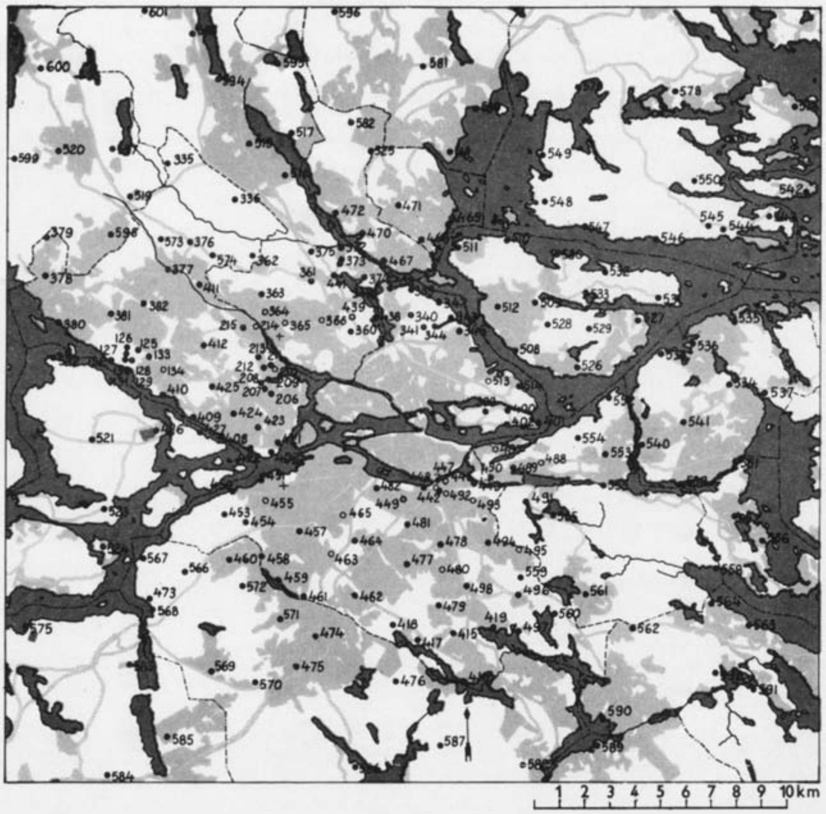


Fig. 11 a. Station map. Black dots = stations with lichens; rings = stations without lichens. Figures = the numbers of the stations.

and wide thus receives the figure combination "111", while a crown that is low, dense and narrow will receive "212". The commonest type of crown is "111" with 53.32 %; next to this, "121" with 23.11 %.

III. *Appearance of trunk*

(*a*) *Growth habit*

Simple ± vertical	0
Divided into two or more	1
Inclined	2

(*b*) *Length of trunk*

< 2½ m	4	4–5 m	1
2½–3 m	3	> 5 m	0
3 –4 m	2		

(*c*) *Appearance of bark*

Undamaged	0	Moderately damaged	2
Slightly damaged	1	Severely damaged	3

The combination "000" thus denotes a tree with a simple, vertical trunk whose crown begins at a height above ground level exceeding 5 metres, and whose bark does not show any visible damage.

Where possible, simple vertical trunks have been chosen (86.71 %). Similarly, trees with undamaged bark have been preferred to those with bark damage, provided that they have otherwise been comparable. Severe bark damage (3) occurs on 0.30 % of all station trees. The commonest trunk height (28.25 %) is 2 $^1/_2$–3 metres. In 41.09 %, the trunk is shorter than 3 metres, and 70.22 % of these have wide crowns. The length of the trunk as well as the width of the crown are of some importance for example where the light factor is concerned: the higher the trunk is, the less affected are its lower parts by shadowing, etc., from the crown.

IV. *Exposure*

(*a*) *Place of growth*

Isolated trees	0
Trees in rows or avenues	1
Trees in borders of parks, skirting woods or in similar positions	2
Trees in thinly wooded parks, copses or the like	3
Trees in densely wooded parks, copses or the like	4

(*b*) *Distance to nearest tree, building wall or the like*

< 2 m	9	6–7 m	4
2–3 m	8	7–8 m	3
3–4 m	7	8–9 m	2
4–5 m	6	9–10 m	1
5–6 m	5	> 10 m	0

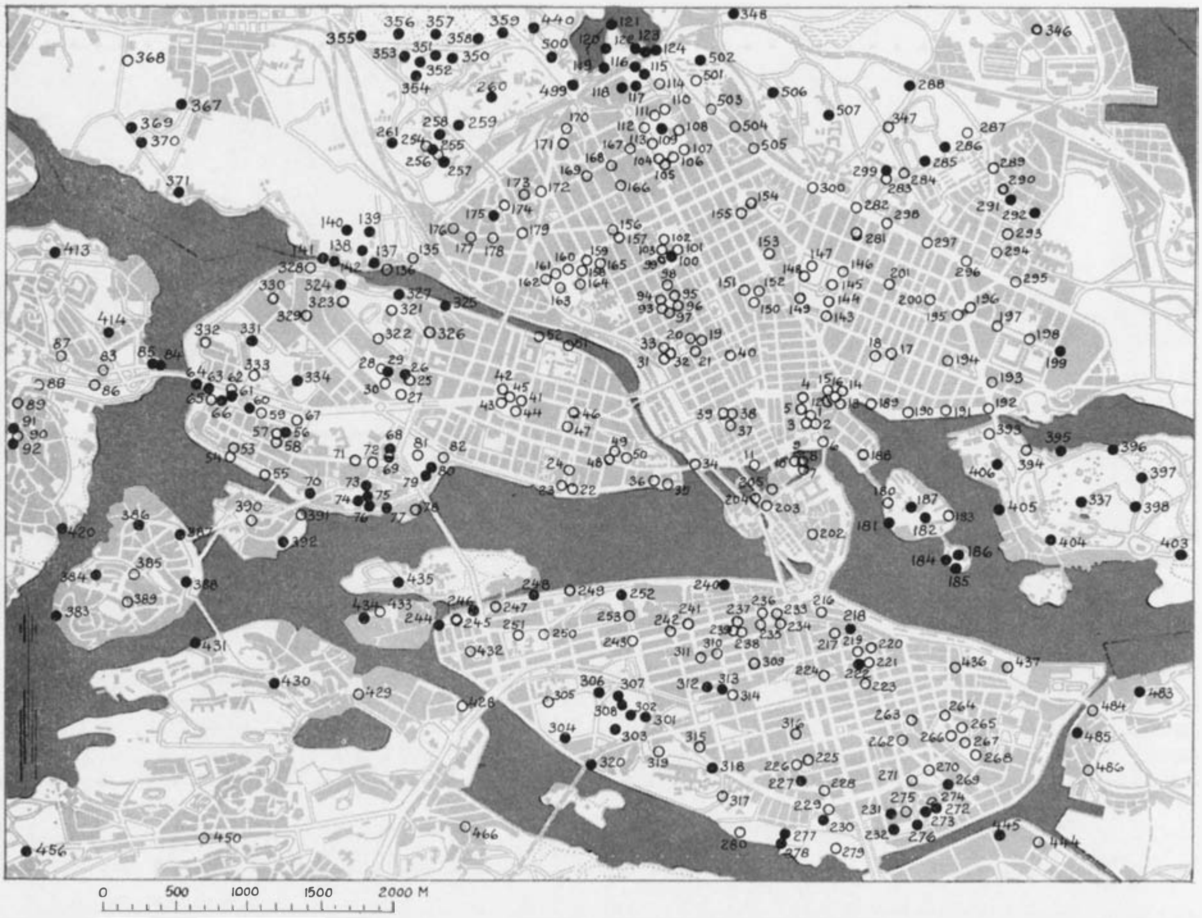


Fig. 11 b. Station map. Black dots = stations with lichens; ring = stations without lichens. Figures = the numbers of the stations.

(c) *Distance to nearest bush*

< ½ m	9	4–5 m	4
½–1 m	8	5–6 m	3
1–2 m	7	6–7 m	2
2–3 m	6	7–8 m	1
3–4 m	5	> 8 m	0

The distance to the nearest tree, bush etc. has been estimated. The code is constructed so that the lower the figures are, the greater is the exposure referred to. A tree receiving the combination "000" is thus isolated, with no other tree within a distance of 10 metres from it. The nearest bush is at a greater distance than 8 metres. The combination "499", however, is a station tree in a densely wooded park or the like, with less than 2 metres to the nearest tree and $^1/_2$ a metre to the nearest bush. According to the tables, 6 % of the station trees can be described as very strongly exposed, 21 % as strongly exposed, 55 % as moderately exposed, 14 % as slightly exposed and 5 % as protected. It is very difficult to obtain a correct expression for the degree of exposure. Nor is it certain, moreover, that the conditions for the trunk's epiphytes are equivalent because the trees are equally exposed. The appearance of the crown and its height above ground level affect, as has already been pointed out, the exposure of the trunk. This factor is not taken into account in this specification.

V. *Vegetation cover*

No vegetation = 0 %	0
Scanty vegetation = 20 %	1
Rather scanty to abundant vegetation = 20 %–80 %	2
Very abundant vegetation = 80 %	3

This refers to lichen vegetation only. The degree of cover has been subjectively estimated without any attempt to make measurements. The figure "3" refers to very rich stations, "1" to poor stations. "2" thus describes stations with relatively good to fairly abundant lichen vegetation. "Normal stations" often have "2". See Figs. 11 and 88.

SUBDIVISION OF THE INVESTIGATED AREA

The numbers of the stations give no indication of their whereabouts; rather of the order in which they have been investigated. To give a survey of the investigated area, this has therefore been divided into 9 subareas (Fig. 1). This subdivision was made on the map after conclusion of the field work. Square 5 contains a total of 386, while the other squares have an average of 27.6 stations. Square 5 has therefore been further subdivided into 6 subsquares numbered from A to F (Fig. 1 *b*). Even after this subdivision, the subsquares contain in most cases twice as many stations as the other squares. Most stations—112—are in square 5 B; least—21—in square 6.

An advantage of this system of subdivision is that it is possible for the reader to locate the different stations even if he is entirely without knowledge of the local conditions.

In the tabular specification of the natural conditions etc. at the various stations, which will be found on pp. I–V, the data are thus arranged by areas.

Distribution of Particular Species in the Investigated Area

COMMENTARY ON THE DISTRIBUTION PATTERN

As the tables (VI–XIV) show, there are great differences in the number and composition of species between the parts of the investigated area lying in its periphery, and those parts that are more centrally placed. It can also be seen from the tables that it is often the same combination of species which independently of substrate is to be found penetrating most deeply into the area. There is thus a transitional zone (Sernander's "kampzon") between the lichen-free area in the centre of the investigated area (Sernander's "lichen desert") and the more or less unaffected outer part of the area. (See Sernander 1926, pp. 161 ff.)

Different ways have been tried of determining a zoning system around the lichen-free area. The material can for example be grouped according to the number of species per station. I have made such a classification of my material, i.e. presented in the paper by von Ubisch and Nilsson (1966, Fig. 57) and by Skye (1967, p. 5).

The area can also be divided according to the distribution of certain species, which would then rank as indicator species. In this case, the extent of the various zones would then be affected to quite a considerable degree by a number of irrelevant factors such as, for example, the competition between different species; in fact, by all other factors influencing the details of the distribution pattern of each species. In my view it is therefore more profitable to classify the material with respect to the combination of species. The following classification can be made on the basis of the mapped species of lichens:

(1) Species penetrating far in towards the centre of the investigated area:

(A) Species usually occurring most abundantly in a ring around the heart of the city and then declining in frequency towards the outlying districts, as far as the material presented here is concerned. Belonging to this group are *Lecanora conizaeoides, Bacidia chlorococca, Hypogymnia physodes, Lecidea scalaris* and *Lepraria incana.*

(B) Species that do not show such a maximum frequency but occur abundantly also in the peripheral parts of the area. Among these are *Cetraria chlorophylla* and *Parmelia sulcata.* Some of the species mentioned under (A), especially *Hypogymnia physodes,* would also appear in this category if all kinds of trees were proportionately represented (cf. Lundström's results quoted above).

(2) Species penetrating only moderately deeply into the investigated area:

(A) Species not occurring, or occurring only rarely, on the trees examined in the outskirts of the investigated area (cf. 1 A above). The following can be included in this group: *Cladonia coniocraea, Cetraria glauca, C. pinastri, Calicium hyperellum, Parmeliopsis ambigua* and *Physcia dubia.*

(B) Species also occurring in the edges of the area (cf. 1 B above). For species in this group, the distribution pattern not infrequently shows two lichen-free areas: one covering the central parts of Stockholm and of Nacka, and one covering Solna–Sundbyberg. In this category are *Alectoria jubata, Buellia punctata, Candelariella xanthostigma, Evernia prunastri, Lecanora subfuscata, L. expallens, Ochrolechia androgyna, Parmelia fuliginosa, Pertusaria amara, Phlyctis argena, Physcia entheroxantha, Ph. orbicularis, Ph. tenella, Xanthoria fallax* and *X. parietina.* In this group are also *Hypnum cupressiforme* and *Pylaisia polyantha* as well as *Hysterium pulicare.* On the borders of 1 B above are *Lecanora subfuscata, L. expallens* and *Ochrolechia androgyna.*

All the species mentioned under (A) above would be in this category if all kinds of trees had been considered.

(3) Species occurring primarily in the periphery of the investigated area:

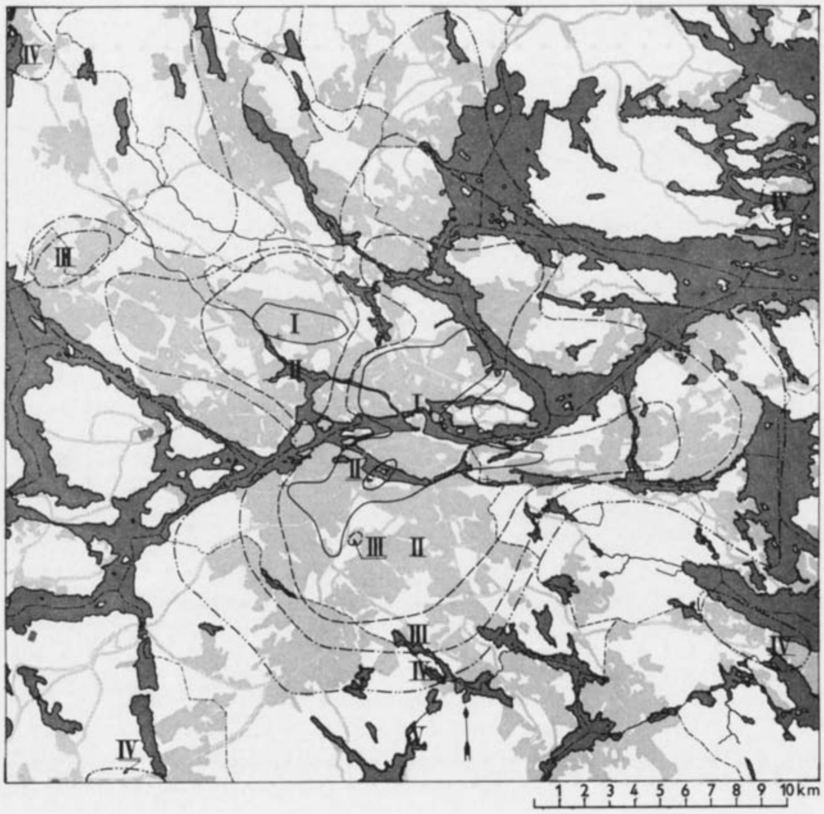


Fig. 12. Zonal subdivision (II–IV) between lichen-free zones (I) and normal zone (V) in the Stockholm area.

The following species belong to this group: *Anaptychia ciliaris, Bacidia luteola, Lecanora chlarotera, L. carpinea, Lecidea olivacea, Ochrolechia microstictoides, Parmelia exasperatula, P. subargentifera, Pertusaria coccodes* v. *coccodes, P. globulifera* v. *discoidea, Physcia ascendens, Ph. farrea, Ph. pulverulenta, Ramalina farinacea, R. fraxinea* and *Xanthoria polycarpa.* Of these species, *Bacidia luteola* and *Ramalina fraxinea* seem to have the smallest area. They belong perhaps to a group 4, species outside the transitional zone (*Ramalina,* however, occurs farther into the transitional zone in the form of indeterminable remnants). *Leucodon sciuroides* also belongs to this group. On the border towards 2 B above are *Ochrolechia microstictoides* and *Pertusaria coccodes* v. *coccodes.*

The species that appear so sparsely in the investigated area that they have not been mapped here have also been assigned to some of the above-mentioned groups.

Fig. 12 above gives an idea of the geographical extent of the various zones. With the aid of this classification the investigated area can be subdivided in the following way with respect to the epiphyte flora and primarily to the lichens:

(I) Lichen-free or almost entirely lichen-free area including the city centres of Stockholm, Solna, Sundbyberg and Nacka. As far as epiphyte vegetation is concerned, the lichen-free area is characterized by the fact that the trees are quite free from epiphytes or show growths of algae. Here and there, however, *Lecanora conizaeoides* appears sparsely. Small islands of *Hypogymnia physodes* may also occur. (At a few stations, other species from group 1 also appear.)

(II) Inner part of the transitional zone, containing a more or less wide belt around the lichen-free area. It is typical of this zone with regard to epiphyte vegetation that the few species which occur here (point 1 above) occasionally appear fairly abundantly.

(III) The central part of the transitional zone, comprising parts of the southernmost suburbs of Stockholm, parts of Nacka, Lidingö and Djursholm, and finally the western suburbs of Stockholm. The species found in the last-mentioned zone appear here together with the species listed under point 2. The lichen vegetation is still scarce, but occasionally a particular species may appear in some numbers.

(IV) The outer part of the transitional zone extends in a belt, a kilometre or so wide, surrounding the last-mentioned zone. Distinctive of this zone as

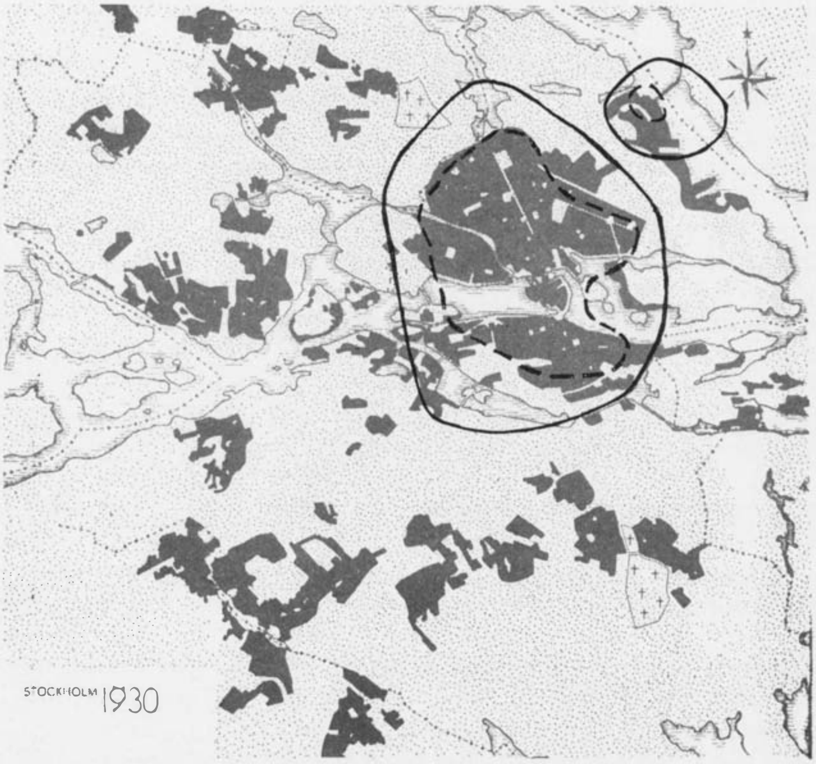


Fig. 13. Sernander's (1926) and Høeg's (1934) subdivision into lichen desert (lavöken), struggle zone (kampzon) and normal zone in Stockholm area. (Constructed by Erik Skye.)

far as epiphyte vegetation is concerned is the addition of species listed under point 3 above. However, several of the species belonging to groups 1 A and 2 A begin to disappear or to appear more and more rarely on the examined trees.

(V) An area with normal or almost normal lichen vegetation. This area covers the outskirts of the map picture. Distinctive features of the epiphyte vegetation are that inter alia *Bacidia luteola* and determinable specimens of *Ramalina fraxinea* occur to a normal extent and that such species as *Bacidia chlorococca, Cetraria pinastri, Cladonia coniocraea, Lecanora conizaeoides, Lecidea scalaris, Lepraria incana* and *Parmeliopsis ambigua* disappear more or less entirely from the deciduous trees that normally support *Xanthorion* vegetation. Moreover, several of the species included in groups 2 B and 3 become common or abundant only outside the outer transitional zone. This applies to such species as *Alectoria jubata, Anaptychia ciliaris, Calicium hyperellum, Lecanora subfuscata, Pertusaria coccodes* v. *coccodes, P. globulifera* v. *globulifera, Phlyctis argena, Physcia ascendens, Ph. farrea, Ph. orbicularis, Ramalina farinacea, Xanthoria fallax* and *X. parietina.* Around Kallhäll, Vaxholm, Tyresö and Tumba there are exclaves of areas which show more or less strongly affected epiphyte vegetation; in certain cases they have the same character as the outer part of the transitional zone, and in some few cases the lichen vegetation seems to have been even more affected.

Sernander's (1926) division into "lichen desert", "struggle zone" and "normal zone" has been accepted by many researchers, including Haugsjå (1930), Høeg (1934) and Vareschi (1936).

Sernander (1926, p. 161) stated that in the "kampzon" ("struggle zone") "the trunks begin to be covered by lichens, exclusively nitrophytic but only up to a *riklig* degree of cover" (i.e. $^{1}/_{2}$ of surface). The lichens of the present equivalent zone, now far more distant from the city centre (e.g. the "normalzon" started already on Kungsholmen) are certainly not nitrophytic to any appreciable extent (discussed on p. 83).

Høeg's (1934) "kampzon" in Stockholm was still very narrow. The normal zone also started immediately outside the built-up area.

Haugsjå has interesting information regarding the species penetrating most deeply into the lichen desert. He states, for example (p. 78), that *Lecanora Hageni* is found almost everywhere in Oslo and that it is therefore impossible to determine any inner boundary for the distribution of this species. He writes: "*Lecanora Hageni* ist diejenige Flechte, die ich am häufigsten innerhalb der Stadtgrenze gefunden habe. An vielen Stellen scheint die Flechte gut zu gedeihen, oft viele gut entwickelte Apothecien, aber der Thallus ist häufig mit Chlorophyceae bedeckt." The description agrees well with the way in which *Lecanora conizaeoides* appears in Stockholm. Most of Haugsjå's *L. Hageni* from Oslo might be *L. conizaeoides.* The present author has thanks to prof. Eilif Dahl been able to see part of Haugsjå's material. This however, was neither *L. Hageni* nor *L. conizaeoides.* Among other species which tolerate the city air, the following are notable according to Haugsjå: *Parmelia physodes* (= *Hypogymnia physodes*), *P. exasperatula, P. sulcata* and *Physcia tribacea* (= *Ph. dubia*). The latter species was very common. "Nur *Lecanora Hageni* habe ich auf mehreren Stellen angetroffen" (l.c., p. 87). Among the species that have strongly reacted negatively to the effect of the urban environment are *Evernia prunastri, Parmelia aspidota* (= *P. exasperata*), *P. scortea* (= *P. tiliacea*), *P. subaurifera* and *Ramalina fraxinea.*

Vaarna (1934) divides the "Kampfzone" in Helsinki into two zones, namely the "stunted foliose lichen zone" and the "stunted fruticose lichen zone". The inner boundary for *Evernia prunastri* forms the boundary between these two zones. *Phlyctis argena* penetrates almost up to the border of the lichen desert. Other species which penetrate far into the "Kampfzone" are *Parmelia physodes* (= *Hypogymnia physodes*), *Physcia tribacea* (= *Ph. dubia*) and *Xanthoria parietina.*

There seem to be strong resemblances but also some differences in the material from the three Scandinavian capitals Oslo, Stockholm and Helsinki. In all cases, for example, *Hypogymnia physodes* and *Physcia dubia* penetrate far towards the lichen-free area. In Helsinki and Oslo *Lecanora conizaeoides* is absent. *Xanthoria parietina* penetrates more deeply into Helsinki than into the two other cities, etc.

When comparing the results of Sernander's and Høeg's investigations in Stockholm with this we must bear in mind the changes that have occurred since the 1930's.

Profound changes since the 1930's:

1. Horse traffic has disappeared almost completely, even from rural areas.
2. Motor traffic has increased enormously.
3. Gravel roads are treated with salts (calcium chloride) or sulphite liquor to decrease dust-raising.
4. Permanent surfaces have been laid on major roads.
5. New roads have been built, also chiefly with permanent surfaces. On an average, though not always, less dust is raised from roads than formerly. The dust is different, too:

(*a*) Droplets of dirty and oily water are raised in wet weather, while dry dust has become insignificant except along narrow roads that still have a dirt surface.

(*b*) Chemical composition of road dust has changed —less nitrogen compounds, more soot and oil, traces of Pb from petrol etc. In certain cases, remnants of salts or sulphite liquor.

6. The railways were electrified between 1926 and 1947 (—the Nynäs Railway in 1962).

On an average, agricultural dust has probably also been reduced, but it remains a positive factor for some lichens. Reasons: Less fallow land. Weeds are controlled by chemicals rather than by working the soil. Shorter periods of working bare arable soil (harrowing etc.). Fertilizers are spread by machine, no longer by hand. However, the extensive spraying of fields, roadsides and gardens with insecticides, herbicides and fungicides may possibly affect nearby epiphytic vegetation.

Despite these changes, one has a general even if not well-documented impression that the composition of roadside epiphytic vegetation has changed remarkably little in areas with heavy traffic but situated away from densely-populated areas or smoke-creating industry. This complicated problem deserves a more specialized study, however.

Beschel (1958, pp. 13 ff.) differentiates between five zones in the Austrian cities, including Innsbruck and Salzburg, that he has investigated. In zone I (the "Normalzone") "oxyphile Vereine" are dominant. Among these he includes (l.c., pp. 49 ff.) *Usneion barbatae* and *Parmelion physodes.* In zone II (the "äussere Kampfzone") the "oxyphile Vereine" are not always so clearly dominant. "Allerdings werden sie bereits von einigen neutrophilen Arten begleitet." The "neutrophile Vereine" have their optimal development in zone III (the "mittlere Kampfzone"). "Arten der Zone I finden sich nur mehr untergeordnet als Beimengungen." Beschel (p. 51) includes *Xanthorion parietinae* among the bark neutrophytes. Zone IV (the "innere Kampfzone") "enthält nur mehr immer stärker verarmende neutrophile Vereine auf Laubholzrinde, Holz und Kalk, während Nadelholzrinde und Silikat kaum mehr besiedelt werden". Zone V is almost lichen-free territory (a "Flechtenwüste im Sinne Vareschis"). Entirely lichen-free areas are absent.

Bortenschlager and Schmidt (1963) have a similar classification and obtain the same subdivisions of vegetation in Linz as Beschel (1958) obtained from other Austrian cities.

However, the present author has not observed anything similar in the Stockholm area. The differences are dealt with further on p. 83. His classification seems to agree more closely with the zonation that Barkman (1963) describes from Belgium. While the present author does not make a distinction between any plant communities but draws the boundary according to the distribution of different combinations of species, Barkman considers (p. 44) that "The epiphytic vegetation is a clear indicator of the degree of air pollution. In this respect it is an even better standard than the epiphytic flora."

Domrös (1966) divides the transitional zone in the Ruhr region into three parts according to the lichen vegetation. However, he pays chief attention to the degree of cover. Unfortunately he does not publish his primary material, and it is therefore impossible to make any comparisons.

List of Species

LICHENS

The following list of all the collected epiphytic lichen species includes a very brief autecological survey with information regarding the distribution of the species, their choice of substrate, etc.

A large number of lichen species in this material have a southern distribution. Almborn (1948) divides the southern lichen species in Scandinavia into five groups according to their distribution. Two of these are concerned in this connection. The *Umbilicaria pustulata* group contains species whose northern limit can extend to approximately 65° north latitude. This group is called the *U. pustulata* group in the list below. The other group is called by Almborn the *Parmelia acetabulum* group. It contains species which extend in Scandinavia from the west and south coast of Norway obliquely up through Sweden to the coast about 200 km north of Stockholm. This group is called the *P. acetabulum* group below.

For the species which are not mapped, all occurrences from the investigated area are mentioned. Only the generic name of the phorophyte is stated. The number of the station is given after the name of the phorophyte.

The distribution group in the investigated area to which the species belongs is also stated. It has been possible to distinguish a group 4, which contains species that are found only in the "normal area" (see p. 25).

Under the heading "Older occurrences" there is a list of those of the occurrences and records noted in the Stockholm region which are of the greatest interest for this investigation and which have been collected and listed by Dr. T. Hasselrot, at the botanical department of the Museum of Natural History in Stockholm, throughout many years. He has kindly made the whole of his great material available to me and has thus made it possible to obtain a historical perspective over occurrences of lichens in the investigated area.

The report is given with the genera in alphabetical order without regard to family or ecological grouping. The species within each genus then follow in alphabetical order. The same system is used for mosses (p. 58) and fungi (p. 62).

Alectoria Ach.

A. implexa (Hoffm.) Nyl.

The species belongs to the *U. pustulata* group. Magnusson (1929) mentions *A. implexa* as a common conifer-lichen.

Older occurrences: Thedenius (1852, p. 163, and 1859, p. 112) described the species as fairly common in the Stockholm region. Degelius found *A. implexa* at Bromma, Ålsten 1926 on *Picea*. Håkanson (1950, p. 226) noted it at scattered localities in Lidingö.

Occurrences in the investigated area:

Huddinge: Snättringe, *Quercus*, 571; Sollentuna: Tureberg, *Acer*, 515, sparse; Stockholm: Skarpnäck, Flaten, *Quercus*, 560; Västerled, Nockebyhov, *Acer*, 409, sparse; Ålsten, *Quercus*, 423, sparse; Tyresö: Kumla, *Tilia*, 590, sparse; Österåker: Bullerhöjden, *Betula*, 577 *b*, sparse; Resarö, Ytterstrand, *Betula*, 576 *b*, sparse.

The species probably belongs to group 2 B. Its distribution in the wooded parts of the investigated area is probably considerably more extensive than this limited material suggests.

A. jubata (L.) Ach.

Presumably found throughout Sweden. Magnusson (1929, p. 100) describes it as very common on trees, especially

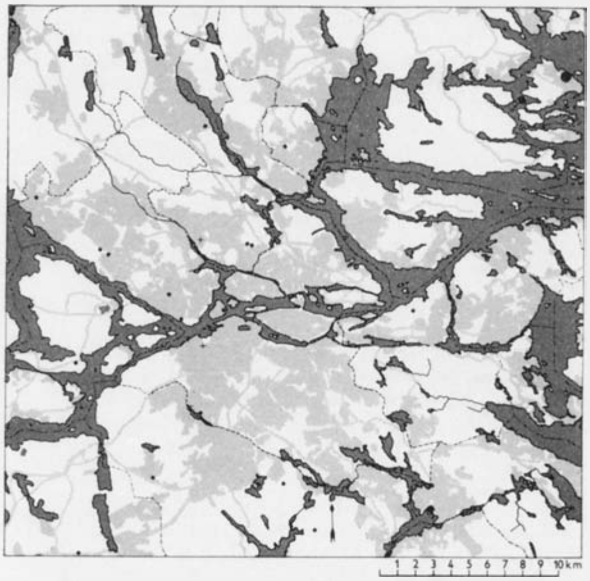


Fig. 14. Alectoria jubata.

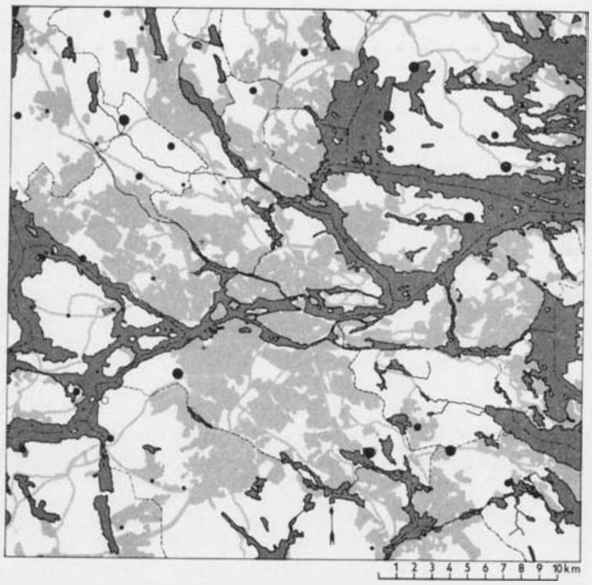


Fig. 15. Anaptychia ciliaris. Not vital specimens = circles.

conifers. Considerably more common in the wooded sections of the periphery of the investigated area than the map picture indicates.

Older occurrences: Thedenius describes the species as common in the Stockholm region (1852, p. 163; 1859, p. 112). Solna: Nytomta, *Betula,* 1906 (Täckholm); Northern Cemetery, *Tilia,* (Høeg 1934, p. 132); Stockholm: Bromma, Traneberg 1910 (Du Rietz); Bergian Botanical Gardens (Wittrock and Juel 1891, p. 1).

A. jubata belongs to group 2 B (Fig. 14).

Alectoria sp.

Lidingö: Koltorp, *Quercus,* 528, sparse.

Anaptychia Kbr.

A. ciliaris (L.) Kbr.

The species belongs to the *U. pustulata* group. Magnusson (1929, p. 116) describes it as common in southern and central Sweden on the trunks of deciduous trees in open positions, on roadsides, etc.

Older occurrences: Thedenius describes *A. ciliaris* as common in the Stockholm region (1852, p. 165; 1859, p. 114). Håkanson (1950, p. 229) says from Lidingö that *A. ciliaris* is frequently remarkably sparse and badly developed and that it obviously avoids the most densely built-up areas. Cleve gathered *A. ciliaris* at Solna: Haga Park 1855; Hesselman found it there in 1891 and Täckholm in 1906. Occurrences were noted at Ulriksdal by Täckholm 1906, Östman 1922 and Hasselrot 1958. It was found at Överjärva in 1910 (Hülphers), at Bergshamra in 1958 (Hasselrot). Høeg (1934, p. 132) notes *A. ciliaris* at the Northern Cemetery on *Tilia.* The following occurrences have been noted in Stockholm: Bromma, Alvik 1911 (Du Rietz); Djurgården, *Populus tremula,* 1854, 1886 and other years (Thedenius), 1861 (Henschen), 1871 (Dusén), 1910 (Hülphers); Enskede, Pungpinan 1910 (Hülphers). Lundqvist gathered the species at the latter locality in 1911.

A. ciliaris belongs to group 3. Fig. 15.

The species seems to have declined during the present century.

Arthonia Ach.

A. radiata (Pers.) Ach.

The species belongs to the *U. pustulata* group. It prefers deciduous trees to conifers. Older occurrences: Thedenius describes the species as fairly common in the Stockholm region (1852, p. 172, and 1859, p. 118). Håkanson found *A. radiata* in 1924 in Lidingö: Stockby, and E. Almquist gathered it at Stockholm: Brännkyrka in 1872.

Occurrences in the investigated area: Järfälla: Henningstorp, *Fraxinus,* 599, sparse; Säby Gård, *Tilia,* 597; Österåker: Östra Ryd, Bogesund, *Fraxinus,* 546; Rydboholm, *Fraxinus,* 579, sparse. All finds are in the "normal area".

Arthopyrenia Mass.

Arthopyrenia alba (Schrad.) Zahlbr. Syn. *A. gemmata* (Ach.) Mass.

The species belongs to the *P. acetabulum* group. Usually found on deciduous trees, especially *Quercus, Fagus* and *Tilia,* isolated and in copses (Keissler 1938, p. 165; Erichsen 1957, p. 33). Its ecology seems to be similar in the south of Sweden.

Older occurrences: Thedenius (1859, p. 9) mentions it as occurring in Kungsholmen, Marieberg (1852, p. 174, and 1859, p. 36). Lindberg found the species on a *Tilia* outside the building with the address 9, Garvaregatan, Kungsholmen, Stockholm, year ?. Cleve gathered *A. alba* in 1859 at Djurgården.

Present occurrences in the investigated area:

Boo: Ormingelandet, *Fraxinus,* 535, sparse; Danderyd: *Acer,* 472, sparse; Stockholm: Hägersten, Vårberg, *Fraxinus,* 567, sparse; Spånga, Järvafältet, *Fraxinus,* 335, sparse; Tyresö: Raksta, *Fraxinus,* 591, sparse; Österåker: Östra Ryd, Bogesund, Broknäs, *Ulmus,* 550; Röskär, *Fraxinus,* 549, sparse.

The species belongs to group 3.

The species is not now found at any of the older places, and an obvious decline can therefore be noted.

A. biformis (Borr.) Mass.

Found in southern and central Sweden (Santesson 1949, p. 142). Prefers the bark of deciduous trees, primarily *Quercus, Populus* and *Fraxinus* (Keissler 1938, p. 172). Otherwise it has the same habitat requirements as the preceding species.

Older occurrences: Thedenius (1852, p. 174) mention the species as occurring in Solna: Karlberg. Thedenius (1859, p. 119) describes it as rare in the Stockholm region.

One occurrence in the investigated area: Lidingö: Elfvik, *Fraxinus,* 531, sparse.

A. fallax (Nyl.) Arn. Syn. *Didymella fallax* (Nyl.) Vain.

Keissler (1938, p. 133) states that the fungal component occasionally lives symbiotically, occasionally parasitically. *A. fallax* prefers the smooth bark of various kinds of trees, but avoids conifers (Keissler, l.c.).

Older occurrences: Rare in the Stockholm region, Thedenius (1852, p. 174; 1859, p. 119). Nacka: *Betula,* Thedenius (1852, p. 174, s.n. *Verrucaria epidermidis fallax*); Nackabergen, *Betula,* Thedenius (1852, p. 178), by Nacka bridge, The-

Fig. 16 b. Bacidia chlorococca.

denius (1859, p. 56, according to a reference on p. 119, s.n. *Verrucaria epidermidis fallax).*

One occurrence in the investigated area: Sollentuna: Överby, *Fraxinus,* 601, sparse.

A. sphaeroides (Wallr.) Zahlbr.

A. sphaeroides belongs to the *P. acetabulum* group. It appears to prefer deciduous trees (Keissler 1938, p. 169).

Older occurrences: Malme found the species at Boo: Lövberga on *Sambucus* (1915); Rensätra (1910); Rensätra–Lövberga (1909); Stockholm: Brännkyrka, Liljeholmen (1889).

Present occurrences, all on *Fraxinus*: Järfälla: Henningstorp, 599; Sollentuna: Sollentuna Churchyard, 593, sparse; Stockholm: Spånga, Järvafältet, 376, sparse.

The species probably belongs to group 3 and seems to have declined during the present century.

Bacidia Zahlbr.

B. Beckhausii Krb.

A deciduous-tree species. Ubiquitous in Sweden, but is believed to become rarer towards the north.

Older occurrences: Only Malme seems to have gathered it in the investigated area—at Boo: Hamndalen (1907); Kum-

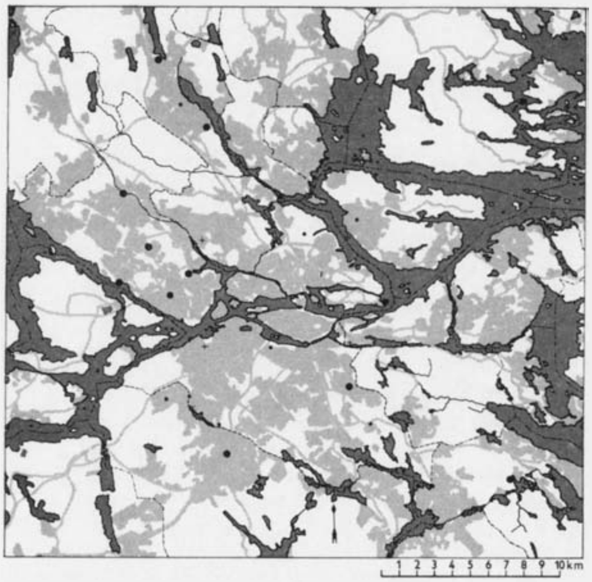


Fig. 16 a. Bacidia chlorococca.

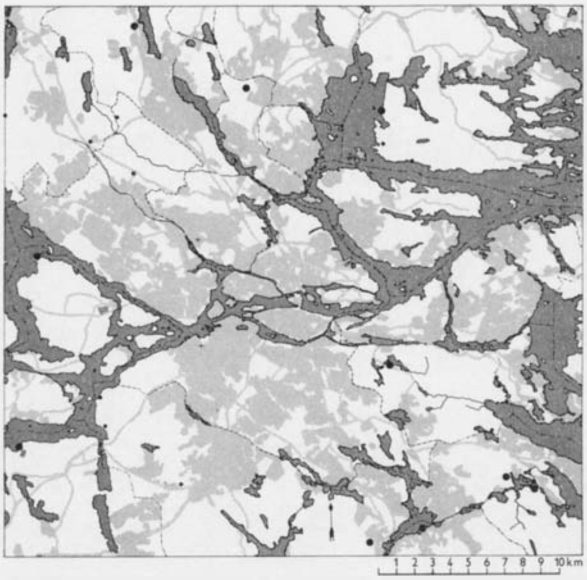


Fig. 17. Bacidia luteola.

melnäs (1906, 1909); Lövberga (1906, 1908, 1909, 1910, 1913); Stockholm: Experimentalfältet (1889) (v. *obscurior*).

Present occurrences: Lidingö: Gåshaga, *Tilia,* 527, sparse; Sollentuna: Häggvik, *Acer,* 594; Stockholm: Spånga, Järvafältet, *Acer,* 573; Tyresö: Tyresö, *Fraxinus,* 563.

The species thus occurs predominantly in the periphery of the investigated area and can probably be allocated to group 3.

The extension of the distribution does not appear to have changed, but the scanty material makes a more precise evaluation impossible.

B. chlorococca (Graewe) Lettau

The species belongs to the *U. pustulata* group. It occurs on conifers as well as on deciduous trees.

A total of 48 occurrences has been noted in this material. Lundström (1966) notifies appearances of the species at a further 3 places. It penetrates relatively deeply into the transitional zone and can be referred to group 1 A. Fig. 16.

Older occurrences: Malme gathered the species in 1910 at Danderyd: Ösby.

The species has either been previously overlooked or it has increased very strongly in the Stockholm region.

B. luteola (Schrad.) Mudd.

The species belongs to the *P. acetabulum* group. A fairly common species on isolated deciduous trees in the south of Sweden.

Older occurrences: Thedenius (1852, p. 169, and 1859, p. 116, s.n. *Biatora luteola*) describes the species as fairly common. Cleve found *B. luteola* in Solna: Karlberg 1857; Thedenius says that it was plentiful in Karlberg Park (1852, p. 169; cf. 1859, p. 33). Malme found it at Järva in 1907. Occurrences were noted in Stockholm by Stenhammar, "prope Holmiam in Fraxino", year ?, by Malme in 1889 in Kungsholmen and in 1897 at Djurgården (Malme 1926, p. 54).

21 occurrences have been noted in the investigated area. The species belongs to group 3 or group 4. Nearly all the occurrences are outside the outer transitional zone. Fig. 17. The species seems to have declined very strikingly and to have entirely disappeared from the areas mentioned above.

B. Naegelii (Hepp.) Zahlbr.

The species belongs to the *U. pustulata* group, and prefers isolated deciduous trees.

Older occurrences: Du Rietz found the species at Bromma, Minneberg 1910, S. Almquist gathered it at Brännkyrka, Lyran 1870. Malme found it at Solna: Järva 1907.

7 occurrences have been noted in the investigated area: Boo: Boo Old Church, *Ulmus,* 551; Ormingelandet, *Acer,* 537, sparse; Stockholm: Sankt Göran, Marieberg, *Fraxinus,* 73, sparse; *Ulmus,* 76, sparse; Spånga, Järvafältet, *Tilia,* 336, sparse; Vaxholm: *Fraxinus,* 542, abundant; Österåker: Östra Ryd, Bogesund, *Ulmus,* 550, sparse.

B. Naegelii penetrates fairly deeply into the central parts of the investigated area and probably belongs to group 2 B.

Biatorella De Not.

B. moriformis (Ach.) Th. Fr.

Apparently ubiquitous in Sweden. Occurs both on conifer bark and lignum. Koskinen (1955, p. 151) describes the species as hemerophilous.

Older occurrences: Du Rietz gathered the species in Stockholm: Bromma, Alvik 1911 on *Pinus.* Th. M. Fries (1874, p. 402) notes it from Graewe.

The following occurrences have been noted: Lidingö: Hersby, *Acer,* 509, sparse; Solna: Northern Cemetery, *Acer,* 357, sparse; Stockholm: Brännkyrka, Örby Slott, *Ulmus,* 464, sparse; Hägersten, *Acer,* 456, sparse; Oscar's, Djurgården, *Acer,* 403, sparse; Spånga, Bromsten, *Ulmus,* 411, sparse; Västerled, Smedslätten, *Ulmus,* 421, sparse.

B. moriformis can probably be assigned to group 2 B in the investigated area, possibly bordering on group 1 B.

The species was probably overlooked formerly, and it is therefore impossible to say whether any changes have occurred in the distribution pattern.

Buellia De Not.

B. alboatra (Hoffm.) Br. et Rostr.

Belongs to the *U. pustulata* group. Prefers stone but is also found on lignum and bark.

Older occurrences: Thedenius describes *Lecidea alboatra* as rare in the Stockholm region (1852, p. 171; 1859, p. 117) while *Lecidea alboatra corticola* is said to have occurred in several places (1852, p. 170) and *Lecidea murina* (*L. alboatra*) to be common (1852, p. 171; 1859, p. 117). Nacka: Danviksbergen, Thedenius (1852, p. 171, s.n. *Lecidea alboatra*); Solna: Karlberg, 1852 (Cleve); Stockholm: Djurgården, Thedenius (1852, p. 170, s.n. *Lecidea alboatra* v. *corticola*).

Two occurrences in the investigated area: Järfälla: Henningstorp, *Fraxinus,* 599; Sollentuna: Sollentuna Churchyard, *Fraxinus,* 593.

The species was clearly commoner in the outskirts of Stockholm a hundred years ago.

B. disciformis (Fr.) Mudd.

Probably ubiquitous in Sweden. It is very rare in northwestern Germany (Erichsen 1957, p. 371). Epiphyte, growing on both conifers and deciduous trees.

Older occurrences: Thedenius (1852, p. 170; 1859, p. 117) describes *B. disciformis* as fairly common on smooth deciduous-tree bark in the Stockholm region. Nylander (1853, p. 97) mentions the species.

The following occurrences have been noted: Lidingö: Koltorp, *Quercus*, 528, sparse; Stockholm: Brännkyrka, Långsjö, *Alnus*, 461, sparse; Spånga, Grimsta, *Quercus*, 129; Tyresö: *Fraxinus*, 563, sparse; Österåker: Östra Ryd, Bogesund, *Ulmus*, 550.

Despite the scanty material, the species can probably be assigned to group 2 B. The species has obviously disappeared from many localities in the surroundings of Stockholm.

B. griseovirens (Turn. et Borr.) Almb. Syn. *Buellia betulina* (Hepp.) Th. Fr.

Belongs to the *U. pustulata* group. The species seems to prefer smooth deciduous-tree bark.

Older occurrences: Both by Malme 1909—at Bo; Hamndalen, and Sollentuna: Tureberg–Järva.

The following occurrences have been noted: Boo: Mensättra, *Quercus*, 541, sparse; Huddinge: Segeltorp, *Quercus*, 572; Lidingö: Norra Sticklinge, *Fraxinus*, 511; Nacka: Erstavik, *Fraxinus*, 558; Hellasgården, *Quercus*, 565, sparse; Saltsjöbaden: *Fraxinus*, 556; Sollentuna: Södersätra, *Quercus*, 595, sparse; Stockholm: Hägersten, Bredäng, *Quercus*, 453, sparse; Skarpnäck, Pungpinan, *Quercus*, 496, sparse.

B. griseovirens belongs to group 2 B.

B. pharcidia (Ach.) Malme

Distribution in Sweden appears to be southern (Malme 1927, p. 257) although Almborn 1948 does not mention the species. Occurrs primarily on the bark of deciduous trees but also on lignum.

Older occurrences: Solna: Karlberg, year unknown (Lindberg), Järva 1910 (Malme); Stockholm, Bromma 1907 (Malme), at many places in the Stockholm region (Malme 1910 *b*, p. 164). Malme also states (1927, p. 257) that *Buellia pharcidia* is commoner around Stockholm than *B. alboatra*.

The following occurrences have been noted: Järfälla: Henningstorp, *Fraxinus*, 599; Lovö: Lovön, Lambarudd, *Fraxinus*, 522, sparse; Sollentuna: Häggvik, *Acer*, 594; Täby: Rönäll, Viggbyholm, *Fraxinus*, 580; Österåker, Östra Ryd, Bogesund, *Fraxinus*, 549, sparse.

The occurrences seem to indicate that *P. pharcidia* belongs to group 3.

The species has disappeared from many localities in the surroundings of Stockholm.

B. punctata (Hoffm.) Mass.

B. punctata seems to belong to the *U. pustulata* group. It appears on older isolated trees, stumps and lignum but also on stone, earth etc. The species belongs to group 2 B in the present material (Fig. 18).

In the Stockholm region generally, on old pines (Thedenius 1852, p. 170, s.n. *Lecidea disciformis* v. *myriocarpa*), fairly common (Thedenius 1859, p. 117, s.n. *Lecidea disciformis myriocarpa*). Older occurrences: Solna: Haga Park, year unknown (Åkerman); Stockholm: Bromma, Minneberg, *Ulmus* 1910 (Du Rietz); Sandvik 1911 (Lundqvist s.n. *B. myriocarpa*); Brännkyrka, Nybohov, *Tilia* and *Ulmus* (Høeg 1934, p. 132, v. *chrolopolia*). Bergielund, 1906 (Malme s.n. *B. myriocarpa*); Djurgården 1852 (herb. C. F. Nyman s.n. *Lecidea chloropolia*); Uggleviken, *Alnus*, 1906 (Täckholm); Roslagstull, *Tilia* (Høeg 1934, p. 132).

The species has withdrawn somewhat during the last halfcentury.

Buellia sp.

Tyresö: *Fraxinus*, 563, sparse.

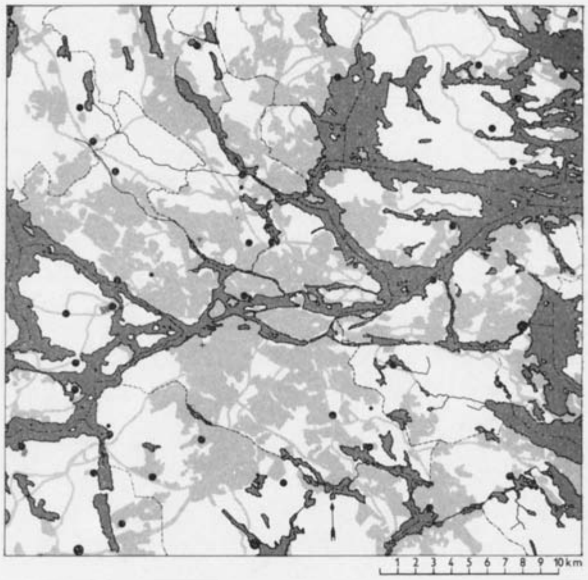


Fig. 18. Buellia punctata.

Calicium Pers.

C. Floerkei Zahlbr. Syn. *Embolidium italicum* Sacc.

Distribution in Scandinavia ubiquitous. Grows on bark and lignum.

Two occurrences have been noted in the investigated area, both in Stockholm: Hägersten, Mälarhöjden, *Quercus*, 452, sparse; Oscar's, Djurgården, *Alnus*, 401, sparse.

No older occurrences have been noted.

C. hyperellum Ach. Syn. *C. viride* Pers.

Distribution from Skåne to Norrland (Santesson 1949, p. 176). Grows primarily on old oaks and spruces in light copses, parks and avenues.

Older occurrences: Solna: Karlberg (Thedenius 1852, p. 172), 1859 (Cleve); Stockholm: Kungsholmen, Marieberg (Thedenius 1852, p. 172; 1859, p. 118). Thedenius says (l.c.) that *C. hyperellum* occurs in several places. *C. viride*, however, is said to have been rare. Nylander (1853, p. 95) says: "Non est nisi varietas hyperelli".

C. hyperellum belongs to group 2 A (Fig. 19).

The species has apparently retreated from the immediate surroundings of Stockholm since the 1850s.

Caloplaca Th. Fr.

C. aurantiaca (Lightf.) Th. Fr.

Assigned to the *U. pustulata* group. Grows both on bark (especially on that of *Populus tremula*) and on stone. *Populus tremula*, however, is almost excluded from the present material.

Older occurrences: Fairly common in the Stockholm region (Thedenius 1852, p. 167; 1859, p. 115). Solna: Överjärva 1910 (Hülphers); Frösundavik, *Populus* 1907 (Täckholm); Stockholm: Bromma, Sandvik, 1911 (Lundqvist); Brännkyrka, Liljeholmen 1897 (Malme); Enskede, Pungpinan, 1910 (Hülphers), 1837 (herb. Swartz); Rörstrands Hage, 1841 (Westberg).

11 occurrences were noted, all on *Fraxinus* except the two otherwise indicated. The following occurrences have been

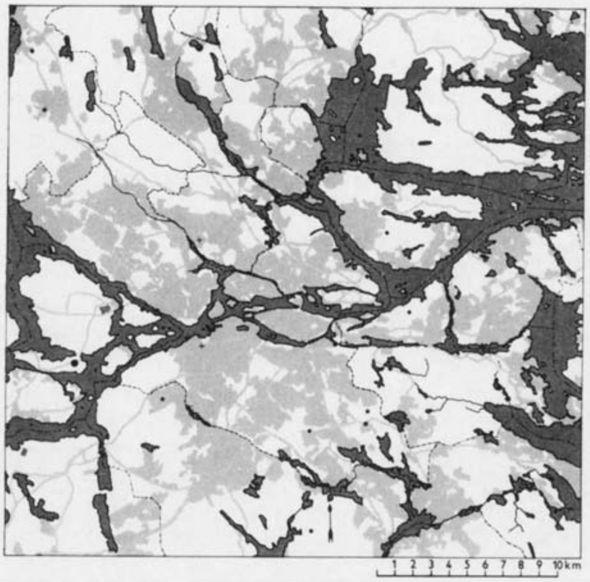


Fig. 19. Calicium hyperellum.

noted: Botkyrka: Tullinge, 585; Huddinge: Vistaberg School, *Populus balsamifera,* 570, sparse; Järfälla: Henningstorp, 599; Lovö: Lovön, Lambarudd, 522; Nacka: Erstavik, 558; Älta, 561; Sollentuna: Sollentuna Churchyard, 593, sparse, not vital; Stockholm: Hägersten, Bredäng, 454; Tyresö: Raksta, 591; Österåker: Östra Ryd, Bogesund, 546; Bogesund, *Acer,* 547, sparse.

C. aurantiaca belongs to group 3.

The species has apparently disappeared from large parts of the suburbs of Stockholm.

C. cerina (Ehrh.) Th. Fr.

Distribution in Scandinavia apparently ubiquitous. Grows mainly on the bark of isolated trees, especially *Populus* and *Quercus.* Seldom passes to lignum.

Thedenius states (1852, p. 167; 1859, p. 115) that the species is common in the Stockholm region. Other occurrences: Danderyd: Djursholm, Slott, *Ulmus glabra* 1959 (Hasselrot); Lidingö: Mission School, *Populus* 1932 (Degelius); Sticklinge 1926 (Håkanson); Solna: Järva 1910 (Malme); Ulriksdal 1909 (Malme); Huvudsta, *Populus* 1906 (Täckholm); Karlberg (Th. M. Fries 1871, p. 49); Stockholm: Djurgården 1890 (Kugelberg).

Occurrences in the investigated area: Botkyrka: Norsborg, *Acer,* 575, sparse; Tullinge, *Fraxinus,* 585, sparse; Huddinge: Vistaberg School, *Populus balsamifera,* 570, sparse; Nacka: Erstavik, *Fraxinus,* 558, sparse.

C. cerina can probably be assigned to group 2 B (bordering on group 3).

The species has withdrawn from the surroundings of Stockholm since the 1910s.

C. chlorina (Flot.) Sandst.

Has a ubiquitous distribution in Sweden but seems to be sparse to the north. It grows chiefly on stone, and occurs somewhat infrequently on dust-impregnated trees.

Older occurrences: Degelius found the species in Stockholm: N. Djurgården, Stora Skuggan on *Ulmus* 1937.

The following occurrences have been noted: Danderyd: Djursholm, *Quercus,* 471, sparse; Järfälla: Church, *Ulmus,* 519, sparse; Stockholm: Brännkyrka, Örby Slott, *Ulmus,* 464, sparse; Hägersten, *Ulmus,* 451; Sankt Göran, Marieberg, *Fraxinus,* 73, sparse; Västerled, Äppelviken, *Salix fragilis,* 91, sparse.

C. chlorina belongs to group 2 B.

C. luteoalba (Turn.). Syn. *Candelariella luteoalba* (Turn.) Lettau, *Callopisma luteoalba* (Turn.).

The species seems to belong to the *P. acetabulum* group. Grows on isolated deciduous trees, exceptionally also on stone. One occurrence was noted in the investigated area. It belongs to the main form (f. *ulmicola* (DC) Lettau).

Österåker: Bullerhöjden, *Ulmus,* 577 *a,* sparse.

No older occurrences have been recorded.

Candelaria Mass.

C. concolor (Dicks.) Arn.

Assigned to the *U. pustulata* group. Apparently prefers isolated deciduous trees.

Older occurrences: Solna: Karlberg (herb. Thedenius); Haga 1910 (Hülphers); Haga–Järva, *Pinus,* 1910 (Hülphers); Northern Cemetery, *Tilia* (Høeg 1934, p. 132); Stockholm: Brännkyrka, Nybohov, *Tilia, Ulmus glabra* (Høeg 1934, p. 132); S. Djurgården, *Ulmus glabra* 1937 (Degelius); Enskede, Skarpnäck, *Quercus robur* 1945 (Santesson); Lilljansskogen/Margaretavägen, *Alnus,* Roslagstull, *Tilia*; Valhallavägen, *Acer platanoides,* sparse; Skanstull, Götgatan 111, *Fraxinus excelsior* (Høeg 1934, p. 132); "Usque ad Holmiam" (Nylander), Th. M. Fries (1871, p. 148).

11 occurrences: Boo: Ormingelandet, *Acer,* 537, sparse; Botkyrka: Alby, *Tilia,* 583; Huddinge: Sundby Manor House, *Quercus,* 586, abundant; *Järfälla*: Säby Gård, *Tilia,* 597; Solna: Ulriksdal, *Tilia,* 373 *b*; Stockholm: Bromma, Ulvsunda industrial estate, *Fraxinus,* 209, sparse; Västerled, Smedslätten, *Ulmus,* 421, sparse; Stocksund: Danderyd, Stockby, *Acer,* 467, sparse; Tyresö: Kumla, *Tilia,* 590, sparse; Österåker: Östra Ryd, Bogesund, *Fraxinus,* 548; Rydbo Saltsjöbad, *Fraxinus,* 578.

C. concolor belongs to group 2 B, but apparently borders on group 3.

The species has clearly definitely retreated during the past 30 years.

Candelariella Müll. Arg.

C. vitellina (Ehrh.) Müll. Arg.

C. vitellina is ubiquitous in Fennoscandia (Hakulinen 1954, pp. 74, 104 ff.). It is primarily confined to siliceous stone and lignum, but occurs also on calcareous rock, bark and other substrates (l.c., p. 105).

There are no records of older occurrences on growing trees in the area. The species appears fairly commonly, however, in Södermanland and Uppland (Hakulinen 1954, p. 75, fig. 9).

Three sparse occurrences have been noted in the investigated area: Lidingö: Elfvik, *Fraxinus,* 531, sparse; Saltsjöbaden: Neglinge, *Acer,* 557, sparse; Österåker: Bullerhöjden, *Ulmus,* 577 *a,* sparse.

C. xanthostigma (Pers.) Lettau

Hakulinen (1954, p. 96) has a map showing the distribution of the species in Fennoscandia. He writes: "Die Verbreitung der Art ist in Fennoskandien eng an das Auftreten der Laubbäume gebunden." It is also said to be ubiquitous in Fennoscandia (l.c., p. 104). It seems to prefer the trunks of deciduous trees but occurs also on lignum and, in rare cases, on stone.

Older occurrences: The species was observed mainly in the 1950s and 1960s. Some older occurrences existed nevertheless. Malme observed the species at Boo: Kummelnäs in 1909; Degelius in Ekerö Churchyard on *Tilia* in 1938. Malme found the species in Kungsholmen, Stockholm, in 1889, and Degelius in 1937 on *Tilia* in Tyresö Slott Park, Tyresö.

C. xanthostigma belongs to group 2 B in the investigated area (Fig. 20).

Catillaria Th. Fr.

C. Ehrhartiana (Ach.) Th. Fr.

Belongs to the *U. pustulata* group. Occurs on lignum and on old deciduous trees, especially *Quercus*.

Older occurrences: Stockholm region, in several places (Thedenius 1852, p. 174; 1859, p. 119, s.n. *Cliostonum corrugatum*). Solna: Karlberg (Thedenius 1852, p. 174, s.n. *Cliostonum corrugatum*); Stockholm: Brännkyrka, *Quercus robur* 1916 (Hülphers); Djurgården 1852 (Nyman, s.n. *Cliostonum corrugatum*); Kastellholmen (s.n. *Biatora Ehrhartiana*); Kungsholmen, *Quercus robur*, 1838 (herb. C. F. Nyman, s.n. *Cliostonum corrugatum*); Kungsholmstull, *Quercus robur* (s.n. *Biatora Ehrhartiana*); Djurgården (*Thedenius* 1852, p. 174, s.n. *Cliostonum corrugatum*); Djurgården, Framnäs, *Quercus robur* (Thedenius 1859, p. 9, s.n. *Cliostonum corrugatum*.

Two occurrences have been noted in the investigated area: at Huddinge: *Quercus*, 476, and at Nacka: Nyckelviken, *Quercus*, 554.

Even if it may sometimes be difficult to identify the species, it is quite obvious what a difference there is in distribution between these older occurrences, more than a hundred years old, and the present ones.

C. globulosa (Flk.) Th. Fr.

Distribution in Scandinavia can practically be described as ubiquitous. Seems to prefer such deciduous trees as *Acer*, *Fraxinus* and *Ulmus* and appears in copses, avenues, parks etc.

Older occurrences: Several places in the Stockholm region (Thedenius 1852, p. 169; 1859, p. 116, s.n. *Biatora anomala*). Solna: Järva, 1907 (Malme); Stockholm: Brännkyrka, Jakobsberg 1870 (S. Almquist); Liljeholmen, 1897 (Malme); Blommensberg, *Quercus robur* (Thedenius 1852, p. 169, s.n. *Biatora anomala*).

The following occurrences have been noted: Boo: Ormingelandet, *Tilia*, 538, abundant; Lovö: Lovön, Drottningholm, *Ulmus*, 426, sparse; Nacka: Nacka old cemetery, *Acer*, 491, sparse; Stockholm: Spånga, Järvafältet, *Tilia*, 336.

The species seems to belong to group 3.

C. Griffithii (Sm.) Malme

Belongs to the *U. pustulata* group. Apparently grows mainly on deciduous trees, seldom on conifers. Prefers open plantations, copses etc.

Older occurrences (one only): Stockholm: Brännkyrka, Jakobsberg, 1870, 1871 (S. Almquist).

Only one occurrence was noted in the investigated area: Stockholm: Hägersten, Bredäng, *Quercus*, 453, sparse.

It is remarkable that the locations of these two occurrences are probably quite close to each other.

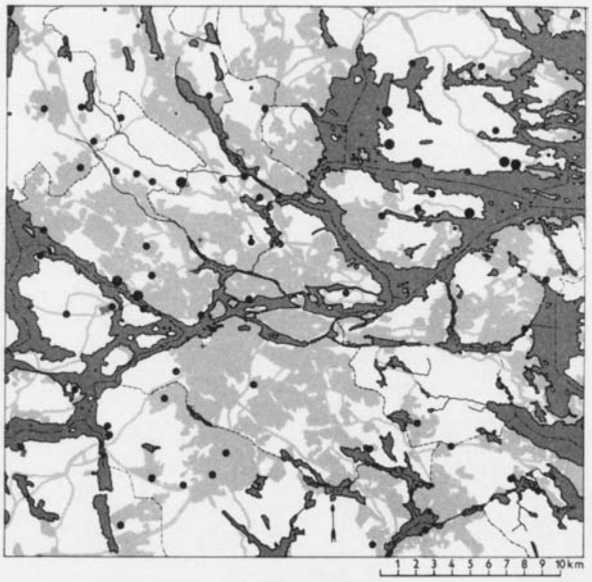


Fig. 20. Candelariella xanthostigma.

C. prasina (Fr.) Th. Fr.

Belongs to the *U. pustulata* group. Seems to prefer deciduous trees to conifers; grows also on lignum.

Older occurrences: Boo: Lövberga and Rensättra; both noted by Malme in 1908.

One occurrence only: Österåker: Bullerhöjden, *Ulmus*, 577 *a*, sparse.

Cetraria Ach.

C. chloropylla (Willd.) Vain.

Belongs to the *U. pustulata* group. Grows on tree trunks and twigs, on wooden fences and, though rarely, on stone (Magnusson 1929, p. 93). Santesson (1949, p. 198) says that the species prefers *Betula*, *Picea* and similar substrates.

Older occurrences: Thedenius (1852, p. 164; 1859, p. 113) describes it as common in the Stockholm region. Lidingö: Common throughout the area (Håkanson 1950, p. 225); Solna Haga Park 1910 (Hülphers); Bergshamra, *Acer*, and Ulriksdal, *Tilia*, 1958 (Hasselrot); Northern Cemetery, *Tilia* (Høeg 1934, p. 132); Stockholm: Royal College of Forestry, *Quercus cerris*, etc., 1956 (Hasselrot); Bergielund, 1913 (Florin); Enskede, Pungpinan 1910 (Hülphers); Djurgården, about 100 metres west of the "Gotthem" restaurant (near station 395), *Populus* (Høeg 1934, p. 132).

C. chlorophylla is assigned to group 1 B in this investigation (Fig. 21).

It is hardly possible to ascertain any change in the distribution area of the species if a comparison is made between older and more recent information. The species has possibly become sparser, but this is not certain either.

C. glauca (L.) Ach.

Santesson (1949, p. 198) writes: "On trees (especially birch, spruce etc.), on bare wood, rocks etc., Skåne–Norrland. Very common." Magnusson (1929, p. 94) considers that the species is more sparse in the northern parts of Norrland.

Older occurrences: Lidingö: Very common throughout the area with the exception of the densely built-up parts (Håkan-

Fig. 21 b. Cetraria chlorophylla.

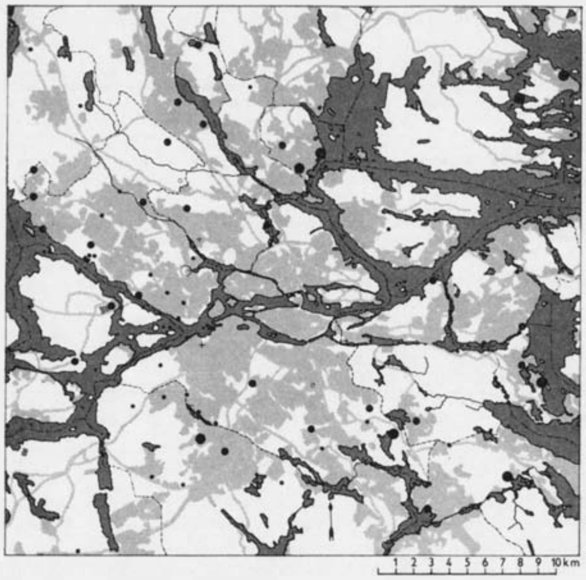


Fig. 21 a. Cetraria chlorophylla.

son 1950, p. 225); Nacka: Danviksbergen 1907 (Täckholm); Solna: Ulriksdal, *Tilia,* sparse, 1958 (Hasselrot); Stockholm: Ladugårdsgärdet 1911 (Lundqvist); Stora Essingen 1892 (Hesselman); N. Djurgården, Uggleviken, on trees 1905 (Täckholm).

C. glauca belongs to group 2 A. If there had been more conifers and birches among the phorophytes, the species would have turned up more generally in the outskirts of the investigated area. This is shown by Lundström's (1966, p. 54) report. Fig. 22.

By all appearances, *C. glauca* has disappeared from certain parts of its old distribution area.

C. pinastri (Scop.) S. Gray

Common on bark, etc. throughout Sweden (Santesson 1949, p. 198). Grows most frequently on root collars and bases of trunks. Du Rietz (1945 *b,* p. 158) states that the species is common, but often sparse on "poor bark".

Older occurrences: Thedenius (1852, p. 164; 1859, p. 113) describes the species as fairly common in the Stockholm region. Lidingö: Common, especially in conifer areas on *Pinus, Picea, Betula* and other "poor bark" trees, as a rule more or less sparsely in the localities (Håkanson 1950, p. 226);

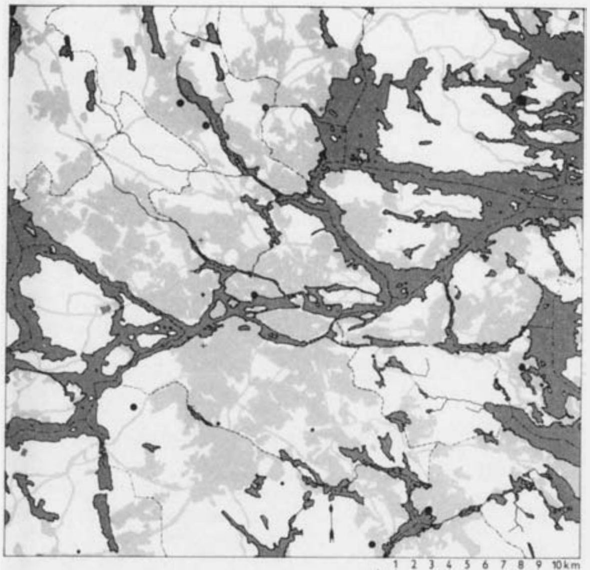


Fig. 22. Cetraria glauca.

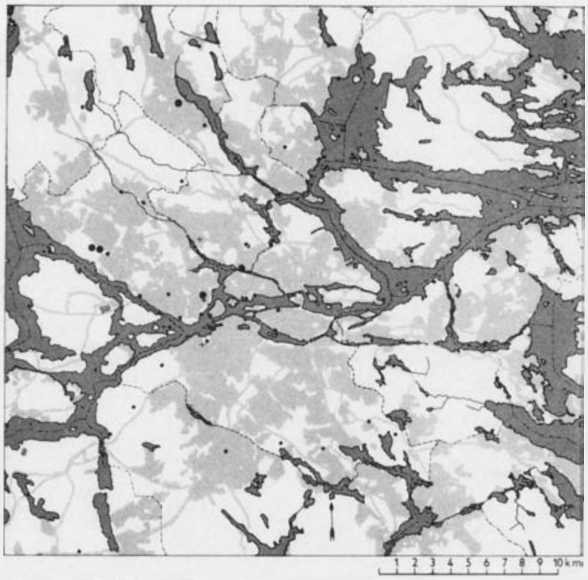


Fig. 23. Cetraria pinastri.

Nacka: Danviksbergen, *Pinus,* 1907 (Täckholm), 1910 (Hülphers); Stockholm: Bromma, Traneberg, on bark of decayed deciduous tree 1907 (Täckholm), 1910 (Du Rietz); Sandvik 1911 (Lundqvist); Brännkyrka, Liljeholmen 1859 (Retzius); Royal College of Forestry, *Salix,* 1956 (Hasselrot); Bergian Botanical Gardens, *Pinus,* 1944 (Grapengiesser); Enskede, Pungpinan, 1910 (Hülphers); Stora Essingen 1892 (Hesselman).

The species belongs to distribution group 2 A. Fig. 23.

If conifers and other "poor bark" trees had been more general in the material, *C. pinastri* would have occurred more generally in the outskirts of the investigated area. This is shown by Lundström's (1966, p. 55) material.

C. pinastri has manifestly vanished from parts of its former distribution area.

Cladonia (Hill.) Vain.

C. coniocraea (Flk.) Vain.

Apparently ubiquitous in Fennoscandia. Grows on bases of trunks, primarily on conifers and *Betula,* and on stumps and moss.

Older occurrences: Håkanson (1950, p. 219) mentions the species as occurring on decayed stumps, moss-covered stones etc. common in Lidingö. Stockholm: North Djurgården, Sjöstugan, trunk base of *Quercus,* abundant, 1958 (Hasselrot); Sofia, Sickla Point, base of *Quercus,* 1965 (Ahlner).

The species is assigned to group 2 A in the investigated area (Fig. 24).

No great difference in distribution can be ascertained, as the species has only recently been recorded from the area.

C. fimbriata (L.) Fr.

Ubiquitous in Sweden. Santesson (1949, p. 188) describes the species as common from Skåne to Norrland. Grows on earth, decayed wood, bases of trees etc.

Older occurrences: Lidingö: on varying substrates, common (Håkanson 1950, p. 220); Stockholm: South Djurgården, near "Gotthem" restaurant (near station 395), *Ulmus* (Høeg 1934, p. 132); North Strandvägen, *Ulmus* (Høeg, l.c., p. 134).

The following occurrences were noted: Botkyrka: Tumba, *Quercus,* 584, sparse; Huddinge: Ågesta, *Quercus,* 587; Sollentuna: Sjöberg, *Quercus,* 517; Stockholm: Bromma, Blackeberg, *Quercus,* 133; Oscar's, Djurgården, *Quercus,* 398; Tyresö: Raksta, *Fraxinus,* 591; Täby: Näsby Slott Park, *Tilia,* 518, sparse.

C. fimbriata belongs principally to group 3.

The species seems to have disappeared from the inner parts of the distribution area around Stockholm.

Cladonia sp.

Several stations with badly developed examples of epiphytic *Cladonia* have been listed here. In all cases the occurrence is sparse to very sparse. Most of them are probably *C. coniocraea.*

Ekerö: Gällstaö, *Ulmus,* 524; Huddinge: Sundby Manor House, *Quercus,* 586; Lidingö: Stockby, *Acer,* 529; Lovö: Lovön, Drottningholm, *Ulmus,* 426; Nacka: Nyckelviken, *Quercus,* 554; Sollentuna: Södersätra, Väsjö, *Quercus,* 595; Stockholm: Spånga, Grimsta, *Betula,* 127; Sankt Göran, Marieberg, *Fraxinus,* 77; Marieberg, Rålambshov, Pontoniärsparken, *Salix,* 80; Österåker: Östra Ryd, Bogesund, Frösvik, *Fraxinus,* 548.

Coniocybe Ach.

C. hyalinella Nyl. Syn. *C. nivea* (Hoffm.) Arn.

Belongs to the *P. acetabulum* group. Occurs on bark of various kinds of trees.

Older occurrences: Thedenius (1852, p. 173; 1859, p. 118) describes the species as fairly rare. Solna: Karlberg Park 1948 (Sjögren); 1886 (Kugelberg), Karlberg (Th. M. Fries 1852, p. 49; Thedenius 1852, p. 173); Stockholm: Brännkyrka, Jakobsberg 1871 (S. Almquist); Djurgården (Thedenius 1852, p. 173); Framnäs, *Quercus* (Thedenius 1859, p. 9).

The following occurrences have been noted: Huddinge: Länna, *Ulmus,* 588, sparse; Stockholm: Hägersten, Vårberg, *Fraxinus,* 567, sparse; Spånga, Järvafältet, *Tilia,* 336, sparse;

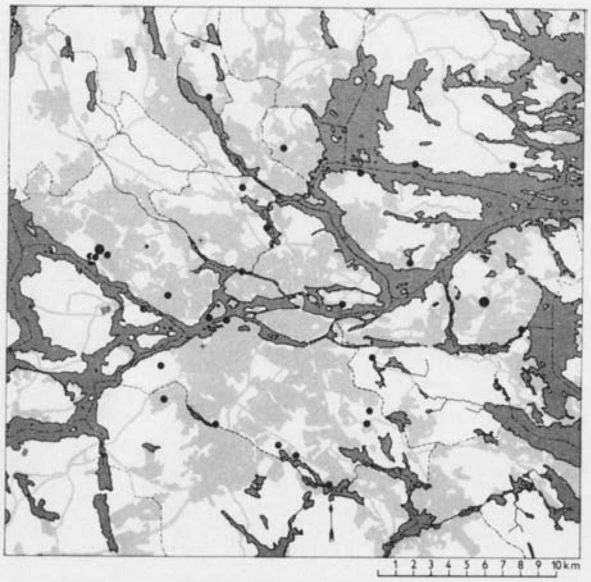


Fig. 24. Cladonia coniocraea.

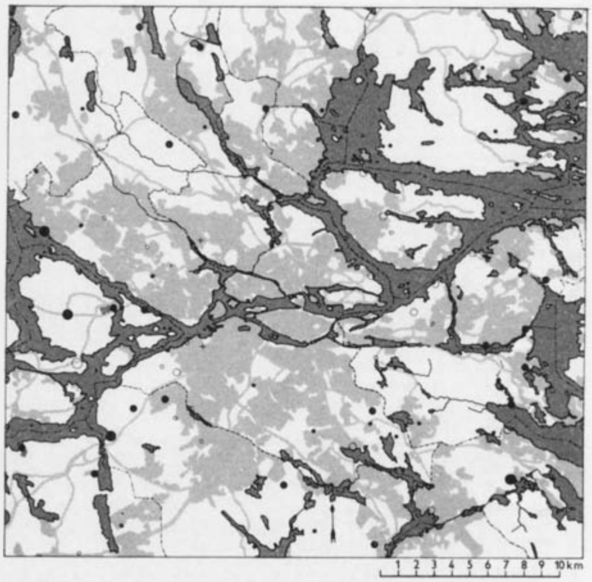


Fig. 25. Evernia prunastri.

Tyresö: Alby Rectory, *Fraxinus,* 592 *a*; Österåker: Östra Ryd, Bogesund, *Ulmus,* 550, sparse.

C. hyalinella can apparently primarily be assigned to group 3.

The older occurrences seem to indicate that a hundred years ago the species appeared also at the edge of the city of that time. The survival until at least 1948 in Karlberg Park should be noted.

Evernia Ach.

E. prunastri (L.) Ach.

Belongs to the *U. pustulata* group. Grows on tree trunks and branches, often on bushes (especially *Prunus spinosa*), on wood and—though rarely—on stone.

Older occurrences: Thedenius (1852, p. 163; 1859, p. 112) describes *E. prunastri* as common in the Stockholm region. Stockholm: Bromma, Alvik, *Populus,* 1911 (H. Du Rietz); "Holmiae" 1837 (Nyman); 1852 (Thedenius); Ladugårdsgärdet 1911 (Lundqvist); Djurgården, Fröding statue, *Populus* (near station 400), east of "Gotthem" restaurant, *Ulmus,* sparse (near station 395), near the "I Tankar" statue (near station 396), just outside Rosendal (near station 399) (Høeg 1934, p. 132); vicinity of Djurgården Theatre 1859 (Thedenius).

E. prunastri belongs to group 2 B. Fig. 25.

The species has disappeared from many of its previous localities. The changes have been striking in the last 30 years alone.

Hypogymnia (Nyl. in Hue) W. Wats.

H. Bitteriana (Zahlbr.) Räs. Syn. *Parmelia Bitteriana* Zahlbr., *P. farinacea* Bitter.

Belongs to the *U. pustulata* group. Prefers pine bark and wooden fences, but also occurs on other bark and on stone (Magnusson 1929, p. 80).

Older occurrences: Solna: Ulriksdal, *Tilia,* 1958 (Hasselrot); Järva (Malme 1907, p. 338); Northern Cemetery, *Tilia* (Høeg 1934, p. 132); Stockholm: Bromma, Alvik, *Pinus* (H. Du Rietz); N. Djurgården, S. Sjöstugan, *Quercus,* 1958 (Hasselrot), Fiskartorpet 1911 (Vestergren), Uggleviken, *Alnus,* 1911 (Vestergren); Enskede, beyond Hammarby Gård, *Betula,* 1907 (Täckholm); Djurgården, Fröding statue, *Populus* (Høeg 1934, p. 132).

Only four occurrences have been noted in the material for this thesis: Botkyrka: Tumba, *Quercus,* 584, sparse; Danderyd: Enebyberg Gård, *Acer,* 582; Tyresö: Alby Rectory, *Alnus,* 592 *b*; Österåker: Bullerhöjden, *Betula,* 577 *b,* abundant.

In Lundström's report (1966) the species is not mentioned, and this supports the view that group 3 is probably more correct than group 2 B. However, there is no doubt that *H. Bitteriana* is considerably more numerous in the wooded parts of the investigated area's outskirts than the map indicates.

The species thus penetrated much more deeply into the city until quite recently, and it should be observed that its absence in the present material does not prove that it has disappeared entirely. Most of the older occurrences were on *Pinus,* with some on *Betula.*

H. physodes (L.) W. Wats. Syn. *Parmelia physodes* (L.) Ach.

Occurs throughout Fennoscandia. Grows on many different substrates.

Older occurrences: Lidingö: On bark and lignum of most lignosa and on stone. Extremely common and community-forming throughout the area (including the small islands); also appears even in the most densely built-up parts (Håkanson 1950, p. 223); Solna: Karlberg, 1857 (Cleve); Haga Park, 1910 (Hülphers); Haga, 1910 (Hülphers); Northern Cemetery, *Tilia,* sparse (Høeg 1934, p. 132); Stockholm: Bromma, Minneberg, with damaged cortical layer, 1910 (Du Rietz); ditto c. ap. 1910 (H. Du Rietz); Nockeby, c. ap. 1932 (Vesterlund); Djurgården, *Betula,* 1926 (Degelius); S. Djurgården, *Acer pseudoplatanus,* 1937 (Degelius); Djurgården, 1861 (Henschen); ditto deciduous tree, 1905 (Täckholm); ditto avenue between Djurgårdsbrunn and "Manilla", 1923 (Vestergren); Enskede, Pungpinan, *Betula,* 1910 (Hülphers); Skanstull, 1864 (Dahlgren); S. Djurgården, near "Gotthem"

Fig. 26 b. Hypogymnia physodes.

restaurant (near station 395), *Populus* (Høeg 1934, p. 132); ditto *Ulmus* (Høeg, l.c.); N. Strandvägen (near station 396), *Ulmus* (Høeg 1934, pp. 132, 134); outside Rosendal (near station 399), *Acer* (Høeg, l.c.); Margaretavägen, *Betula, Alnus* (Høeg 1934, p. 132); along Mellanvägen, *Picea* (Høeg, l.c., pp. 132, 134); Roslagstull, *Tilia* (Høeg, 1934, p. 132); Skeppsholmen, *Acer pseudoplatanus* + *Fraxinus* (Høeg 1934, pp. 132, 134).

Common in the Stockholm region (Thedenius 1852, p. 165; 1859, p. 113).

H. physodes belongs to the lichens penetrating farthest into the investigated area. It thus belongs to group 1 A. Fig. 26. (See also Lundström 1966, p. 72.)

It is interesting to note that many of the older occurrences in Stockholm were also on such deciduous trees as *Fraxinus, Acer, Ulmus* and *Tilia.* Some decline has apparently occurred.

H. tubulosa (Schaer) Havaas. Syn. *Parmelia tubulosa* (Schaer) Bitter

Ubiquitous in Scandinavia, but is believed to become rarer towards the north (Magnusson 1929, p. 80). Santesson (1949, p. 194) describes it as common. Grows on thin branches and

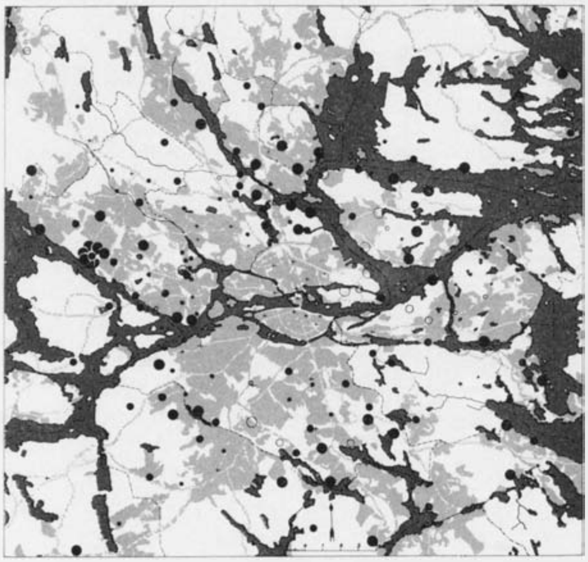


Fig. 26 a. Hypogymnia physodes.

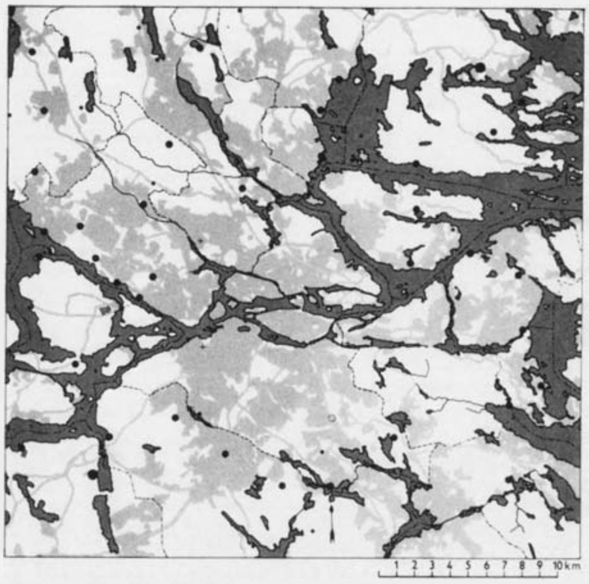


Fig. 27. Lecanora carpinea.

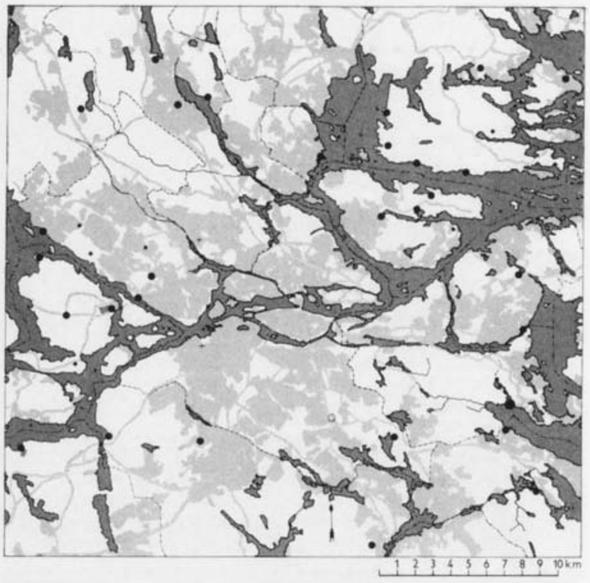


Fig. 28. Lecanora chlarotera.

twigs of conifers and deciduous trees, on trunks and wood, seldom on stone or earth.

Older occurrences: Lidingö: On various kinds of trees (also on juniper), both in natural vegetation and on roadsides, etc. Sterile. Fairly common but mostly sparse (Håkanson 1950, p. 223); Stockholm: Bromma, Alvik, 1911 (Lundqvist, Du Rietz); Fredriksberg, Minneberg (Du Rietz), Lilljansskogen, Margaretavägen, *Betula* (Høeg 1934, p. 133), Bergian Botanical Gardens, 1907 (Ridderstolpe); Enskede, Pungpinan, 1910 (Hülphers).

The following occurrences have been noted: Huddinge: Segeltorp, *Quercus,* 460, sparse; Stockholm: Skarpnäck, *Quercus,* 560; Tyresö: Kumla, *Tilia,* 590; Täby: Näsby Slott Park, *Tilia,* 518, sparse.

Belongs to distribution group 3.

The species is presumably considerably more common in the periphery of the investigated area than—because of the choice of phorophytes—this investigation shows. It formerly penetrated farther into the inner parts of the city than now.

Lecanora Ach.

L. allophana (Ach.) Nyl.

Belongs to the *U. pustulata* group. According to Magnusson (1932, p. 79) the substrate is mainly aspen bark.

Older occurrences: Solna: Haga, 1959 (Retzius); Järva, 1907 (Malme); Överjärva, 1910 (Hülphers); Stockholm: Djurgården, 1861 (Thedenius); Ladugårdslandet, 1861 (Thedenius); Enskede, Pungpinan, 1910 (Hülphers).

Present material: Järfälla: Järfälla Church, *Ulmus,* 519; Lidingö: Elfvik, *Fraxinus,* 531; Lovö: Lovön, Lambarudd, *Fraxinus,* 522; Nacka: Bollmora, *Fraxinus,* 562; Älta, *Fraxinus,* 561; Stockholm: Skarpnäck, Orhem, *Fraxinus,* 497; Spånga, Järvafältet, *Fraxinus,* 335, 376; Västerled, Nockebyhov, *Acer,* 425; Österåker: Östra Ryd, Bogesund, Broknäs, *Ulmus,* 550; Bogesundslandet, *Fraxinus,* 543.

The species belongs to group 3.

L. allophana has retreated from many localities in the surroundings of Stockholm.

L. carpinea (L.) Vain.

Belongs to the *U. pustulata* group. Magnusson (1932, p. 86) suggests that *L. carpinea* embraces "eine Menge von Formen und vielleicht auch Arten". In the present material, too, the appearance of the species varies within quite wide limits. The name may therefore be regarded as a collective designation. *L. carpinea* occurs both on isolated deciduous trees and —although more rarely—on conifers and lignum.

Older occurrences: Solna: Haga, *Alnus,* 1910 (Hülphers); Ulriksdal, 1909 (Malme); 1910 (Hülphers); Överjärva (id.); Stockholm: Ulvsunda, *Tilia,* 1927 (Degelius); Vibergslund, *Corylus,* year? (H. Du Rietz).

Thedenius (1852, p. 173) describes *Pertusaria communis* as fairly common in the Stockholm region and adds "but only sterile = *Lichen carpineus*" common in Stockholm region (l.c., p. 167; 1859, p. 114) s.n. *Parmelia albella* f. *angulosa.*

L. carpinea belongs to group 3. Fig. 27.

L. carpinea has retreated decidedly from the more central parts of the Stockholm area.

L. chlarona (Ach.) Nyl.

Magnusson (1932, p. 81) believes that the species is not unusual in Scandinavia. Erichsen (1957, p. 295) considers that it is rare in north-western Germany. *L. chlarona* is apparently a deciduous-tree species.

Older occurrences: Boo: Kummelnäs, 1909, Lövberga, 1906, Rensätra, 1907, Huddinge: 1908 (Malme); Solna: Överjärva, 1910 (Hülphers).

The following occurrences have been noted: Boo: Anneberg, *Tilia,* 552; Boo Church, *Tilia,* 534, sparse; Huddinge: Stuvsta, *Acer,* 474; Ågesta, *Quercus,* 587; Lidingö: Bodal, *Quercus,* 508; Bosön, *Aesculus,* 530, abundant; Saltsjöbaden: *Fraxinus,* 556, sparse; Sollentuna: Edsviken, *Populus nigra,* 516; Häggvik, *Acer,* 594; Stockholm: Brännkyrka, Herrängen, *Alnus,* 459; Skarpnäck, Pungpinan, *Quercus,* 496; Tyresö: Alby Rectory, *Alnus,* 592 *b,* abundant; Täby: Röhäll, Viggbyholm, *Fraxinus,* 580; Österåker: Bullerhöjden, *Ulmus,* 577 *a*; Resarö, Ytterbystrand, *Betula verrucosa,* 576 *b,* sparse.

The species can be assigned to group 2 B.

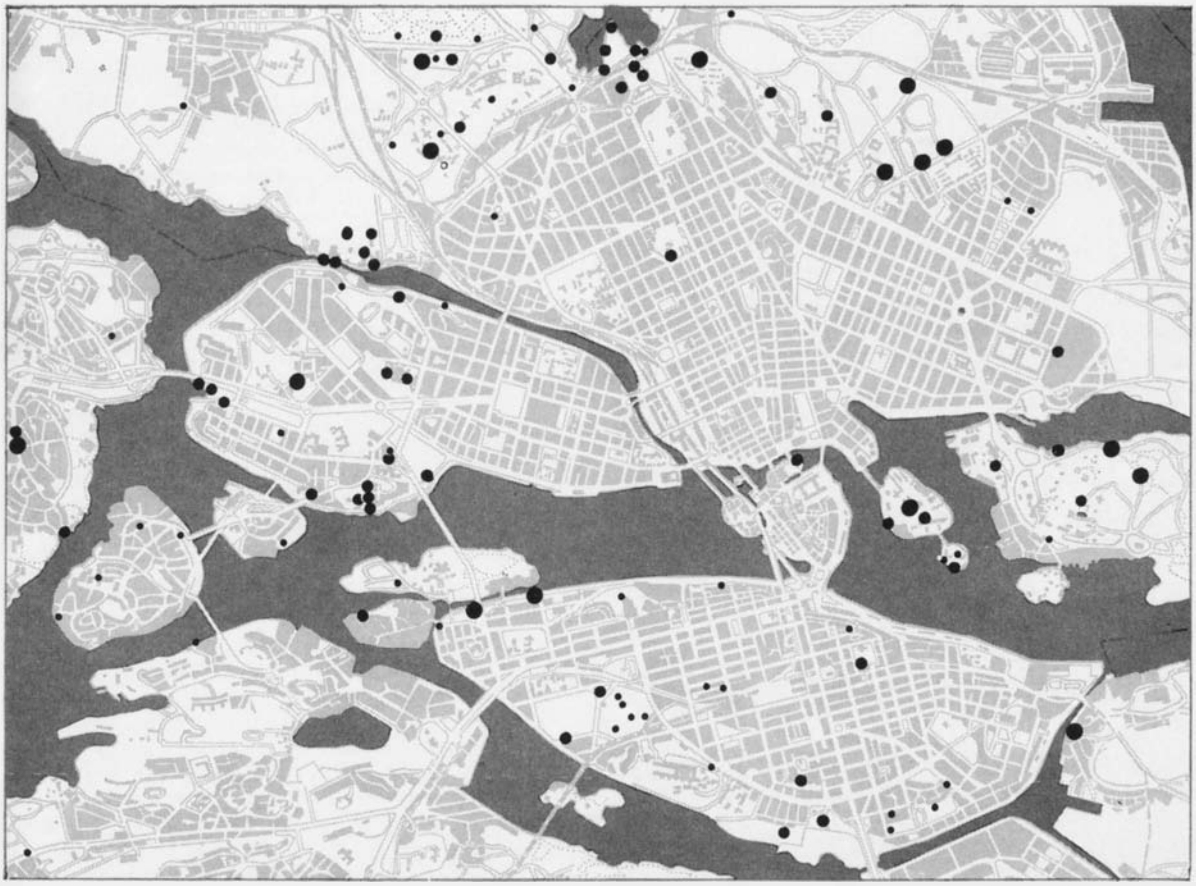


Fig. 29 b. Lecanora conizaeoides. (Also on stations 240, 244 and 246, compare Fig. 11 *b.*)

The species was clearly overlooked formerly, and it is therefore difficult to compare the present with the former distribution.

L. chlarotera Nyl.

Magnusson (1932, p. 85) writes that *L. chlarotera* appears to be a common lichen in central and southern Europe and that it extends in Sweden to at least as far as Uppsala. The species belongs to the *P. acetabulum* group. It seems to prefer deciduous trees.

L. chlarotera belongs to group 3 in the present material. Fig. 28.

There are no records of older occurrences.

L. conizaeoides Cromb. Syn. *L. pityrea* Erichs.

Almborn (1948, p. 20) includes *L. pityrea* in the *P. acetabulum* group. It could now be more appropriately placed in the *U. pustulata* group, as occurrences of *L. conizaeoides* have been noted as far north as in Ångermanland (Moberg 1966, p. 40). However, it is remarkable, as Ahti (1965, p. 91) shows, that the species is apparently not found in Finland. It is thus a western species that occurs over large parts of western Europe (see for example Almborn 1943;

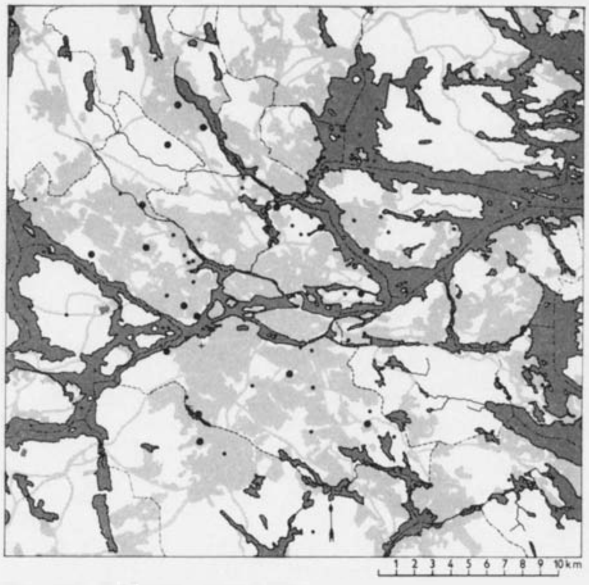


Fig. 29 a. Lecanora conizaeoides.

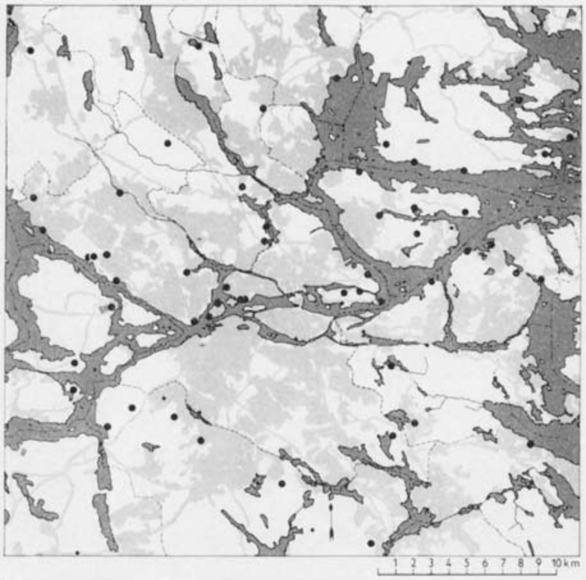


Fig. 30. Lecanora expallens.

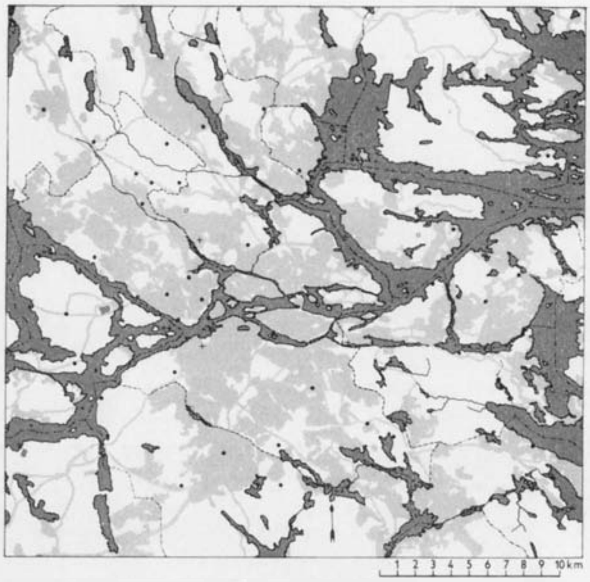


Fig. 31. Lecanora subfusca coll.

Fenton 1960; Kershaw 1963, p. 68; Degelius 1961, 1966, p. 5; Barkman 1963; Adelheid Schmid 1957; Laundon 1967, p. 292). It is apparently expanding vigorously.

L. conizaeoides appears on bark, lignum and siliceous stone and is regarded by several writers, including Barkman (1958) as toxitolerant.

The species belongs to group 1 A. Fig. 29.

No older occurrences have been recorded in the Stockholm region.

L. crassula H. Magn.

Magnusson (1932, p. 81) states that *L. crassula* is certainly a common species in the southern parts of Sweden. It is assigned to the *P. acetabulum* group. *L. crassula* is a deciduous-tree species and seems according to Magnusson to prefer sites affected by dust.

The following occurrences have been noted: Boo: Boo Church, *Tilia,* 534, sparse; Boo Old Church, *Ulmus,* 551; Huddinge: *Quercus,* 476, sparse; Lidingö: Mölna, *Tilia,* 526, sparse; Lovö: Lovön, Lindö, *Quercus,* 523; Lovö Church, *Acer,* 521, sparse; Nacka: *Quercus,* 553; Hellasgården, *Quercus,* 565; Stockholm: Brännkyrka, Örby Slott, *Ulmus,* 464; Farsta, Fagersjö, *Quercus,* 418; Skarpnäck, Flaten, *Quercus,* 560, sparse; Spånga, Järvafältet, *Acer,* 573; Tyresö: Tyresösand, *Fraxinus,* 564; Vaxholm: *Fraxinus,* 542; Österåker: Östra Ryd, Bogesund, *Acer,* 547.

The species can probably be assigned to group 2 B.

No older occurrences in the investigated area have been recorded.

L. expallens Ach.

Assignable to the *P. acetabulum* group. Occurs on all kinds of trees in not too illuminated situations (Almborn 1952, p. 251).

Older occurrence (one only): Sollentuna: Churchyard 1954 (Sundell).

The species belongs to group 2 B. Fig. 30.

L. Hageni Ach.

Ubiquitous in Sweden but seems to be sparse northwards. Grows on all kinds of bark, on lignum and (rarely) on stone etc.

Older occurrences: Solna: Ulriksdal, 1909 (Malme); Stockholm: Bromma, 1914 (Du Rietz); Täby: Populus, 1911 (Vestergren).

Occurrences in the investigated area: Botkyrka: Alby, *Tilia,* 583; Huddinge: Vistaberg School, *Populus,* 570, sparse; Lidingö; Elfvik, *Fraxinus,* 531, sparse; Stockholm: Spånga, Grimsta, *Fraxinus,* 132; Österåker: Östra Ryd, Bogesund, *Fraxinus,* 545.

The species belongs to group 3, and has declined in the Stockholm area during the last 50 years.

L. maculata (Erichs.) Almb. syn. *Pertusaria maculata* Erichs.

Belongs to *P. acetabulum* group. *L. maculata* is "frequent mainly on deciduous trees in woods" (Almborn 1952, p. 251).

Older occurrences: Boo: Myrsjön, 1910; Rensätra, *Ulmus,* 1913 (Malme), (Magnusson 1937 *a,* p. 132); Myrsjön, (Malme 1937, p. 178); Rensätra (Malme, l.c.); Österåker: S. Täljö, *Alnus glutinosa,* 1958 (Hasselrot); Påta, *Alnus glutinosa,* 1961 (Hasselrot).

The following occurrences have been noted: Järfälla: Henningstorp, *Fraxinus,* 599, abundant; Järfälla Church, *Ulmus,* 519; Huddinge: *Quercus,* 476; Sollentuna: Sollentuna Churchyard, *Fraxinus,* 593, sparse; Stockholm: Hägersten, Skärholmen, *Quercus,* 566; Österhaninge: Vendelsö, *Acer,* 589, sparse.

The species can probably be assigned to group 3.

A comparison between older and more recent occurrences gives no indication of possible changes in the distribution pattern.

L. subfusca coll. (L.) Ach.

In many cases it was impossible to decide definitely which species within the *L. subfusca* group was concerned. The

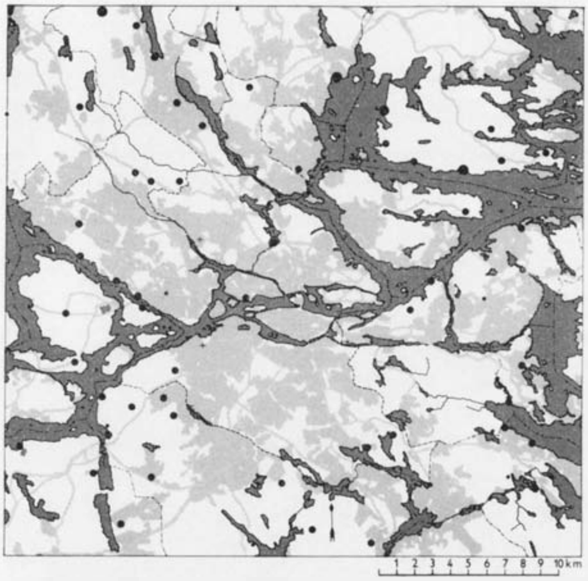


Fig. 32. Lecanora subfuscata.

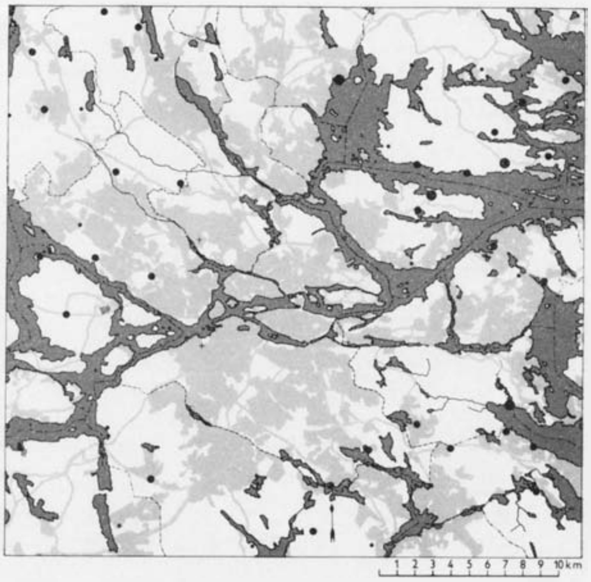


Fig. 33. Lecidea olivacea.

designation *L. subfusca* probably conceals primarily *L. crassula*, *L. chlarotera* and *L. subfuscata*. Fig. 31.

As the map shows, it is mainly a question of sparse occurrences, frequently with small and ill-developed specimens.

Høeg (1934, p. 132) mentions *L. subfusca* on *Tilia* at Roslagstull and in Valhallavägen. Thedenius (1852, p. 166; 1859, p. 114) describes it (s.n. *Parmelia subfusca*) as common in the Stockholm region.

Høeg's two occurrences are situated nearer the city centre than at present, which indicates a decline in present distribution of the *L. subfusca* group.

L. subfuscata H. Magn.

Belongs to the *U. pustulata* group. Magnusson (1932, p. 80) considers that the species has "eine weite Verbreitung und ist wenigstens in Schweden bis Uppland eine häufige Flechte". *L. subfuscata* occurs on trees of all kinds.

The species belongs to group 2 B. Fig. 32.

No older occurrences in the Stockholm region have been noted.

L. symmicta Ach. Syn. *Lecidea* (*Biatora*) *symmicta* Ach.

The species seems to belong to the *U. pustulata* group.

L. symmicta grows on bark and lignum.

Older occurrences: (only a few have been recorded). Malme noted the species in 1909 and 1910 in Boo: Lövberga. Thedenius (1852, p. 167; 1859, pp. 114, 115) describes *L. symmicta* as fairly common in the Stockholm region.

The following occurrences have been noted: Boo: Mensättra, *Quercus*, 541, sparse; Huddinge: *Quercus*, 476, sparse; Stuvsta, *Acer*, 474, sparse; Lidingö: Bosön, *Aesculus*, 530, sparse; Stockholm: Skarpnäck, Flaten, *Quercus*, 560, sparse; Spånga, Grimsta, *Quercus*, 129; Västerled, *Acer*, 409, sparse.

The species probably belongs to group 2 B.

L. umbrina (Ehrh.) Röhl.

Distribution in Sweden is ubiquitous. *L. umbrina* occurs on lignum, but also grows on bark and stone.

The following occurrences have been noted: Huddinge: Vistaberg School, *Populus*, 570; Lidingö: Elfvik, *Fraxinus*, 531; Stockholm: Bromma, S. Ängby, *Ulmus*, 410; Spånga, Järvafältet, *Acer*, 573; Stocksund: Danderyd, Stockby, *Acer*, 567, sparse; Tyresö: Alby Rectory, *Alnus*, 592 *b*, sparse; Täby: Ensta, Hästängen, *Acer*, 581, sparse; Österåker: Östra Ryd, Bogesund, *Fraxinus*, 545.

The species probably belongs to group 3.

No older occurrences of *L. umbrina* have been recorded in the Stockholm region.

Lecanora sp.

It has not been possible to identify the following occurrences of *Lecanora*. In all cases the occurrences were scanty and often with poor fertility.

Lidingö: Södergarn, *Fraxinus*, 532; Solna: Southern Cemetery, *Acer*, 360; Norrbacka, *Ulmus*, 352; Stockholm: Skarpnäck, *Quercus*, 559; Sankt Göran, Marieberg, *Fraxinus*, 73; Spånga, Grimsta, *Pinus*, 125; Järvafältet, *Fraxinus*, 335; Tyresö: Kumla, *Tilia*, 590.

Lecidea (Ach.) Th. Fr.

Lecidea efflorescens (Hedl.) Erichs. Syn. *L. helvola* (Koerb.) Th. Fr. f. *efflorescens* Hedl.

Belongs to the *U. pustulata* group. Grows frequently on *Quercus*, etc., and according to Almborn (1952, p. 252) is not infrequent (though hitherto overlooked).

The following occurrences have been noted: Boo: Ormingelandet, *Tilia*, 538; Lidingö: Koltorp, *Quercus*, 528; Stockby, *Acer*, 529; Huddinge: Länna, *Ulmus*, 588; Nacka: Nacka Old Cemetery, *Acer*, 491; Erstavik, *Fraxinus*, 558; Saltsjöbaden: Neglinge, *Acer*, 557; Solna: Northern Cemetery, *Acer*, 357; Stockholm: Engelbrekt, Brunnsviken, *Alnus*, 339, sparse; Farsta, *Quercus*, 415; Fagersjö, *Quercus*, 418; Skärholmen, *Quercus*, 566, sparse; Oscar's, Djurgården, *Quercus*, 398; Sankt Göran, Marieberg, *Fraxinus*, 73; Västerled, Ålsten, *Quercus*, 423, sparse; Tyresö: *Fraxinus*, 563; Raksta, *Fraxinus*, 591; Österåker: Östra Ryd, Bogesund, *Tilia*, 544.

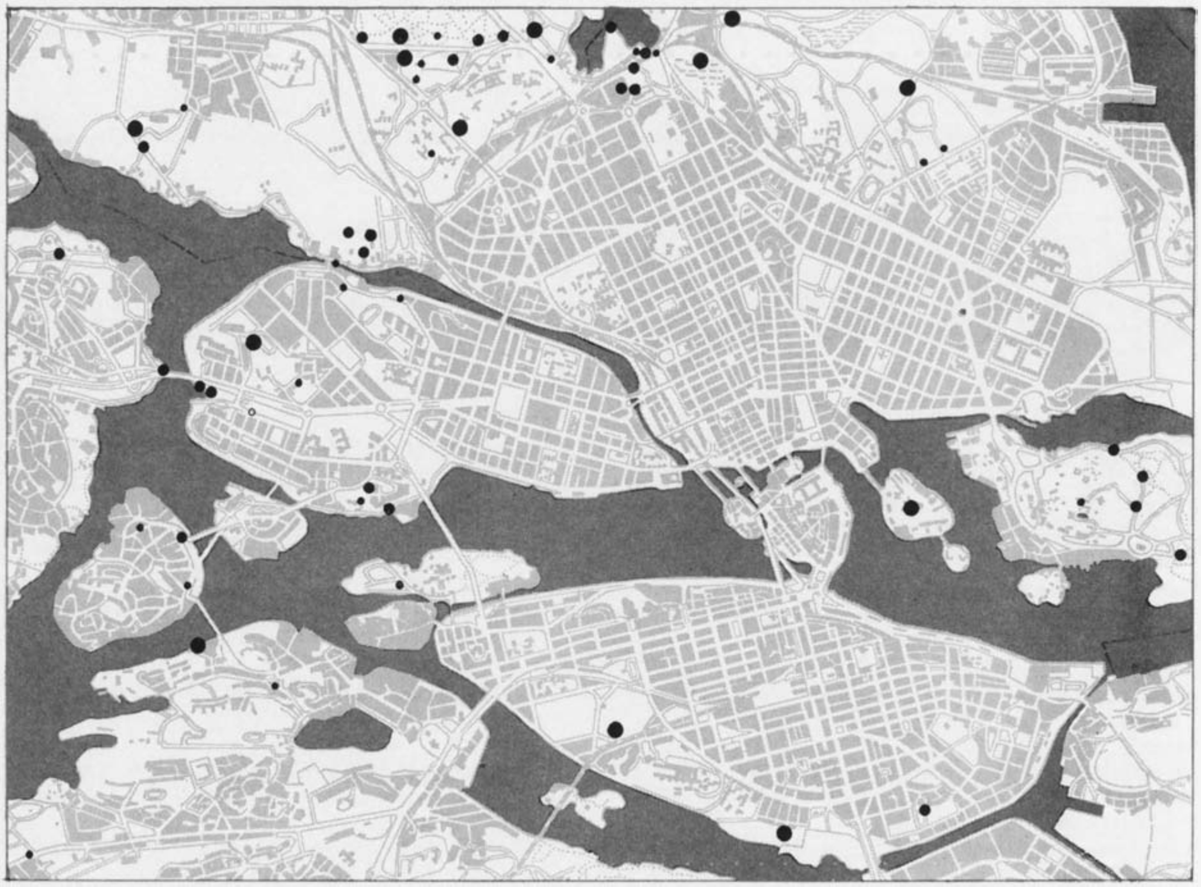


Fig. 34 b. Lecidea scalaris.

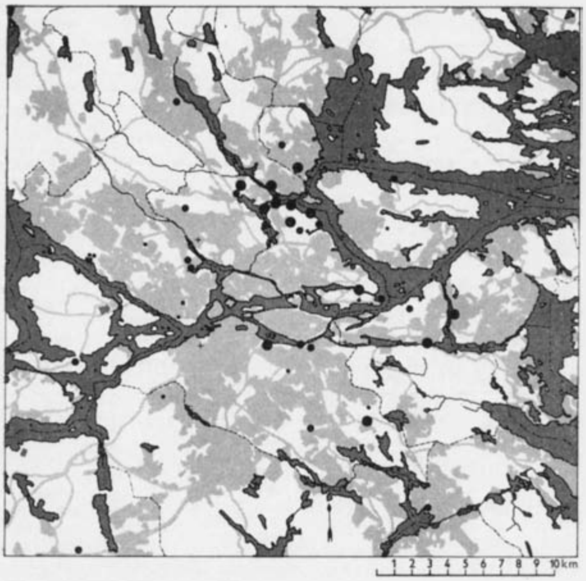


Fig. 34 a. Lecidea scalaris.

L. efflorescens belongs to group 2 B.

No older occurrences have been recorded.

L. glomerulosa (DC) Steud. Syn. *L. euphorea* (Flk.) Nyl.

Ubiquitous in Sweden, but seems to become rarer towards the north. Grows on bark and wood.

Older occurrences: Thedenius (1852, p. 170; 1859, p. 117, s.n. *L. parasema*) describes the species as common in the Stockholm region. Lidingö: Stockby, 1926 (Håkanson); Solna: Ingentingsskogen, 1907 (Täckholm); Överjärva, 1910 (Hülphers); Karlberg, 1851 (Th. M. Fries) and 1862 (Henschen); Stockholm: Enskede, Pungpinan, 1910 (Hülphers); Jakobsberg, 1870 (S. Almquist); Djurgården, 1890 (Kugelberg); Kungsholmen, near Rålambshov on avenue trees 1862 (Henschen), around Stockholm Th. M. Fries (1874, p. 546, s.n. *L. elaeochroma Laureri* (*euphorea* v. *Laureri*).

The following occurrences were noted: Botkyrka: Tullinge, *Fraxinus*, 585; Huddinge: Ågesta, *Quercus*, 587; Nacka: Erstavik, *Fraxinus*, 558; Tyresö: Raksta, *Fraxinus*, 591; Österåker: Bullerhöjden, *Ulmus*, 577, sparse; Resarö, Ytterstrand, *Ulmus*, 576 *a*; Östra Ryd, Bogesund, *Fraxinus*, 548.

All the occurrences were in the "normal zone", and the species should therefore properly be assigned to a group 4. It would also be possible to include for example *Bacidia luteola* in this group (see p. 30).

In a comparison between the older and the more recent occurrences it appears that the species has lost very much territory during the last few decades. All the older occurrences except one are more than 50 years old. The oldest, from Karlberg and Kungsholmen, are more than 100 years old. No occurrences have been noted since 1926 despite the fact that the area has been thoroughly searched by several lichenologists.

L. helvola (Kbr.) Th. Fr.

The species is probably ubiquitous in Scandinavia. It appears to grow on bark of deciduous trees.

Older occurrences: Malme found *L. helvola* on several occasions and at several different places in Boo parish during the years 1907–1910 and in Nacka: Nackanäs, in 1907.

Only one occurrence has been noted: Sollentuna: Edsviken, *Populus*, 516, sparse.

L. olivacea (Hoffm.) Mass.

Ubiquitous in Scandinavia. Seems to prefer smooth bark but is also found on lignum. Common.

Older occurrences: Thedenius (1852, p. 170; 1859, p. 117, s.n. *L. dolosa* (v. *dolosa*) describes the species as rare in the Stockholm region. Lidingö: Kanada, 1930 (Håkanson); Nacka: Nackanäs–Lilla Sickla, *Corylus*, 1931 (Degelius); Stockholm: Frescati, Museum of Natural History, *Populus*, 1956 (Hasselrot).

L. olivacea belongs to group 3 in the investigated area. Fig. 33.

L. quernea (Dicks.) Ach.

Belongs probably to the *P. acetabulum* group. In southern and central Sweden it seems to prefer such deciduous trees as *Acer*, *Fraxinus*, *Ulmus* etc. Almborn (1952, p. 252) describes *L. quernea* as "Rather frequent, mainly on deciduous trees in not too illuminated situations".

Older occurrences: Only one has been noted—at Tyresö: Borgviken, *Alnus*, 1948 (Magnusson & Hasselrot).

The following occurrences have been noted: Botkyrka: Alby, *Tilia*, 583, sparse; Norsborg, *Acer*, 575; Tumba, *Quercus*, 584, sparse; Järfälla: Säby Gård, *Tilia*, 597; Sollentuna: Häggvik, *Acer*, 594; Tyresö: Alby Rectory, *Alnus*, 592 *b*; Kumla, *Tilia*, 590, sparse; Österåker: Resarö, Ytterstrand, *Ulmus*, 576 *a*; Östra Ryd, Rydbo Saltsjöbad, *Fraxinus*, 578.

L. quernea can probably be assigned to group 3.

L. scalaris Ach. Syn. *L. ostreata* (Hoffm.) Schaer.

Ubiquitous in Scandinavia. Santesson (1949, p. 184) states "Skåne–Norrland. Common". Grows on bare wood, stumps, wooden fences, barns, pine bases and the like (l.c.).

Older occurrences: Most of the records are only about 10 years old. It is mainly Hasselrot himself who has noted them. The majority of the occurrences are from wooded sections in the outskirts of the investigated area and are therefore not so interesting. Høeg (1934, p. 132) however mentions the appearance of the species at several places in Stockholm, and Håkanson (1950, p. 216) several places in Lidingö. Degelius gathered *L. scalaris* in 1937 in Djurgården, Blockhusudden, on *Alnus*, and at Fiskartorpet on an old *Quercus*, in the same year in Södermalm, Danvikslunden, on young *Fraxinus* and in 1941 on *Ulmus* at the Biological Museum, Djurgården. Several other earlier finds in Djurgården, etc., show that the species has passed to *Acer*, *Fraxinus* etc.

In the more central parts of the investigated area it also occurs abundantly on deciduous trees. In the peripheral parts it disappears from this substrate and occurs in the outskirts of the investigated area generally on pines. (See also Lundström 1966.) Is assigned to group 1 B (Fig. 34).

Compared with Høeg's notes of occurrences in 1934, it appears that the species has withdrawn from some of the innermost localities, for example in the northern part of the inner city.

Lepraria Ach.

L. candelaris (L.) Fr.

Common on bark and wood throughout Sweden (Santesson 1949, p. 173). Three occurrences have been noted—Huddinge: Vårby, *Fraxinus*, 568, sparse; Österåker: Östra Ryd, Bogesund, *Tilia*, 544; *Ulmus*, 550.

All these occurrences lie outside the external transitional zone and could therefore be assigned to a group 4 together with, for example, *Lecidea glomerulosa* and *Bacidia luteola*.

Older occurrences: most of these date from the end of the 1950s and were noted by Hasselrot. Distribution of these recent occurrences coincides well with those mentioned by me above. The following occurrences may be of interest: Sollentuna: Tureberg, *Alnus*, 1956 (Greta Sernander-Du Rietz); Ravalen, *Quercus robur*, 1962 (Hasselrot); Solna: Haga Park, *Quercus robur*, 1910 (Vestergren det. Hultin); Ulriksdal, *Quercus robur*, 1914 (Florin).

The species has very likely been dislodged from certain parts of its former distribution area.

L. incana (L.) Ach. Syn. *L. aeruginosa* (Wigg.) Sm.

Apparently ubiquitous. Almborn (1952, p. 253) describes the species as "Very frequent, mainly in the crevices of rough bark, preferring shaded exposure". The species can also pass over to earth. Fig. 35.

In the investigated area, the species belongs to group 1 B.

Older occurrence: Stockholm: Oscar's, Strandvägen–Karlavägen, *Acer*, 1919 (Greta Sernander). Cf. also Høeg (1934, p. 132).

Nephroma Ach.

N. parile Ach.

Magnusson (1929, p. 42) describes the species as common in Sweden and says that it grows on mossy stones and tree trunks.

Older occurrences: Stockholm region, fairly common (Thedenius 1852, p. 164; 1859, p. 113, *N. resupinatum papyraceum*—according to Hasselrot this probably refers mainly to *N. parile*). Boo: Lövberga, 1909 (substrate?) (Malme); Stockholm: Bromma, Riksby, Fredriksberg, Måsen, *Populus*, 1911 (Du Rietz); Djurgården (substrate?), 1854 (Thedenius); Täby: north-east of the Grindstugan, *Populus*, 1956 (Hasselrot); Österåker: Knaborg, *Populus*, 1959 (Hasselrot); Östra Ryd: southwest of railway station, *Populus*, 1955 (Hasselrot).

One occurrence was noted—Tyresö: Raksta, *Fraxinus*, 591. This is in the "normal area".

Some of these occurrences are inside the now separated central transitional zone.

Fig. 35 b. Lepraria incana.

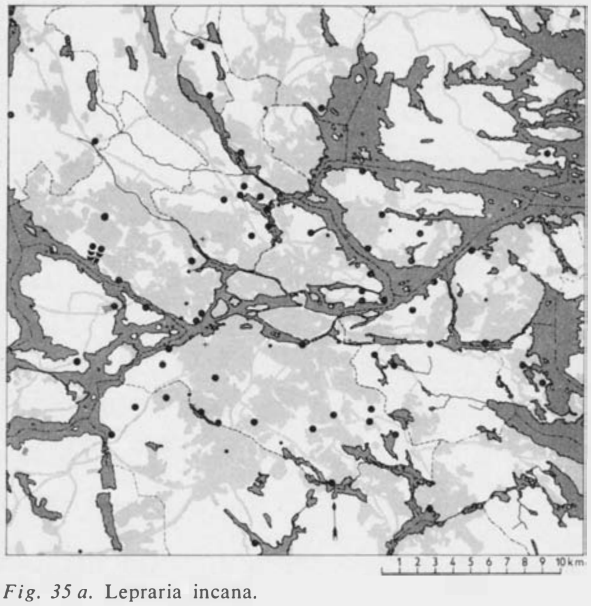


Fig. 35 a. Lepraria incana.

Ochrolechia Mass.

O. androgyna (Hoffm.) Arn. Syn. *O. subtartarea* (Nyl.) Mass.

Almborn (1952, p. 253) describes the species as "Frequent, mainly on rough bark of deciduous trees". The species can go over to moss and lignum.

No records of older occurrences in the Stockholm region have been found.

O. androgyna belongs to group 2 B in this material. Fig. 36.

O. microstictoides Räs. Syn. *Pertusaria silvatica* H. Magn.

Almborn (1952, p. 254) writes: "Frequent, mainly on wood-trees (non-eutrophiated bark)".

No records of older occurrences in the Stockholm region have been found.

The species belongs to group 3. Fig. 37.

O. subviridis (Høeg) Erichs.

Seems to belong to the *P. acetabulum* group. Prefers isolated deciduous trees and copses.

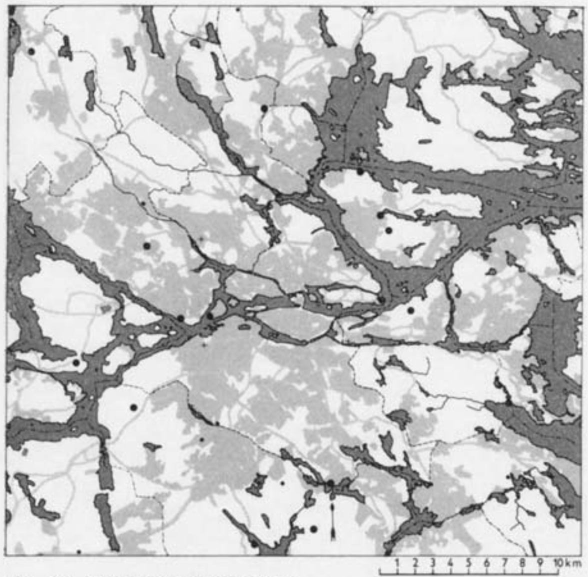


Fig. 36. Ochrolechia androgyna.

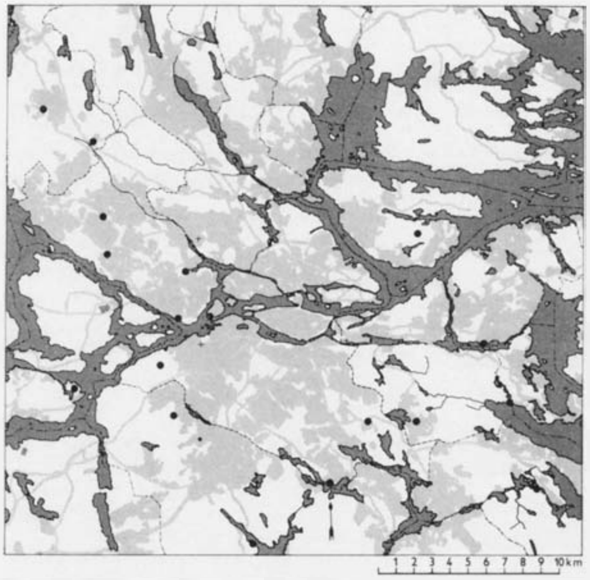


Fig. 37. Ochrolechia microstictoides.

Older occurrence (one only): Tyresö: Hammarberget, *Quercus* (one specimen) 1954 (Degelius, Hasselrot, Lindahl).

One occurrence in the investigated area: Stockholm: Farsta, Fagersjö, *Quercus*, 418, sparse.

Opegrapha Humb.

O. varia Pers.

Almborn (1948) does not include *O. varia* among the southern species. Santesson (1949, p. 176) states, however, that the species is frequent from Skåne to Gästrikland. It prefers old, cracked bark—chiefly on such deciduous trees as *Acer, Ulmus, Fraxinus*, etc.

Older occurrences: Solna: Haga Park, on deciduous tree, 1906 (Täckholm); Järva, 1907 (Malme); Karlberg Park (year?) (Stenhammar); Stockholm: Djurgården, 1894 (Romell); L. Skuggan, *Quercus*, 1907 (Täckholm); Täby: Gribbylund avenue, *Fraxinus*, 1956 (Hasselrot).

Occurrences in the investigated area: Boo: Ormingelandet, *Fraxinus*, 535, abundant; Huddinge: Länna, *Ulmus*, 588; Lidingö: Elfvik, *Fraxinus*, 531, sparse; Lovö: Lovö Church, *Acer*, 521; Stockholm: Hägersten, Vårberg, *Fraxinus*, 567; Spånga, Grimsta, *Fraxinus*, 132; Järvafältet, *Tilia*, 336; Tyresö: Raksta, *Fraxinus*, 591; Österhaninge: Vendelsö, *Acer*, 589, sparse; Österåker: Bullerhöjden, *Ulmus*, 577 *a*; Östra Ryd, Bogesund, *Ulmus*, 550; *Fraxinus*, 546, 549, sparse; Bogesundslandet, *Fraxinus*, 543.

The species does not appear until the "normal area" and should therefore be assigned to group 4.

The species seems to have left large territories in the more central parts of the investigated area. It is a well documented case of such a retreat.

Opegrapha sp.

Tyresö: Raksta, *Fraxinus*, 591, sparse.

Pachyphiale Lönnr.

P. fagicola (Hepp.) Zw.

From Skåne to the northern most part of Sweden. It occurs mostly on bark of deciduous trees (*Acer, Alnus, Fagus*, etc.).

No information has been obtainable regarding older occurrences in the Stockholm region.

Occurrences in the investigated area: Österåker: Bullerhöjden, *Ulmus*, 577 *a*; Resarö, Ytterstrand, *Ulmus*, 576 *a*, abundant; *Betula*, 576 *b*, abundant.

Both localities are in the "normal area".

Parmelia Ach.

P. acetabulum (Neck.) Duby

Greta Sernander (1923) studied the ecology (incl. distribution) of *P. acetabulum* and stated (l.c., p. 319) that the species with few exceptions is to be found on trees by roadsides and on trees in churchyards and parks. See also Du Rietz 1945 *b* (p. 153).

Almborn (1948, p. 17) applies *P. acetabulum* to designate a southern group of lichens in Scandinavia, which have their northern limits largely coinciding with the northern limit for *Quercus robur*. Almborn publishes also a revised map showing distribution in Scandinavia (Fig. 4, p. 19).

Older occurrences: Solna: Överjärva, 1910 (Hülphers), *Quercus robur* (Greta Sernander 1923, p. 308); Bergshamra, *Acer platanoides*, 1958 (Hasselrot); Ulriksdal, *Tilia*, 1958 (Hasselrot); Stockholm: Spånga, Hjulsta, *Populus*, 1915 (Du Rietz) (Greta Sernander 1923, p. 308); Bromma, Alvik, *Fraxinus excelsior*, 1921 (Greta Sernander, l.c., p. 307); Brännkyrka, *Acer platanoides, Ulmus glabra*, 1919 (Greta Sernander, l.c., p. 307); S. Djurgården, *Acer platanoides*, 1920 (Vestergren) (Greta Sernander, l.c., p. 307).

The following occurrences were noted: Botkyrka: Alby, *Tilia*, 583, c.ap.; Danderyd: Enebyberg Gård, *Acer*, 582, sparse; Huddinge: Glömsta, *Fraxinus*, 569; Snättringe, *Quercus*, 571, sparse; Sollentuna: Sollentuna Churchyard, *Fraxinus*, 593, abundant; Stockholm: Hägersten, Bredäng, *Fraxinus*, 454; Skarpnäck, Flaten, *Quercus*, 560, sparse, not vital; Spånga, Järvafältet, Rinkeby, *Acer*, 574, sparse; Sankt Göran, Marieberg, *Ulmus*, 74; Täby: Ensta, *Acer*, 581, sparse; Hagby, *Ulmus*, 596, sparse; Österåker: Östra Ryd, Bogesund, *Acer*, 547, sparse; Rydbo Saltsjöbad, *Fraxinus*, 578, sparse.

The species belongs to group 2 B.

A comparison between the present and the older occur-

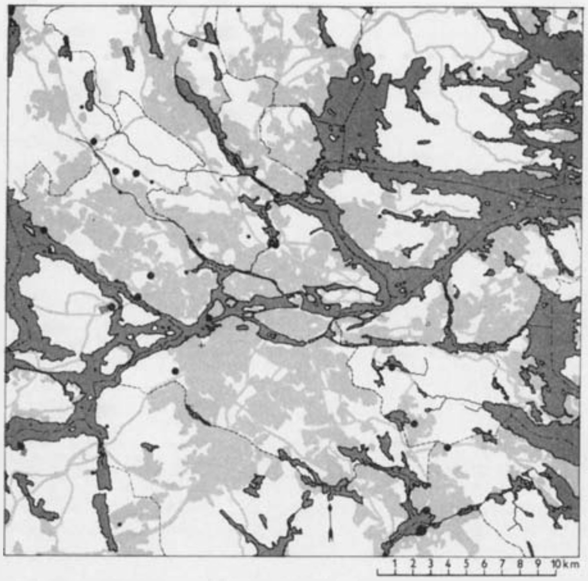


Fig. 38. Parmelia exasperatula.

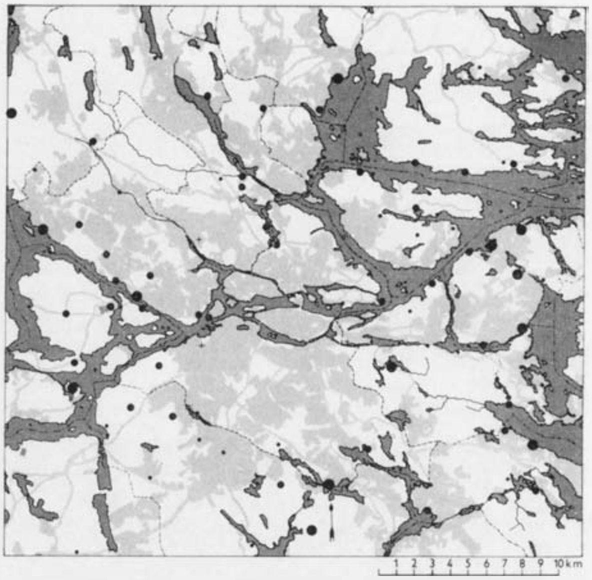


Fig. 39. Parmelia fuliginosa.

rences gives one the impression that the species has disappeared from certain parts of its former territory.

P. exasperata De Not. Syn. *P. aspera* Mass., *P. aspidota* (Ach.) Poetsch.

Assigned to the *U. pustulata* group. Grows on branches and trunks of deciduous trees, seldom on stone (Magnusson 1929, p. 85). Common. Santesson (1949, p. 163) states that the species is found in nearly all parts of Sweden.

Older occurrences: Lidingö: On bark, especially if it is young and smooth, on trunks or (more frequently) branches and twigs of deciduous trees and deciduous bushes (observed on *Populus, Acer, Aesculus hippocastanum*), predominantly on localities exposed to dust impregnation. C. ap. in several places (presumably fairly common) (Håkanson 1950, p. 223), Church, *Acer platanoides,* 1949 (Hasselrot); innermost part of Kyrkviken, *Acer platanoides,* 1950 (Hasselrot); Södergarn, *Fraxinus excelsior,* 1949 (Hasselrot); Elfvik, *Aesculus hippocastanum,* 1949 (Hasselrot); Stora Höggarn, *Fraxinus excelsior,* 1949 (Hasselrot). At many places in the Stockholm region on old, slightly shaded branches of aspen and apple trees (Malme 1910 *a,* p. 115).

Occurrences in the investigated area: Huddinge: Stuvsta, *Quercus,* 476, *Acer,* 474, sparse; Saltsjöbaden: Neglinge, *Acer,* 557, sparse; Sollentuna: Edsviken, *Populus,* 516, not vital; Stockholm: Spånga, Hässelby Villastad, *Fraxinus,* 380; Järvafältet, Rinkeby, *Acer,* 574; Österåker: Bullerhöjden, *Ulmus,* 577 *a,* sparse; Resarö, Ytterstrand, *Betula,* 576 *b,* sparse; Östra Ryd, Bogesund, *Acer,* 547.

The species can probably be assigned to group 3.

P. exasperata is retreating from the more central parts of the investigated area.

P. exasperatula Nyl.

Belongs to the *U. pustulata* group. Grows on tree trunks, especially of avenue trees, seldom on stone (Magnusson 1929, p. 87). Santesson (1949, p. 163) describes it as common on the trunks of deciduous trees etc. almost throughout Sweden, though rarer towards the north.

Older occurrences: Håkanson mentions the species as occurring in several places in Lidingö (1950, p. 223), Hasselrot also—for example at the Church, on *Acer* 1949, Kyrkviken, *Acer* 1950. It was noted in Sollentuna on *Acer* 1955 by Greta Sernander-Du Rietz, at Häggvik on *Tilia* in 1962 by Hasselrot. Solna: Järva, 1909 (Malme); Bergshamra, *Acer* and Ulriksdal, *Tilia,* 1958 (Hasselrot); Stockholm: Frescati, Museum of Natural History, *Fraxinus,* 1927 (Degelius); Enskede, Pungpinan, 1910 (Hülphers).

P. exasperatula belongs to group 3. Fig. 38.

P. exasperatula is clearly withdrawing from the suburbs of Stockholm.

P. fuliginosa (Duby) Nyl.

Belongs to the *U. pustulata* group. The chief form is fairly frequent on stone and not uncommon on trees, while v. *laetevirens* is frequent on trees and rare on stone (Magnusson 1929, p. 86).

Older occurrences: Lidingö: Fjäderholmarna islets (southern islet), common on bark, 1937 (Degelius); several places (Håkanson 1950, p. 223); Nacka: Långsjön lake, apparently common but often small specimens, 1931 (Degelius); Solna: Järva, bark, 1909 (Malme); Stockholm: Bromma, Traneberg, 1911 (Lundqvist); South Djurgården by the "I Tankar" statue, *Ulmus* (Høeg 1934, p. 132).

The species belongs to group 2 B. Fig. 39.

P. fuliginosa has retreated to some extent.

P. saxatilis (L.) Ach.

Probably ubiquitous in Sweden. Grows on rock and stone extremely commonly, on tree trunks fairly commonly and occurring throughout Sweden (Magnusson 1929, p. 89). Similar information is given by Santesson (1949, p. 196).

Older occurrences: Lidingö: Not uncommon also on tree trunks (especially the basal parts) (Håkanson 1950, p. 224).

Occurrences in the investigated area: Huddinge: Ågesta, *Quercus,* 587, sparse; Lidingö: Stockby, *Acer,* 529; Nacka: Erstavik, *Fraxinus,* 558, sparse; Hellasgården, *Quercus,* 565; Sollentuna: Sjöberg, *Quercus,* 517; Södersätra, Väsjö, *Quer-*

cus, 595, sparse; Stockholm: Farsta, Farsta Gård, *Betula,* 416 *b,* sparse; Hägersten, Skärholmen, *Quercus,* 566; Spånga, Grimsta, *Betula,* 127, sparse; Västerled, Ålsten, *Fraxinus,* 422; Täby: Näsby Slott Park, *Tilia,* 518, sparse, dead; Österåker: Bullerhöjden, *Ulmus,* 577 *a, Betula,* 577 *b.*

The species belongs to group 3.

P. subargentifera Nyl.

Santesson (1949, p. 163) writes that *P. subargentifera* grows on avenue trees, etc., and that it is fairly frequent in southern and central Sweden but rare in Norrland. Grows also, though rarely, on stone (Magnusson 1929, p. 88). Almborn (1948) does not include the species in his group classification.

Older occurrences: Lidingö: Hustegaholm avenue, *Ulmus,* 1949 (Hasselrot), (Håkanson 1950, p. 225); Elfvik, *Fraxinus,* 1949 (Hasselrot); Churchyard, *Acer,* 1949 (Hasselrot); Ekholmsnäs, *Quercus* and *Acer* (Håkanson); St. Höggarn, *Acer* and *Fraxinus,* 1949 (Hasselrot); Nacka: Lilla Sickla, *Tilia,* 1931 (Degelius); Solna: Järva, 1908 (Malme); Haga Park, 1910 (Hülphers); between Haga and Järva, *Tilia,* 1910 (Hülphers); Järva, *Tilia* (Malme 1910 *a,* p. 122); Stockholm: Bromma, Åkeshov, *Tilia,* 1911 (Du Rietz); Ulvsunda, *Tilia,* 1927 (Degelius); Church, *Acer* (Du Rietz).

P. subargentifera belongs to group 3. Fig. 40.

The species previously extended farther into the inner city.

P. subaurifera Nyl.

Belongs to the *U. pustulata* group. Occurs on the bark of deciduous and coniferous trees (especially on branches) more rarely on wood and stone.

Older occurrences: Stockholm region on deciduous trees, rarer on *Pinus* and on lignum. Very frequent (Malme 1910 *a,* p. 121). Lidingö: Kyrkviken, *Acer,* sparse, 1950 (Hasselrot), (Håkanson 1950, p. 225); Tranholmen, *Fraxinus,* 1949; St. Höggarn, *Fraxinus,* 1949 (Hasselrot), (l.c.). May be more common than the few records states (Håkanson, l.c.). Solna: Järva, 1909 (Malme); Överjärva c. ap. 1910 (Hülphers); Stockholm: Bromma, *Populus tremula, Alnus, Quercus, Betula, Acer* (Du Rietz); Brännkyrka, 1910 (Hülphers); Djurgården, 1910 (Hülphers); Grindshage, 1962 (Henschen).

Occurrences in the investigated area: Boo: Lännersta, *Quercus,* 539, sparse; Huddinge: Ågesta, *Quercus,* 587, sparse; Stockholm: Farsta Gård, *Quercus,* 416 *a,* sparse; Spånga, Hässelby V.-stad, *Quercus,* 379.

P. subaurifera belongs to group 3.

Small specimens of *P. subaurifera* may have been overlooked by the present auther.

P. sulcata Tayl.

The species is common throughout Sweden and grows both on tree trunks and on boulders.

Older occurrences: Stockholm: Bromma, *Ulmus,* common on deciduous trees, Alvik, Fredriksberg, Johannelund, Minneberg, Traneberg (Du Rietz); Stockholm: *Tilia,* 1910 (Hülphers); "Gotthem" restaurant (near station 395) (Høeg 1934, p. 133); S. Djurgården (near station 396), *Ulmus,* sparse (Høeg, l.c., p. 133); Rosendal (near station 399), *Acer* (Høeg, l.c., p. 133); Götgatan 111, *Fraxinus* (Høeg, l.c.); Tantolunden, *Ulmus,* sparse (Høeg, l.c.); Valhallavägen, *Tilia* (Høeg, l.c., pp. 133, 134), sparse.

P. sulcata belongs to group 1 B. Fig. 41.

This species also, which penetrates so far into the inner city, has manifestly disappeared from its innermost localities during the last 30 years.

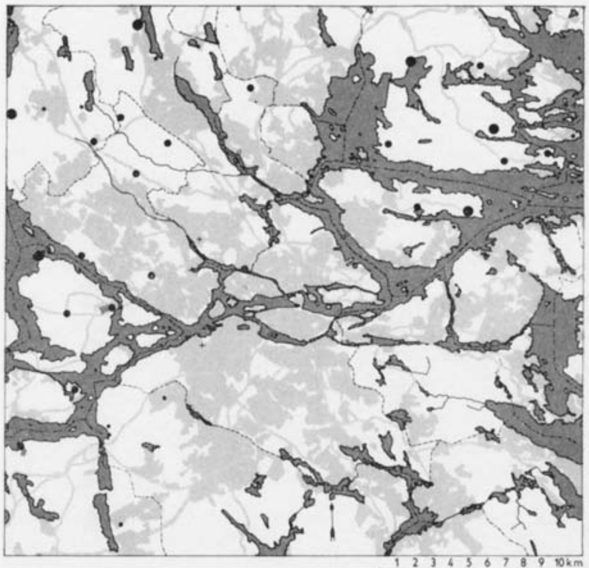


Fig. 40. Parmelia subargentifera.

Parmeliopsis Nyl.

P. aleurites (Ach.) Lettau. Syn. *P. pallescens* (Hoffm.) Zahlbr.

Ubiquitous in Sweden. Grows on pine bark, stumps and the like, and is fairly frequent throughout Sweden (Santesson 1949, p. 160).

The species does not appear in the material that is the basis of this thesis. However, if coniferous trees had been more abundantly represented among the phorophytes, *P. aleurites* would have been included in the periphery of the investigated area. This is shown by Lundström's (1966, p. 76) material.

The species can probably be assigned to group 3.

Older occurrences: Fairly frequent in the Stockholm region (Thedenius 1852, p. 165; 1859, p. 133). Lidingö: Wooded areas, mainly on *Pinus,* also noted on *Juniperus, Picea* and *Betula.* Common (though formerly more than now), (Håkanson 1950, p. 222); Solna: Haga Park, 1862 (Henschen); Stockholm: Bromma, Alvik, 1911, Traneberg, *Pinus,* 1912 (Du Rietz); 1912 (Lundqvist); fairly common, *Pinus* (Du Rietz s.n. *Cetraria a.*); Djurgården, *Pinus* (herb. C. F. Nyman), Lilljansskogen, *Pinus,* 1906, 1907 (Täckholm).

The species has obviously disappeared from many of its previous localities.

P. ambigua (Wulf.) Nyl.

Ubiquitous in Sweden. Grows on bare wood, frequently decayed wood, stumps, bark of growing trees and—although rarely—on stone.

Older occurrences: Lidingö: on bark and lignum of most lignoses, particularly abundant on trunk bases. Extremely common (Håkanson 1950, p. 222); Nacka: Nackanäs, *Pinus* c. ap. (Malme); Solna: Haga Park, 1862 (Henschen); Järva, *Pinus,* c. ap. 1907 (Malme); Stockholm: Bromma, Sandvik, 1911 (Lundqvist); Traneberg, deciduous trees, 1907 (Täckholm); ditto *Pinus,* 1912 (Lundqvist); Alvik, Fredriksberg, Johannelund, Minneberg, Riksby, Vibergslund (Du Rietz); Ladugårdsgärdet, 1861 (Thedenius); Sandsjön, 1858 (Cleve);

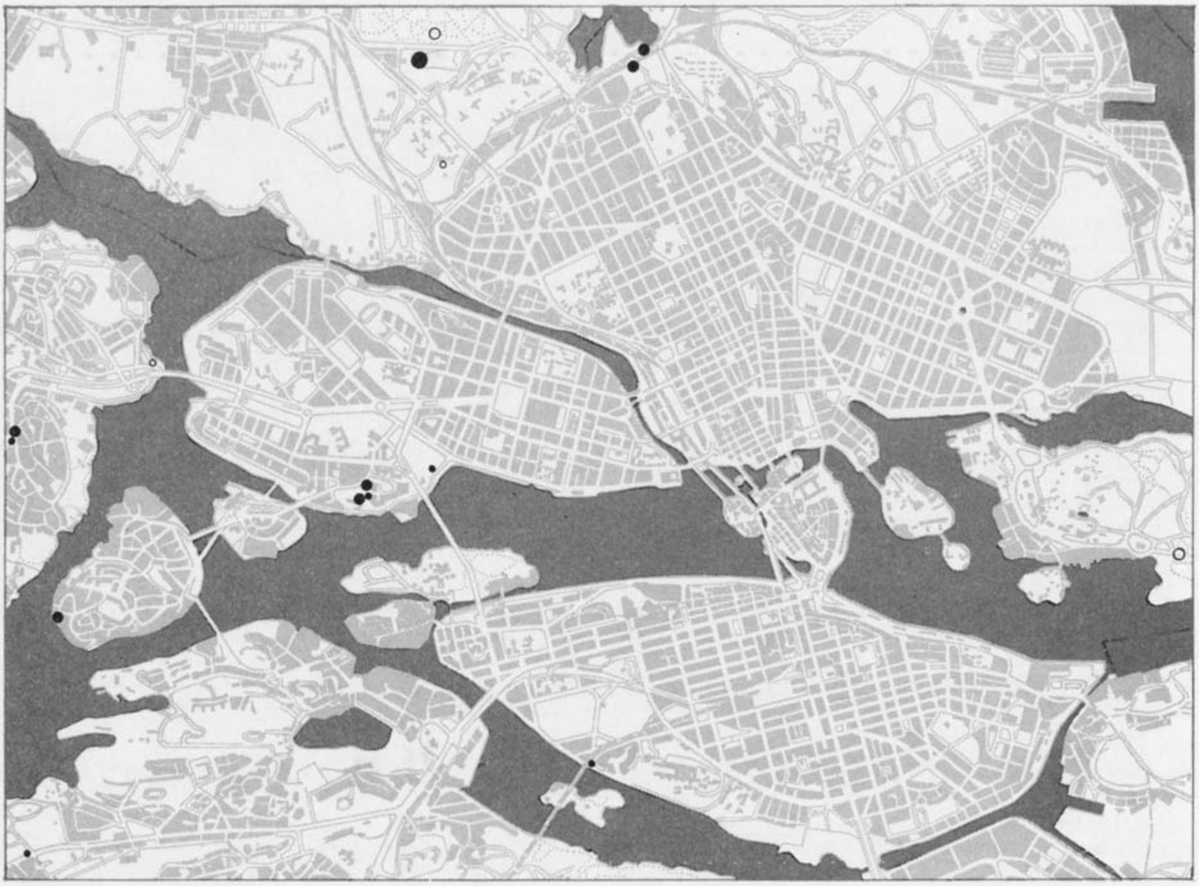


Fig. 41 b. Parmelia sulcata.

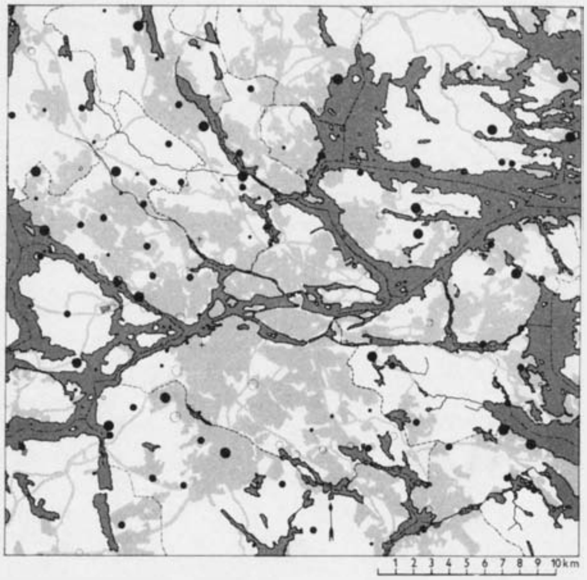


Fig. 41 a. Parmelia sulcata.

Bergian Botanical Gardens, *Pinus,* 1944 (Grapengiesser); Djurgården, 1852 (herb. C. F. Nyman); N. Djurgården, Sjöstugan, *Quercus* and *Populus tremula,* 1958 (Hasselrot).

P. ambigua belongs to group 2 A in this material (Fig. 42). If conifers had been more abundantly represented among the phorophytes, the species would have turned out to be considerably commoner in the peripheral parts of the investigated area. This is shown by Lundström's (1966, p. 77) list.

The species formerly penetrated farther into the inner city.

P. hyperopta (Ach.) Arn.

Common in the north of Sweden, sparse towards the south (Hasselrot 1953, p. 95 and Fig. 25). The choice of substrate agrees with that of *P. ambigua.*

Older occurrences: Lidingö: On bark and lignum, especially trunk bases, externally running roots and stumps of *Pinus.* Formerly abundant on old wooden fences (Håkanson 1950, p. 223); Stockholm: Bromma, Alvik, Fredriksberg, Johannelund, Minneberg (Du Rietz, cf. Hasselrot 1953, p. 164); "Prope Holmiam ad radicem *Pini*" c. ap. 1909 (Magnusson);

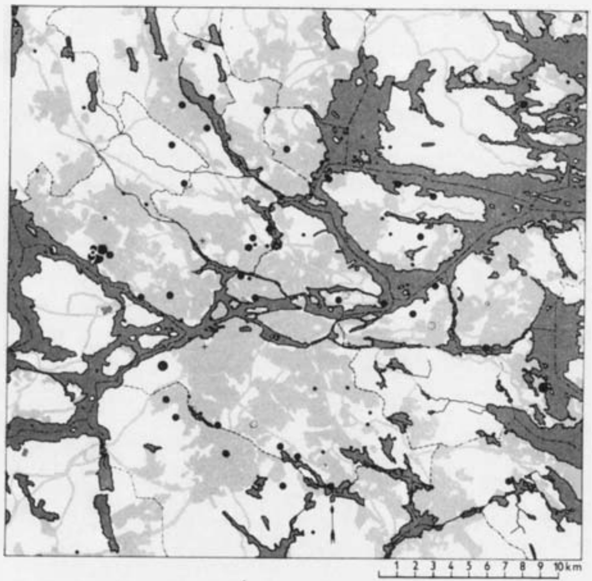


Fig. 42. Parmeliopsis ambigua.

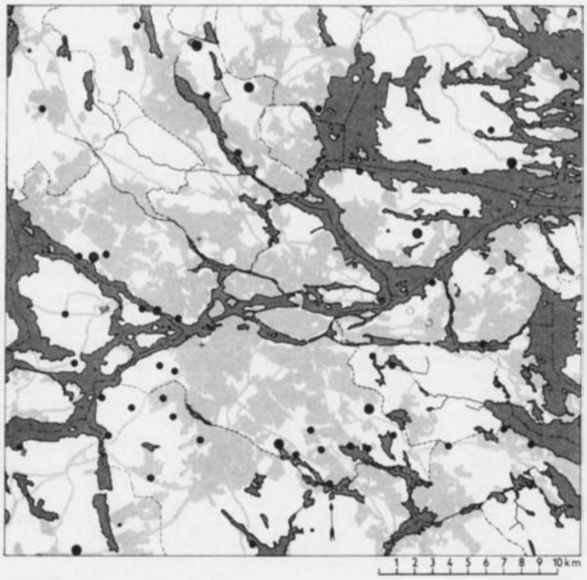


Fig. 43. Pertusaria amara.

Bergian Botanical Gardens (Wittrock and Juel, 1891, p. 2, s.n. *P. diffusa*).

One occurrence: Djursholm: Danderyd, *Quercus,* 471.

The species is very scarce in Lundström's (1966, p. 79) material also. All the occurrences of *P. hyperopta* are within an area with a radius of a few kilometres.

Many of the older occurrences were observed inside the present limit of the species towards the inner city.

Peltigera. Pers.

P. canina (L.) Willd.

Ubiquitous in Sweden. Grows primarily on the ground, usually among moss. When it occurs on the trunk bases of living trees, it always grows on moss. The species is common in its distribution area (less so in the north).

Two occurrences were noted, both on *Fraxinus:* Lovö: Kärsön, 427, sparse; Lidingö: Norra Sticklinge, 510.

Both occurrences are in the "normal area".

Pertusaria D.C.

P. albescens (Huds.) Choisy et R. G. Wern v. *corallina* (Zahlbr.) Laund.

One occurrence only: Stockholm: Essinge, Stora Essingen, *Quercus,* 387, sparse.

No older occurrence.

P. amara (Ach.) Nyl.

Belongs to the *U. pustulata* group. Occurs on the bark of both deciduous and coniferous trees, more rarely on worked wood and on stone (Erichsen 1936, p. 563). Common except in the northern part of its distribution area (Santesson 1949, p. 192). According to Almborn (1952, p. 256) the species appears "mainly in rather illuminated situations".

Older occurrences: Solna: Haga Park, 1910 (Hülphers); Karlberg, *Corylus,* 1906 (Täckholm); Northern Cemetery, *Tilia* (Høeg 1934, p. 133); Stockholm: Bromma, Alvik, *Populus tremula, Alnus,* 1911 (Du Rietz); Brännkyrka, Farsta, Marieberg, *Tilia,* 1958 (Hasselrot); Uggleviken, *Alnus,* 1905 (Täckholm); ditto 1911 (Vestergren); S. Djurgården, North Strandvägen (near station 396) (Høeg 1934, p. 134); immediately outside Rosendal (near station 399), *Acer* (Høeg l.c., p. 133); immediately outside Skansen, *Ulmus* (Høeg, l.c.).

P. amara belongs to group 2 B of the present material. Fig. 43.

The species has obviously disappeared from many places in Stockholm.

P. coccodes (Ach.) Nyl. v. *coccodes* Almb.

Belongs to the *P. acetabulum* group. Occurs especially on the bark of older deciduous trees, isolated as well as in thinly wooded areas. Rare on conifers. *P. coccodes* can also appear on worked wood and—though extremely rarely—on stone (Erichsen 1936, p. 354). Almborn (1952, p. 256) writes that *P. coccodes* is "somewhat coniophilous".

Older occurrences: Stockholm: S. Djurgården, near Gröndal, *Acer,* 1937 (Degelius); Djurgården, S. Djurgården, near "Gotthem" restaurant (near station 395), *Ulmus,* outside Rosendal (near station 399), *Acer* (Høeg 1934, pp. 133 ff.).

The species belongs to group 3 in this material. Fig. 44.

The variety has withdrawn from localities nearest to the inner city.

P. coccodes (Ach.) Nyl. v. *coronata* (Ach.) Almb. Syn. *P. coronata* (Ach.) Th. Fr.

P. coccodes v. *coronata* has a southern distribution in Sweden. Almborn (1948) does not mention it, however. Erichsen (1936, p. 396) states that *P. coronata* grows on the bark of deciduous trees and in thinly wooded areas. It appears exceptionally on stone.

There is only one occurrence in the investigated area—Huddinge: Sundby Manor House, *Quercus,* 586.

No older occurrences have been recorded.

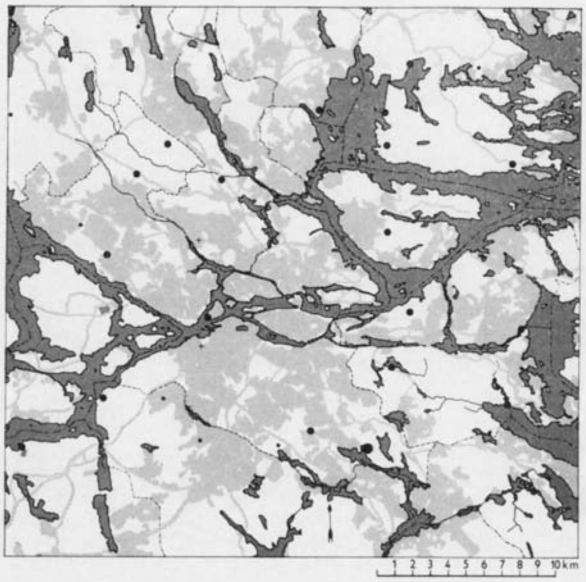


Fig. 44. Pertusaria coccodes v. coccodes.

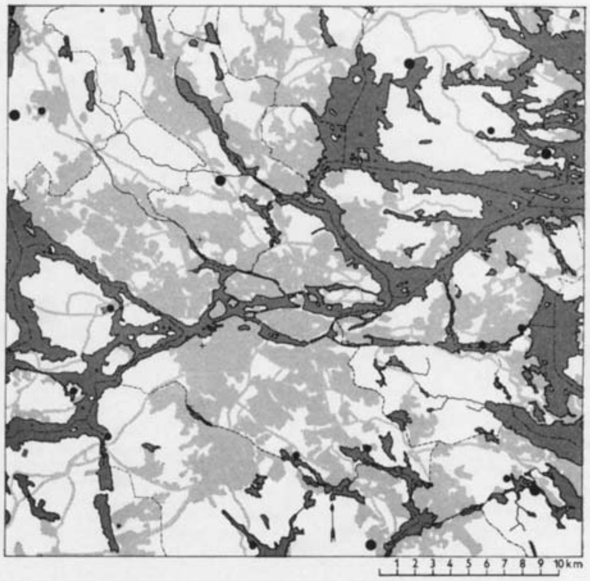


Fig. 45. Pertusaria globulifera v. discoidea.

P. globulifera (Turn.) Mass. v. *discoidea* (Pers.) Almb. Syn. *P. discoidea* (Pers.) Malme

Belongs to the *U. pustulata* group. Grows on the bark of deciduous trees, seldom on conifers, and prefers open situations, particularly along roadsides (Erichsen 1936, p. 666).

P. globulifera v. *discoidea* belongs to group 3 in this investigation. Fig. 45.

No records of older occurrences.

P. globulifera (Turn.) Mass. v. *globulifera* Almb. Syn. *P. globulifera* (Turn.) Mass.

Assigned to the *P. acetabulum* group. Grows on all kinds of deciduous trees, passing occasionally to moss, seldom to wood or stone. It prefers isolated trees at roadsides but also occurs in thinly wooded areas (Erichsen 1936, p. 657).

Older occurrences: Stockholm: Bromma, Alvik, *Populus tremula* (Du Rietz) (s.n. *Variolaria globulifera*); S. Djurgården, just outside Rosendal, *Acer* (Høeg 1934, p. 133).

The following occurrences were noted: Boo: Boo Church, *Tilia*, 534, sparse; Järfälla: Jakobsberg, *Acer*, 520; Lidingö: Södergarn, *Fraxinus*, 532, sparse; Lovö: Lovö Church, *Acer*, 521; Sollentuna: Häggvik, *Acer*, 594; Solna: Haga, *Acer*, 438; Stockholm: Brännkyrka, Herrängen, *Quercus*, 458, abundant; Essinge, Stora Essingen, *Quercus*, 383; Tyresö: Kumla, *Tilia*, 590, sparse; Täby: Näsby Slott Park, *Tilia*, 518; Österåker: Östra Ryd, Rydbo Saltsjöbad, *Fraxinus*, 578, sparse.

P. globulifera v. *globulifera* belongs to group 2 B.

The species has very likely disappeared from the inner parts of the Stockholm region.

P. leioplaca (Ach.) DC.

Belongs to the *U. pustulata* group. Occurs on smooth bark, especially on that of young deciduous trees, seldom on conifers (Erichsen 1936, p. 475).

Older occurrences: Nacka: Nackanäs–Lilla Sickla, *Corylus*, 1931 (Degelius); Saltsjöbaden: Gåsölandet, *Fraxinus*, 1954 (Hasselrot); Solna: Järva, 1910 (Malme); Stockholm: Bromma, Johannelund, *Sorbus* (Du Rietz).

Only one occurrence has been noted—Huddinge: Segeltorp, *Quercus*, 572 (outer transitional zone).

The species has withdrawn from its formerly innermost localities in the surroundings of Stockholm.

P. leprarioides Erichs. Syn. *P. silvatica* H. Magn.

Belongs to the *P. acetabulum* group. Erichsen (1936, p. 679) states laconically "An Rinden".

Three occurrences: Huddinge: *Quercus*, 476; Lidingö: Norra Sticklinge, *Fraxinus*, 511; Stockholm: Ulvsunda, *Quercus*, 208, sparse.

The species penetrates far into the investigated area, but it is impossible to decide from the scanty material whether it belongs to group 1 B or 2 B.

No older occurrences have been noted.

P. lutescens (Hoffm.) Lamy

Belongs to the *P. acetabulum* group. Occurs on the bark of deciduous trees, especially *Quercus* and *Fagus*, seldom on conifers. Prefers well-lighted habitats in wooded areas (Erichsen 1936, p. 651). Almborn (1952, p. 258) describes it as "frequent", Santesson (1949, p. 159) as fairly common.

Older occurrences: Stockholm: Bromma, Margretelund, *Quercus*, year? (Du Rietz); Djurgården, *Quercus* (Thedenius 1852, p. 173, s.n. *P. Wulfenii* v. *variolosa*); Framnäs district, *Quercus* (Thedenius 1859, p. 9, s.n. *P. Wulfenii* v. *variolosa*); Stockholm region, rare (Thedenius 1852, p. 173; 1859, p. 119; s.n. *P. Wulfenii* v. *variolosa*).

The following occurrences were noted: Boo: Boo Old Church, *Ulmus*, 551; Ekerö: Gällstaö, *Ulmus*, 524; Sollentuna: Sjöberg, *Quercus*, 517; Stockholm: Essinge, Stora Essingen, *Quercus*, 383; Skarpnäck, Flaten, *Quercus*, 560, sparse; Orhem, *Fraxinus*, 497; Tyresö: Tyresösand, *Fraxinus*, 564; Österåker: Östra Ryd, Bogesund, *Ulmus*, 550; Rydboholm, *Fraxinus*, 579.

P. lutescens belongs to group 3.

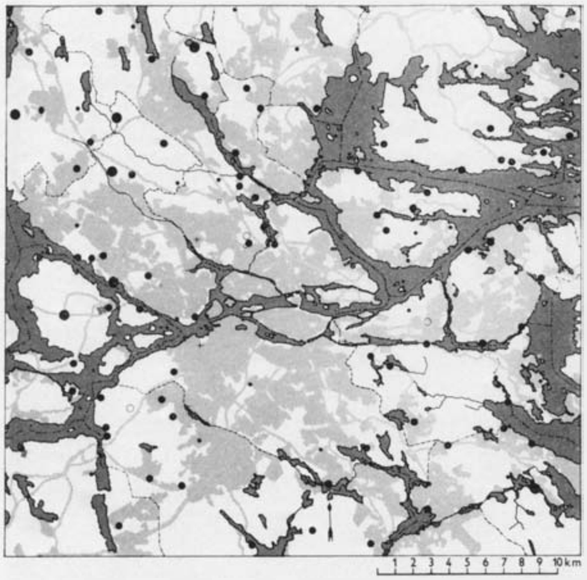


Fig. 46. Phlyctis argena.

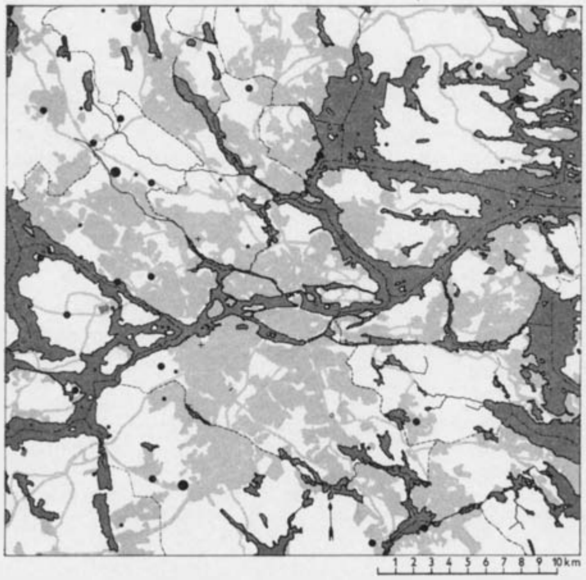


Fig. 47. Physcia ascendens.

The species apparently penetrated formerly more deeply into the inner city.

P. pertusa (L.) Tuck.

Belongs to the *P. acetabulum* group. Grows on all kinds of trees, rarely on lignum. Common.

Older occurrences: Lidingö: Stålebo, 1933 (Håkanson): Stockholm: Bromma, *Populus tremula,* several places (Du Rietz, s.n. *P. communis*); S. Djurgården, *Acer,* sparse (Høeg 1934, p. 133, s.n. *P.* cf. *communis*).

One occurrence was noted in the investigated area: Stockholm: Farsta, Fagersjö, *Quercus,* 418.

Phlyctis (Wallr.) Flot.

P. argena (Ach.) Flot.

Assigned to the *U. pustulata* group. Grows on the bark of deciduous trees and is common in its distribution area (Santesson 1949, p. 160).

Older occurrences: Solna: Haga (Høeg 1934, p. 133); Haga Park southern gates, old park trees, here almost the only lichen (Høeg 1934, p. 131); Northern Cemetery, *Acer* (Høeg 1934, p. 133); Stockholm: Bromma, Ulvsunda, *Quercus,* 1927 (Degelius); Lillsjönäs, 1907, *Populus tremula* (Malme 1926, p. 7); Brännkyrka, Nybohov, *Tilia, Ulmus* (Høeg 1934, p. 133); Djurgården 1891 Leg.?; South Djurgården, c. 100 metres east of "Gotthem" restaurant (near station 395), ditto Northern Strandvägen, ditto immediately outside Rosendal, *Acer* (near station 399), Lilljansskogen, Margaretavägen, Valhallavägen c. 15 metres from street, *Acer,* sparse, Södermalm, Ringvägen, *Acer,* sparse, Ringvägen–Rosenlundsgatan, *Acer,* Skanstull, Götgatan 111, *Fraxinus* (Høeg 1934, pp. 133, 134); at many places in the Stockholm region, mainly on old *Populus tremula,* less often on *Quercus, Juniperus* and *Betula.* Apothec. by no means rare (Malme 1910 *b*).

Belongs to group 2 B in the present material. Fig. 46.

The species has disappeared since the 1930s from the inner parts of its former distribution area around Stockholm.

Physcia Vain.

Ph. aipolia (Ehrh.) Hampe.

Occurs on the bark of deciduous trees (especially avenue trees and *Populus tremula*) and is common throughout Sweden (Santesson 1949, p. 204).

Older occurrences: Lidingö: Hustegaholm, *Populus tremula,* 1949 (Hasselrot), (Håkanson 1950, p. 228); Solna: Northern Cemetery, *Tilia* (Høeg 1934, p. 133); Stockholm: Bromma, Ålsten, *Populus tremula,* 1913 (Du Rietz); *Populus tremula, Ulmus* (Du Rietz); Stockholm (Thedenius).

The following occurrences were noted: Boo: Ormingelandet, *Fraxinus,* 535; Botkyrka: Tullinge, *Fraxinus,* 585, abundant; Huddinge: Vårby, *Fraxinus,* 568; Järfälla: Henningstorp, *Fraxinus,* 599; Järfälla Church, *Ulmus,* 519, sparse; Lovö: Lovön, Lambarudd, *Fraxinus,* 522, abundant; Sollentuna: Sollentuna Churchyard, *Fraxinus,* 593; Stockholm: Hägersten, Bredäng, *Fraxinus,* 454, sparse; Spånga, Grimsta, *Fraxinus,* 132; Järvafältet, Hägerstalund, *Fraxinus,* 335; Kista avenue, *Tilia,* 336; Stora Tensta Gård, *Acer,* 574; Tyresö: Alby Rectory, *Fraxinus,* 592 *a,* sparse; Österåker: Resarö, Ytterstrand, *Ulmus,* 576 *a,* sparse; Östra Ryd, Bogesund, Frösvik, *Fraxinus,* 548; Röskär, *Fraxinus,* 549, sparse; Rydboholm, *Fraxinus,* 579; Rydbo Saltsjöbad, *Fraxinus,* 578.

Ph. aipolia belongs to group 3.

The species has noticeably lost territory.

Ph. ascendens Bitter

Belongs to the *U. pustulata* group. Fairly common in its distribution area. Grows on bushes and wood, sometimes also on stone (Santesson 1949, p. 171).

Older occurrences: Common in the Stockholm region (Thedenius 1852, p. 165; 1859, p. 114). Lidingö: Elfvik, *Acer,* 1949 (Hasselrot); St. Höggarn, *Acer,* 1949 (Håkanson 1950, p. 228); Solna: Järva, 1910 (Malme); Bergshamra, *Acer,* 1958; Ulriksdal, *Acer,* 1958 (Hasselrot): Stockholm: Brännkyrka, Liljeholmen, 1862 (Henschen); Stockholm (Thedenius, s.n. *Parmelia stellaris*), Djurgården, on wood, 1862 (Henschen, s.n. *Ph. stellaris* v. *tenella*). By the road to Ma-

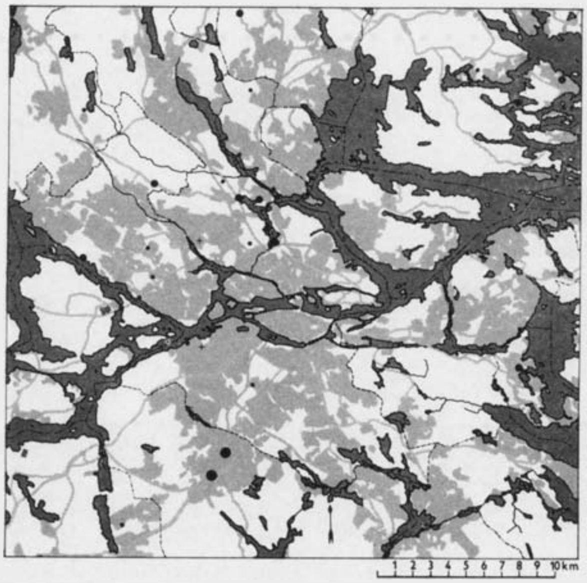


Fig. 48. Physcia dubia.

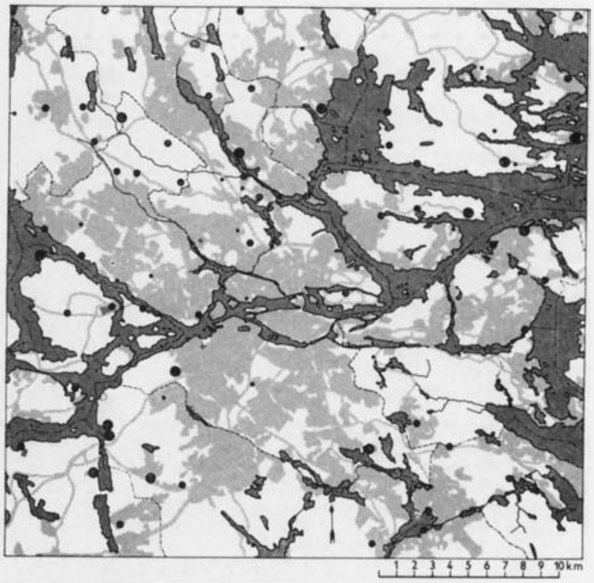


Fig. 49. Physcia entheroxantha.

rieberg 1862 (Henschen, s.n. *Ph. stellaris*), Skanstull, Götgatan 111, *Fraxinus* (Høeg 1934, p. 133).

Ph. ascendens belongs to group 3. Fig. 47.

The species apparently penetrated more deeply into the inner city previously.

Ph. caesia (Hoffm.) Hampe

Ubiquitous in Sweden. Common, occurring mainly on stone, especially if it is dust-impregnated or calcareous (Santesson 1949, p. 204). Also occurs on the bark of growing trees, especially roadside trees, particularly at the base of the trunk.

Older occurrences: Species not previously noted on the bark of growing trees.

The following occurrences were noted: Botkyrka: Alby, *Tilia*, 583, sparse; Huddinge: Fullersta, *Ulmus*, 475; Nacka: Bollmora, *Fraxinus*, 562, sparse; Sollentuna: Sollentuna Churchyard, *Fraxinus*, 593, sparse; Stockholm: Spånga, Järvafältet, *Tilia*, 336; Österåker: Bullerhöjden, *Ulmus*, 577 *a*, sparse; Östra Ryd, Bogesund, *Fraxinus*, 548.

The species probably belongs to group 4, i.e. *Ph. caesia* on the bark of growing trees is found almost exclusively in the "normal area".

Ph. dubia (Hoffm.) Lynge. Syn. *Ph. tribacea* (Ach.)

Frequent throughout Sweden. Grows on stone (high rocks frequented by birds), avenue trees and the like (Santesson 1949, p. 172).

Older occurrences: Lidingö: On rocks and boulders subject to dust impregnation or bird excreta, occasionally also on roadside trees (Håkanson 1950, p. 228); Sollentuna: Tureberg, *Tilia*, a few examples, 1956 (Greta Sernander-Du Rietz).

The species belongs to group 2 B. Fig. 48.

Ph. entheroxantha Nyl. Syn. *Ph. grisea* (Lam.) Lettau p.p.

Probably assignable to the *U. pustulata* group. It is common on roadside trees, at least in eastern Svealand.

The species belongs to group 2 B. Fig. 49.

There are no records of older occurrences in the investigated area.

Ph. farrea (Ach.) Vain. Syn. *Ph. grisea* (Lam.) Lettau p.p.

Also probably assignable to the *U. pustulata* group. Apparently rather more sparse than *Ph. entheroxantha*, at least in eastern Svealand. Its habitat-requirements coincide largely with those of the last-mentioned species.

Ph. farrea belongs to group 3. Fig. 50.

No older occurrences in the investigated area have been noted.

Ph. nigricans (Flk.) Stiz.

Assignable to the *U. pustulata* group. Occurs on trees and stones by roadsides and is fairly frequent (Santesson 1949, p. 173).

Older occurrences: Lidingö: Ekolmsnäs, *Acer*, 1949 (Hasselrot), (Håkanson 1950, p. 228); Elfvik, *Fraxinus*, 1949 (Hasselrot); Stockholm: Bromma, Alvik, *Acer*, 1920 (Du Rietz).

The following occurrences were noted in the investigated area: Danderyd: Enebyberg Gård, *Fraxinus*, 582; Huddinge: Fullersta, *Ulmus*, 475, sparse; Glömsta, *Fraxinus*, 569, sparse; Vistaberg School, *Populus*, 570, sparse; Järfälla: east of Church, *Ulmus*, 519, sparse; Lidingö: Elfvik, *Fraxinus*, 531, sparse; Sollentuna: Överby, *Fraxinus*, 601, sparse; Stockholm: Brännkyrka, Örby Slott, *Ulmus*, 464, sparse; Tyresö: Alby Rectory, *Fraxinus*, 592 *a*.

The species belongs to group 3 and has manifestly retreated from large parts of its former distribution area.

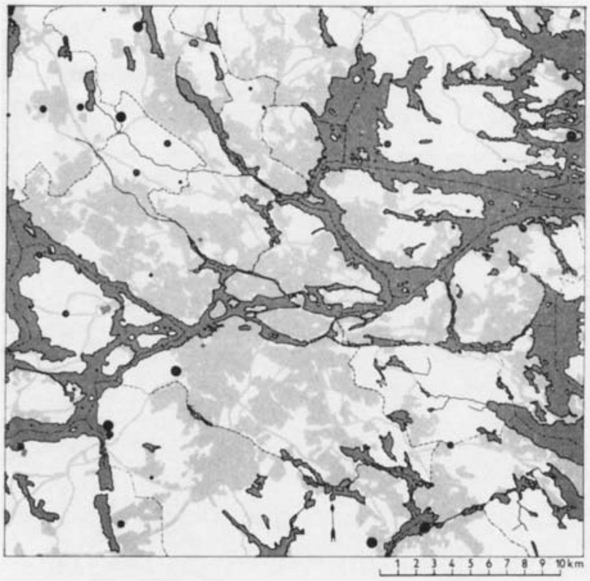


Fig. 50. Physcia farrea.

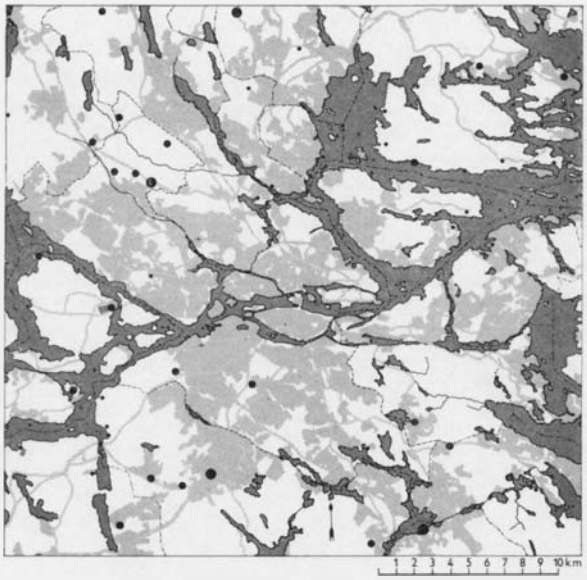


Fig. 51. Physcia orbicularis.

Ph. orbicularis (Neck.) DR

Assigned to the *U. pustulata* group. Occurs on the bark of avenue trees and the like, on stone (mainly calcareous stone) and is common throughout the investigation area (Santesson 1949, p. 173).

Older occurrences: Rare in the Stockholm region (Thedenius 1859, p. 114, s.n. *Parmelia virella*). Lidingö: Ekholmsnäs, *Acer*, Hustegaholm avenue, *Ulmus*, Elfvik, *Acer*, 1949 (Hasselrot); Stockby, 1855 (Thedenius, s.n. *Parmelia obscura*) (Håkanson 1950, p. 228); Stockholm: Bromma, Minneberg, *Populus tremula* (Du Rietz); Brännkyrka, Nybohov, *Ulmus* (Høeg 1934, p. 133); S. Djurgården, Blockhusudden, *Tilia*, 1937 (Degelius); Experimentalfältet, *Ulmus*, 1956 (Hasselrot); Ringvägen road at point of departure for road to Eriksdal Baths, *Acer* (Høeg 1934, p. 133); found in the Stockholm region by Weber according to Wikström's flora, 1840, p. 155 (Thedenius 1852, p. 166, s.n. *Parmelia virella*).

The species belongs to group 2 B. Fig. 51.

The species has disappeared from the inner parts of its former distribution area around Stockholm.

Ph. pulverulenta (Schreb). Hampe

Belongs to the *U. pustulata* group. Grows on the bark of deciduous trees, especially on avenue trees. Frequent, but becomes rare northwards (Santesson 1949, p. 204). The species can exceptionally pass over to stone. Du Rietz (1945 *b*, p. 183) describes *Ph. pulverulenta* as a typical "rich-bark" species.

Older occurrences: Common in the Stockholm region (Thedenius 1852, p. 165; 1859, p. 114, *Parmelia p.*). Ditto fairly common (Thedenius 1852, p. 165; 1859, p. 114, v. *venusta* s.n. *Parmelia pulverulenta venusta*). Lidingö: On roadside and park trees, isolated or on *Populus tremula* and *Fraxinus*, etc., in thinly wooded country. Not especially common, and often with surprisingly low abundance. Almost entirely absent in the most densely built-up areas. C. ap. or sterile (Håkanson 1950, p. 229). Solna: Haga Park, 1854 (Thedenius); Haga, 1906 (Täckholm); Haga Park, 1910 (Hülphers v. *argyphaea*); Nytomta, *Fraxinus*, 1906 (Täckholm); Stockholm: Traneberg, *Ulmus*, Alvik, Fredriksberg, Lillsjönäs, Minneberg, Vibergslund (Du Rietz); Brännkyrka, 1910 (Hülphers v. *allochroa*); Farsta, Marieborg, *Tilia*, 1958 (Hasselrot); Nybohov, *Populus* (Høeg 1934, p. 133); Kräftriket, 1857 (Cleve); Frescati, Museum of Natural History, *Populus nigra* v. *italica*, 1956 (Hasselrot); 1837 (herb. C. F. Nyman); 1880 (Thedenius); 1917 (Lundqvist); Djurgården, 1910 (Hülphers); Skanstull, 1861 (Henschen).

Ph. pulverulenta belongs to group 3. Fig. 52.

Many older occurrences were noted on the inner side of the present limit towards the inner city.

Ph. stellaris (L.) Nyl.

Common throughout Sweden (Santesson 1949, p. 171). Grows on the bark and twigs of deciduous trees.

Older occurrences: Mostly from branches and twigs of *Populus tremula*. Substrate not stated in some cases. Täckholm mentions it as occurring at Norrtull Station in 1910 on *Tilia* or *Acer*.

The following occurrences were noted: Huddinge: Glömsta, *Fraxinus*, 569, sparse; Österåker: Östra Ryd, Bogesund, *Acer*, 547. Both localities are in the "normal area".

The occurrences would presumably have been more numerous if the epiphytes of the twigs and branches had been included.

The occurrence seems however to indicate a great reduction in distribution around Stockholm.

Ph. tenella (Scop.) Bitt.

Belongs to the *U. pustulata* group. Grows on bark and stone (Santesson 1949, p. 172). *Ph. tenella* is frequent in its distribution area.

Older occurrences: Lidingö: On various deciduous trees (noted on *Populus tremula, Fraxinus, Ulmus, Acer, Populus nigra* v. *italica, Aesculus hippocastanum*) mainly in localities exposed to dust impregnation. Usually sterile. Could probably be described as common (Håkanson 1950, p. 229). Stockholm: Bromma, *Populus tremula* and other coniophilous deciduous trees, common (Du Rietz); Stockholm, 1862 (Hen-

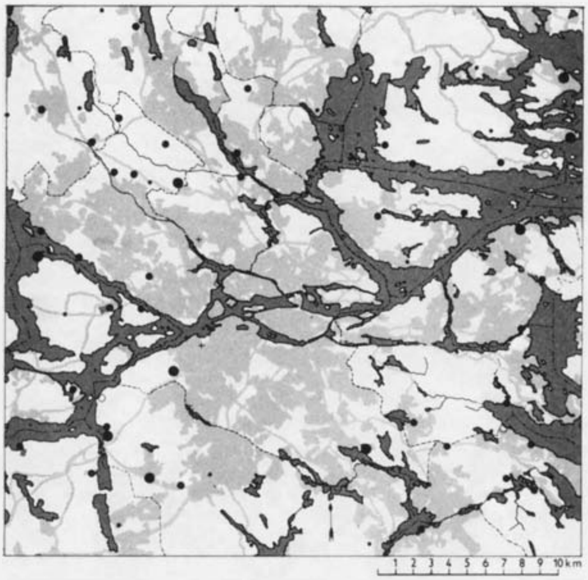


Fig. 52. Physcia pulverulenta.

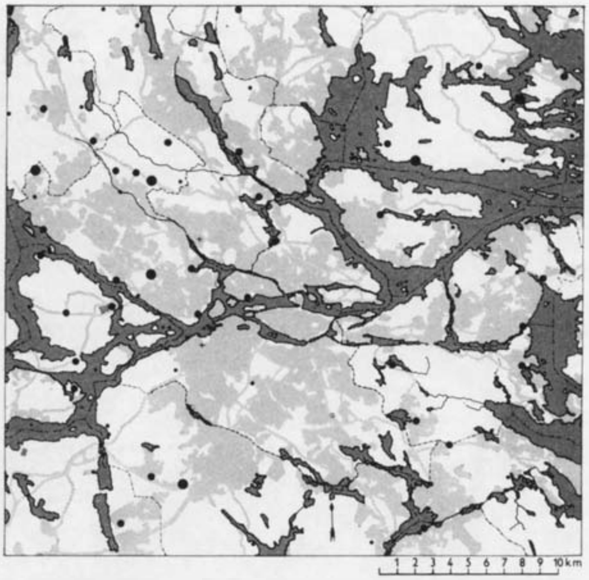


Fig. 53. Physcia tenella.

schen); on deciduous trees, 1906 (Täckholm); Enskede, Pungpinan, 1910 (Hülphers); Lilljansskogen, Margaretavägen, *Betula,* Roslagstull, *Tilia,* Tantolunden, *Ulmus,* sparse, Valhallavägen, *Acer,* sparse, ditto c. 130 metres from street, *Tilia,* sparse, Ringvägen–Rosenlundsgatan, *Acer,* sparse (Høeg 1934, pp. 133, 134).

The species belongs to group 2 B. Fig. 53.

The species has manifestly disappeared from several of its former localities in Stockholm.

Physcia sp.

One unidentifiable *Physcia* appears in the collected material. It was found at Nacka: Saltsjö Duvnäs, *Tilia,* 555, sparse, not vital.

Pseudevernia Zopf

P. furfuracea (L.) Zopf. Syn. *Parmelia furfuracea* (L.) Ach.

Belongs to the *U. pustulata* group. Very common in its distribution area. Grows on branches and trunks, mostly of conifers, but also on lignum and stone (Santesson 1949, p. 194). Du Rietz (1945 *b*, p. 149) says that *P. furfuracea* is one of the commonest lichens on "poor bark", primarily on trunks and branches of *Pinus, Picea* and *Betula* in the more southern parts of Scandinavia. It is also common on siliceous rocks.

Older occurrences: Lidingö: Håkanson (1950, p. 224) describes the species as common in coniferous areas and mentions that it was observed in several places on avenue trees, etc., but that it is absent or sparse in the more densely populated areas. Solna: Northern Cemetery, *Tilia* (Høeg 1934, p. 132); Stockholm: Bromma, Traneberg and Sandvik, 1911 (Lundqvist); Djurgården, *Betula,* 1891 (Hamberg); *Tilia,* 1910 (Hülphers); Blockhusudden, *Alnus,* 1897 (Lindblom); Enskede, Pungpinan, 1910 (Hülphers); Margaretavägen, *Betula* (Høeg 1934, p. 132).

Occurrences in the investigated area: Djursholm: Danderyd, *Tilia,* 468, sparse; *Fraxinus,* 469; Huddinge: Snättringe, *Quercus,* 571; Järfälla: Säby Gård, *Tilia,* 597, sparse; Lovö: Lindö, *Betula,* 523 *b*; Saltsjöbaden: Neglinge, *Acer,* 557; Solna: Norrbacka, *Tilia,* 353, sparse; Tyresö: Alby Rectory, *Alnus,* 592 *b,* sparse; Österåker: Bullerhöjden, *Betula,* 577 *b,* abundant; Resarö, Ytterstrand, *Betula,* 576 *b,* sparse.

P. furfuracea belongs mainly to group 2 A.

If conifers and *Betula* had been more abundant among the phorophytes, there is no doubt that the species would have been more numerous in the outskirts of the investigated area. Lundström (1966, p. 70) gives support to such an impression in his specification, and so do the numerous occurrences noted by Hasselrot and others of the species in coniferous areas around Stockholm.

The species has withdrawn from large parts of its former distribution area around Stockholm.

Ramalina Ach.

R. farinacea (L.) Ach.

Belongs to the *U. pustulata* group. Occurs on trunks and branches of deciduous trees, mainly on roadsides and in fields, but also in woods. Frequent in the distribution area.

Older occurrences: Common in the Stockholm region (Thedenius 1852, p. 163; 1859, p. 112). Lidingö: Appears with a remarkably low frequency and abundance in the area. Observed only as sterile (Håkanson 1950, p. 227); Solna: Haga, 1891 (Hesselman); Ulriksdal, *Tilia,* 1922 (Östman), *Tilia,* sparse, 1958 (Hasselrot); Stockholm: Bromma, *Populus tremula,* frequent, Alvik, Johannelund, Minneberg, Måsen, Traneberg, Vibergslund (Du Rietz); Brännkyrka, Liljeholmen Park, 1855 (Thedenius); Enskede, Pungpinan, 1910 (Hülphers); S. Djurgården, *Acer* (Høeg 1934, p. 133).

The species belongs to group 3 in this material. Fig. 54.

The species penetrated farther into the inner city formerly.

R. fastigiata Ach.

Assigned to the *U. pustulata* group. The habitat-requirements of the species agree quite well with those of *R. farinacea.*

Older occurrences: "Holmia" (Thedenius, Th. M. Fries 1871, p. 36). Lidingö: Sticklinge, avenue trees (Håkanson), Elfvik, *Acer,* St. Höggarn, *Fraxinus,* 1949 (Hasselrot), (Hå-

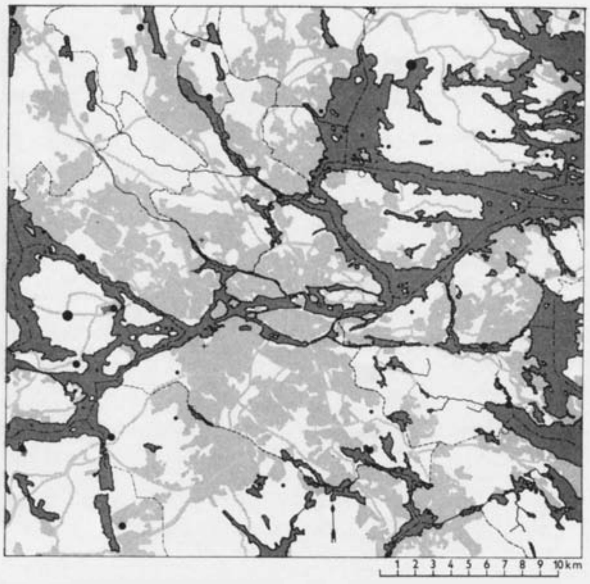


Fig. 54. Ramalina farinacea.

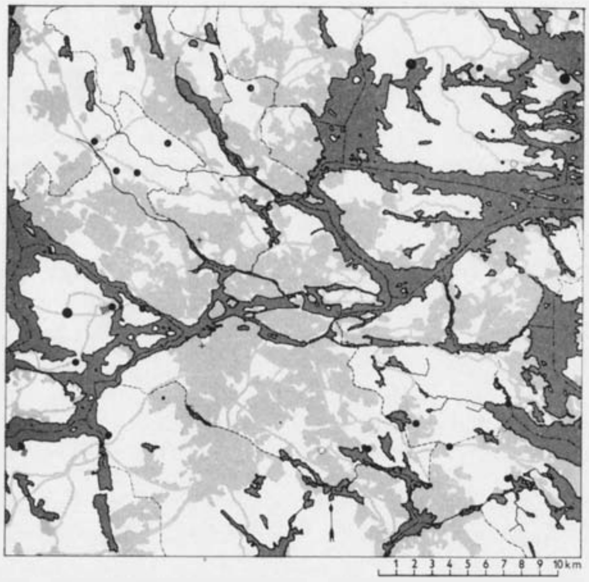


Fig. 55. Ramalina fraxinea.

kanson 1950, p. 227); Solna: Haga, 1891 (Hamberg); Ulriksdal avenue, 1906 (Täckholm); Stockholm: Bromma, *Populus tremula,* several places, Johannelund, *Populus tremula,* c. ap. (Du Rietz); Djurgården, *Populus tremula,* 1871, 1873, ditto tree trunks 1873 (Dusén).

The following occurrences were noted: Danderyd: Enebyberg Gård, *Fraxinus,* 582, sparse; Nacka: Erstavik, *Fraxinus,* 558; Stockholm: Skarpnäck, Orhem, *Fraxinus,* 497; Spånga, Järvafältet, *Tilia,* 336; Österåker: Bullerhöjden, *Ulmus,* 577 *a,* sparse.

R. fastigiata belongs to group 4, i.e. all occurrences are in the "normal area".

The species has disappeared from many localities in the more central parts of the investigated area.

R. fraxinea (L.) Ach.

Belongs to the *U. pustulata* group. Generally speaking, the species has the same habitat-requirements as *R. farinacea.*

Older occurrences: Frequent in the Stockholm region (Thedenius 1852, p. 163; 1859, p. 112). Lidingö: Sticklinge, Avenue trees (Håkanson 1950, p. 227); Hustegaholm avenue, *Acer,* sparse and sterile, 1949, Elfvik, *Acer,* 1949, Härsby, *Fraxinus,* 1 sterile example 1949; Stockby, 1 poorly developed sterile example (Håkanson, l.c.); Solna: Haga, 1891 (Hamberg); Ulriksdal avenue, 1906 (Täckholm); Stockholm: Bromma, Margretelund, *Acer,* 1910, several localities, deciduous trees, c. ap., Alvik, Johannelund, Minneberg, Traneberg (Du Rietz); Friesens Park, 1859 (Thedenius & Cleve); Enskede, Pungpinan, 1910 (Hülphers); Djurgården (vicinity of Djurgården Theatre and villas) (Thedenius 1859, p. 7).

R. fraxinea belongs to group 3 but borders on group 4. Fig. 55.

The species is disappearing from the transitional zone. Unidentifiable *Ramalina* vestiges are presumed to be mainly *R. fraxinea.*

R. pollinaria Ach.

Fairly common throughout Sweden (Santesson 1949, p. 168). Grows on rocks and tree trunks, preferring shaded habitats (Du Rietz 1945 *b,* p. 173).

Older occurrences: Several places in the Stockholm region (Thedenius 1852, p. 163; 1859, p. 112). Lidingö: Hustegaholm avenue, *Tilia,* 1949 (Hasselrot); Elfvik, *Fraxinus,* sparse, 1949 (Hasselrot), (l.c.); St. Höggarn, *Fraxinus,* sparse, 1949 (Hasselrot), (Håkanson 1950, p. 227); Nacka: (Thedenius 1852, p. 163), near Nacka Bridge (Thedenius 1859, p. 56); Solna: Järva, 1907 (Malme); Stockholm 1837 (herb. C. F. Nyman) (Thedenius, Th. M. Fries 1871, p. 39), Kungsholmen, Rålambshov (Thedenius 1859, p. 35).

Occurrences in the investigated area: Botkyrka: Norsborg, *Acer,* 575; Järfälla: east of Church, *Ulmus,* 519; Lovö: Lovön, Drottningholm, *Ulmus,* 426; Lovö Church, *Acer,* 521; Stockholm: Spånga, Grimsta, *Fraxinus,* 132; Täby: Näsby Slott Park, *Tilia,* 518, sparse, not vital; Österåker: Östra Ryd, Bogesund, *Fraxinus,* 546, sparse; 549, abundant; Bogesundslandet, *Fraxinus,* 543, sparse.

R. pollinaria belongs to group 3 in this material.

The species penetrated more deeply into the inner city formerly.

Ramalina sp.

Quite a large part of the *Ramalina* material from this investigation is so scanty and badly developed that it was impossible to identify it. However, most of the examples found probably belong to *R. fraxinea.* It was possible to identify poorly-developed *R. farinacea* with the aid of thin-layer chromatography. According to Hale (1961, p. 60), the species contains salasinic acid, which colours K+ red and P+ orange.

Occurrences in the investigated area: Boo: Kummelnäs, *Ulmus,* 536; Botkyrka: Tullinge, *Fraxinus,* 585; Tumba, *Quercus,* 584; Danderyd: *Acer,* 472; Huddinge: Glömsta, *Fraxinus,* 569; Länna, *Ulmus,* 588; Snättringe, *Quercus,* 571, not vital; Sundby Manor House, *Quercus,* 586; Vistaberg School, *Populus,* 570, not vital; Vårby, *Acer,* 473; Ågesta, *Quercus,* 587; Järfälla: Henningstorp, *Fraxinus,* 599; Jakobsberg: *Acer,* 520, not vital; Kallhäll, *Quercus,* 600; Lidingö: Gåshaga, *Tilia,* 527; Hersby, *Acer,* 509; Södergarn, *Fraxinus,* 532; Yttringe, *Fraxinus,* 533, not vital; Sollentuna: Häggvik, *Acer,* 594, not vital; Södersätra, Väsjö, *Quercus,* 595; Solna: Bergshamra, *Acer,* 374; Haga, *Acer,* 438; Ulriksdal, *Tilia,* 373 *b;*

Stockholm: Bromma, Blackeberg, *Quercus,* 133; S. Ängby, *Ulmus,* 410; Farsta, Hökarängen, *Quercus,* 479; Hägersten, Mälarhöjden, *Quercus,* 452, not vital; Skärholmen, *Quercus,* 566; Vårberg, *Fraxinus,* 567, not vital; Oscar's, Djurgården, *Quercus,* 398; Skarpnäck, Flaten; *Quercus,* 560; Spånga, Grimsta, *Quercus,* 129; Hässelby Gård, *Quercus,* 381; Västerled, Nockebyhov, *Acer,* 425; Ulvsunda, *Quercus,* 208, dead vestiges; Tyresö: *Fraxinus,* 563; Täby: Enebyberg, *Acer,* 525; Hagby, *Ulmus,* 596; Österhaninge: Vendelsö, *Acer,* 589.

Rinodina S. Gray

R. exigua (Ach.) S. Gray

Belongs to the *U. pustulata* group. Grows on the bark of deciduous trees.

Older occurrences: Thedenius (1852, p. 166; 1859, p. 114) mentions *Parmelia confragosa* v. *metabolica* as occurring at several places in Stockholm, but it is not clear which species is referred to. Sollentuna: Church, *Fraxinus,* 1954 (Sundell); Stockholm: Bromma (Magnusson 1947, p. 285); Åkeshov, *Tilia* (Du Rietz); Rörstrand woods, *Pinus,* 1859 (Cleve, s.n. *Parmelia confragosa* v. *pinicola*), Kräftriket, 1906 (Malme); f. *scanica* (Magnusson 1947, p. 285).

Four occurrences were noted: Botkyrka: Norsborg, *Acer,* 575; Huddinge: Segeltorp, *Quercus,* 460, sparse; Lovö: Lindö, *Quercus,* 523; Lovö Church, *Acer,* 521.

Three of the occurrences were in area 7, the fourth in area 4 (Fig. 1 *a*). This means that all of them were in the south-western part of the investigated area. One of the occurrences is from the outer part of the transitional zone; the others from the "normal area".

The species has greatly declined in the Stockholm area.

Usnea Wigg.

U. hirta (L.) Wigg.

Belongs to the *U. pustulata* group. Common throughout Sweden. Grows on roadside trees, lignum, etc., but prefers *Pinus* according to Santesson (1949, p. 169).

Older occurrences: Common in the Stockholm region (Thedenius 1852, p. 163; 1859, p. 112). Lidingö: several places (Håkanson 1950, p. 227); Nacka: Saltsjö–Storängen–Sickla, *Pinus silvestris,* 1931 (Degelius); Solna: Ulriksdal, *Pinus silvestris,* 1914 (Florin det. Motyka 1929); Northern Cemetery, *Tilia,* sparse (Høeg 1934, p. 133); Stockholm: Bergian Botanical Gardens (Wittrock and Juel 1891, p. 1).

Occurrences in the investigated area: Boo: Lännersta, *Quercus,* 539, sparse, not vital; Botkyrka: Tumba, *Quercus,* 584, sparse; Huddinge: Snättringe, *Quercus,* 571, sparse, not vital; Sundby Manor House, *Quercus,* 586, sparse; Vårby, *Fraxinus,* 568, sparse; Lovö: Lovön, Drottningholm, *Ulmus,* 426, sparse; Lindö, *Quercus,* 523, sparse; Kärsön, *Fraxinus,* 427, sparse; Saltsjöbaden: Neglinge, *Acer,* 557, sparse; Sollentuna: Södersätra, Väsjö, *Quercus,* 595, sparse; Stockholm: Skarpnäck, Flaten, *Quercus,* 560, sparse; Spånga, Hässelby Gård, *Quercus,* 381, sparse; Hässelby Villastad, *Fraxinus,* 380, sparse; Tyresö: Kumla, *Tilia,* 590, sparse; Österåker: Bullerhöjden, *Betula,* 577 *b*; Resarö, Ytterstrand, *Betula,* 576 *b*; Östra Ryd, Bogesund, *Acer,* 547, sparse.

U. hirta belongs to group 3. If more *Pinus* trees had been examined in the outskirts of the investigated area, the species would have probably been more abundantly represented there. Lundström (1966, p. 80) does not distinguish *U. hirta,* but all his *Usnea* occurrences except one are outside the central transitional zone as defined in the present investigation.

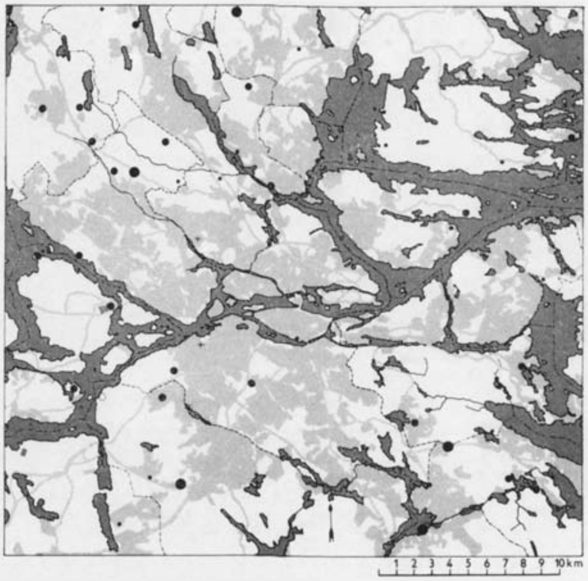


Fig. 56. Xanthoria fallax.

The distribution area of *U. hirta* seems to have been greatly reduced since the early part of this century. Most of the occurrences I have noted are sparsely situated, i.e. there are few and generally small individuals per station. Also, at a few of the stations the appearance of *U. hirta* has been such that I have designated it "not vital".

Usnea sp.

It has not been possible to identify some of the *Usnea* occurrences, namely those from Boo: Anneberg, *Tilia,* 552; Stockholm: Hägersten, Skärholmen, *Quercus,* 566; Täby: Näsby Slott Park, *Tilia,* 518.

These may very possibly be *U. hirta* also, but the material was far too scanty for an identification to be made. One of the occurrences is in the central transitional zone, the others in the outer transitional zone.

Xanthoria Th. Fr.

X. candelaria (L.) Arn.

Ubiquitous in Scandinavia. Grows on stone (especially big boulders frequented by birds), bark (trunk bases, etc.) or wood, and is common (Santesson 1949, p. 204).

Older occurrences: Thedenius (1852, p. 165; 1859, p. 113) describes *X. candelaria* as frequent in the Stockholm region. Lidingö: Kyrkviken, *Acer,* 1950 (Hasselrot), (Håkanson 1950, p. 227); Solna: Karlberg, 1857 (Cleve); Stockholm: Kungsholmen (Afzelius); Bergian Botanical Gardens (Wittrock and Juel 1891, p. 2).

Occurrences in the investigated area: Boo: Boo Old Church, *Ulmus,* 551; Danderyd: *Acer,* 472, sparse; Huddinge: Segeltorp, *Quercus,* 460; Sundby Manor House, *Quercus,* 586, sparse; Järfälla: Säby Gård, *Tilia,* 597; Lovö: Lovön, Drottningholm, *Ulmus,* 426; Lambarudd, *Fraxinus,* 522; Sollentuna: Edsviken, *Populus,* 516, sparse; Stockholm: Engelbrekt, Brunnsviken, *Quercus,* 344; Johannes, Vasastaden, *Acer,* 121, sparse, not vital; Spånga, Bromsten, *Ulmus,* 411, sparse; Hässelby Gård, *Quercus,* 381, abundant; Tyresö: Alby Rectory, *Alnus,* 592 *b,* sparse; Kumla, *Tilia,* 590, sparse; Täby: Hagby, *Ulmus,* 596; Österåker: Östra Ryd, Rydbo Saltsjöbad, *Fraxinus,* 578, abundant.

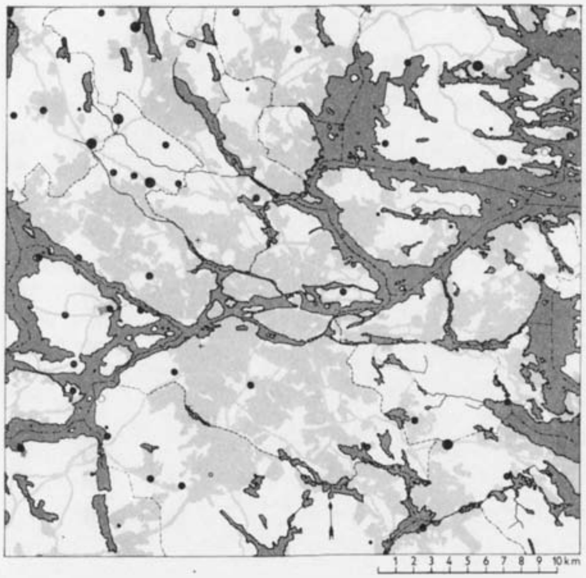


Fig. 57. Xanthoria parietina.

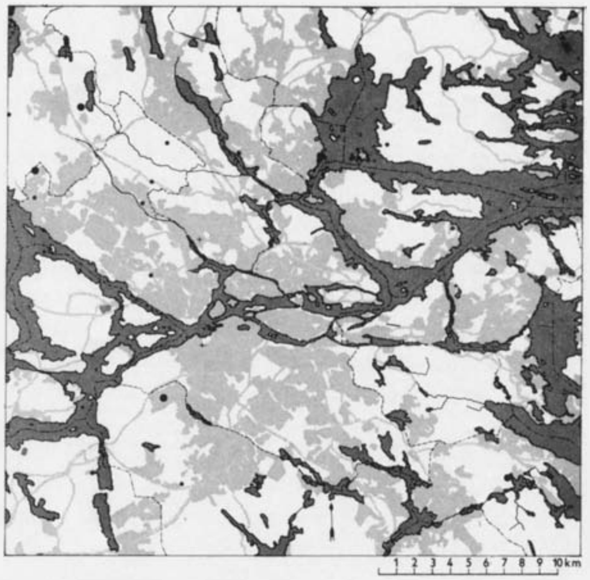


Fig. 58. Xanthoria polycarpa.

The species belongs to group 1 B.

The species is admittedly scarcer than usual in the investigated area, but penetrates in any case far into the inner part of the transitional zone. No major change in the extent of the distribution area seems to have occurred.

X. fallax (Hepp.) Arn.

Assigned to the *U. pustulata* group. Grows on bark, especially of deciduous trees, particularly avenue trees.

Older occurrences: Lidingö: Håkanson (1950) mentions the species as occurring in several places; Nacka: Sickla, 1920 (Vestergren), (Du Rietz 1921, p. 188); Nackanäs, avenue trees, 1931 (Degelius); Solna: Bergshamra, *Acer*, sparse, Ulriksdal, *Tilia, Acer*, 1958 (Hasselrot); 1920 (Vestergren), (Du Rietz 1921, pp. 188–189); Stockholm: Bromma, Ulvsunda, *Tilia*, 1927 (Degelius); Alvik, Sandvik, Traneberg, 1920 (Du Rietz 1921, p. 188); Bromma Church, 1925 (Du Rietz 1925, p. 82); Brännkyrka, Nybohov, *Tilia* (Høeg 1934, p. 133); Frescati, Museum of Natural History, *Populus*, 1956 (Hasselrot); Bergian Botanical Gardens, *Acer*, abundant, 1964 (Ahlner); Albano, 1920 (Du Rietz 1921, p. 188); Södermalm, Tantolunden, *Ulmus*, sparse, Ringvägen, corner of Rosenlundsgatan, *Acer*, sparse (Høeg 1934, p. 133).

The species belongs to group 2 B. Fig. 56.

X. fallax has disappeared since the 1920s from the Ulvsunda area, for example, and also from other parts of its former distribution area.

X. parietina (L.) Th. Fr.

Belongs to the *U. pustulata* group. Very common except in innermost northern Scandinavia (Magnusson 1929). According to Du Rietz (1945 *b*, p. 181) *X. parietina* is the most characteristic species of "rich-bark" trees, and he defines the boundary between "rich-bark" and "poor-bark" vegetation according to its frequent presence in the former. The species is favoured by the effect of dust, but also occurs in dust-free localities. Du Rietz points out that the species can appear in quantity around roads and farms not only on "rich-bark" trees but also, if the dust effect is sufficiently great, on "poor-bark" trees such as *Pinus, Picea* and *Betula*, especially in calcareous areas. It also occurs on calcareous boulders and on siliceous stone, but only when this latter is affected by calcareous dust, sea water or bird excreta.

Older occurrences: Lidingö: the species is absent or extremely sparse in the most densely built-up areas, otherwise it is more or less usual on many deciduous trees and deciduous bushes, including—in localities affected by dust—even *Quercus* (Håkanson 1950, p. 228). Hasselrot, too, has gathered the species in several places. Nacka: Nackanäs, 1931 (Degelius); Dammtorp, Cemetery, *Acer*, 1961 (Hasselrot); Solna: Karlberg, 1857 (Cleve); Haga, 1895 (Nordström); Stockholm: Bromma, Traneberg (H. Du Rietz); Brännkyrka, Nybohov, *Ulmus* (Høeg 1934, p. 133); Enskede, Pungpinan, 1910 (Hülphers); Skarpnäck, 1911 (Lundqvist); Södermalm, 1861 (Henschen); Djurgården c. 100 metres west of "Gotthem" restaurant (near station 395), *Populus* (Høeg 1934, p. 133).

X. parietina belongs to group 2 B in this material. Fig. 57.

The species has disappeared from parts of its former distribution area.

X. polycarpa (Ehrh.) Rieber

Belongs to the *U. pustulata* group. Prefers twigs of bushes and trees, but also occurs on trunks. Frequent in its distribution area (Santesson 1949, p. 171).

Older occurrences: Fairly common in the Stockholm area (Thedenius 1852, p. 165; 1859, p. 113). Lidingö: on deciduous trees and deciduous bushes in open situations. Favoured by dust impregnation generally c. ap. (Håkanson 1950, p. 228); Ekholmsnäs, *Acer*, 1949 (Hasselrot); Church, *Acer*, 1949, Elfvik, *Acer, Fraxinus*, abundant, 1949 (Hasselrot); Solna: Överjärva, 1910 (Hülphers); Stockholm: Bromma, fairly common on young branches of various bushes and deciduous trees, 1910 (Du Rietz); Frescati, Museum of Natural History, *Populus nigra* v. *italica*, 1927 (Degelius); ditto 1956 (Hasselrot); Experimentalfältet, *Salix* and *Populus* (Täckholm); Kungsholmen opposite Sabbatsberg, year? (Afzelius).

The species belongs to group 3 in this material. Fig. 58.

The species has disappeared from the more central parts of the investigated area.

MOSSES

Thanks to the fact that Docent Erik Sjögren of Uppsala has identified the mosses for me, it has been possible to include a report on the moss material collected.

In making a selection of station trees when field work was carried out, attention was paid chiefly to the occurrence of lichens. If otherwise equivalent station trees were available, those richest in lichens were always selected. The material therefore contains no special "moss trees". This should be borne in mind when a study is made of the occurrences of mosses in this investigation.

Lundström also (1966, pp. 81 ff.) included the mosses occurring at his lichen stations. In addition to five of the species reported below, he found also *Ptilidium ciliare* (on *Pinus*), *Aulacomnium androgynum, Lophocolea sp., Plagiothecium denticulatum* (on *Picea*). All these species occurred only at one or a few stations.

For general distribution in the area, reference is made to von Krusenstjerna (1964).

Hepaticae

Ptilidium Nees.

Pt. pulcherrimum (Web.) Hampe

Ubiquitous in Sweden, but ascends rarely above the upper limit of the birch in the high mountains. It is common throughout the coniferous zone (Arnell 1956, p. 44).

The following occurrences were noted in the investigated area: Djursholm: *Quercus,* 471; Järfälla: Kallhäll, *Quercus,* 600; Lidingö: Hersby, *Acer,* 509; Norra Sticklinge, *Fraxinus,* 510; Nacka: Nacka Old Cemetery, *Acer,* 491; Stockholm: Farsta, Farsta Gård, *Betula,* 416 *b*; Spånga, Grimsta, *Pinus,* 125; *Picea,* 126; *Betula,* 127, 130; Hässelby Villastad, *Quercus,* 379, sparse; Österåker: Bullerhöjden, *Betula,* 577 *b.*

Lundström (1966, pp. 82 ff.) found the species at 16 stations (*Pinus* and *Picea*) at Täby, Danderyd and Djursholm.

The species belongs to distribution group 2 B.

Radula Dum.

R. complanata (L.) Dum.

Common throughout Sweden except in the alpine areas. Grows on cliffs and boulders and on trunks of deciduous trees.

Occurrences in the investigated area: Boo: Ormingelandet, *Fraxinus,* 535; Botkyrka: Norsborg, *Acer,* 575; Ekerö: Gällstaö, *Ulmus,* 524; Nacka: Nacka Old Cemetery, *Acer,* 491; Stockholm: Spånga, Järvafältet, *Acer,* 574; Täby: Näsby Slott Park, *Tilia,* 518; Österåker: Östra Ryd, Bogesund, *Acer,* 547; Bogesundslandet, *Fraxinus,* 543.

R. complanata belongs to distribution group 3.

Musci

Amblystegium Br. Eur.

A. serpens (Hedw.) Br. and Sch.

Ubiquitous and common throughout the territory. Grows on soil or rocks on calcareous as well as on acid ground, on tree trunks, roots, decaying wood etc. in moist and shaded habitats from the lowlands to the subalpine region of the mountains (Nyholm 1965, p. 484).

The following occurrences were noted in the investigated area: Solna: Frösvik, *Ulmus,* 361; Ulriksdal, *Acer,* 372; Stockholm: Spånga, Hässelby Villastad, *Fraxinus,* 380; Täby: Näsby Slott Park, *Tilia,* 518.

A. serpens probably belongs to distributioon group 2 B.

Von Krusenstjerna (1964, p. 101) describes it as common throughout the Stockholm region.

Amblystégiella Loeske

A. subtilis (Hedw.) Loeske

Southern in Sweden. Grows on trunks or roots of trees, rarely on rocks.

The following occurrences were noted in the investigated area: Sollentuna: Sollentuna Churchyard, *Fraxinus,* 593; Stockholm: Hägersten, Vårberg, *Fraxinus,* 567; Tyresö: Alby Rectory, *Fraxinus,* 592 *a*; Vaxholm: *Fraxinus,* 542; Österåker: Östra Ryd, Rydboholm, *Fraxinus,* 579.

Practically all occurrences are in the "normal area".

Von Krusenstjerna (1964, p. 101) writes that *A. subtilis* often grows in fairly dense carpets at the bases of tree trunks (*Ulmus, Fraxinus, Acer, Tilia*). The species is rare in the Stockholm region.

Barbula Hedw.

B. vinealis Brid.

Nyholm (1956, pp. 118 ff.) states that *B. vinealis* is southern in Sweden. The main species is found only in the southernmost calcareous provinces (Skåne, Öland, Gotland). It grows on calcareous, more or less sandy soil, on walls, etc.

V. *cylindrica* (Tayl.) Boul. is more common in Fennoscandia than the type and with a wider distribution. It extends to the comparison area immediately north of the investigated area.

Occurrences in the investigated area: Stockholm: Hägersten, Sagatun, *Ulmus,* 451; Västerled, Nockebyhov, *Acer,* 409.

One of the sites is in the central, the other in the outer transitional zone. The distance between the two stations is only 4 km.

Von Krusenstjerna (1964) does not mention the species as occurring in the Stockholm region.

Brachythecium Br. Eur.

B. velutinum (Hedw.) Br. and Sch.

The species is common in the southern and central part of the territory, scattered or rare towards the north and in the mountains. *B. velutinum* grows on tree trunks (Nyholm 1965, p. 538), more seldom on the ground.

The following occurrences were noted: Huddinge: Länna, *Ulmus,* 588; Järfälla: Björkeby, *Tilia,* 598; Stockholm: Bromma, *Tilia,* 412; Johannes, Vasastaden, *Betula,* 116; Spånga, Grimsta, *Quercus,* 129.

The species probably belongs to group 1 B.

Von Krusenstjerna (1964, p. 97) does not mention the species as occurring on bark but only on dry sandy soil beneath conifers, mostly at the edges of woods. In the Uppsala area, however, it grows on stumps and tree roots (von Krusenstjerna 1945). *B. velutinum* is common in the Stockholm region.

B. salebrosum (Web. & Mohr.) Br. and Sch.

Ubiquitous distribution in Sweden. Grows on soil, tree bases, stumps and boulders in wooded areas, from the lowlands to high up in the mountains. *B. salebrosum* is frequent throughout the distribution area (Nyholm 1965, p. 554).

One epiphytic occurrence in the investigated area: Österåker: Östra Ryd, Rydbo Saltsjöbad, *Fraxinus*, 578.

The site is in the "normal area".

Von Krusenstjerna describes the species as common in the whole of the Stockholm region.

B. glareosum (Bruch.) Br. and Sch.

Southern distribution in Sweden. Favours limestone and grows mainly on rocks or calcareous soil. Nyholm (1965, p. 556) describes the species as "widespread in suitable localities".

One occurrence in the investigated area—Österåker: Östra Ryd, Bogesund, *Fraxinus*, 548.

The locality is in the "normal area".

Von Krusenstjerna (1964, p. 94) writes that *B. glareosum* is to be found throughout the Stockholm region on calcareous clayey soil, occasionally on boulders or slabs of primaeval limestone, but that it is unfrequent. There are no records of any occurrences on the bases of growing trees.

B. populeum (Hedw.) Br. and Sch.

Nyholm (1965, p. 539) describes the species as "common, often frequent in the south and central part of the territory, rare or absent in the north". Grows on rocks, trunks and roots of trees, sometimes on soil, chiefly in the lowlands.

The following occurrences were noted in the investigated area: Nacka: Bollmora, *Fraxinus*, 562; Stockholm: Farsta, Farsta Gård, *Betula*, 416 *b*; Johannes, Vasastaden, *Acer*, 123; Oscar's, Djurgården, *Quercus*, 398; Spånga, Grimsta, *Fraxinus*, 132; Järvafältet, *Acer*, 573; Västerled, Traneberg Strand, *Ulmus*, 85.

B. populeum probably belongs to group 1 B.

Von Krusenstjerna (1964, p. 95) writes that in the Stockholm area the species grows on boulders and low slabs beneath deciduous trees and is fairly frequent throughout most of the area.

Bryum Hedw.

B. capillare Hedw.

Ubiquitous in Sweden. Nyholm (1958, p. 243) describes it as "common or nearly so throughout the territory". Grows on forest humus, in rock crevices on boulders or on tree trunks.

Occurrences in the investigated area: Boo: Ormingelandet, *Fraxinus*, 535; Danderyd: *Acer*, 472; Lovö: Kärsön, *Fraxinus*, 427; Stockholm: Spånga, Järvafältet, *Fraxinus*, 362; Västerled, Olovslund, *Acer*, 424; Täby: Ensta, Hästängen, *Acer*, 581.

B. capillare belongs to distribution group 3 in this investigation.

Von Krusenstjerna (1964, p. 70) mentions the species as occurring in the Stockholm region on rocks and boulders, occasionally on park trees and mostly in localities not excessively exposed to sunlight. Common to fairly frequent throughout the area.

Ceratodon Brid.

C. purpureus (Hedw.) Brid.

Cosmopolitan and, according to Nyholm (1954, p. 26) "Common from the lowlands to high up in the mountains". Grows on all kinds of substrate, especially on open, sandy or burnt soil.

One occurrence, on a growing tree (on the trunk base), was noted in the investigated area—Österåker: Resarö, Ytterstrand, *Betula*, 576 *b*.

The site is in the "normal area".

Von Krusenstjerna (1964, p. 48) describes it as very common throughout the whole of the Stockholm area.

Dicranum Hedw.

D. scoparium Hedw.

Nyholm (1954, p. 64) describes the species as common throughout Sweden. Grows usually on rocks and boulders or on the ground in conifer woods and on heaths, but also often in deciduous woods. Occurs also on tree roots, stumps and trunk bases.

The following occurrences were noted in the investigated area: Lidingö: Mölna, *Tilia*, 526; Norra Sticklinge, *Fraxinus*, 510; Stockholm: Farsta, Farsta Gård, *Betula*, 416 *b*; Spånga, Grimsta, *Betula*, 130; Hässelby Villastad, *Quercus*, 379, sparse; Sankt Göran, Marieberg, *Salix*, 80.

Lundström (1966, p. 82) found *D. scoparium* at two places (*Pinus*) and (*Picea*) in Täby.

D. scoparium belongs to group 2 B.

Von Krusenstjerna (1964, p. 54) describes the species as very common, occurring for example on the base of *Betula* trunks in the Stockholm area.

Drepanocladus Roth

D. uncinatus (Hedw.) Warnst.

Ubiquitous in Sweden. According to Nyholm (1965, pp. 430 ff.) it is "common, often frequent, throughout the territory". It grows in moist or wet habitats, on soil, rocks and tree trunks, from the lowlands up to the high-alpine belt of the high mountains.

One epiphytic occurrence was noted in the investigated area, in Stockholm: Spånga, Hässelby Villastad, *Quercus*, 379.

The locality is in the outer transitional zone.

Von Krusenstjerna (1964, p. 108) describes *D. uncinatus* as common in the Stockholm area, even in the outermost skerries of the Archipelago. It grows on boulders, rocks and tree roots in moist situations.

Hypnum Hedw.

H. cupressiforme Hedw.

According to Nyholm (1965, p. 586) it is cosmopolitan and occurs almost throughout Sweden. It is common, often frequent in the southern and central parts of the territory, rare or absent in the far north and in the high mountains. Grows on soil, rocks, tree trunks and rotten wood in dry or moist habitats, on acid or calcareous ground. It is a lowland and subalpine plant (Nyholm, l.c.).

Lundström (1966, p. 82) found *H. cupressiforme* at 5 stations (*Picea*) in Täby.

H. cupressiforme as an epiphyte belongs to group 2 B (Fig. 59).

Von Krusenstjerna (1964, p. 113) describes the species as

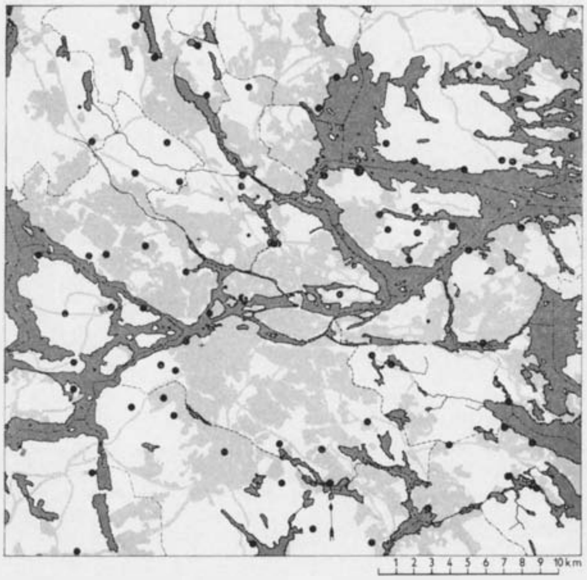


Fig. 59. Hypnum cupressiforme.

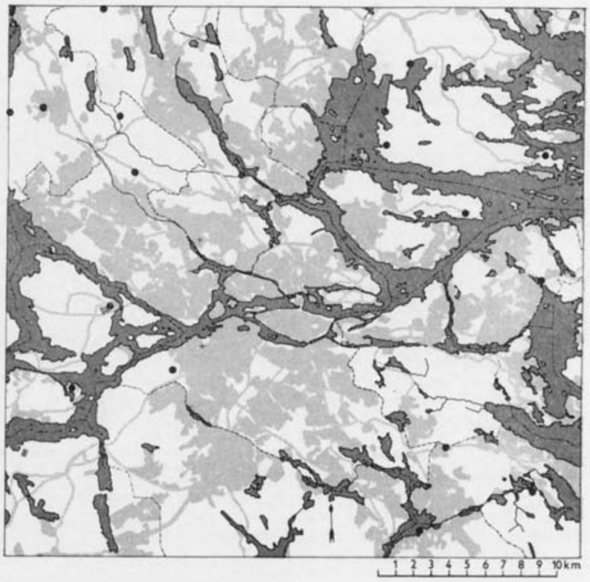


Fig. 60. Leucodon sciuroides.

very common on rocks and boulders, tree trunks and tree roots in the whole of the Stockholm area.

Leucodon Schwaegr.

L. sciuroides (Hedw.) Schwaegr.

The species is ubiquitous. Nyholm (1960, p. 373) writes that *L. sciuroides* is "widespread in the lowlands, rare in the mountains and towards the north". It grows on tree trunks in the southern part of the territory, usually on rocks in the northern part.

The species belongs to group 3 (Fig. 60).

According to von Krusenstjerna (1964, p. 90) *L. sciuroides* occurs in the Stockholm area commonly on old park trees and avenue trees throughout the region, but with diminishing frequency towards the Archipelago.

Mnium Hedw.

M. cuspidatum Hedw.

Nyholm (1958, p. 271) states that *M. cuspidatum* "occurs on shaded, damp ± sandy soil in woods, on tree stumps, walls and rocks etc. at lower altitudes". It is common in suitable localities throughout the territory (Nyholm, l.c.).

The following occurrences were noted: Lovö: Kärsön, *Fraxinus,* 427; Lidingö: Norra Sticklinge, *Fraxinus,* 510; Nacka: Bollmora, *Fraxinus,* 562; Stockholm: Johannes, Vasastaden, *Betula,* 116.

M. cuspidatum may probably be assigned to group 2 B.

Von Krusenstjerna (1964, p. 78) mentions the species as occurring on boulders in shady parks and groves, on tree trunk bases, stumps, etc., throughout the area and extending to the outer skerries of the Archipelago. He considers that *M. cuspidatum* is not common but is to be found occasionally on churchyard walls.

Orthodicranum Loeske

O. montanum (Hedw.) Loeske

Ubiquitously distributed in Sweden. Nyholm (1964, p. 72) writes that it is "Common in forests from the lowlands to high in the mountains, but rarely above the forest line; Sweden, Norway, Finland throughout the territory". Grows on decayed wood, tree trunk bases, rocks and boulders and —although very rarely—on the ground as well.

The following occurrences were noted: Lidingö: Koltorp, *Quercus,* 528; Stockholm: Farsta, Fagersjö, *Quercus,* 418; Farsta Gård, *Betula,* 416 *b*; Oscar's, Djurgården, *Quercus,* 398; Spånga, Grimsta, *Betula,* 130; Sankt Göran, Marieberg, *Salix,* 80.

Lundström (1966, p. 82) mentions the species as occurring in 3 localities (*Pinus* and *Picea*).

O. montanum belongs to distribution group 2 B.

In the Stockholm area the species is common throughout the region, especially in wooded parts. If there had been more conifers and such deciduous trees as *Betula* and *Alnus* in the investigation, it is probable that the occurrences noted would have been more numerous.

Orthotrichum Hedw.

O. affine Brid.

According to Nyholm (1960, p. 333), a variable and diffuse species in Scandinavia. It has a southern distribution in Sweden. Grows on the trunks of deciduous trees, rarely on rocks. *O. affine* is common in the southern part of the territory, rare or scattered towards the north according to Nyholm.

The following occurrences were noted in the investigated area: Danderyd: Enebyberg Gård, *Fraxinus,* 582, not vital; Lidingö: Hersby, *Acer,* 509; Sollentuna: Sjöberg, *Quercus,* 517; Stockholm: Spånga, Järvafältet, *Fraxinus,* 376.

O. affine belongs primarily to group 2 B.

Von Krusenstjerna (1964, p. 84) includes the species in *O. octoblephare* Brid. in his flora of the Stockholm region. On trunks of decideous trees, rather common (von Krusenstjerna, l.c.).

O. pallens Bruch in Brid.

Has a southern distribution in Sweden. Grows on deciduous trees, rarely on rocks (Nyholm 1960, p. 343).

The following occurrences were noted: Sollentuna: Sollentuna Churchyard, *Fraxinus*, 593; Österåker: Östra Ryd, Rydbo Saltsjöbad, *Fraxinus*, 578.

Both occurrences are in the "normal area".

Von Krusenstjerna (1964, p. 85) describes *O. pallens* as very rare in the Stockholm region. It grows on park trees or on stones beneath them. The species does not appear to have been encountered previously in the present investigated area.

O. pumilum Schwaegr. Syn. *O. fallax* Bruch.

Southern distribution in Sweden. Grows on the older trunks of such deciduous trees as *Fraxinus*, *Ulmus*, etc. and elsewhere, and is described as widespread in the lowlands (Nyholm 1960, p. 345).

Two occurrences were noted: Lovö: Lovön, Lambarudd, *Fraxinus*, 522; Österåker: Bullerhöjden, *Ulmus*, 577 *a*.

Both occurrences are in the "normal area".

Von Krusenstjerna (1964, p. 84) describes the species as rather uncommon, especially in the Archipelago. Grows in the Stockholm area on deciduous trees, mainly on *Fraxinus*, *Ulmus*, *Acer*, and *Tilia* in parks and avenues and in churchyards (l.c.).

O. speciosum N.

Found throughout Sweden except in the northernmost parts. Rarer towards the north and in the mountains (Nyholm 1960, p. 333). Grows mainly on deciduous trees, seldom on boulders.

Occurrences in the investigated area: Boo: Ormingelandet, *Fraxinus*, 535; Danderyd: Enebyberg Gård, *Fraxinus*, 582; Lidingö: Södergarn, *Fraxinus*, 532; Österåker: Resarö, Ytterstrand, *Ulmus*, 576 *a*.

O. speciosum could probably be assigned to group 3.

According to von Krusenstjerna (1964, p. 85), *O. speciosum* is common throughout the Stockholm area. It grows on the trunks of sundry deciduous trees, but occasionally also appears on dead conifer twigs. In rare cases it may be found on siliceous boulders beneath deciduous trees.

O. stramineum Hornsch. in Brid.

Southern distribution in Sweden. Grows mainly on such deciduous trees as *Fraxinus*, *Acer*, etc. and on *Populus tremula*, seldom on stone. Frequent in the southern and southwestern part of the distribution area.

One find in the investigated area—Stockholm: Spånga, Järvafältet, *Fraxinus*, 362.

The locality is in the centre of the transitional zone, on the border of the outer transitional zone.

Von Krusenstjerna (1964, p. 85) describes the species as rare in the Stockholm region.

Orthotrichum sp.

Boo: Boo Old Church, *Ulmus*, 551; Ormingelandet, *Fraxinus*, 535; Botkyrka: Alby, *Tilia*, 583; Norsborg, *Acer*, 575; Tullinge, *Fraxinus*, 585; Danderyd: Enebyberg Gård, *Fraxinus*, 582; Huddinge: Glömsta, *Fraxinus*, 569; Vistaberg School, *Populus*, 570; Vårby, *Acer*, 473; *Fraxinus*, 568; Järfälla: Henningstorp, *Fraxinus*, 599; Säby Gård, *Tilia*, 597; Lidingö: Gåshaga, *Tilia*, 527; Mölna, *Tilia*, 526; Nacka: Bollmora, *Fraxinus*, 562; Sollentuna: Överby, *Fraxinus*, 601; Solna: Bergshamra, *Acer*, 374; Ulriksdal, *Acer*, 372; Stockholm: Bromma, *Tilia*, 412; Hägersten, Bredäng, *Fraxinus*. 434; Vårberg, *Fraxinus*, 567; Johannes, Vasastaden, *Betula*, 116; Spånga, Järvafältet, *Fraxinus*, 376; Tyresö: Raksta, *Fraxinus*, 591; Täby: Ensta, Hästängen, *Acer*, 581; Näsby Slott Park, *Tilia*, 518; Vaxholm: *Fraxinus*, 542; Österåker: Bullerhöjden, *Ulmus*, 577 *a*; Resarö, Ytterstrand, *Ulmus*, 576 *a*; Östra Ryd, Bogesund, *Acer*, 547; *Fraxinus*, 549.

Plagiothecium Br. Eur.

P. silvaticum (Brid.) Br. Eur.

A southern species, occurring scattered in the southern and central part of the territory. Extends northwards to about as far as the investigated area (Nyholm 1965, p. 645). Mainly on boulders and tree bases in forests.

Occurrences in the investigated area: Stockholm: Johannes, Vasastaden, *Betula*, 116; Sankt Göran, Marieberg, *Acer*, 75, sparse.

Both localities are in the central transitional zone.

Von Krusenstjerna (1964, p. 112) indicates that *P. silvaticum* has not been gathered in the Stockholm region, and that it is primarily *P. succulentum*, but also *P. denticulatum* etc., that are concealed in the herbaria under the name.

Pohlia Hedw.

P. nutans Lindb.

Grows on dry or wet siliceous soil, in rock crevices, on heaths, decaying wood, etc. The species is common throughout Sweden (Nyholm 1958, p. 205).

Epiphytic occurrences in the investigated area: Huddinge: Stuvsta, *Acer*, 474; Lovö: Kärsön, *Fraxinus*, 427; Lovön, Drottningholm, *Ulmus*, 426; Stockholm: Farsta, Farsta Gård, *Betula*, 416 *b*; Oscar's, Djurgården, *Quercus*, 398; Spånga, Järvafältet, *Fraxinus*, 362; Västerled, Olovslund, *Acer*, 424; Österåker: Resarö, Ytterstrand, *Betula*, 576 *b*.

Lundström (1966, p. 82) mentions the species as occurring at one station (*Pinus*) in Täby.

P. nutans as an epiphyte belongs to group 2 B.

Very common in the Stockholm region on dry acid soil of various kinds, mostly in coniferous woods, decayed stumps, peaty soil, etc. (von Krusenstjerna 1964, p. 76). No occurrences on the base of growing trees seem to have been noted.

Pohlia sp.

Unidentifiable mosses of the genus *Pohlia* were gathered at the following stations: Lidingö: Mölna, *Tilia*, 526; Solna: Karlberg, *Quercus*, 139; Ulriksdal, *Pinus*, 373 *a*; Stockholm: Johannes, Vasastaden, *Acer*, 121; *Ulmus*, 124; Sankt Göran, Marieberg, *Ulmus*, 74.

All the occurrences are in the centre of the transitional zone.

Pseudoleskeella Kindb.

P. nervosa Brid.

The species occurs in nearly all parts of Sweden. It is common in some districts, scattered in others. It grows on calcareous stones and rocks, but also on tree trunks in the lowlands to the low alpine belt of the mountainous regions (Nyholm 1960, p. 394). Sjögren (1961, p. 45) describes it as continental.

The following occurrences were noted in the investigated area: Boo: Ormingelandet, *Acer*, 537; Botkyrka: Norsborg, *Acer*, 575; Ekerö: Gällstaö, *Ulmus*, 524; Huddinge: Vårby, *Acer*, 473; Järfälla: *Ulmus*, 519; Lovö: Kärsön, *Fraxinus*, 427; Lovön, Drottningholm, *Ulmus*, 426; Tyresö: Raksta, *Fraxinus*, 591; Täby: Ensta, Hästängen, *Acer*, 581; Österåker:

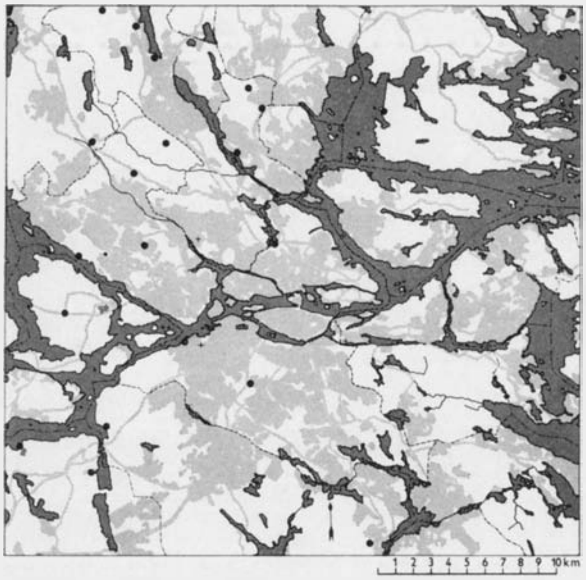


Fig. 61. Pylaisia polyantha.

Bullerhöjden, *Ulmus,* 577 *a*; Östra Ryd, Bogesund, Frösvik, *Fraxinus,* 548; Bogesundslandet, *Fraxinus,* 543.

P. nervosa can probably be assigned to distribution group 3.

Von Krusenstjerna (1964, p. 93) writes that the species occurs throughout the Stockholm region but becomes rare in the Archipelago. It grows mainly on the trunks of park and avenue trees and on boulders underneath them.

Pylaisia Bruch et Schimp.

P. polyantha (Hedw.) Br. Sch.

Widespread, sometimes common in the central and southern part of the territory, rare towards the north and in the mountains. It is found on deciduous as well as coniferous trees and on shaded rocks (Nyholm 1965, p. 576).

The species belongs to group 2 B (Fig. 61).

P. polyantha occurs commonly throughout the Stockholm region, but seems to diminish eastwards and to be absent in several parts of the Archipelago (von Krusenstjerna 1964, p. 114). In the area it grows (l.c.) mostly on "park trees" and *Populus tremula,* in rare cases on stones and if so beneath trees.

Stroemia Hag.

S. gymnostoma (Bruch) Hag.

Southern distribution in Sweden. Grows on deciduous trees, almost exclusively on old *Populus tremula* (Nyholm 1960, p. 350).

One occurrence in the investigated area—Österåker: Resarö, Ytterstrand, *Ulmus,* 576 *a.*

This station is in the "normal area".

According to von Krusenstjerna (1964, p. 86) the species is somewhat uncommon in the Stockholm region, but has probably been much overlooked.

S. obtusifolia (Brid.) Hag.

Occurs throughout Sweden except in the northernmost parts. Grows on deciduous trees, chiefly *Populus tremula,* rarely on rocks (Nyholm 1960, p. 350).

Occurrences in the investigated area: Boo: Ormingelandet, *Fraxinus,* 535; Järfälla: *Ulmus,* 519; Nacka: Bollmora, *Fraxinus,* 562; Sollentuna: Överby, *Fraxinus,* 601; Stockholm: Spånga, Järvafältet, *Fraxinus,* 376; Täby: Ensta, Hästängen, *Acer,* 581; Österhaninge: Vendelsö, *Acer,* 589, sparse; Österåker: Östra Ryd, Bogesund, *Acer,* 547; *Fraxinus,* 549.

The species belongs to distribution group 4, i.e. it occurs almost exclusively in the "normal area".

Common in the Stockholm region except in the Archipelago, where it is rare. Found on such deciduous trees as *Fraxinus, Ulmus,* etc., and on *Populus tremula* by roadsides and gardens as well as in woods (von Krusenstjerna 1964, p. 86).

Tortula Hedw.

T. pulvinata (Jur.) Limpr.

Southern distribution in Sweden (Nyholm 1956, p. 111). Not previously gathered as far north as in the Stockholm region. *T. pulvinata* grows on deciduous trees, rarely on shaded rocks.

Occurrences in the investigated area: Botkyrka: Norsborg, *Acer,* 575; Huddinge: Segeltorp, *Quercus,* 460; Stockholm: Hägersten, Bredäng, *Fraxinus,* 454; Skarpnäck, Orhem, *Fraxinus,* 497; Spånga, Grimsta, *Fraxinus,* 132; Järvafältet, *Fraxinus,* 335; *Tilia,* 336; Täby: Näsby Slott Park, *Tilia,* 518; Österåker: Östra Ryd, Bogesund, *Fraxinus,* 545.

The species belongs to distribution group 3.

Von Krusenstjerna (1964) does not mention the occurrence of the species in the Stockholm region.

T. ruralis (Hedw.) Crome

Ubiquitous in Sweden. Common throughout the territory from the lowlands to high up in the mountains. It grows on trunks of trees, on damp shaded rocks or walls (Nyholm 1956, p. 108).

Only two occurrences in the investigated area: Lovö: Kärsön, *Fraxinus,* 427; Järfälla: Henningstorp, *Fraxinus,* 599.

Grows on shaded boulders, rocks and walls in parks or underneath deciduous trees in woods, also on the bark of "park trees". Common throughout the area (von Krusenstjerna 1964, p. 59).

FUNGI

Trees that have been visibly attacked by stem-parasitic fungi have, with one exception, been rejected as station trees. The fungi listed below are therefore exclusively those which live as saprophytes on bark. The material has been scanty and the availability of fully developed spores very small, and therefore only the genus has been stated in most cases. Otherwise, the remarks made concerning mosses apply likewise to fungi. They have been "thrown in" and I have devoted only secondary attention to them. The report below therefore makes no claim to completeness. Docent Lennart Holm and Rolf Santesson have been kind enough to check my identifications on a few occasions.

Dasyscypha Fries

Dasyscypha sp.

One occurrence in the outer transitional zone—Huddinge: Snättringe, *Quercus*, 571, sparse.

Hysterium Walbg.

H. pulicare Fries

Nannfeldt (1949, p. 326) describes the species as common on the bark of deciduous trees, especially *Alnus* and *Betula*.

H. pulicare belongs to group 2 B in this investigation. Fig. 62.

Leprosphaeria Ces. et De Not.

Leprosphaeria sp.

The following three finds were noted in the investigated area: Huddinge: Länna, *Ulmus*, 588; Solna: Bergshamra, *Acer*, 374; Stockholm, Skarpnäck, *Quercus*, 559.

All these occurrences are outside the inner transitional zone (group 2 B).

Metasphaeria Sacc.

M. grisea (Körb.) Vain.

One occurrence in the central transitional zone: Stockholm: Sankt Göran, Marieberg, *Fraxinus*, 73.

Metasphaeria sp.

One occurrence in the normal zone—Huddinge: Länna, *Ulmus*, 588, sparse.

Pleospora Rabenh.

Pleospora sp.

Ten occurrences in the investigated area: Botkyrka: Tullinge, *Fraxinus*, 585; Danderyd: *Acer*, 472; Enebyberg Gård, *Fraxinus*, 582; Lidingö: Elfvik, *Fraxinus*, 531; Sollentuna: Södersätra, Väsjö, *Quercus*, 595; Solna: Järva, *Fraxinus*, 375; Stockholm: Hägersten, Bredäng, *Fraxinus*, 454; Spånga, Järvafältet, *Fraxinus*, 376; Tyresö: Alby Rectory, *Fraxinus*, 592 *a*; Österåker: Östra Ryd, Bogesund, *Fraxinus*, 548.

All these occurrences are outside the central transitional zone (group 3).

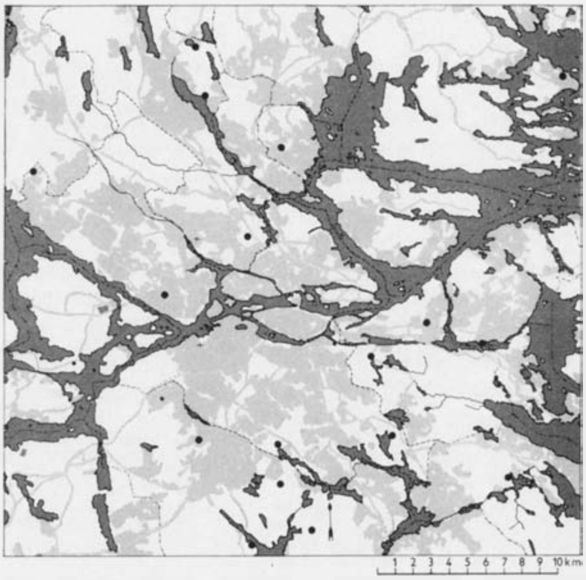


Fig. 62. Hysterium pulicare.

Trematosphaeria Fuckel

Trematosphaeria sp.

Seven occurrences, all of them outside the inner transitional zone (group 2 B).

Botkyrka: Norsborg, *Acer*, 575; Huddinge: Stuvsta, *Acer*, 474; Järfälla: Jakobsberg, *Acer*, 520; Nacka: Bollmora, *Fraxinus*, 562; Solna: Northern Cemetery, *Acer*, 360; Stockholm: Spånga, Vällingby, *Quercus*, 382; Västerled, Nockebyhov, *Acer*, 409.

III. ANALYSIS OF THE IMPORTANCE OF SOME ENVIRONMENTAL FACTORS FOR THE DISTRIBUTION PATTERN

Introduction

The environmental conditions of the epiphytic cryptogams have been thoroughly studied by Barkman (1958), who also gives an exhaustive bibliography.

As far as Sweden is concerned there are several works dealing more or less exhaustively with the ecology of corticolous lichens, including those of Sernander (1912), Greta Sernander-Du Rietz (1923, 1926, 1957), Degelius (1935, 1964), Du Rietz (1945 *a*), Ahlner (1948), Almborn (1948, 1953, 1955). The ecology of epiphytic mosses is dealt with by Waldheim (1944), von Krusenstjerna (1945), Sjögren (1961) and others.

In the present work, the ecological factors will be analysed on the basis of the differences existing between the habitat conditions in the agricultural landscape and in the innermost part of the investigation area. The aim is to try to evaluate these differences with respect to the effect they have on the distribution of the epiphytes, primarily of the lichens, in the investigation area. Thus the purpose is not to endeavour to give a complete account of the ecology of the epiphytes.

The Atmospheric Factors

GENERAL

Our knowledge of the chemistry of the atmosphere is admittedly still very inadequate, but Table 3 nevertheless gives an idea of the chemical composition of the troposphere. The mixture constituting the atmosphere normally includes solid and liquid particles.

In addition there is a large number of gaseous and solid organic compounds which have not yet been sufficiently studied. Coniferous forests, for instance, probably supply large quantities of organic substances of the terpene type to the atmosphere. Land areas also add organic particles such as pollen and gases from the biological turnover to the atmosphere. Large amounts of particles also come from wind-eroded areas. Great quantities of sea salt and other compounds are carried up into the air from the sea. Volcanic activity enriches the air with gases and particles.

The times spent by different substances in the atmosphere are of greatly varying length. Gases mostly remain longer than particles, and certain gases stay permanently or apparently so (e.g. nitrogen) whereas others are gradually depleted (e.g. sulphur dioxide).

The size of the particles occurring in the air varies within wide limits. Those remaining there for some considerable time, however, are smaller than 10 micrometres. The total number of suspended particles varies within such wide limits as 100–100,000 per cm^3. Liquid particles are usually formed by the condensation of water vapour on easily soluble particles. Such condensation-nuclei play an important role in the formation of clouds and precipitation. The size of the particles in this case is normally between 0.001 and 0.1 micrometres (Statens offentliga utredningar 1967: 43).

The gases that are chiefly of interest for this inquiry are sulphur dioxide and nitrogen compounds, also including ammonia. Carbon monoxide is added especially in urban environments.

Sulphur dioxide is included in the sulphur cycle. It is estimated that the approximate amount of 80 mill. tons normally formed annually as a result of the burning of sulphur-containing fossil fuels forms a minor part of this cycle (l.c. s. 14). Other intermediate compounds present in the air are sulphates and sulphuretted hydrogen.

Nitrogen oxides, primarily nitrogen dioxide, are formed—as also is ozone—in the course of photochemical processes in the upper atmosphere.

Ammonia is formed in connection with the biological turnover of nitrogen compounds. Non-acid soils can lose ammonia to the air, and the largest supply to the air is probably derived from well-fertilized agricultural land. Locally, ammonia is added to the atmosphere around certain types of chemical works. The effect of this is dealt with later, on p. 83.

Table 3. *Chemical composition of the troposphere (1 atm. pressure).*
After Eriksson (1961, p. 202).

Compounds	Formula	Partial pressure (atm)	Concentration (micrograms per m^3)	Remarks
Nitrogen	N_2	0.78101		Constant
Oxygen	O_2	0.20946		Constant
Water	H_2O	~0.02		Very variable
Argon	Ar	0.00917		Constant
Carbon dioxide	CO_2	3.3×10^{-4}		Somewhat variable
Neon	Ne	1.82×10^{-5}		Constant
Helium	He	5.24×10^{-6}		Constant
Methane	CH_4	1.5×10^{-6}		Constant
Krypton	Kr	1.14×10^{-6}		Constant
Nitrous oxide	N_2O	5×10^{-7}		Constant
Hydrogen	H_2	5×10^{-7}		Constant
Ozone	O_3	$\sim 5 \times 10^{-7}$		Very variable
Carbon monoxide	CO	1×10^{-7}		Variable
Xenon	Xe	8.6×10^{-8}		Constant
Sulphur dioxide	SO_2	1×10^{-9}		Somewhat variable
Ammonia	H_3N	$\sim 5 \times 10^{-9}$		Variable
Hydrochloric acid	HCl	$\sim 10^{-8}$		Variable
Nitrogen dioxide	NO_2	$\sim 10^{-9}$		Variable
Iodine	I_2	$\sim 2 \times 10^{-13}$		Variable
Chloride	Cl^-		1~	Very variable
Sulphate sulphur	$SO_4 - S$		1~	Very variable
Ammonia nitrogen	$H_3N - N$		1~	Very variable
Nitrate nitrogen	$NO_3 - N$		1~	Very variable
Sodium	Na^+		1~	Very variable
Calcium	Ca^{2+}		1~	Very variable
Magnesium	Mg^{2+}		~0.5	Very variable
Potassium	K^+		~0.5	Very variable

DISTINCTIVE FEATURES OF THE CITY CLIMATE

The climate of cities has been studied by many writers. There are exhaustive bibliographies in Kratzer (1956) and Geiger (1961). Facts concerning the present investigation area and its surroundings are to be found summarized in Ångström (1958). The climate of the Stockholm area is being investigated, and data dealing with the precipitation have so far been published by Modén and Nyberg (part 1, 1965). According to information received, part 2 exists complete in manuscript form. Geiger (1961) emphasizes the difficulty of determining the effect of the city on the climate. He believes that there are two methods of investigating this effect. One is to study really long series of measurements and observations for a town which has developed into a large city in recent years (cf. Fig. 73). The second method is to carry out measurements, as did Sundborg (1951) and others, during journeys in the city. Ångström (1958, p. 126) also emphasizes the difficulty of surveying the differences between the urban climate and that of the surrounding agricultural landscape. Many different factors, which in some cases cooperate with and in others counteract one another, enter the picture. The density and extent of the built-up area and the existence of parks, gardens and watercourses probably play an important role in this connection.

The city is warmer than its environment. In the summer, this is reflected in the fact that the night temperature is higher in the built-up area than in the green areas, partly because radiation is obstructed by the screening effect of the buildings (cf. below). In large cities (Munich, London, etc.) the minimum temperature is about 2°C higher than it is in the surrounding rural areas. The additional warmth in the winter is probably mostly due to artificial heating. It must certainly be a factor of some importance in the summer too.

Geiger also draws attention the large cupola of haze (*Dunsthaube*) which lies over the city and which absorbs an appreciable part of solar and celestial radiation (cf. also Grunow 1936, p. 70). The city sky is for example whiter than normal (Geiger 1965, p. 492). When inward radiation is predominant, e.g. during the hours around noon, the haze captures some of the heat. Especially during the autumn and the spring, the midday temperature may rise in the city. In some cases, however, it has been possible to confirm precisely the opposite effect. More unmistakable is the protection against outward radiation formed by the haze. At night, and particularly in the winter, the big city is in consequence warmer than its surroundings.

The great built-up area of the city warms up slowly and cools down slowly. In high summer, therefore, mornings in the city are cool and evenings mild. A study of temperature and wind in the outskirts of a large city has been carried out by Berg (1959, pp. 9 ff.).

The additional heat received by the city prevailing partly as the result of the screening effect and of artificial heating, certainly affects only the lower strata of the air. The vertical temperature gradient must therefore be considerably steeper over the inner parts of a city than it is over the surrounding rural areas. Heat is then removed more easily from the heart of the city by means of air movements.

The city heart may thus form a circulation system of its own, and this is most pronounced during warm, almost windless summer middays (cf. however Grunow 1956). The city's outskirts thus obtain an additional supply of fresh air from the surrounding rural areas. In such cases, cumulus clouds may form over the city. The amount of cloud reflects the particular conditions existing in the air in other ways too. The haze supplies an abundance of condensation-nuclei to high-lying clouds. On the other hand, low-lying clouds sometimes dissolve over a large city because of the lower atmospheric humidity prevailing there.

The summer maximum of relative humidity occurs (according to Mentzler 1935 quoted by Geiger) at about 6 a.m. in the heart of the city, approximately 8 hours later than in the country. The value is also about 10% lower. The 24-hour average is according to the schedule in Geiger (1950) as far as Hannover is concerned 5% lower than for the surrounding rural areas. The city climate is thus drier than that of the country, this being explained by the absence of evaporating surfaces and the speedy removal of rainwater. In Stockholm, however, the large water areas in particular, but also parks and undeveloped land, form important evaporating surfaces.

In spite of its drier air, the city is foggier than the country. It is believed that the abundance of condensation-nuclei in the city air is the reason for this. Fog often arises first of all in the vicinity of smoke-producing factories, railway yards, etc.

The large city thus has a certain influence on the quantity of precipitation. Labilization and the supply of condensation-nuclei to an atmosphere that is already prepared for precipitation can bring about an increase in the rainfall. Localized drizzle that is never recorded is probably not unusual.

A comparison made by Ångström (1958, p. 143) is of interest for this inquiry. He compares annual temperature, July and January temperatures and annual precipitation in the years 1860–1957 for Lund in the southernmost part of Sweden, Stockholm, and the small town of Haparanda in the northernmost part of the country. Though these cities and towns are so different, a remarkable parallelism is evident in the development of annual temperature and precipitation. Stockholm does not seem to differ from the rest of the country in these respects.

The climate of a large city is also characterized by the air's content of particulate and gaseous inpurities (Geiger 1961, Ångström 1958, p. 126). Locally, the addition of particulate impurities from combustion and industrial activity may be very large.

If there are light winds or a calm, three strata of air pollution can be discerned in the city. There is a stratum near the ground, consisting of particulate impurities from street traffic and of heavy smoke-clouds. An intermediate stratum at a height of about 20–30 metres derives its impurities mainly from the chimneys of buildings. An upper stratum, often at a height of 50–60 metres, is supplied with air pollution from tall factory-chimneys and large central-heating plants. Turbulence and strong winds mix the impurities, and so in most cases there is an unstratified mass of air over the city.

THE CHEMICAL NATURE OF STOCKHOLM AIR

Investigations carried out

The impurities existing in Stockholm air have been studied since 1962. In 1962–63 there were 10 measuring stations in operation, distributed over the central part of Stockholm and its suburbs. These investigations were begun by the National Institute of Public Health. Measurements were made of concentrations of sulphur dioxide, nitrogen dioxides and dust. Some measurements were made of the contents of benzopyrene also. The measurements showed that the normally occurring contents—fairly low in comparison with such cities as London and New York—increase very rapidly during the quite numerous periods of atmospheric stagnation (Alm, Cederlöf, Dalhamn, Friberg and others 1963). Mobile sampling apparatus has been in use since 1963–65, and with its aid it has also been possible to take samples from Stockholm harbour and from the waterways around Lidingö. There have been two stations in Solna,

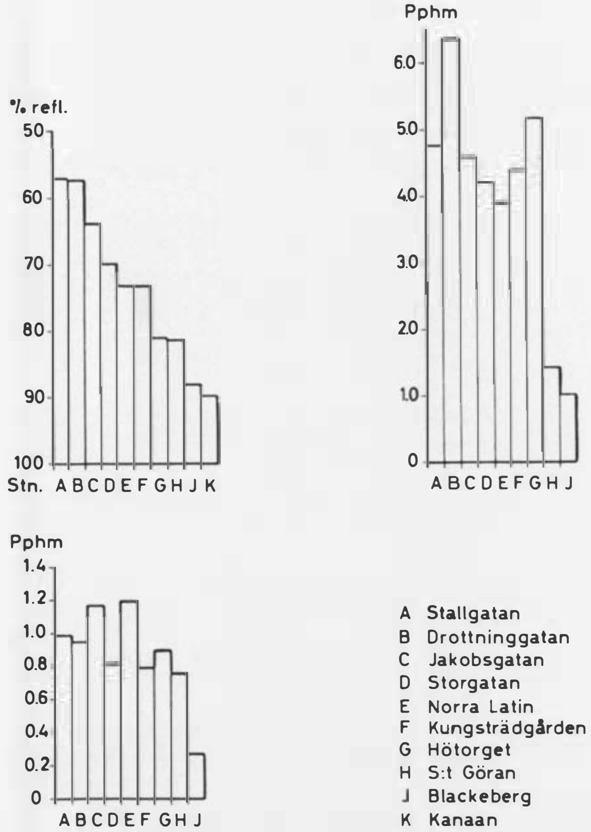


Fig. 63. Mean figure of four-week medians for dust, SO_2 and NO_2 respectively during year of activity 1962–63. Stations A–G are in the lichen-free zone, H–K in the transitional zone. (After Alm, Cederlöf *et al.* 1963 Fig. 14.)

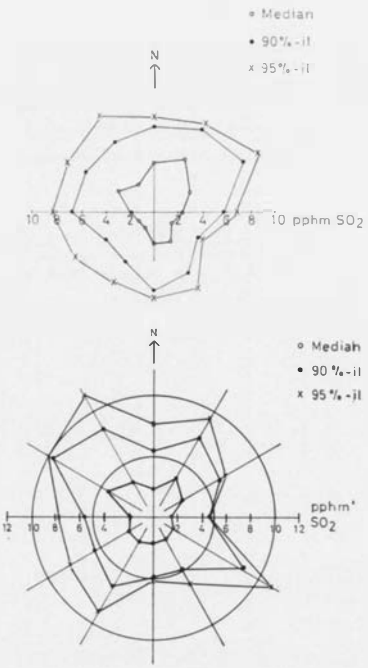


Fig. 64. Wind diagram for St. Clara Church H 1964–65 (above) and 1963–64 (below). (After von Ubisch and Nilsson 1966 Figs. 50 and 53.)

situated in the neighbourhood of the present stations 363 and 365 respectively. A permanent station for measurements at heights of 2 metres, 25 metres and 100 metres above ground level was established in St. Clara Church in central Stockholm and in an adjacent building (adjoining the present stations 37–39) in September 1963 (von Ubisch and Nilsson 1966; see also Nilsson 1964). With regard to apparatus, methodology etc., reference is made to the above-mentioned literature. Despite the fact that the data obtained from 1962–65 are few and that the sampling period has been short, certain tendencies can be ascertained.

In St. Clara Church, distance-reading thermometers were set up at heights of 5, 40, 65 and 100 metres above ground level. The data obtained do not seem to have been processed, however. On account of inadequate grants, unfortunately no measurements could be made during the unusually cold winter of 1965–66. In September 1966, air pollution investigations were resumed at the permanent station in St. Clara Church, this time under the direction of the Board of Public Health in Stockholm.

In cooperation with the Stockholm Board of Public Health and on the initiative of one of the Stockholm daily newspapers (*Svenska Dagbladet*) I started a long-term investigation in an area at Spånga. The investigations are intended to show the changes in the contents of sulphur dioxide, nitrogen dioxides and dust which are the consequence of building development in the area. Sampling and analyses are being attended to by the Stockholm Board of Public Health, and are being carried out on the same lines as those used in the 1962–63 inquiry. The sampling locations at Spånga adjoin station 376 (Spånga Church) and 573 (Stora Tensta farm). Samples are taken during a fortnightly period four times a year, and at the same time from the central part of the city.

The SO_2 contents are determined in all these investigations according to the so-called TCM method; NO_2, which is used here as a common designation for nitrogen dioxides according to Salzman's method (Salzman 1949). As the absorption of NO_2 is only half as large as of SO_2, the values stated below for NO_2 must be expected to be rather too low; on the other hand, the variation pattern is probably correct. The dust contents are evaluated with a reflectometer. (Cf. Alm, Cederlöf, *et al.* 1962.)

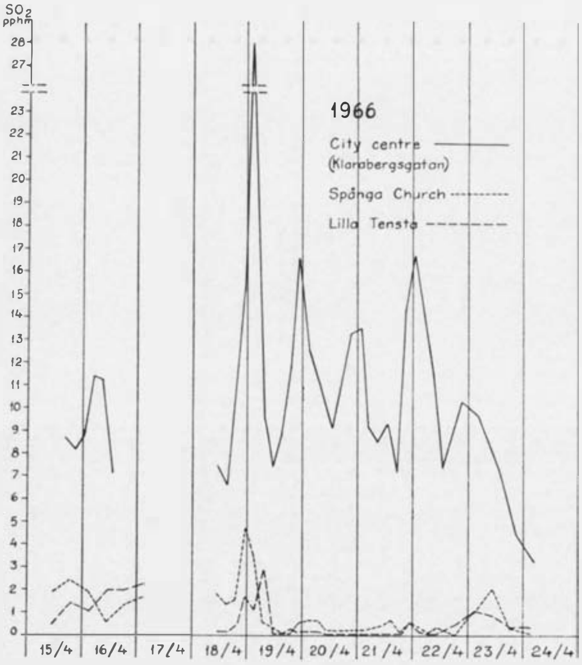


Fig. 65. Comparison between SO_2 contents of air in centre of Stockholm, at Spånga Church and at Tensta during the period 15th April–24 April 1966. During periods with very high SO_2 contents in the city centre, the values rise in the Spånga–Tensta area also, but the lichen vegetation has not yet been so much affected that it has been possible to ascertain any changes.

Horizontal distribution of air pollution

During the sampling period 1962–63, an attempt was made to gain an idea of the horizontal distribution of air contaminants. It was found that the whole of central Stockholm had approximately an equally high content of sulphur dioxide in the air. It was also found that the variations for the nitrogen oxides in central Stockholm were very small but that on the other hand the content of dust varies widely (Alm, Cederlöf, Dalhamn, Friberg and others 1963, Fig. 14). In the western part of Kungsholmen, the content of SO_2 begins to fall rapidly, and in Blackeberg the values are even lower. The NO_2 contents fall more slowly (Fig. 63).

The stations in Solna show SO_2 contents which can be compared with those for Blackeberg (von Ubisch and Nilsson 1966). They reach approximately one-third of Stockholm's and correspond to those for a quite clean suburb of Stockholm. With regard to NO_2 contents and dust, however, it is considered that the greater intensity of traffic in Solna makes its presence felt. The values here are comparable with the 25-metre level of Stockholm.

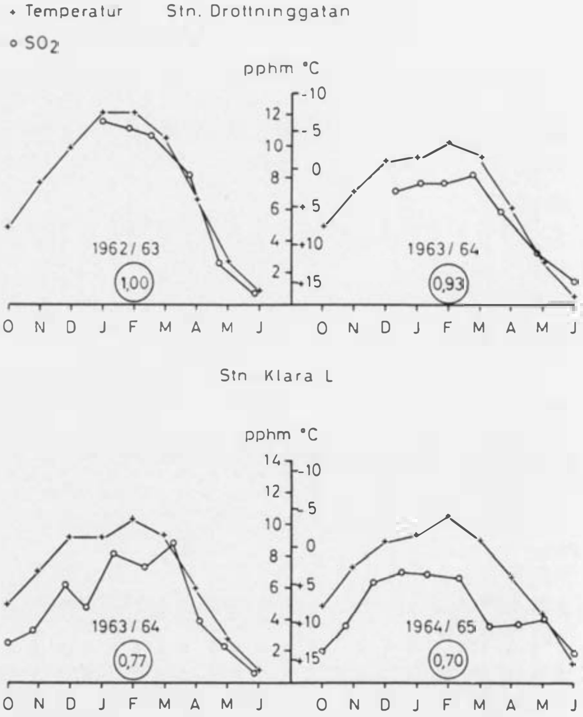


Fig. 66. Seasonal relationships between SO_2 and temperature for two stations. Drottninggatan (station B in Fig. 63, p. 67) and St. Clara low. (After von Ubisch and Nilsson 1966 Fig. 22.)

Measurements of the SO_2 contents carried out from boats in Stockholm harbour and around the island of Lidingö in different wind conditions apparently confirm that the pollution of the air in the inner harbour of Stockholm and in Lilla Värtan is "identically correlated" with that of the inner city. The contents of impurities are relatively high on the east-western straits around Lidingö, but low on the east, i.e. the leeward side of Lidingö. This phenomenon is explained by von Ubisch and Nilsson by the theory that the air follows the straits, while in passing over the land the air masses are spread by turbulence, and in these circumstances greater absorption of SO_2 can also occur.

Djurgården shows contents which are 40%–50% of the inner-city level during those parts of the year in which the vegetation does not actively absorb SO_2.

The results of the measurements at Spånga are not directly comparable with those mentioned above, as of course merely random samples are concerned, but show nevertheless that the SO_2 contents are fairly low, while NO_2 and dust still show fairly high values. The tendency is thus the same as that shown in the 1962–63 inquiry. In Figs. 64–65 a comparison has been made between some of the results gained hitherto from the investigation.

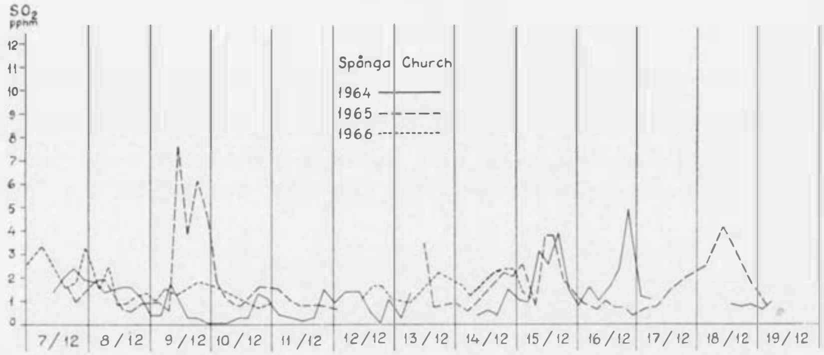


Fig. 67. Comparison between SO_2 contents at Spånga Church during the period 7th December–19th December, 1964–66.

Temporal variation of air pollution

The chronological report on air pollution in Stockholm is based on four-week periods. This form, according to von Ubisch and Nilsson (1966) is thoroughly suitable for studies of seasonal variations as well as for making comparisons between different stations and between different heating-seasons.

In the 1962–63 report (Alm, Cederlöf and others 1963) it is pointed out that the curves showing four-week mean values for sulphur dixide and dust show a clear seasonal trend for all the stations. Attention is also drawn to the similarity between the SO_2 curve and the temperature curve, although differences of detail occur. It appears, the report says, reasonable to assume that the main part of the variation in the four-week mean values for SO_2 emanate from similar variations in the intensity of domestic heating. In any case the seasonal variations in the ventilation conditions of the atmosphere probably cannot account for the great variation observed in the mean number for SO_2.

Von Ubisch and Nilsson (1966) state that a 1°C fall in temperature is connected with an increase in the sulphur dioxide contents by about 0.3 pphm. Even at about 0°C there is so much heating that the sulphur dioxide contents exceed the medical control value of 5 pphm.

Heating and traffic show both a weekly and a daily rhythm. The meteorological factors also have a daily rhythm. As regards the weekly rhythm, the curve in von Ubisch and Nilsson is difficult to interpret, partly because of the sampling technique employed. With respect to the daily variations, the course of the curve seems to be rather more distinct. A minimum in the sulphur dioxide contents during the cold season of the year seems to appear in the afternoon, and a secondary minimum in the later part of the night. Between these, there is a maximum in the forenoon and one in the evening and before midnight. A corresponding tendency can be discerned also during the warmer season of the year, i.e. at the start of the heating season in the autumn. There does not appear to be any clear variation as far as the nitrogen oxides are concerned. On the other hand the dust contents seem to be higher in the daytime than at night.

Vertical distribution of air pollution

Establishment of the measuring stations in St. Clara Church have rendered it possible to make some studies of the vertical distribution of air pollution. Thus for example von Ubisch and Nilsson show that the sulphur dioxide contents at a height of 100 metres above ground level average 75 % of the contents registered at a height of 25 metres. A 25-metre level is at the same height as the roofs of the buildings in surrounding blocks. The dust contents show a similar tendency, while the nitrogen dioxides are only insignificantly higher at the 25-metre level than they are at the 100-metre level. At a height of a few metres above the ground, the contents in some cases are very much higher than they are at the 25-metre level (Fig. 68).

Other impurities

The air of Stockholm contains in addition to the impurities mentioned a good many others, even if sulphur dioxide is the commonest and can therefore serve as an index of air pollution. Automobile exhaust gases alone are estimated to contain 150 or 200 different substances (Gerhardsson 1966, p. 13). As the result of the combustion of organic substances, carbon monoxide and carbon dioxide are formed, for example. The content of carbon monoxide in Stockholm streets is in certain cases disturbingly high (Friberg 1966, pp. 37 ff.). The carbon dioxide contents are higher in the central parts of the investigation area than in its outskirts—a fact that should be to the advantage of vegetation in the built-up area.

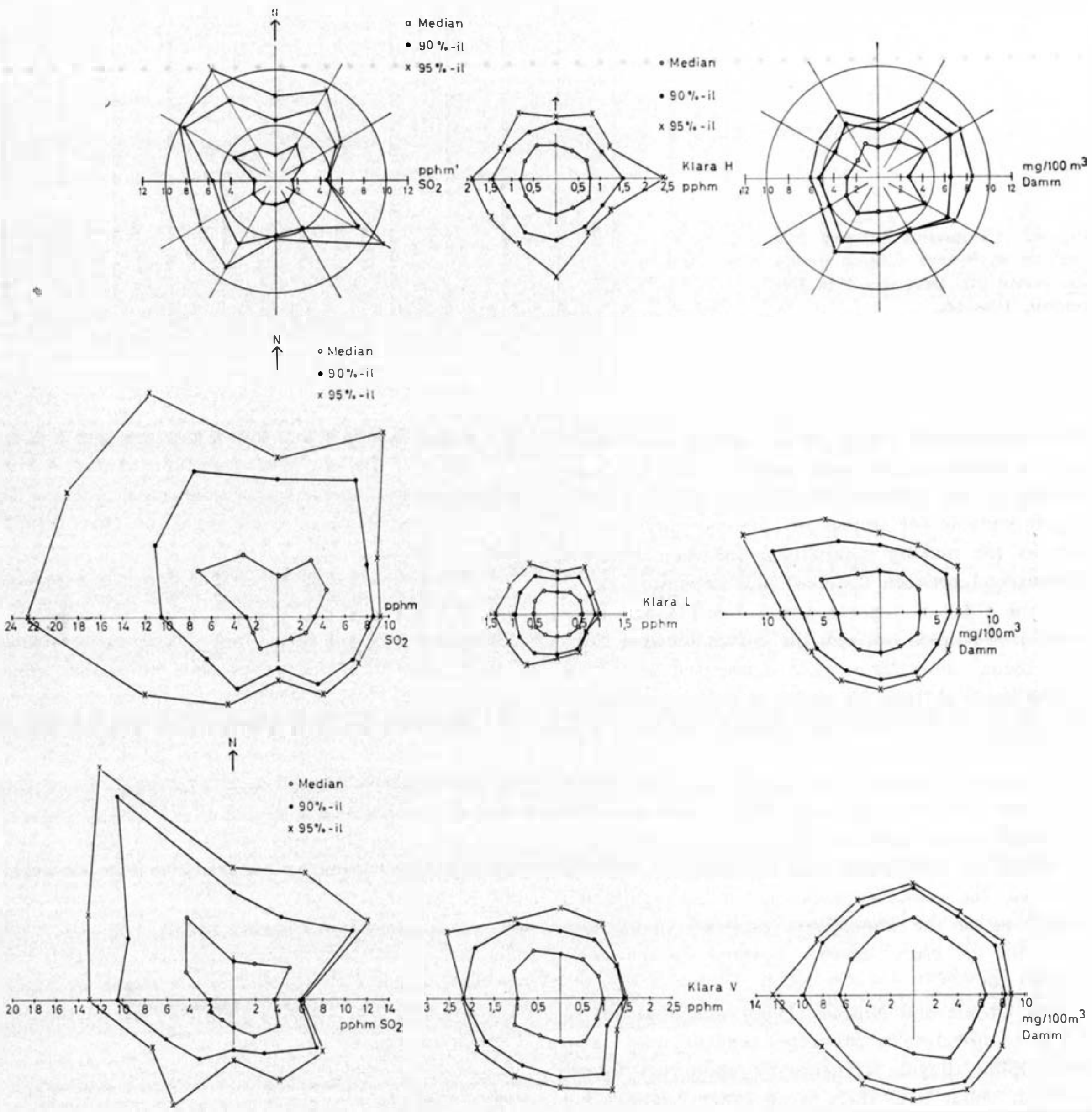


Fig. 68. Vertical distribution of air pullution (SO_2, NO_2 and dust) as shown by measurements in St. Clara Church, Stockholm (1964–65). "Klara H" = 100 meters above ground level. "Klara L" = 25 meters above ground level, and "Klara V" = 2 meters above street level (equivalent to ground-level height at the church). (After von Ubrich and Nilsson 1966.)

Origin of air pollution

The Stockholm area seems to obtain its air contaminants from two main sources: domestic heating and motor vehicle traffic. The variations in the sulphur dioxide content as they appear in the investigations indicate that domestic heating is responsible for most of this pollution. The nitrogen dioxides and the particulate impurities mainly emanate from or are affected secondarily by motor traffic. However, it has been impossible to obtain reliable measurements from traffic as a source of air pollution. Unsuccessful attempts have also been made to distinguish the dust from motor tyres and highway surfaces from other dust and soot (von Ubisch and Nilsson 1966, p. 10).

On the occasion of the changeover to right-hand driving in Sweden on 3rd September 1967, all motor traffic in Stockholm with the exception of police cars and a certain amount of other indispensable transport was prohibited from 10 a.m. on 2nd September until

3 p.m. on 3rd September. In connection with these traffic restrictions, measurements were made of the extent of air pollution at different heights above ground level in central Stockholm during three consecutive weekends: 26th–27th August, 2nd–3rd September and 9th–10th September. For practical reasons, the measurements were restricted to the measurement of sulphur dioxide and soot (particles and dust).

The measurements revealed that the content of sulphur dioxide in the air during the 24 hours in which motor traffic was very sparse corresponded to the values that are normal for a 24-hour Saturday-Sunday period. The sulphur dioxide originates overwhelmingly from domestic heating etc., and the absence of the minor proportion emanating from diesel-driven vehicles is not noticeable in the numerical data. The soot content, however, fell greatly. The table below shows the average figures obtained by the reflectometer method for the periods from 10 a.m. on Saturday until 3 p.m. on Sunday.

Table 4. *Measurements of the extent of dust at different heights above ground level in central Stockholm during three consecutive weekends in 1967.*

	Height above ground level		
Time	2 m[a]	10 m[b]	18 m[c]
26th–27th August	7.0	2.5	4.5
2nd–3rd September	3.0	1.0	2.5
9th–10th September	9.0	3.0	5.0

Measuring stations: [a] Stallgatan 3; [b] Torkel Knutssonsgatan 20; [c] Klarabergsgatan 33. (Information obtained from Press Bulletin from the Board of Health, issued 19th September 1967 p. 20.)

The reflectometer method measures the degree of darkening of a dust sample. It thus gives no indication of the quantity of dust but merely of the amount of dark dust and soot.

The investigation gives a certain indication of the proportion of dust derived from motor traffic.

LIGHT AND VISIBILITY

The effect of light on lichens has been studied by Almborn (1948, 1953, 1955), Barkman (1958), Degelius (1935, 1965), Ertl (1951), Stålfelt (1939) and others.

Light has a certain importance for the distribution of the epiphytes. It is stated for example that there are photophilous, phototolerant and photosensitive species among both lichens and mosses. See for example Almborn (1953, 1955) and Waldheim (1944). It is necessary to distinguish here between the effect of sunlight and of diffuse daylight, and this is not easily done. It is also difficult to differentiate between the direct influence of light on vegetation and the indirect influence of irradiation, via temperature and moisture. Thus for example Sjögren (1961, p. 69) confirms that a moss covering is absent on the parts of the trunks most strongly exposed to light when no other factors alleviate desiccation.

The species dealt with in this treatise—because of the structure of the work—are photophilous and phototolerant ones. The light factor may be of importance here for the location of the lichens on the trunk, probably in conjunction with the factors of temperature and humidity, cf. Almborn (1948, p. 219) and Degelius (1965, p. 7).

Number of hours of sunshine and total inward radiation

Fig. 69 shows a comparison between the number of hours of sunshine per month for Stockholm, Karlstad and Erken (*Swedish Meteorological and Hydrological Institute* (*SMHI*), *Yearbook* 2: 2, supplement, 1960–61) and refers to the years 1957–59. Erken, which is a thoroughly rural station situated about 60 km NNE from Stockholm, shows manifestly lower figures than Stockholm, while Karlstad in certain cases shows somewhat higher values than Stockholm.

Fig. 70 shows a comparison between the total inward radiation in cal/cm^2 from sun and sky on a horizontal surface for Stockholm, Karlstad, Erken and Ultuna. In this respect, Stockholm is surpassed by Karlstad but shows higher values than Erken. It is hardly possible from these scanty data, considering the regional climatic differences, to demonstrate any differences between the large city, the small city and the countryside, but it is worth noticing that the values for Stockholm are not at the bottom of the table.

Visibility conditions

A comparison by months for the years 1938–41 and 1950–60 between the visibility conditions in Stockholm, Linköping (about 204 km south-west) and Karlstad (about 310 km west of Stockholm) is shown in Fig. 71. The visibility conditions are throughout worse in Stockholm than in Karlstad and even worse than in Linköping, except as far as the best visibility is concerned. The differences are biggest in the winter months, which cannot merely be explained by the somewhat higher frequency of fog in Stockholm (Fig. 76) during this period.

It is difficult to make a complete evaluation of

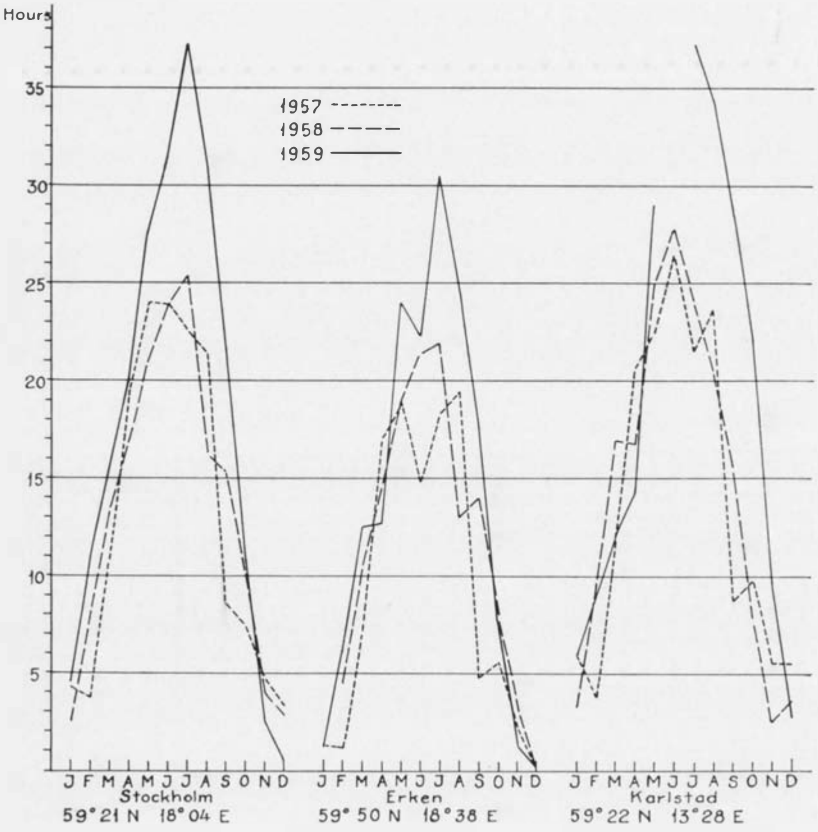


Fig. 69. Number of hours of sunshine in Stockholm, at Erken and in Karlstad, 1957–59. Erken is a typical rural station, while Karlstad is a small city compared with Stockholm.

the ecological effect of this phenomenon. The haze cupola (Kratzer's *Dunsthaube*) typical of large cities exists apparently over Stockholm too. Its effect on the temperature climate has already been mentioned (p. 65).

It seems less probable that the changes in light intensity would have any effect on the lichen flora. The changes are not of that scale of magnitude, and should the light intensity fall so that the photophilous species were to disappear, it would be reasonable to assume that they would to some extent be replaced by sciophilous species. The investigation area offers, moreover, so many different light-conditions that a general diminution in light would have highly varied consequences. The extent to which possible changes in the composition of light may contribute towards making the city poor in lichens cannot be appraised, but this does not appear to be likely either.

TEMPERATURE

The air temperature in the Stockholm area is shown in Fig. 72, in which the monthly mean values from Stockholm (Observatorielunden), Stockholm Airport (Bromma), Experimentalfältet, Beckomberga, Farsta and Kårsta are given. The values are taken from the *SMHI Yearbook* and refer for Stockholm to 30 years (1931–1960), for Stockholm Airport to 21 years (1940–1960), for Experimentalfältet to 30 years (1931–1960), for Beckomberga to 4 years (1957–1960), for Farsta to 30 years (1931–1960) and for Kårsta to 8 years (1953–1960).

As the figure shows, the course of the curve differs for the various stations during the winter and summer months, while the spring and autumn seem to be similar with respect to the temperature climate.

The mildest winters occur in the inner city of Stockholm (Observatorielunden) and at Experimentalfältet. The curves for these two stations are almost identical. Farsta and Beckomberga have a winter temperature that is, generally speaking, 0.5 °C lower. It is somewhat colder still at Stockholm Airport, and the severest winter climate is at Kårsta, which is 1.5 °C colder than Stockholm. (It should be noted, however, that the recordings cover a period of only 8 years.)

Ångström (1958, p. 138) points out that the mean value for a 10-year period cannot be expected to coincide exactly with the mean figure for another 10-year period. The probable difference is in the

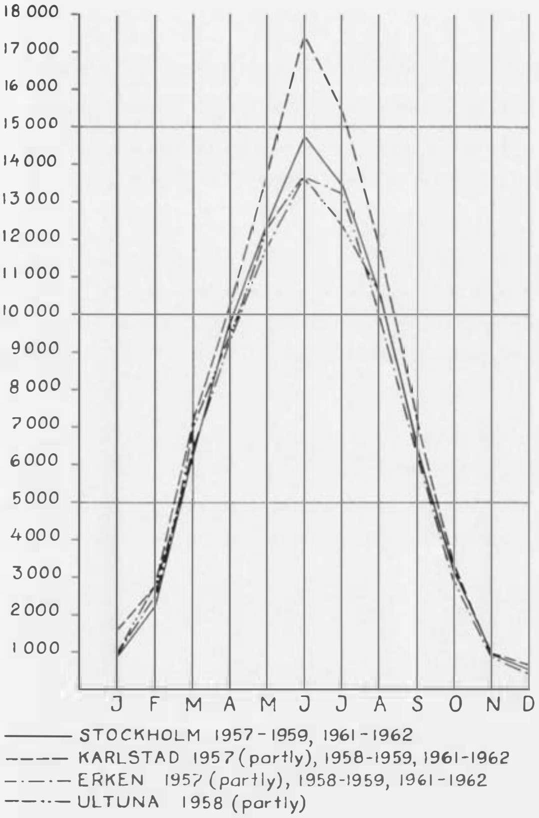


Fig. 70. Total inward radiation in Stockholm, Karlstad, Ultuna (near Uppsala) and at Erken.

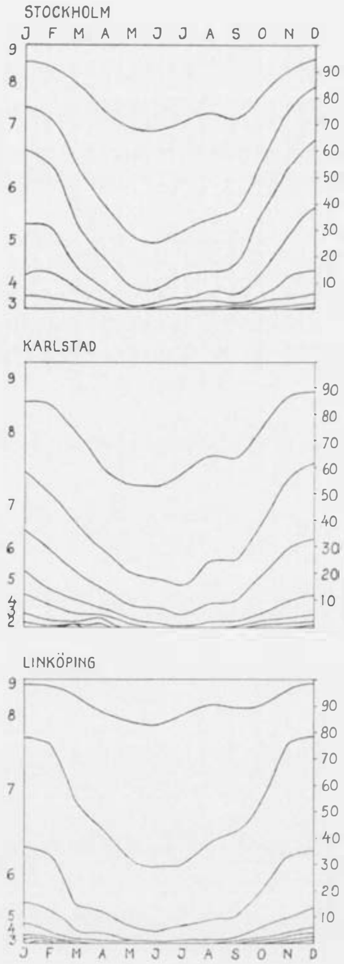


Fig. 71. Visibility conditions in Stockholm, Karlstad and Linköping, expressed in a nine-grade scale. The curves show percentile distribution throughout the months of the year. (Mean values for the years 1930–61.) The visibility conditions during the winter half of the year are decidedly worse in Stockholm than in the other two cities.

region of 0.5°C to 1.0°C. The January temperature in Stockholm for the 10-year period 1911–20 is for example 1.6°C lower than the mean value for the 10-year period 1901–10.

The summer temperature is highest in central Stockholm, Stockholm Airport, Beckomberga and at Experimentalfältet. Farsta and Kårsta have a somewhat lower temperature. The difference is a matter of about 1.0°C for Kårsta and of about 0.6°C for Farsta. According to these figures, central Stockholm is no warmer in the summer than are the suburbs, but is between 0.5°C to 1.0°C warmer than the surrounding countryside.

Ångström (1958, p. 123) emphasizes that on a sunny summer's day the temperature over an asphalt roadway can rise some tens of degrees C above the temperature in an open park in the vicinity. At the same time the temperature in the shade of large blocks of buildings can be considerably lower than in the park. (Cf. for example Grunow 1936, p. 70.)

A comparison between the maximum and minimum temperature in Stockholm and Nyköping from 1919 until 1961 is shown in Fig. 73. The figure seems to show that the minimum temperature in Stockholm has risen by 1.5°C to 2.0°C since 1920. The maximum temperature has until the most recent years been slightly higher in Nyköping than in Stockholm. Whether these differences are due to the urban environment, however, is difficult to say.

Ångström (1958, p. 140) shows how winter temperature in Stockholm has risen by 2°C since the middle of the 18th century, while the summer temperature on the other hand has remained practically unchanged (see also Bergsten 1930, pp. 252 ff.). The annual temperature has risen by about 0.5°C but the increase began, generally speaking, at the turn of the century. The rise in the winter temperature is believed to be due to the fact that extremely cold

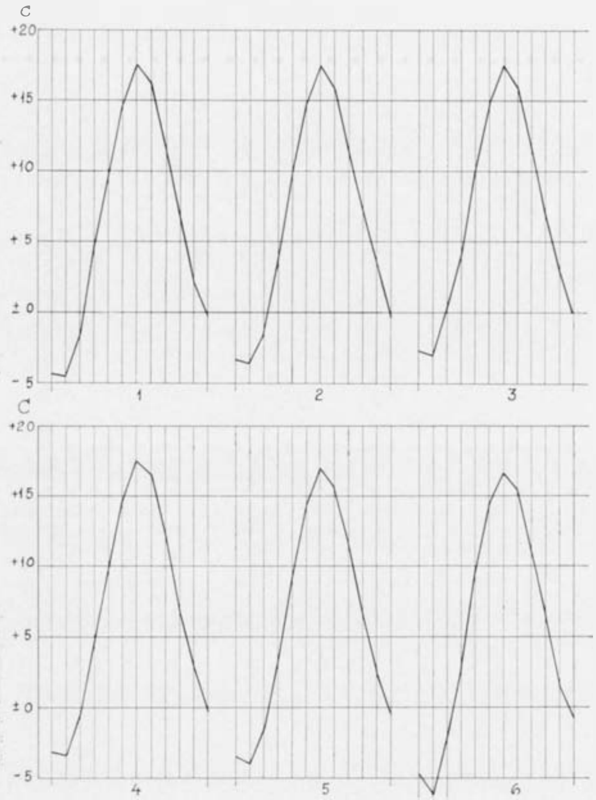


Fig. 72. Air temperature expressed as monthly mean values. 1 = Stockholm Airport (Bromma), 2 = Beckomberga, 3 = Stockholm (Observatorielunden), 4 = Experimentalfältet, 5 = Farsta, 6 = Kårsta.

winters have become rarer, and applies not only to Stockholm but to the country as a whole.

From the available data, it is difficult to obtain an exact idea of the extent to which the temperature climate of Stockholm differs from that of its surroundings. The additional heat apparently prevails mainly in the cold season of the year. During the warm part of the year it is less pronounced. If temperature (as a feature of macro-climate) is of any importance for the origin of the distribution pattern, it is therefore the winter temperature that is decisive.

Temperature and lichens

The importance of temperature for lichens has been studied by several writers. In addition to the works mentioned by Barkman (1958, p. 61), the following may be mentioned: Bertsch (1966), Bliss and Handley (1964), Lange (1965).

Lange (1953) has studied the reactions of lichens to high temperatures and found that sciophytic forms of air dry *Alectoria implexa* show a sharp decline in respiration after a heat shock of 70°C in half an hour. An 80°C shock almost kills the lichen. All *Alectoria* and *Usnea* species are sensitive, but all Lange's specimens survived 5 hours at 58°C. After 3 hours at 66°C the respiration of *Evernia prunastri* (from an oceanic region) was greatly inhibited. With *Alectoria implexa, Evernia prunastri* and *Usnea dasypoga,* alga and fungus seem to be equally sensitive, but with *Lobaria pulmonaria* and *Pseudevernia furfuracea* the alga is injured before the fungus. On the other hand the fungus is more sensitive than the alga in *Ramalina farinacea* and *Usnea florida.* Lange also shows that the lichens are considerably more sensitive to heat in a moist condition than in dry air. Species that are sensitive to dry heat are also sensitive to moist heat.

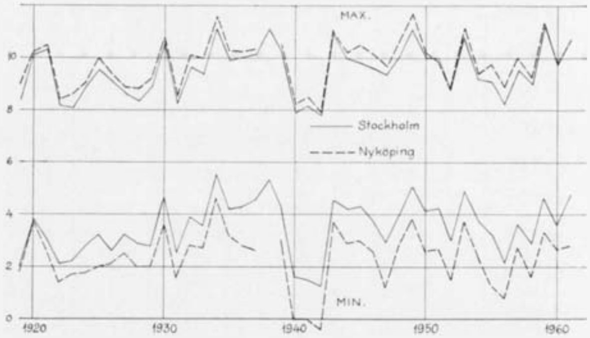


Fig. 73. Maximum and minimum temperatures in Stockholm and Nyköping, 1919–61.

He also says (p. 73) "Die Beobachtung an Flechten weisen ebenfalls auf einen inneren Zusammenhang zwischen der Resistenz gegen feuchte und trockene Hitze und gegen Austrocknung hin".

Lange (1953, p. 83) notes that it appears from climatological data and from determinations of water content in natural habitats that prolonged periods of drought never occur in our climatic region, even in dry habitats. Even during rainless periods the lichen thalli absorb sufficient moisture from damp or fog or dew for them to be able to assimilate. After having noted that the longest dry period in Göttingen during the period 1898–1951 was 40 days (p. 82) he notes (p. 91) that: "Keine der untersuchten Flechtenarten kann an irgendeinem natürlichen Standort (unseres Klimagebietes) von so langen Trockenperioden betroffen werden, dass eine unmittelbare Trokkenschädigung eintreten und dadurch ihre Verbreitung eingeschränkt werden könnte". This however does not exclude a selective influence of the varying response towards high temperatures and prolonged desiccation, when the competition between species is considered.

Desiccated mosses behave in the same way as desiccated lichens.

Bünning (1947) observed a parallel between resistance to heat and resistance to sulphur dioxide in tropical algae, and believed that there is a connection between the two. Bogen (1948) regarded heat-resistance as a special case which can be explained by a general resistance in the plasma, determined by its structure.

The epiphytes encounter extremely varying temperature conditions in their natural habitats. Sun-exposed thalli of epigeic species can be subjected to a temperature lying 40°C above the air temperature. No such high temperatures have been measured in the case of epiphytes. In one of Lange's experiments, *Pseudevernia furfuracea* received a max. temperature of 26.9°C. The air temperature was then 20°C.

As Sjögren emphasized in 1961, it is difficult to distinguish the direct influence of the temperature on respiration and transpiration, from the indirect influences on the other habitat-factors. Lange's experiments, however, seem to give support to the view that the air temperature in summer cannot cause such a scarcity of lichens as that existing in Stockholm, and also that it cannot be regarded as a contributory cause of this scarcity. Moreover, Stockholm differs far too little from its surrounding agricultural landscape.

The mild winters in the built-up parts of the city probably cause the vegetation period to be prolonged in autumn. Light is of course then greatly reduced, at the fairly high latitude of Stockholm, and in October–November the time during which respiration prevails is much longer than the time when photosynthesis is also possible. During the seasons concerned (especially in the late autumn) there is usually a sufficient supply of water for the lichens. Barkman (1958, p. 17) points out that the lichens do not need very strong light during the cold season of the year in order to be capable of assimilation. The temperature for a maximally effective photosynthesis falls from 17°C to 5°C when the length of the day changes from 18 to 3 hours.

Stålfelt (1939) worked with *Cetraria glauca, Evernia prunastri, Hypogymnia physodes, Ramalina farinacea, R. fraxinea, Usnea dasypoga* and other species, and found that the production apparatus of these species is so adjusted that it operates intensively in the winter and extensively in the summer. The winter is not an absolute resting-period for the mosses either (Hagerup 1935, p. 64). Most growth, however, occurs chiefly in the autumn and spring (Romose 1940, pp. 73 and 103).

The relatively mild winters in the city thus lead to increased activity in lichens and mosses during the part of the year when air pollution is at its highest—a circumstance which is certainly not without significance in this connection, but which has to some extent doubtlessly been disregarded in the discussion on lichens and the urban environment.

EVAPORATION

Evaporation from buildings and paved streets is minimal during the summer, while from ground covered by vegetation it is generally of the same magnitude as from a water surface.

Evaporation represents a removal of heat from the ground surface of the same magnitude as the heat surplus (inward radiation—outward radiation) which is supplied from the sun and the sky onto the same ground surface.

Evaporation surfaces in the form of large water areas and undeveloped ground in the central parts of Stockholm are shown in Figs. 1 *a* and 1 *b*. In Stockholm these areas are extraordinarily large and have a clear effect on the local climate.

PRECIPITATION

The dryness of the city climate (Geiger 1961, p. 512) has been held responsible by some writers for the death of the lichens (see for example Rydzak 1953, Klement 1958, 1966, and Natho 1964). There are therefore reasons for dealing with the water factor in somewhat more detail.

Lichens acquire water in the form of rain, dew, fog and atmospheric humidity. Rain, however, is the most important factor for the supply of lichens with water.

Precipitation conditions in the Stockholm area have been studied by Modén and Nyberg (1965). The investigation shows that Stockholm (Observatoriekullen) has a mean annual value of 555 mm (for the period 1931–60), which is 33 mm lower than the mean value for the whole of Sweden. (For the period 1881–1920, precipitation amounted to 548 mm according to Bergsten 1930.) The eastern and southern parts of the Stockholm area have a heavier annual precipitation than the western and northern parts. This dissimilarity appears primarily in the distribution of precipitation during the autumn (September–November) and winter (December–February). For the rest of the year, precipitation is more evenly distributed over the whole area except in July and August, in which the western parts of the area have the heaviest precipitation. The spring is drier than the other seasons of the year. Precipitation

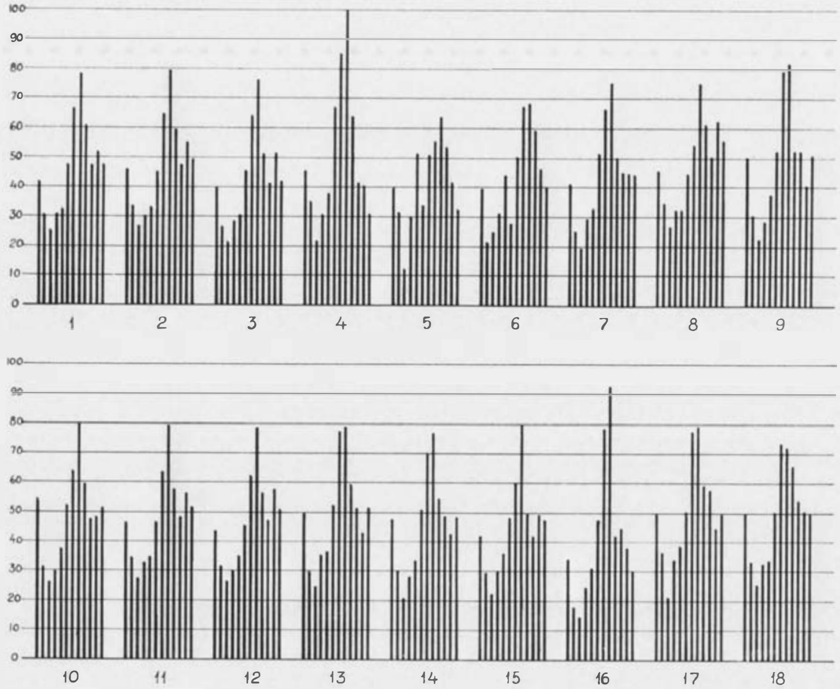


Fig. 74. Monthly mean values of precipitation in the Stockholm area. 1 = Stockholm (Observatorielunden), 2 = Experimentalfältet, 3 = Stockholm Airport (Bromma), 4 = Lidingö, 5 = Skansen, 6 = Ulvsunda, 7 = Barkarby, 8 = Farsta, 9 = Sätra gård, 10 = Tyresö, 11 = Norsborg, 12 = Bergaholm, 13 = Österåker, 14 = Vallentuna, 15 = Nyckelby, 16 = Lyckås, 17 = Röskär, 18 = Kårsta.

conditions in the investigated region are shown in Fig. 74.

In the summer months, rain falls mainly in the middle of the day. Maximum precipitation then coincides with maximum temperature. A secondary maximum occurs in the later part of the night. Of the two minima thus occurring, that in the evening hours is the most marked. (Cf. relative humidity, Fig. 75.) During other seasons there are relatively small variations in the distribution of precipitation over the various hours of the day and night.

The mean intensity of precipitation—i.e. the precipitation, measured in millimetres, which has fallen per precipitation hour—has a daily periodicity which is little marked during the winter and spring. In the summer, however, the variations are considerable. The greatest intensity in precipitation is attained at the same time as the maximum for the quantity of precipitation, i.e. between noon and 2 p.m. The minimum is reached in the mornings between 6 a.m. and 8 a.m., which is rather later than the time for the secondary minimum of the quantity of precipitation. During the autumn, maximum precipitation intensity occurs between 4 p.m. and 6 p.m., while the minimum value is reached between midnight and 2 a.m.

As regards the duration of precipitation, Modén and Nyberg note that the winter—not unexpectedly—is the season when the duration of precipitation is at its greatest. In the winter half of the year, light snowfall or light drizzle may be very persistent and yet give only small quantities of precipitation. During the summer the duration of precipitation is short. However, in this season too there is occasional drizzle which gives such small quantities of precipitation that no registration occurs. In the summer, rain usually falls in the form of quite short showers (see also Ångström 1958, p. 69). The heavy afternoon showers which sometimes occur in Stockholm during the summer are probably due to the larger vertical temperature gradient and thus to the more labile stratification which appears in air layers over the city as compared with its surrounding. Local downpours may also possibly appear in places where no registration is made (see p. 66). On the other hand, the greater dryness of the air in the densely built-up areas must counteract the occurrence of showers.

In addition to precipitation, an important part is also played by dew, fog and atmospheric humidity for the water economy of the lichens. Dew and fog occur when the lowest air strata have cooled down below dewpoint, and water is then deposited in the form of particles. The moister the air, the less cooling-down is required in order that dewpoint shall be reached.

Dew as a supplier of water to lichens in the heart of the city is probably a factor of importance primarily in park areas such as Tantolunden, Skinnarviksparken, Humlegården and Lilljansskogen, and in the islands of Skeppsholmen and Kastellholmen. In-

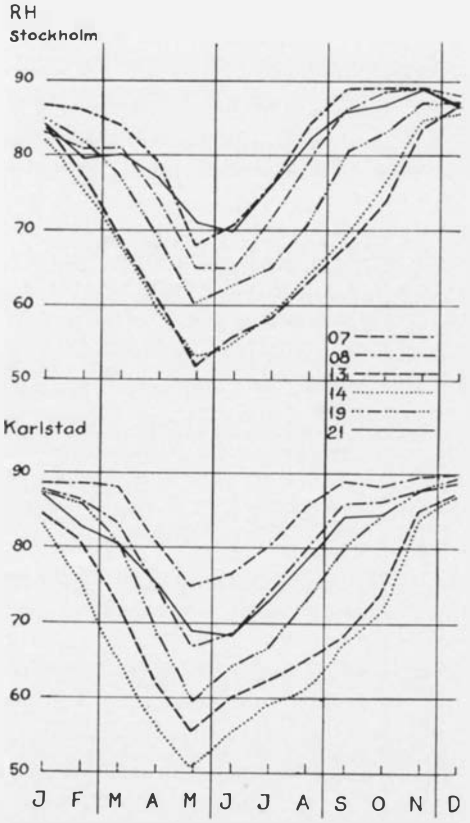


Fig. 75. Monthly mean values of relative humidity (RH) in Stockholm and Karlstad at 6 different times during the day and night (7, 8, 13, 14, 18 and 21 hrs.).

formation regarding the occurrence of dew is scanty in the *SMHI Yearbook*, probably because the dew vanishes very early in the morning, but experience suggests that August and September are probably the summer months in which dew frequency is greatest.

The frequency of fog is shown in Fig. 76. The summer months are the least foggy ones, while November and December have a high fog frequency as compared for example with Karlstad, and a considerably higher one than for example Örebro, Jönköping and Gothenburg (Ångström 1958, p. 87, Fig. 35).

Atmospheric humidity depends on temperature, wind conditions and precipitation. Presumably it is less important than precipitation for supplying the epiphytes with water.

Although Karlstad Airport can be regarded as a "rural station" (situated about 3 km SW of the centre of Karlstad) its relative humidity averages only about 1 % lower than Stockholm. As regards humidity pressure, the Stockholm values are about 0.05 mm Hg higher than the values from Karlstad. Whether this small difference is significant or not is hard to judge, as it seems difficult to obtain reliable figures for atmospheric humidity.

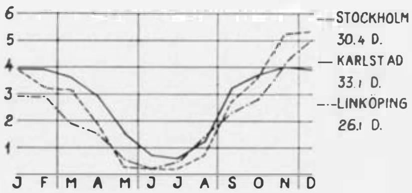


Fig. 76. Frequency of fog in Stockholm, Karlstad and Linköping. Stockholm has 30.4 foggy days per year. Not unexpectedly, autumn is the foggiest season.

July and August seem in fact to be the only months in which the humidity pressure varies throughout all the hours of the day and night. The highest values as far as Stockholm is concerned are reached at 8 a.m. and 9 p.m., the lowest at 1 p.m. In Karlstad the highest value is attained at 9 p.m., with a secondary maximum at 8 a.m. The lowest value is reached at 1 p.m. The values at 2 p.m. are also higher than those at 7 p.m.

As regards relative humidity, it is mainly during the morning hours that the two stations differ. At this time Stockholm is noticeably drier than Karlstad, and this is especially marked in May (7 %) and June (5 %), Stockholm also shows lower values at 1 p.m. in May, June, and July (see also Fig. 75).

Apparently Stockholm does not—judging from the numerical data—show the features that according to Geiger distinguish a large city with respect to atmospheric humidity (cf. p. 66). With respect to relative humidity, Stockholm in all probability does not differ appreciably from other meteorological stations in the eastern part of the province of Svealand. Naturally of course the values for some parts of the built-up area of the city probably differ from those measured, precisely as is the case with respect to temperature, but it is not possible to ascertain this from the *SMHI* official figures. The reason for the favourable humidity climate may possibly be the relatively large evaporation areas existing in the region, but as previously pointed out the values are manifestly somewhat unreliable.

The different types of precipitation vary somewhat in their reaction to air impurities. Berge (1963) points out for example that rain and snow lower the content of gaseous, smoke-like and particulate immissions, while fog increases it. In other words, the air is cleaned when the precipitation falls to the ground. In the case of fog, the water droplets are kept in suspension and the concentration of air pollution rises. One of the results of this is that in dry air

Table 5. *Some epiphyte lichens' and mosses' water-absorptive capacity as percentages of fresh weight.*

Species	Mean number	Mean errors	Number of samples
Hypogymnia physodes	549.2	107.2	6
Parmelia			
sulcata	431.7	131.9	6
acetabulum	325.8	111.3	2
subargentifera	249.6		1
saxatilis	450.2		1
tiliacea	362.1		1
Ramalina			
fraxinea	328.7	55.5	8
farinacea	413.6	55.5	3
Evernia prunastri	405.8	85.6	5
Anaptychia ciliaris	424.0	71.1	7
Cetraria glauca	449.3	46.7	6
Physica pulverulenta	281.0	12.5	2
Pseudevernia furfuracea	413.2	45.5	3
Xanthoria parietina	525.6	48.4	3
Alectoria jubata	1144.8	56.9	2
Usnea sp.	660.4		1
Hypnum cupressiforme	831.5		1
Leucodon sciuroides	1195.3		1
Tortula ruralis	710.5		1

completely harmless concentrations of sulphur dioxide, for example, can cause severe damage to vegetation if the atmospheric humidity increases.

Lichens receive water from yet another source, namely the stem flow. During and after rain, quite large quantities of water run from the treetop down the trunk. This flow of water is of great importance for both the water economy of the lichens and their distribution. These problems will be dealt with later (p. 103).

Lichens and precipitation

The water economy of the lichens has been dealt with by many writers. Barkman (1958) gives a list. In addition some later authors may be mentioned: Beschel (1958), Ried (1960), Lange and Bertsch (1965), Bertsch (1966), Rao and Le Blanc (1966).

Lichens can absorb water in quantities of up to several times their own weight (see Table 5). Fraymouth (1928) has investigated *Hypogymnia physodes* and found that a water content of 200% in relation to the dry weight is optimal for assimilation. If the lichens are excessively full of water, gas exchange is hindered.

Among the species which penetrate deeply into the central parts of the region of investigation, *Hypogymnia physodes* is notable. It is regarded as resistant to drought. Ensgraber (1954, p. 472) says that the plasma in this species is resistant to dryness. His opinion is also that the metabolism is not quite negligible even during long dry periods, but that a conversion of carbohydrate to fat takes place. He also notes that lichen thalli which have been moist on a particular day lower their intensity of assimilation much more quickly if they are thoroughly moistened again on the following day. According to Ensgraber, the resistance of the lichens to dryness manifests itself as a short restitution phase which permits the utilization of short moist periods, and in the degree and length of endurable periods of dryness.

The table below shows the water-containing capacity of some epiphyte lichens. The lichens were air-dried for 24 hours in a laboratory at a temperature of about +21 °C, after which a sample was extracted, weighed and soaked for 4 hours. It was then removed from the water, dried with filter paper for a few seconds and then weighed. All the samples were taken at the same time, so that the RH of the laboratory air was the same in all cases.

Lange (1953, p. 68) shows that *Alectoria sarmentosa* and *Usnea dasypoga,* for example, can resist 40 weeks in an almost entirely waterless environment and yet after saturation reach up to between 75% and 50% of normal respiration. *Evernia prunastri* is not affected by 24 weeks without any water, while *Alectoria implexa* can overcome 32 weeks in a dry environment without being affected. All these species are described by Lange (p. 72) as sensitive to desiccation. It is therefore interesting to see how long the dry periods are that occur in Stockholm. In an examination of the *SMHI Yearbooks* for 1930–62 (33 years) it has been noted that the longest continuous period without precipitation of more than 1 mm was 6 weeks (41 days) in September–October 1951. A continuous dry period of between 5 and 6 weeks (35–42 days) occurred only 4 times during the 33 years investigated. During the 41-day period without precipitation of more than 1 mm, fog was noted on 8 occasions, and dew on 1 occasion. The period was thus not entirely waterless for the lichens. The same applies to the other 3 periods of fair weather lasting longer than 5 weeks. On at least some occasions during each of them, there was precipitation of less than 1 mm. There were also haze, fog

Table 6. *Water-containing capacity of some epiphyte lichens. Air-dried sample = 1.0.*

	Hours								
	0	1	2	3	4	5	6	7	24
Alectoria jubata	6.3	3.8	2.7	1.9	1.4				1.0
Anaptychia ciliaris	5.3	3.3	2.8	2.4	2.0				1.0
Evernia prunastri	3.9	3.2	2.8	2.4	2.0	1.7	1.5	1.3	1.0
Hypogymnia physodes	4.8	3.7	3.2	2.9	2.6	2.4	2.1	1.9	1.0
Parmelia saxatilis	5.9	4.3	3.4	2.9	2.5	2.2			1.0
Parmelia sulcata	4.3	3.2	2.9	2.7	2.6	2.4	2.3	2.1	1.0
Pseudevernia furfuracea	4.3	3.0	2.5	2.1	1.8	1.5			1.0

and light snowfall on several occasions. This applies also to all periods of fair weather lasting longer than 3–4 weeks.

Dryness obviously is a factor of some importance as far as lichens are concerned. Pearson and Skye (1965, p. 1601) show that *Hypogymnia physodes* and *Xanthoria parietina* which have been kept in a thallotron for more than 4 months in relatively dry conditions had a photosynthesis which was equivalent to that of fresh specimens, while specimens which had been kept for the some length of time under moist conditions changed in appearance and consistency and showed a quite different pattern with respect to photosynthesis.

WINDS

The wind has a direct influence on the epiphytes as a dissipator and as a transportation agent for abrasives such as sand, ice crystals, etc., as well as for soot and gaseous air contaminants.

Wind also has the effect of increasing evaporation and thus of desiccation. This effect is strong especially for epiphytes on isolated trees and trees bordering woods and parks. The effect of wind is weaker inside parks and copses.

The wind diagram for Stockholm, Fig. 77 (data compiled from the *SMHI Yearbooks* for 1931–60) shows that south-west, west and south winds are the dominant ones, while east winds have the lowest frequency (only half of that of the south-west winds). In Fig. 78 the wind diagram has been divided up for the different seasons of the year. Note that in this figure the diagrams show the direction in which the winds blow, unlike Fig. 77 which shows the direction from which the winds come (i.e. as all traditional wind diagrams do). Wind diagrams rotated 180° are more suitable than the traditional ones for comparing with the distribution pattern of different organisms.

The four seasons have an almost equally large number of wind incidences. The windiest season is the summer, the calmest the autumn and winter. No account is then taken of wind strength. South-west winds are somewhat less frequent during the autumn and spring than they are in the other seasons, and north winds are more usual during the spring than at other times; otherwise the figures are fairly similar.

Ångström (1952, p. 432) has a table showing the number of incidences of wind strength of 7 metres per second and more per month, on an average for a ten-year period. The table shows that the period November–January has most incidences of strong winds. Strong winds are least frequent in June to August inclusive.

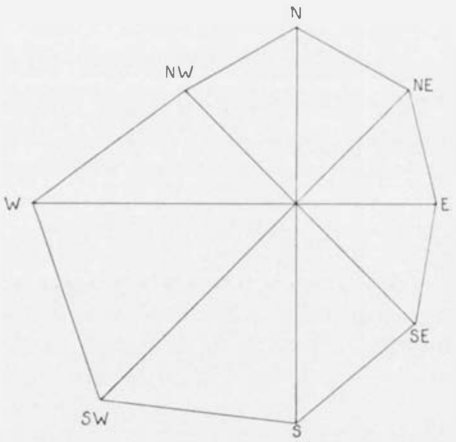


Fig. 77. Wind frequency in Stockholm (years 1931–60).

Local wind conditions at street level probably differ in some cases quite considerably as far as direction (and strength) are concerned, from the officially stated values.

During periods of calm or low wind velocity, the content of sulphur dioxide rises considerably in Stockholm. According to von Ubisch and Nilsson (1966) dust contents are less affected by changes in wind strength. In the case of west winds, a perceptible reduction in contents of sulphur dioxide has first been noted in Djurgården and Lidingö, as the city air is transported eastward.

Wind seems to have increased over western Europe during the past 30 years, with increased evaporation in consequence. Klement (1966) points out that certain species of lichens have disappeared from northern Germany and that desiccation may have caused this. To our knowledge, no such overall effective desiccation as the result of wind has been ascertained in the case of epiphyte vegetation in Sweden. With regard to changes in the Swedish climate, see Ångström (1958, pp. 136 ff.).

Fully evident, however, is the change in the pH of water that has occurred in recent years. Barkman (1958, p. 110) states the normal value for pH in rainwater to be 5.5. (See also Statens offentliga utredningar 1967: 43, pp. 122 ff.) During the summer of 1967, for example, such low pH values as 2.8 have been recorded in rainwater on the west coast of Sweden. Fig. 79, see also Odén 1968.

AIR CIRCULATION

No figures from measurements of air circulation in Stockholm have been available. As a general rule, air at street level in a city on hot summer days is

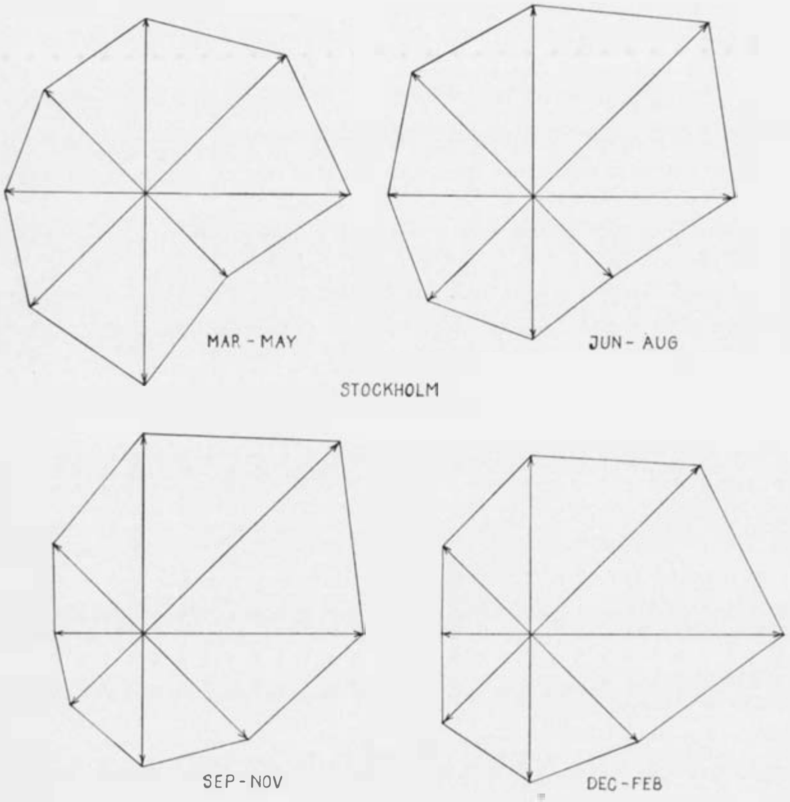


Fig. 78. Wind frequency during different seasons of the year in Stockholm (years 1931–60). In contrast to the conventional wind diagram (Fig. 77) these diagrams show the direction towards which the wind blows (see arrows).

more labile than in the agricultural landscape. This could possibly give rise to local winds blowing in from the outskirts into the heart of the city. See for example Grunow (1936, pp. 71 ff.). The nocturnal temperature-inversion occurs rather later in the evening but lasts longer in the morning. In the winter there is sometimes inversion in the daytime also. When inversions occur, the air is stably stratified and the vertical movements are greatly reduced (see for example Schmidt, in Wijk 1963, p. 347). On these occasions the SO_2 contents etc. rise very quickly to many times higher figures than normal (Figs. 65 and 67).

According to Högström (von Ubisch and Nilsson 1966, p. 9) temperature inversions extending through deep air strata and down to ground level are rare in the centre of Stockholm. However, such inversions occur on an average of 30 % of all of the time, for example at Bromma and Ågesta, i.e. in the outskirts of the city. In the winter, the inversions have a thickness of 500–1000 metres and can in some cases last over several days. The labile air in the heart of the city extends to a height of approximately 100 metres. During inversion situations in the environs, the central part of the city can in rare cases be up to 15 °C warmer than the environs.

AIR POLLUTION AND LICHENS

This review of the atmospheric factors seems to show that it is only the chemical composition of the air that differs drastically from the normal conditions. It also appears to be the only factor which may conceivably operate over such a large area and over one which shows such great variations as far as habitats are concerned.

It might therefore be expected that a parallelism between contents of air impurities and the occurrence of lichens would be evident if the above argument is correct.

Fenton (1962, see also 1964) says that he is the first to have succeeded in correlating the incidence of certain species of lichen with current quantities of measured pollution. He also shows diagrams of particle quantities and sulphur dioxide contents at increasing distances from a source of pollution. The amount of particles is stated in tons per sq. mile and the SO_2 content in mg/m^3. Fenton concludes from the numerical data that no lichens can tolerate smoke and SO_2 contents "in excess of 3.5 parts per 100 million respectively". Thus *Lecanora conizaeoides* appears outside this "lichen desert zone". *Parmelia saxatilis* is the first foliose lichen to appear. The pollution value "does not exceed 10 mg per 100 cubic metres, and the SO_2 concentration is probably not in excess of 0.5 parts per 100 million". Well-developed fruticose lichens do not appear until the air is pure.

I was myself occupied with the problem of SO_2 contents versus the occurrence of special lichen species when I was making investigations at Kvarntorp in the early 1950s. I found, however, that it was very difficult to establish such a correlation as that stated by Fenton. Even if the source of pollution has a constant emission, immission varies with wind and weather. The sensitivity of the plants also varies according to weather, the time of the day, etc. Berge (1963) has admirably investigated the difficulties mentioned with regard to the vascular plants. I contented myself with showing (Skye 1958, p. 159) how the number of lichens and their vitality increases as SO_2 contents fall, without making a more detailed effort to quantify the problem. This applies also to the diagram on p. 330 in Skye 1964 (see below).

As regards this investigation, it appears from e.g. von Ubisch and Nilsson (1966) and from measurements made in the inner city of Stockholm and at Spånga and Stora Tensta that the contents of air impurities in one and the same place vary within wide limits. If the sampling time were shorter than two hours, the variations would appear even more strongly. We do not yet know what the highest contents of impurities are that are harmless to lichens, nor do we know what the importance is of the short-term peak figures, the time factor, the weather, etc.

Gilbert (1965, p. 43) shows that *Parmelia saxatilis* contained 2870 ppm of sulphur at a station where the yearly mean figure for sulphur dioxide (as S) is 0.02 ppm, 695 ppm at a station with a yearly mean figure of 0.014 ppm, and 225 ppm where the air values were even lower. *Parmelia saxatilis* thus contains considerably more sulphate ions than it needs for its metabolism. An effort to obtain an idea of the sulphur content in vegetation has been made for the Stockholm region. The methods used agree largely with those of Gilbert (1965). The result shows that it would be much too hazardous to try to draw any isopleths.

When the first investigation was made of air pollution in Stockholm, the present writer made an attempt to roughly parallelize impurities and the occurrence of lichens (Skye 1964, p. 330). The first lichens appear in the vicinity of the station showing a sulphur dioxide content of 15 pphm in averages of 4-week medians. When the content subsequently falls to 10 pphm, the number of species of lichen increases to 11, which however is not a normal number for the substrate concerned. Adjacent to station No. 10 (Kanaan) in the air investigation (station K in Alm, Cederlöv, etc., 1963) analyses were made of several different phorophytes (stations 125–131) from an area of 1 km^2 in the eastern part of Grimsta park, in order to obtain a comparison between measured contents of impurities and the composition of the lichen flora on different substrates. The region appears in the maps as an accumulation of dots (see for example Fig. 26 *a*). Unfortunately the measuring station was not in operation, so no values for sulphur dioxide contents are in existence.

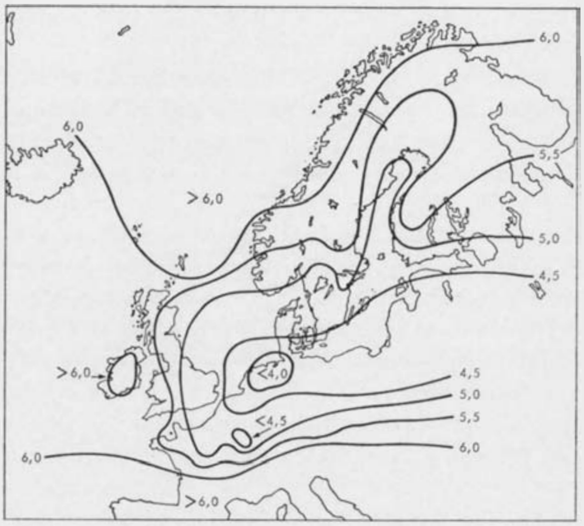


Fig. 79. Curve-fitted annual mean values for degree of acidity of precipitation in Europe, 1962. (After E. Eriksson and S. Odén, Statens offentliga utredningar 1967: 43.)

Von Ubisch and Nilsson (1966) publish a number of wind diagrams for dust, sulphur dioxide and nitrogen dioxide from for various years and heights in St. Clara parish, central Stockholm. The air pollution values in relation to the wind directions supply information as to the bearing and significance of the dominant sources of pollution as seen from the place of observation, in this case St. Clara Church. An attempt has been made to correlate the distribution of lichen vegetation in the Stockholm region (Skye 1967) with these wind diagrams. Von Ubisch and Nilsson say: "The region without lichen vegetation has a quadrangular structure which also seems to exist in Fig. 53 for St. Clara H" (Fig. 64 in this treatise). "If the source strength per surface unit is approximately constant in the area concerned, such a result is reasonable. In the present case, the element of uncertainty is very large—this is evident when for purposes of comparison figures are also included from the previous heating-season, Fig. 50."

The map with which von Ubisch and Nilsson compare their values has been formed in accordance with the number of species per station, regardless of the species composition etc. This means that it is not possible to draw very far-reaching conclusions from the pattern on the map. A comparison with the distribution of each particular species involved would perhaps have been more elucidating. However, it is inadequate to compare the result of air pollution measurements from one particular year with the distribution pattern of such long-lived slowly-growing organisms as lichens, unless—as von Ubisch and Nilsson point out—the source strength per surface unit and the wind conditions are approximately constant in the area over a long sequence of years.

A comparison was carried out between the occurrence of lichens and air pollution in the Spånga–Stora Tensta area. Station 376 (Spånga Church, *Fraxinus excelsior* of fairly great age) has 21 species of lichens, while station 573 (Stora Tensta farm, *Acer platanoides*) has 19 species; in all 28 species have been noted in these two stations. 12 species are found in both stations. The two stations have, generally speaking, a normally developed vegetation belonging to the *Xanthorion* federation. Station 376 was analysed in June 1964 and station 573 in September 1965.

Analyses from the air sampling stations at Spånga Church and Stora Tensta farm are available for four presumably typical periods from December 1964 to October 1965. Unfortunately the analyses from the city centre are in most cases not contemporaneous, and not taken in a constant place. The comparison is therefore rather inaccurate. However, the trend for much higher values in the city centre is unmistakeable (see Fig. 65).

During the sampling period 8th December–20th December 1964, SO_2 contents of between 0.1 and 0.5 pphm were measured at Stora Tensta. The highest value is reached at noon on 15th December. The station is not in operation on 16th December. The mean NO_2 contents are somewhat higher than the SO_2 contents, but the maximum values are equal. At Spånga Church the SO_2 contents are generally over 0.5 pphm. The maximum occurrs on 16th December between 8 and 10 p.m. with 4.6 pphm. A secondary maximum of 3.6 pphm appears between 4 and 6 p.m. The NO_2 contents are below 1 pphm except in the night between the 12th and 13th. The corresponding period shows for the inner city of Stockholm (Götgatan 22, at a height of 10–12 metres above ground level) considerably higher values. The maximum for SO_2 contents occurs between 6 and 8 a.m. on 20th December and reaches 17.8 pphm, and values of around 11 pphm are reached on 3 occasions. On 16th December (when Spånga Church had a maximum) the station ceases to operate at 8 a.m., but the value for the 2-hour period from 6 to 8 a.m. is 7.9 pphm. The Spånga value for this time is between 2 and $2\,^1/_2$ pphm. The NO_2 contents for the inner city are throughout higher than for Spånga, being around 1 pphm.

The sampling period from 30th March to 14th April 1965 shows as far as the SO_2 contents are concerned that the curves for Spånga and Stora Tensta resemble each other quite strongly, but Stora Tensta is throughout a few tenths pphm lower. The Spånga curve has a maximum in the night between 9th and 10th April of 3.9 pphm, which lacks a correspondence at Stora Tensta. A secondary maximum of 3.5 pphm at Spånga is matched by a value of 2 pphm at Stora Tensta. The NO_2 curves are identical in long sections. There are unfortunately no measurements from the inner city of Stockholm, but the period from 8th to 14th March (Drottninggatan 45, 15 metres above ground level) shows that all the values are higher than 11 pphm. The maximum value of 23.9 pphm is reached on 8th March between 6 p.m. and 8 p.m. The NO_2 contents were around 1.5 pphm.

The period from 20th July to 6th August 1965 shows values below 0.4 pphm for Stora Tensta. The Spånga station reaches 0.5 pphm on one occasion, but is otherwise at the same low level. At Stora Tensta the NO_2 curve reaches 0.6 pphm on 21st July, but stays otherwise at between 0.1 and 0.3. As regards Spånga, the values are between 1.1 and 0.1, but mostly below 0.5 pphm. From the inner city of Stockholm (Mäster Samuelsgatan 69, about 4 metres above ground level) there are measurements for the period from 4th to 15th August. A maximum value of 7.3 pphm is measured on 11th August. On 5 occasions the contents are over 4 pphm. The lowest value measured is 0.6 pphm. The NO_2 contents oscillate between 2.5 and 0.5 pphm.

During the period from 13th to 24th October 1965 too, the values are very low for Spånga and Stora Tensta. At Stora Tensta, 0.4 pphm is reached on 18th October and the curve is fairly straight. The station at Spånga Church shows a similar curve, but one that is throughout some tenths pphm higher. The maximum occurs on 16th October and reaches 0.6 pphm. The NO_2 contents are two or three tenths pphm. From the inner city of Stockholm (Torkel Knutssonsgatan 20, 7 metres above ground level) there are values from the period 25th October to 2nd November 1965. The maximum, 7.5 pphm, occurrs on 25th

October between 6 and 8 p.m. A minimum on the curve, 1.6 pphm, is recorded on the 28th between 6 and 8 a.m. Values of over 5 pphm are recorded on 9 different occasions—the NO_2 curve oscillates between 1 and 0.2 pphm.

With regard to the sulphur dioxide contents, the curves for Stora Tensta are thus somewhat lower than those for Spånga, but both stations have low values compared with the inner city. During the heating season, the Spånga station can reach values up to 5 pphm; Stora Tensta does not do so. In the summer and the first months of autumn, the sulphur dioxide contents are very low. The inner city of Stockholm shows high to very high values during the heating season. In the summer and autumn months the values are still high enough to surpass the winter values of the Spånga station.

The nitrogen dioxide curves for Spånga and Stora Tensta are very similar, showing low values throughout. In the inner city of Stockholm, the values are throughout considerably higher, with substantially greater fluctuations.

With respect to both lichens and to air pollution, the sampling locations at Stora Tensta and Spånga Church may mainly be regarded as "normal stations".

Biological Habitat Factors

GENERAL

In this investigation, the biological habitat factors other than the substrate, which is of course biological material, have been dealt with only in passing, if we except the activities of man and their influence on epiphyte vegetation and substrate. The substrate is dealt with in more detail on p. 86.

The influence of lichens on one another and on their surroundings has been studied by several writers. See the list in Barkman (1958). We can also mention Malme (1901), Schutz (1931), Degelius (1935) and others.

MAN AND DOMESTIC ANIMALS

The influence of man on lichen vegetation is little known. Several writers—in Scandinavia Sernander (1926), Räsänen (1927), Degelius (1935) and Ahlner (1948) have dealt with the question from different points of view. Räsänen's observations on the relations of lichens to culture differ in several respects from my own. He says for example (p. 175) that "ammonophile" lichens appear on any substrate as soon as ammonia is available. "Auch Birken und Fichten erhalten z. B. in den Parks der Städte, einen ganz anderen Flechtenüberzug als in Wäldern mit reiner Luft. Die ursprünglichen Epiphyten verschwinden und ammonophile Arten treten als Kulturflechten an ihre Stelle." As examples of "ammonophile Flechten" he adduces (p. 177) first and foremost *Physcia tribacea* (= *Ph. dubia*) *Xanthoria parietina* and *X. polycarpa.* As weaker ammonophiles he includes "folgende kulturholde oder synanthrope Flechten (zu denen auch die vorigen gehören)" namely *Physcia pulverulenta* v. *allochroa, Ph. grisea, Ph. aipolia* v. *anthelina* and v. *acrita, Ph. caesia* and *Anaptychia ciliaris* (see also pp. 25 ff).

Beschel (1958) states (p. 18) that *Physcia orbicularis, Ph. ascendens, Candelaria concolor* and *Lepraria aeruginosa* (= *L. incana*) are to be found on bark in the whole of Bregenz (21,094 inhabitants). With regard to Dornbirn (21,800 inhabitants) he says (p. 21) that "Trotz der Grösse der Stadt fehlt ihr eine innere Kampfzone und mit ihr das Dominieren von *Physcia orbicularis* auf Rinde". In the central parts of Salzburg (102,292 inhabitants) the neutrophile communities ("neutrophile Vereine") are developed. Commonest is *Physcietum ascendentis.* This community changes to *Physcietum orbicularis* farther into the heart of the city. In the lichen-free or almost lichen-free central part of the city only *Lepraria aeruginosa* (l.c., p. 28) occurs. The same applies to Innsbruck (97,884 inhabitants) (p. 36). In the innermost part of the transitional zone remnants appear here of *Physcietum ascendentis* with species such as *Physcia ascendens* and *Ph. orbicularis.* Strongly affected are *Physcia aipolia* and *Ph. stellaris* as well as *Parmelia sulcata.* Only *Physcietum orbicularis* attains any appreciable degree of coverage. In Innsbruck, however, there appears *Lecanoretum Hageni,* which has not been noted for the other cities.

In the comparison area for this investigation, some of the species of the *Xanthorion* federation, for example *Xanthoria parietina,* can appear more abundantly than normally in gardens and fields where the effect of agricultural dust and other particles is large. There is no record of any similar reaction at present in Stockholm, in the data which form the basis of this investigation. The trees in the parks and along the sidewalks of the streets are frequented by dogs. The trunk bases in particular obtain in this way a not inconsiderable addition of various nutrients (which might emit ammonia). However, this has not had the effect indicated by Räsänen. On the contrary, the "canine zone" is poorer in vegetation than the other

Table 7. *Life form and principal method of distribution of the lichen species most frequently occurring in this investigation. Species arranged according to number of occurrences.*

Species	Thallus	Soredia	Isidia	Fruiting bodies	Remarks
Lecanora conizaeoides	Crustose	Common	—	Common	
Lecidea scalaris	Squamulose	Common	—	—	
Hypogymnia physodes	Foliose	Common	—	—	
Lepraria incana	Crustose	Common	—	—	Granules "leprose"
Bacidia chlorococca	Crustose	—	—	Common	
Cetraria chlorophylla	Fruticose	Common	—	—	
Parmeliopsis ambigua	Foliose	Common	—	—	
Parmelia sulcata	Foliose	Common	—	Rare	
Lecanora expallens	Crustose	Common	—	Rare	
Cetraria pinastri	Foliose	Common	—	—	
Lecanora subfusca coll.	Crustose	Rare	—	Common	
Alectoria jubata	Lianoid	Common	—	—	
Cladonia coniocraea	Fruticose	Common	—	—	
Phlyctis argena	Crustose	Common	—	—	
Evernia prunastri	Fruticose	Common	—	—	
Physcia tenella	Foliose	Common	—	—	
Lecanora subfuscata	Crustose	—	—	Common	
Parmelia fuliginosa	Foliose	—	Common	—	
Candelariella xanthostigma	Crustose	—	—	Sparse	
Cetraria glauca	Fruticose	—	Rare	—	
Lecanora carpinea	Crustose	—	—	Common	
Buellia punctata	Crustose	—	—	Common	
Calicium hyperellum		—	—	Common	
Ochrolechia microstictoides	Crustose	Common	—	—	
Lecanora chlarotera	Crustose	—	—	Common	
Physcia dubia	Foliose	Common	—	—	
Pertusaria globulifera v. discoidea	Crustose	Common	—	—	
Ochrolechia androgyna	Crustose	Common	—	—	
Physcia ascendens	Foliose	Common	—	—	
Xanthoria polycarpa	Foliose	—	—	Common	
Pertusaria amara	Crustose	Common	—	—	
Physcia					
pulverulenta	Foliose	—	—	Common	
orbicularis	Foliose	Common	—	Sparse	
Parmelia subargentifera	Foliose	Common	—	—	
Xanthoria parietina	Foliose	—	—	Common	
Parmelia exasperatula	Foliose	—	Common	—	
Physcia entheroxantha	Foliose	Common	—	—	
Lecidea olivacea	Crustose	—	—	Common	
Xanthoria fallax	Foliose	Common	—	—	
Ramalina farinacea	Fruticose	Common	—	—	
Physcia farrea	Foliose	Common	—	—	
Ramalina fraxinea	Fruticose	—	—	Common	
Anaptychia ciliaris	Fruticose	—	—	Sparse	
Bacidia luteola	Crustose	—	—	Common	
Pertusaria coccodes	Crustose	—	Common	—	

parts of the trunk. In some cases, even algae seem to shun the trunk base. The conditions depicted by Räsänen can probably be relegated to the "horse and buggy" era.

The first species that enter the transitional zone in present day Stockholm are certainly not "nitrophytic" or "ammonophile Flechten" either (see Tables VI–XIV). Gilbert (1965, p. 38) points out that in the Tyne valley *Lecanora conizaeoides* often comes first, also *Cladonia coniocraea* followed by *Buellia punctata, Physcia tenella, Parmelia sulcata, Hypogymnia physodes* and *Xanthoria parietina.* (Cf. also e.g. Fenton 1960, 1962, 1964 and Laundon 1967.)

It is difficult to say whether the influence of man on lichen vegetation is other than an indirect one via impurities, climatic changes, spraying—for example of fruit trees—etc. In an area such as Stockholm, a certain amount of wear is of course exerted on bark in parks, especially around playgrounds. The fact that this wear can locally have an almost devastating effect on lichens and mosses cannot be denied, but this can hardly explain the distribution pattern as a whole. Trees with very badly damaged bark have been avoided in the investigation, and the great majority of station trees have bark which does not show perceptible evidence of damage (see p. 21). Trees have also been avoided whose bark may be suspected of having been sprayed.

LIFE FORMS OF LICHENS AND THEIR DISTRIBUTION CONDITIONS

Fenton (1960, 1962, 1964) has found in his investigation in Northern Ireland that the life forms of lichens are of importance for distribution in an area with air pollution. He considers that the crustose lichens are the most resistant, after them the foliose and finally the fruticose lichens. He states (1962) that no lichen can tolerate a sulphur dioxide concentration of 3.5 pphm. *Lecanora conizaeoides* is the first species that appears outside this "lichen desert zone". In the areas where it covers 50% of the substrate, the sulphur dioxide concentration is about 1.5 pphm. Foliose lichens do not appear until there are concentrations of about 0.5 pphm. Well developed fruticose lichens do not appear until the air is quite pure. The first specimens to appear of *Lecanora conizaeoides* are said to be "poorly developed and always sterile". They frequently appear at the bases of trees. In the work from 1964 (p. 155) it is also said that the species is often reduced to a "sterile sorediate form". Kolumbe (1927) considers that strongly sorediose and isidiose forms absorb water vapour more easily than glabrous forms of the same species. See also Nilsson (1903, p. 17). Du Rietz (1924, p. 393) says that high humidity—contrary to what was formerly believed—does not favour the production of soredia. However, he believes he can confirm that for example *Physcia orbicularis, Xanthoria fallax, Pseudevernia furfuracea* and *Usnea hirta* can obtain abnormally strong production of soredia or isidia through the influence of air pollution. Unfavourable habitat conditions seem in general to favour the formation of soredia or isidia in preference to that of apothecia. Almborn (1952, p. 241) points out that lichens that are spread by soredia and isidia are favoured by dust-impregnated habitats in preference to species that are spread only by spores. Sernander-Du Rietz (1957) finds with respect to *Parmelia tiliacea* that the formation of apothecia is associated with the late summer and needs warmth and precipitation before it can begin. In certain species, for example the lianoids, the fragmentation of thalli is the most important way of dispersal (Ahlner 1931, p. 400).

In Table 7 I have made a comparison between the ways of dispersal among the lichens dealt with in this treatise. From these data it is difficult to say in general terms that any particular species is inhibited within the area because of its distribution conditions. However, from field work I have gained the impression that usually fertile species are often sterile or sparsely fertile in their innermost locations. This applies to *Lecanora conizaeoides, Xanthoria parietina, Ramalina fraxinea,* etc. A certain over-representation of usually non-fertile species in the upper part of the table may perhaps be noticed, but it may be caused by factors (see Almborn, above) other than the special environmental conditions prevailing in the investigation area. However, there does not appear to be any lack of diaspores of different kinds in the area.

CONDITIONS FOR LICHENS AS REGARDS COMPETITION AND GROWTH

Some attention has been paid to mutual competition between lichens and to competition between lichens and algae or mosses. In a closed epiphyte vegetation, the opportunities of the different species for growth seem to be fairly limited. Malme (1901) gives an indication, however, of an internal hierarchy. Where the lichens are affected by some factor which causes some species to be inhibited more than others (or to be favoured more than others) it happens that the most favoured prevail over the others. Whether the speed of growth for that reason becomes higher depends on the extent to which the surviving species itself is inhibited. Thus for example *Hypogymnia physodes* and *Cetraria chlorophylla* can in some cases (see for example stations 422, 556, 560, 571, 576 *b* and 577 *b*) entirely or almost entirely dominate the epiphyte vegetation. *Lecidea scalaris* appears abundantly in the environs of Stockholm even on substrates which do not normally show this species. However, the reason for this is certainly not merely the lack of competition (see p. 106). *Lecanora conizaeoides* appears in the otherwise lichen-free area of the central parts of the investigated area. The species appears on both conifers and deciduous trees. On revisiting after four years a number of stations in the otherwise lichen-free area and in the inner parts of the transitional zone I noted that the species is manifestly spreading in the central parts of the investigated area. It is remarkable also that Høeg (1934) did not find it in Stockholm (see p. 39) and that it had not yet been observed in Finland (Ahti 1965, pp. 91–92), while a single locality was found in an SO_2-affected area as far north as in Ångermanland (Moberg 1966, p. 40). Barkman (1958, p. 364) says "The *Lecanoretum pityreae* develops fast", which could possibly agree with my observations that the species is spreading in the central parts of the investigated area.

It has been noted in six stations that some lichens have been overgrown by algae. All these stations are in the inner part of the transitional zone, and are characterized either by very scanty lichen vegetation with very few species, or by obviously damaged such vegetation, i.e. the lichens blacken at the tips of the thalli or are similarly affected. It is mostly *Hypogymnia physodes* and *Parmelia sulcata* that are overgrown by algae. The data available are scanty, but it seems nevertheless possible to assert that the lichen species in question are more easily overcome by green algae when they find themselves at the limit of their area towards the city centre than otherwise. There may be several reasons for this phenomenon. It need not necessarily merely be the case that the lichens have less vitality than normal. The situation may also be due to the fact that the algae, in consequence of nitrogenous air-contaminants, are more vital than they are in the natural landscape. A combination of these factors seems to be even more likely. A factor to be taken into account, however, is that the field work was largely undertaken during a time of the year when the algae are not particularly active.

In the central part of the transitional zone it can be noted here and there on deciduous trees such as *Acer, Fraxinus,* etc., that *Hypogymnia physodes* grows over other lichens, including *Parmelia sulcata.* Several observations have been made in the unaffected area that certain species grow over others, but it seems to be more or less coincidental which is more vital and which is weaker.

The mutual competition between different epiphytic organisms determines to an important extent the composition of vegetation, but can only to a small extent explain the distribution pattern in general in the investigated area.

LICHENS AND ARTHROPODA

The importance of the lichens as an incubation site and a vital environment for a number of arthropoda, including beetles, spiders and mites, has been noted during field work. Thus for example it has been recorded that the spiders living for example in *Cetraria glauca* are also active during the winter if the inward radiation gives a sufficiently high temperature. Gnawholes have also been noted on some lichen thalli on several occasions. Beschel (1958, pp. 81 ff.) remarks on damage to several species of lichens caused by the gnawing of mites. He also says that the damage increases noticeably inwards towards the city. No similar observation has been made in the Stockholm area. Nothing exists to indicate that the activity of these animals has anything to do with the scarcity of lichens in the cities. On the contrary, the absence of the epiphytic lichens presumably denotes not only the enforcement of an evolution towards industrial melanism but also the absence of a vital environment for a large number of organisms. The city's epiphytic arthropoda are affected, by all appearances, thoroughly. However, according to the records made some species seem to be favoured by the fact that others disappear.

The Substrate

Phorophytes

As previously mentioned (p. 8) the investigation includes a relatively large number of those kinds of deciduous trees that have a southern distribution and prefer good soils. One reason for this is to obtain stations that by providing as good conditions as possible for epiphytic growth are mutually comparable, the lichen vegetation not being appreciably hampered by factors other than those related to the urban influence. On the bark of these deciduous trees in open locations there appears a vegetation referable to the *Xanthorion* federation (Ochsner 1928, p. 53; Du Rietz 1945 *a,* p. 148; von Krusenstjerna 1945, p. 94; Almborn 1948, pp. 83 and 221, 1953, p. 815, 1955, p. 13). Almborn (1955, p. 13) considers that *Xanthorion* consists of photophilous, moderately acidiphilous (circumneutrophile) communities and that they occur mostly on naturally eutrophic or auxotrophified bark. He describes as good indicators *Anaptychia ciliaris, Parmelia acetabulum, P. exasperatula,* and species of *Physcia* and *Xanthoria.*

On the other hand, the *Physodion* federation occurs on conifers and birch (Waldheim 1944, p. 90; Du Rietz 1945 *a,* p. 147; von Krusenstjerna 1945, p. 90; Almborn 1948, pp. 47 and 221, 1953, p. 815, 1955, p. 13). According to Almborn (1955, p. 13) *Physodion* consists of photophilous communities on non-eutrophic bark. *Hypogymnia physodes* is as a rule a good indicator, and other ordinary species are *Parmelia subaurifera, P. sulcata* and *Evernia prunastri.* It is also characteristic that several of the *Xanthorion* species are lacking.

Sernander (1912, pp. 850 ff.) noted the similarity in the composition of lichen flora on bird-fertilized stone and on avenue trees. The lichens appearing in such habitats were called by him "nitrophilous" and he believed that they benefited by the additional nitrogen supplied by bird excreta and dust impregnation, at that time effected by horse rather than motor traffic. Three genera, *Xanthoria, Physcia* and *Caloplaca,* were particularly benefited (Sernander 1912, p. 852). On the basis of investigations made by Nienburg (1919, p. 1), Räsänen suggested (1927, p. 177) that Sernander's term "nitrophilous" should

Fig. 80 b. The distribution of stations with *Acer platanoides* (circles) and *A. pseudoplatanus.*

be changed to "ammonophilous". To the best of my knowledge, no investigation has been made to show whether nitrogen or for example phosphorus (see Du Rietz 1932, p. 107) or any other quite different factor or complex of factors is decisive for the composition of the lichen vegetation, although the pH factor has been emphasized (see Du Rietz 1945 *a*). Almborn (1948, p. 223) used Sernander's term "coniophilous" for lichen vegetation on dust-impregnated roadside trees and "coniophobous" for lichen vegetation on dust-free trees. Dust was still largely agricultural dust or dust from dirt roads. It seems premature to attach a label to a phenomenon before it has been investigated properly in all its aspects. In more recent times, the composition and influence of road dust must have changed radically, especially after horses disappeared from the roads and even farm transport became fully motorized.

When conifer bark or birch bark is auxotrophified, *Xanthorion* species often immigrate to this substrate too. This also happens around some kinds of in-

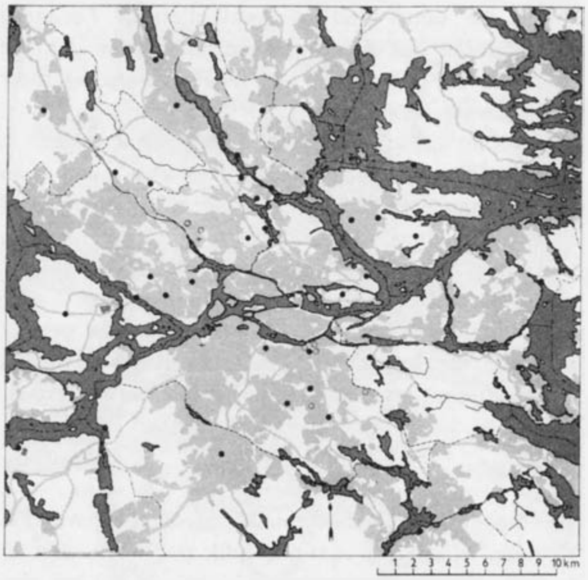


Fig. 80 a. The distribution of stations with *Acer platanoides* (circles) and *A. pseudoplatanus.* (Symbols see also Fig. 11.)

dustrial establishments, for example at Köping and Borlänge, and in calcareous areas, e.g. on the islands of Öland and Gotland (see for example Degelius 1936, p. 91, 1945, pp. 38 and 40, etc.).

Below is a comparison of the occurrence of lichen and moss on different kinds of trees. This comparison will serve as a commentary on Tables VI–XIV. Not vital specimens = circles on Figs. 14–62 and ( ) in Tables VI–XIV.

Acer platanoides

The maple plays an important part as an avenue tree and park tree in the investigated area and the comparison area. Fig. 80 shows how the maple stations are distributed over the investigated area. As the maps show, the distribution is fairly even. In the comparison area, the bark of maple has a pH value of 5.1–6.2, while in lichen-free stations in the central parts of Stockholm it shows a pH value of 2.9–3.7. In the transitional zone with fairly sparse vegetation, the pH value is 3.2–4.5. With reference to methods used for pH determination, see p. 105.

Normally, older isolated maples have a rich lichen vegetation belonging to *Xanthorion*. Table VI shows which species of lichens occur on *Acer platanoides*. *Lecanora conizaeoides* appears on 49 of the 73 lichen-bearing stations, and is the sole species in 17 of them. *Hypogymnia physodes* occurs at 43 stations and is the sole species at 1 of them. While *L. conizaeoides* primarily occurs in the transitional zone, *H. physodes* also appears in the very richest stations. *Lecidea scalaris,* which normally appears on parts of pines near the ground, when growing on maple shows the same kind of distribution as *Lecanora conizaeoides,* but does not penetrate so far into the centre as the latter does, and thus becomes far rarer (20 stations).

Of *Xanthorion* dominants, *Anaptychia ciliaris* is found ± sparsely at 8 stations, *Parmelia acetabulum* sparsely at 3, and *P. exasperatula* at 13—in one of which it is abundant, while at 6 it occurs sparsely.

Among the mosses, *Hypnum cupressiforme* is especially noticeable; it occurs at 13 stations.

Acer platanoides thus has, in the more central parts of the investigated area, a lichen vegetation quite different from that found under normal conditions.

Tilia

The heading *"Tilia"* normally covers primarily *T. vulgaris,* which is a common park tree in Stockholm (see for example Sernander 1926, pp. 94 ff.) but also *T. cordata.* The lime is a very common tree in the more central parts of Stockholm, but it is less common in the outskirts, and it is mainly there that the wild-growing small leaved lime (*Tilia cordata*) is found. Distribution of the lime in the investigated area is shown on Fig. 81. Normally, isolated older trees have an abundant lichen vegetation belonging to *Xanthorion.*

In the agricultural landscape, *Tilia* bark has a pH of 4.1–4.7, in the central parts of Stockholm at lichen-free stations 2.4–2.9. In the transitional zone, on trees with rather poor lichen vegetation, the pH is 2.8–3.3.

Of the investigated stations, Table VII, there is lichen at 37. As on *Acer platanoides,* it is *Lecanora conizaeoides* that penetrates farthest towards the centre of the city. The species is found at 17 stations, at 5 of these as the only species. *Lecidea scalaris* occurs at 18 stations. It is the sole species at only one station. The species penetrates almost as far in towards the centre as *L. conizaeoides,* but is absent from the very richest stations. The commonest species, however, is *Hypogymnia physodes* with 24 stations. Common species are also *Lepraria incana* (15), *Cetraria chlorophylla* (13), *Phlyctis argena* (15), *Lecanora expallens* (11) and *Candelariella xanthostigma* (11).

Xanthoria parietina (4), *Anaptychia ciliaris* (2), *Parmelia acetabulum* (1) and *P. exasperatula* (4) are very rare on *Tilia* and are found only in fairly rich to rich stations.

Among the mosses, *Hypnum cupressiforme* is the commonest, with 11 stations. However, it does not appear unless the lichen vegetation is at least moderately rich.

To sum up, in the more central parts of the investigated area, *Tilia* shows a lichen vegetation that is quite different from what is found under normal conditions. A great many stations in the most central parts are entirely without lichens.

Ulmus

The elm, too, is a relatively common park tree in the Stockholm region. Distribution of the stations at which elms appear is shown on Fig. 82. Lichens occur at 47 of the 105 stations investigated (Table VIII). In normal conditions, isolated elms have a rich lichen vegetation belonging to the *Xanthorion* federation.

The pH value of elm bark varies within wide limits in the comparison area (4.7–7.1, mean value 5.7). In the central parts of the investigated area at lichen-free stations, pH values of 2.4–2.9 have been measured, while in the transitional zone the pH value is 3.1–3.9.

As before, *Lecanora conizaeoides* is the species that penetrates farthest in towards the centre of the

Fig. 81 b. The distribution of stations with *Tilia.*

investigated area. It appears at 27 stations and is the sole species in 15 of these. The next commonest species are *Parmelia sulcata* (19 stations) and *Hypogymnia physodes* (18 stations). *Lecidea scalaris* occurs comparatively rarely (6 stations) and so does *Bacidia chlorococca* (7 stations). Numerous, however, are stations with *Candelariella xanthostigma* (15), *Phlyctis argena* (14), *Physcia tenella* (14), *Ph. entheroxantha* (13), *Lepraria incana* (12) and *Buellia punctata* (12).

The usually dominant species of *Xanthorion* are relatively well represented. *Xanthoria parietina* is found at 10 stations, *Anaptychia ciliaris* at 7 stations, *Parmelia exasperatula* at 6 stations, while *Parmelia acetabulum* appears only at 2 stations.

Hypnum cupressiforme is the commonest moss (9 stations) with *Pylaisia polyantha* (5 stations) taking second place.

With regard to lichen vegetation, what has been said of *Acer* and *Tilia* is equally true of *Ulmus.*

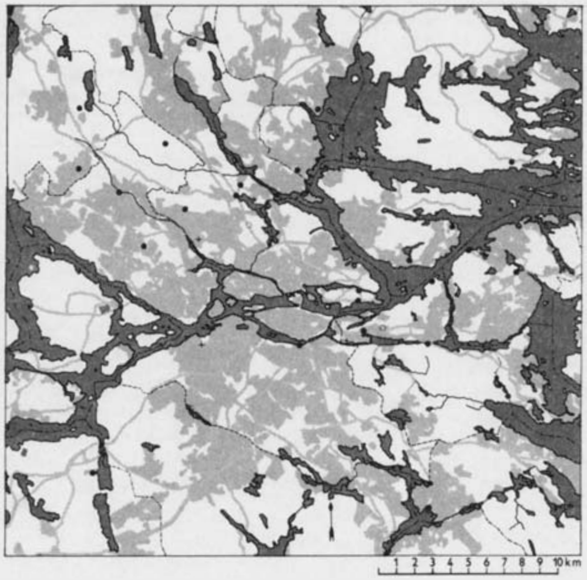


Fig. 81 a. The distribution of stations with *Tilia.*

Fig. 82 b. The distribution of stations with *Ulmus.*

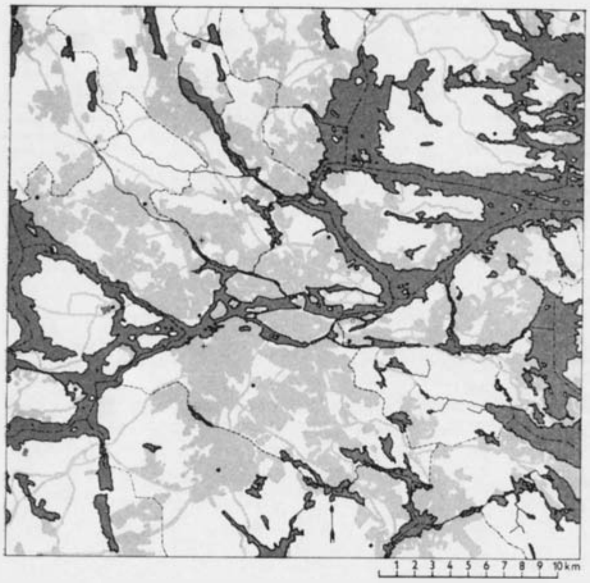


Fig. 82 a. The distribution of stations with *Ulmus.*

Quercus robur

In the investigated area, there are 100 stations containing oak. 80 of them carry lichens. Distribution of the oak stations is shown on Fig. 83. It will be observed that most of the stations are in the outlying parts of the investigated area, and this explains why so many stations bear lichens. The oak is more common in the southern parts of the area than in the northern—a fact that is also reflected in the distribution pattern. Table IX.

Normally, the oak—especially isolated examples of the tree—is rich in lichens. In the comparison area, i.e. in the agricultural landscape, the pH of oak bark is 3.8–4.5. In the more central parts of the investigated area at lichen-free stations, pH values of 2.4–2.8 have been measured; in the transitional zone 2.6–3.2.

Lecanora conizaeoides appears at 40 stations. At 6 of these it is the sole species found. It frequently appears together with *Lecidea scalaris.* At 7 stations,

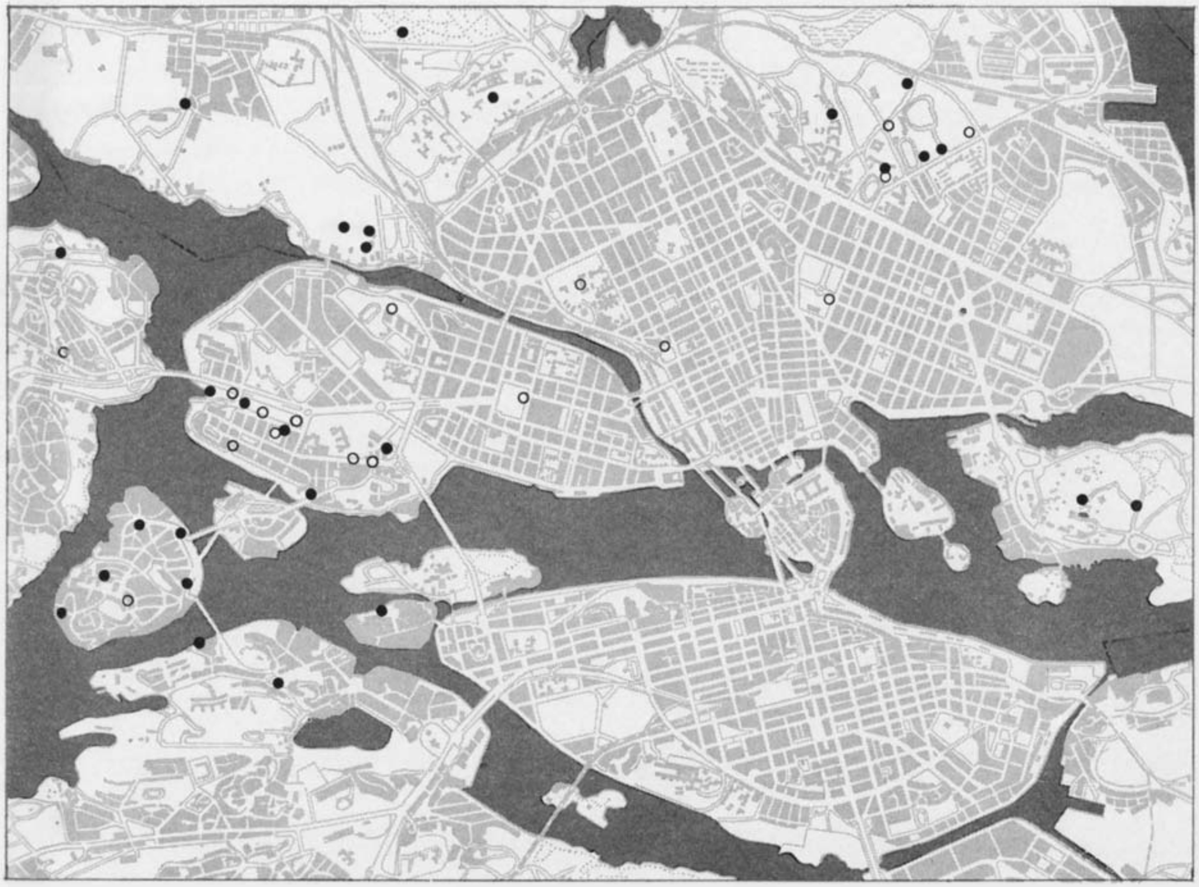


Fig. 83 b. The distribution of stations with *Quercus robur.*

only these two species are found. *Lecidea scalaris* occurs at 34 stations, and, like the former species, it becomes rarer towards the periphery of the investigated area. The commonest species of lichen on oak is *Hypogymnia physodes,* which is to be found at 64 stations. Other common species are *Lepraria incana* (38 stations), *Parmelia sulcata* (33 stations), *Parmeliopsis ambigua* (32 stations), *Cetraria chlorophylla* (27 stations), *Pertusaria amara* (26 stations), *Evernia prunastri* (25 stations), *Parmelia fuliginosa* (22 stations) and *Phlyctis argena* (21 stations). The species of the *Physodion* federation are obviously well represented in this material.

Hypnum cupressiforme occurs at 22 stations.

Of the dominant species of the *Xanthorion* federation, *Physcia entheroxantha* is commonest, with 6 stations (cf. Almborn 1955, p. 13). *Ph. tenella* is found at 5 stations, *Parmelia exasperatula* at 4, *Physcia ascendens* at 3 and *Parmelia acetabulum* at 2 stations. Only 1 station has *Anaptychia ciliaris,*

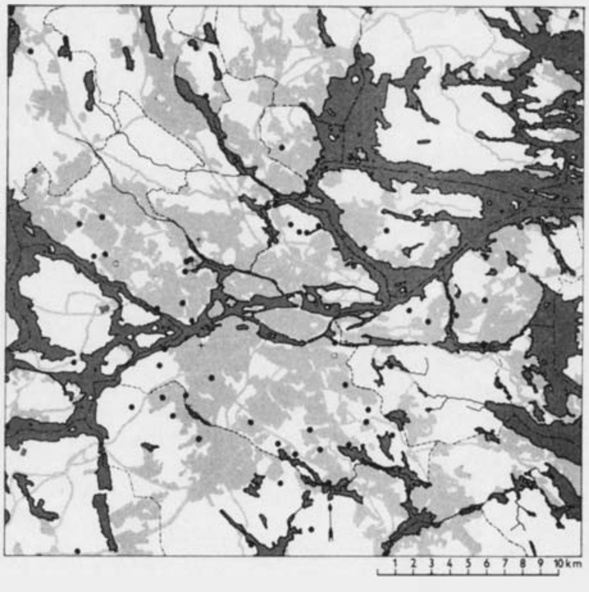


Fig. 83 a. The distribution of stations with *Quercus robur.*

Fig. 84 b. The distribution of stations with *Fraxinus excelsior.*

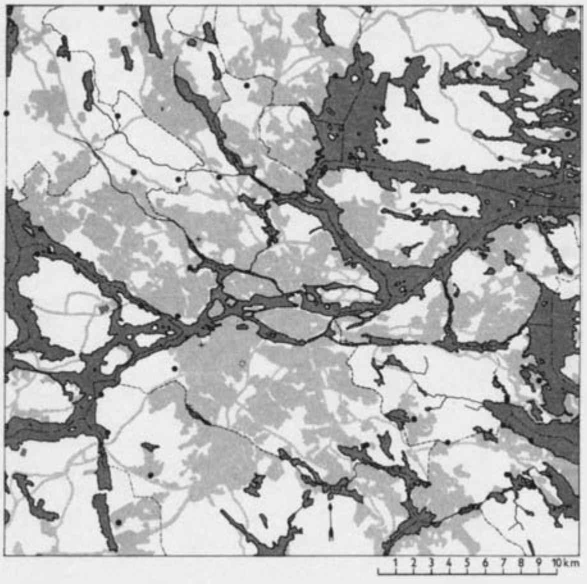


Fig. 84 a. The distribution of stations with *Fraxinus excelsior.*

and the same is true of *Physcia pulverulenta. Xanthoria parietina* is not found at all on any oak trunk. Almborn (1955, p. 26) notes also that *Xanthoria parietina* very rarely makes its way onto oak, this being equally true even when the bark is strongly auxotrophified, and it applies also to several others among the normal constituents of the *Xanthorion* federation.

Lichen vegetation on oak thus undergoes a change —and primarily an impoverishment—the more closely one approaches the centre of the investigated area. This change does not, however, become quite so thorough as among the phorophytes previously dealt with, since the normal vegetation on *Quercus* often belongs to the *Physodion* federation.

Fraxinus excelsior

Fraxinus appears as a station tree at 74 stations. Most of these (59) have lichens. The distribution of

Fig. 85. The distribution of stations with *Aesculus hippocastanum.*

the *Fraxinus* stations is shown on Fig. 84. In the central parts of the investigated area, *Fraxinus* is rather uncommon and hardly appears at all as a park tree. Table X.

The bark of the ash has a pH value of 5.4–5.9 in the comparison area. In the lichen-free part of the investigated area, a pH of 2.9–3.5 has been measured; in the transitional zone 3.5–4.9.

Normally, *Fraxinus excelsior* is a tree on which lichens are abundant, with a vegetation, on isolated trees, belonging to the *Xanthorion* federation.

As on the previously mentioned phorophytes, *Lecanora conizaeoides* penetrates most deeply in towards the centre of the investigated area. The species appears at 15 stations, is the sole species at 5 of them, and occurs together with *Lecidea scalaris* at 3. *Bacidia chlorococca* also appears far into the investigated area. All three species disappear, however, when one moves into areas where the lichen flora on ash trees is richer. *Parmelia sulcata* is found at most of the stations (43), the next commonest being *Phlyctis argena* (39). The subsequent order of frequency is *Physcia pulverulenta* (36), *Candelariella xanthostigma* and *Physcia entheroxantha* (32), *Xanthoria parietina* (31), *Anaptychia ciliaris* and *Lecanora subfuscata* (29), *Hypogymnia physodes* (23), *Physcia ascendens* and *Ph. orbicularis* (22), *Ph. farrea* (21) and *Parmelia fuliginosa* (20). *Parmelia acetabulum* is rare (2), somewhat commoner is *P. exasperatula* (9), but in general the species of the *Xanthorion* federation are well represented, in contrast to the conditions on *Quercus.*

As far as the mosses are concerned, *Fraxinus* shows the greatest variety of species. No fewer than 23 species have been noted. The commonest of them are *Hypnum cupressiforme* (25 stations), *Leucodon sciuroides* (13), *Tortula pulvinata* and *Pylaisia polyantha* (6). The *Orthotrichum* genus is also found, but because of the difficulty of determining the species in part of the material, they have been omitted from this list.

The lichen vegetation on the *Fraxinus* growing in the more central parts of the investigated area thus differs strikingly from that found on *Fraxinus* in the periphery of the investigated area and in the comparison area.

Aesculus hippocastanum

Aesculus hippocastanum is relatively uncommon as a park tree in the investigated area. The distribution of the *Aesculus* stations is shown on Fig. 85, Table XII. In all, 34 stations containing this tree have been investigated. Only 4 stations have lichens. At 3 of them, *Lecanora conizaeoides* is the sole species. On the fourth tree there is a composition of species dominated by those of the *Physodion* federation. In the agricultural landscape, on the other hand, the *Xanthorion* federation is dominant in normal cases. Despite the scanty material, the same conditions can thus be noted as in the cases of the previously mentioned kinds of trees.

No analysis was made of the bark's pH value.

Pinus silvestris

Pine is not particularly abundant in the central parts of the investigated area. Sernander (1926, pp. 161 ff.) points out that the pine tolerates city air better than spruce does, which might be explained by the fact that it retains its needles for only 3 years, while the spruce keeps them more than twice as long. *Pinus* occurs at 16 stations (Fig. 86, Table XI). At 7 of these there is lichen vegetation.

Pine bark in the comparison area has a pH of 3.1–3.4, while in the investigated area's central parts it is 2.5–2.9 and in the transitional zone 2.7–3.0.

As expected, the lichen vegetation belongs to the *Physodion* federation. *Lecidea scalaris* is represented at most of the stations (6). It is the sole species at one station. Other important representatives are *Lepraria incana* and *Hypogymnia physodes,* each with 5 stations. (Under normal conditions, this species is present on every pine tree.) *Lecanora conizaeoides,* on the other hand, is very rare, being found at only one station.

Two moss species were noted.

Thus no general change in the composition, but a marked limitation of the lichen vegetation on pine has occurred. The closer a station is to the centre of the investigated area, the more marked is the rarity of occurrence and the change in dominance conditions. The innermost stations are entirely without lichens. See also below ("Special examination of conifers").

Populus

The *Populus* genus is represented by no fewer than 4 species. Of these, only one is common in the comparison area, namely *Populus tremula.* It is quite rarely found, however, as a park tree in the central parts of the investigated area. *Populus nigra* v. *italica* is found here and there in the investigated area, but is rather unsuitable as a station tree since it lacks a distinct bole. Nevertheless I have deemed it necessary to include this tree at some stations.

No determination of the pH value of *Populus* bark was made.

Distribution of the *Populus* stations is shown on Fig. 87, Table XII. At the 14 stations, lichens are found at 6.

The commonest species are *Lecanora conizaeoides* and *Hypogymnia physodes* (4 stations). *Lecidea scalaris* appears at only one station—together with abundant examples of *Lecanora conizaeoides.* There is an interesting difference in the composition of lichen vegetation between station 516 *Populus nigra* and station 570 *P. balsamifera.* The former has vegetation belonging to the *Physodion* federation, while the latter shows a typical *Xanthorion* combination.

Alnus glutinosa

The common black alder seldom occurs as a park tree in the central parts of the investigated area. In the outskirts, it is found here and there by lakesides and in similar locations. Distribution of the 12 *Alnus* stations is shown on Fig. 87. Lichen has been noted at 11 of them, Table XIII.

In the agricultural landscape the bark of the common alder has a pH of approximately 3.5; pH 2.6 has been measured in the investigated area.

Lecanora conizaeoides occurs at 8 stations and is the sole species at one of them. *Hypogymnia physodes* is also found at 8 stations. *Lecidea scalaris* appears at 5 stations and is the only species at one of them. *Lepraria incana* is found at 6 stations, but like *Hypogymnia physodes* is not the sole species at any of them.

The alder bark epiphytes are members of the *Physodion* federation in cases where there is a comparatively ample supply of light, and of *Leprarion* on the north side of the trunk or where the light conditions are less favourable (see e.g. Almborn 1955, p. 15). Species of the *Xanthorion* federation are rare in the material available.

There are no mosses at the investigated stations.

With regard to changes in the lichen vegetation, the same remarks can be made as with respect to *Pinus.*

Salix

Salix is quite an important element in the investigated area. Planted forms are in many cases hybrids (see p. 14), and therefore only the genus is stated. For

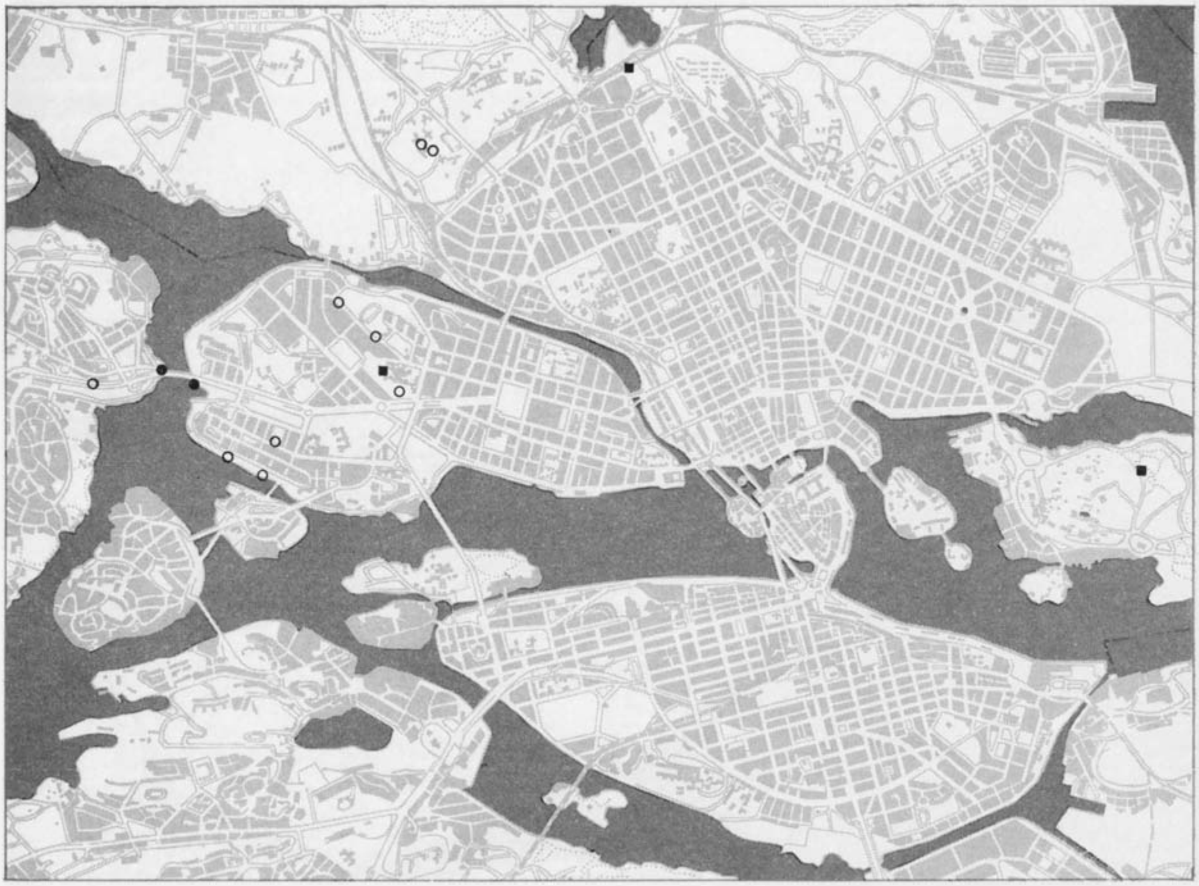


Fig. 86 b. The distribution of stations with *Betula verrucosa* (squares), *B. pubescens* (squares P) and *Pinus* (circles).

example, stations 1 and 2 consists of *Salix babylonica,* while station 80 is *Salix fragilis.*

Salix occurs at 11 stations, and lichens appear at 8 of these. Distribution is shown on Fig. 87 and Table XII.

No determination has been made of the pH value of *Salix* bark.

Lecanora conizaeoides occurs at 6 stations and is the sole species at 4 of them. *Hypogymnia physodes* is also found at 6 stations, but is not the sole species at any of them. *Cetraria pinastri* occurs at 5 stations. *Lecidea scalaris* is quite rare and appears at only 2 stations. Only two stations have one lichen species, the other 6 stations having 6–8. The composition of species indicates that the lichen vegetation belongs to the *Physodion* federation. None of the characteristic species of the *Xanthorion* federation has been noted. In the comparison area, especially in dusty locations, such species normally occur. The changes in the epiphyte vegetation thus seem to be far-reaching.

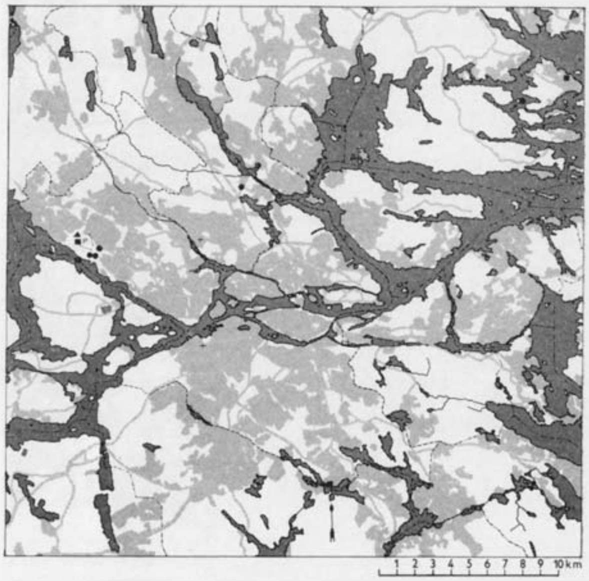


Fig. 86 a. The distribution of stations with *Betula verrucosa* (squares), *B. pubescens* (squares P), *Pinus* (circles) and *Picea.*

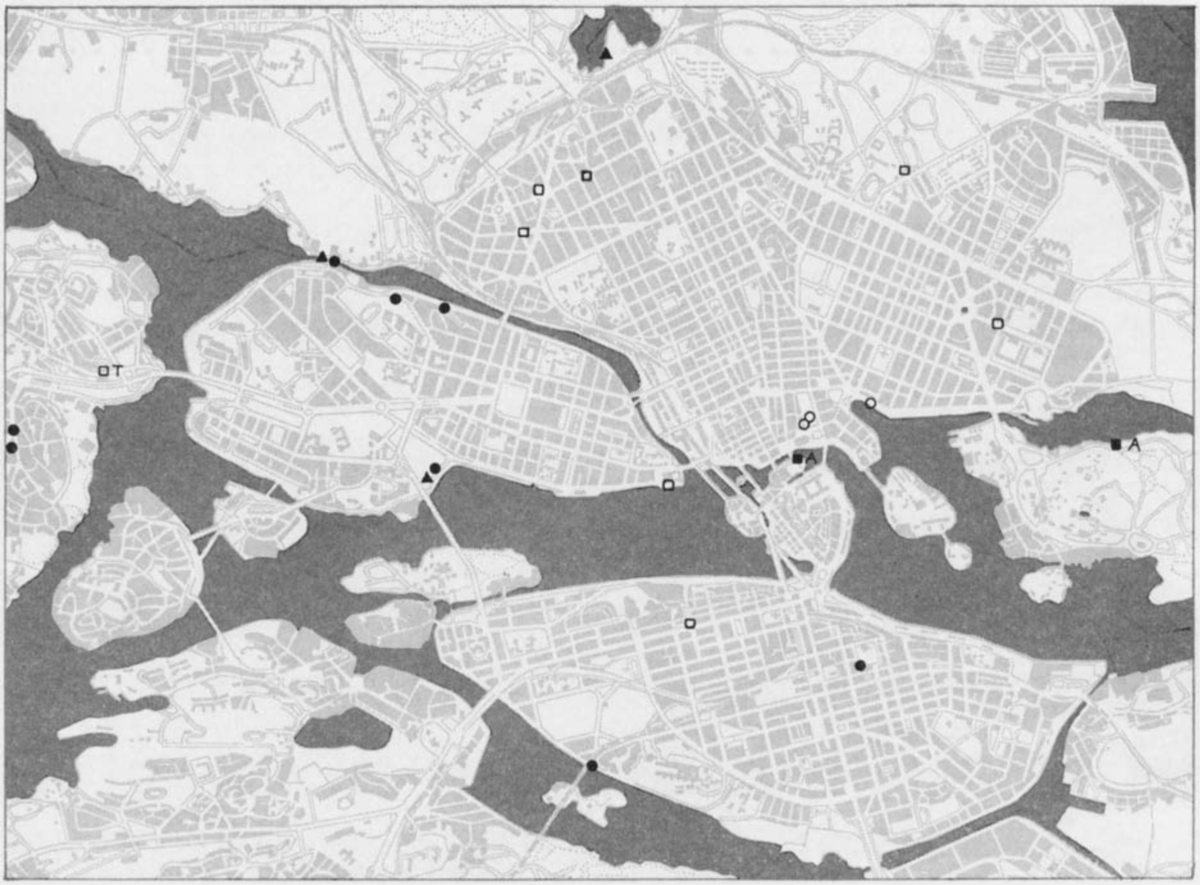


Fig. 87 b. The distribution of stations with *Populus nigra* (squares), *P. alba* (squares a), *P. tremula* (squares t), *P. balsamifera* (squares b), *Salix* (circles) and *Alnus glutinosa.*

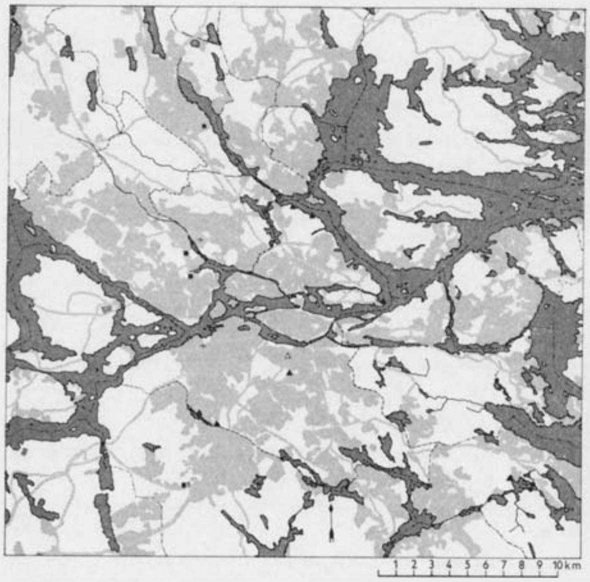


Fig. 87 a. The distribution of stations with *Populus nigra* (squares), *P. alba* (squares a), *P. tremula* (squares t), *P. balsamifera* (squares b), *Salix* (circles) and *Alnus glutinosa.*

Betula

Betula verrucosa and *B. pubescens* are grouped here under the joint heading of *Betula.* The station trees consist of *Betula* at a total of 8 stations. All 8 of them bear lichens. Distribution is shown on Fig. 86 and Table XIV. Birch is found more or less everywhere in the investigated area, but is relatively scarce as a park tree, although it does occur, at least in the larger parks.

Birch bark in the comparison area maintains a pH value of 3.3–4.5, in the investigated area's central and lichen-free parts 2.7–4.1, and in the transitional zone 2.8–3.6.

Hypogymnia physodes occurs at 7 of the 8 stations. It is abundant at 5 of these. *Parmeliopsis ambigua* is the next commonest (5 stations). *Lecanora conizaeoides* is found at 4 stations but is not the sole species at any of them; nor is *Lecidea scalaris.*

As expected, the lichen vegetation belongs mostly to the *Physodion* federation, though *Xanthorion* also appears occasionally, for example at station 576 *b.*

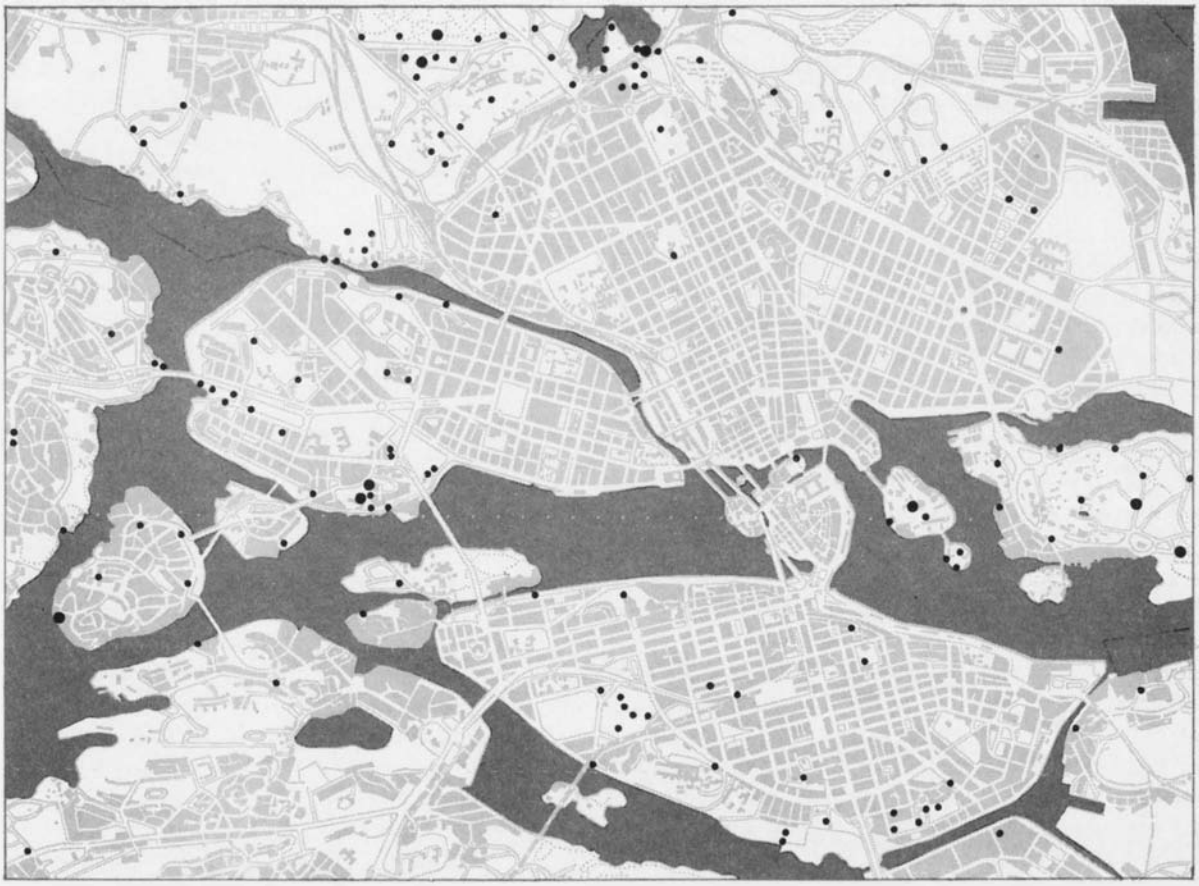


Fig. 88 b. Vegetation cover. Small dots = scanty vegetation (< 20 %), large dots = rather scanty to abundant vegetation (20 %–80 %).

Ptilidium pulcherrimum is the commonest of the mosses.

The remarks concerning lichen vegetation on *Pinus* apply also to *Betula.*

Acer pseudoplatanus

Acer pseudoplatanus is somewhat scarce in Stockholm parks. The species is practically entirely absent from the comparison area. Distribution of the station trees, 4 in number, is shown in Fig. 80. Of these 4 stations, only 1 has lichens, namely station 350 (see Table VI). The species occurring are *Lecanora conizaeoides, Lecidea scalaris, Hypogymnia physodes* and *Bacidia chlorococca.*

No analysis was made of the bark's pH.

Picea abies

Spruce is rare in the central parts of Stockholm (see Sernander 1926, pp. 161 ff.). Only one *Picea abies* (station 126) was investigated, the immediate reason being to obtain a comparison with other kinds of trees in the same place—see Fig. 86 *a.*

No determination of pH was made.

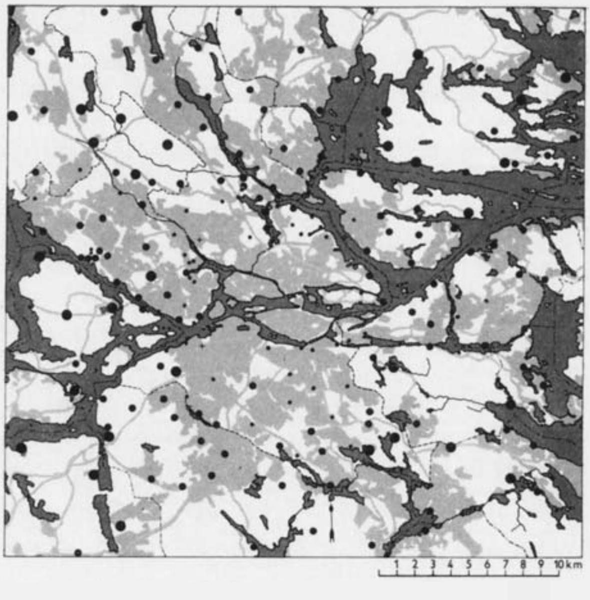


Fig. 88 a. Vegetation cover. Small dots = scanty vegetation (< 20 %), medium dots = rather scanty to abundant vegetation (20 %–80 %) and large dots = very abundant vegetation (> 80 %).

Special examination on conifers

Hans Lundström, B.A., undertook a special examination in the investigation area of the epiphytic lichen flora on *Picea abies* and *Pinus silvestris* along a profile ranging from the borough of Täby to the northern part of the inner city of Stockholm. The profile, which follows longitude 18°5′ as closely as possible, has four minor cross-profiles. Lundström investigated 126 stations, mainly following the method used for this work (Lundström 1966). He identified a total of 25 species of lichen, 9 species of moss and 6 species of algae. However, the latter group has not been processed in the same way as the others.

Table XI shows a list of species and the occurrence of lichens and mosses on *Pinus* in Lundström's examination area. The *Pinus* stations included in the present investigation are also reported in this table. The commonest species is *Hypogymnia physodes*, with 97 stations. *Lecidea scalaris* has been noted at 96 stations. *Parmeliopsis ambigua* has been observed at 59 and *Lepraria incana* at 58. Tolerably well developed *Cladonia coniocraea* has been stated to occur at 56 stations. *Lecanora conizaeoides* occurs at only 19 stations. These are in the southern part of Lundström's examination area. For comparison, it may be mentioned that *Alectoria jubata* appears at 21 stations, but these are in the northern part of the area. *Lecidea scalaris* also is found far to the south, i.e. towards the centre of Stockholm. *Hypogymnia physodes* also appears near the inner city, but becomes clearly affected and scarce. *Lecanora conizaeoides* normally occurs together with *Lecidea scalaris* and *Hypogymnia physodes*. The species is alone only at 2 stations. *Lecidea scalaris*, on the other hand, appears as the sole species at 9 stations. *Lecidea scalaris*, *Hypogymnia physodes* and *Lepraria incana* are not uncommon either. All these combinations of merely a few species occur in the outskirts of the lichens' distribution area.

Lundström's examination also shows that some of the species of the *Physodion* federation, e.g. *Alectoria jubata, Cetraria pinastri, Hypogymnia physodes, Lecidea scalaris, Parmeliopsis ambigua, P. aleurites, Pseudevernia furfuracea, Usnea* sp. etc., are commoner in the peripheral parts of the investigated area than is indicated by the present investigation. This is a consequence of its structure, concentrated as it is on trees of the type found in city parks, etc.

Comparisons between different substrates

Pinus, Picea, Betula and *Quercus* usually have an epiphyte vegetation belonging to the *Physodion* federation. It may therefore be interesting to compare growth on the various phorophytes in a restricted geographical area (in this case the Grimsta area). With respect to the number of species, such a comparison gives the following results:

Table 8. *Comparison between some different substrates with respect to number of species of epiphyte lichens and mosses in a limited geographical area.*

	Species of lichens	Species of moss
Pinus silvestris	6–7	1
Picea abies	5	1
Betula pubescens	7	1
Quercus robur	12	1
Betula verrucosa	6	3

Altogether, 21 different species are concerned at these 7 stations. Of the species, 9 are noted only on *Quercus robur*, 2 on *Betula pubescens* only, and 1 on *Pinus silvestris* only. Five species are found at more than half the number of stations.

Pinus, Picea and *Betula* are thus more or less on an equal footing as regards the number and composition of species. But *Quercus* shows a considerable divergence in both of these respects. If we turn to the prevalence of species, we find the following circumstances. (*Betula* shows more *Lecanora* species than do the conifers.)

Table 9. *Occurrence of the commonest epiphyte lichen species at 7 stations in a limited area* (*Grimsta*).

Species	Number of stations with species
Hypogymnia physodes	7 Stations (i.e.all of them)
Lepraria incana	6
Parmeliopsis ambigua	5
Cladonia coniocraea	5
Cetraria chlorophylla	4
Lecidea scalaris	3
Cetraria pinastri	3
Lecanora expallens	2

In the same way, *Fraxinus, Ulmus* and *Acer* are probably almost equivalent as a substrate and could therefore replace one another.

This material gives no indication of the way in which other kinds of trees are placed from this point of view.

LICHENS AND SUBSTRATE

It is difficult to form an impression of the importance of the substrate as far as the lichens are concerned. Many physical factors in both the bark and the atmosphere have an effect together with the bark's and the air's chemical composition. Tobler (1925) considers for example that lichens live in part as saprophytes on bark. Several other scientists have also expressed doubts as to the autotrophy of the lichens (see e.g. Stålfelt 1939, pp. 27 ff.). Stålfelt finds, however, that the lichens are autotrophic and have a well adapted production apparatus.

The lichens' choice of substrate gives some idea of the importance of the substrate for them. Among the species that are of current interest in this investigation, the following classification can be made:

A. Obligate epiphytes
B. Epiphytes–epixyls
C. Epiphytes–epiliths
D. Epiphytes–epigeans
E. Epiphytes–epixyls–epiliths
F. Epiphytes–epiliths–epigeans
G. Epiphytes–epixyls–epiliths–epigeans

The result is shown in Table 10. In certain cases, however, it has been doubtful to which group a particular species should be referred. Sources have been Almborn (1952), Erichsen (1957) and Magnusson

Table 10. *Substrates principally chosen by the lichen species included in this investigation.*

A. Obligate epiphytes (40)

Alectoria implexa
Arthonia radiata
Arthopyrenia alba
Arthopyrenia biformis
Arthopyrenia fallax
Arthopyrenia sphaeroides
Bacidia Beckhausii
Bacidia chlorococca
Bacidia luteola
Bacidia Naegelii
Buellia disciformis
Buellia griseovirens
Calicium hyperellum
Candelariella xanthostigma
Coniocybe hyalinella
Lecanora allophana
Lecanora chlarona
Lecanora chlarotera
Lecanora crassula
Lecanora expallens
Lecanora maculata
Lecanora pinastri
Lecanora subfuscata
Lecidea efflorescens
Lecidea olivacea
Lecidea quernea
Lecidea scalaris
Ochrolechia microstictoides
Ochrolechia subviridis
Opegrapha varia
Pachyphiale fagicola
Parmelia subaurifera
Pertusaria coccodes
Pertusaria discoidea
Pertusaria leioplaca
Pertusaria leprarioides
Pertusaria lutescens
Phlyctis argena
Physcia aipolia
Ramalina calicaris
Ramalina fraxinea
Rinodina exigua

B. Epiphytes–epixyls (15)

Biatorella moriformis
Buellia pharcidia
Caloplaca aurantiaca
Caloplaca cerina
Candelariella vitellina
Catillaria Ehrhartiana
Catillaria Floerkei
Catillaria globulosa
Catillaria Griffithii
Catillaria prasina
Lepraria candelaris
Lecanora carpinea
Lecanora symmicta
Lecidea glomerulosa
Pertusaria albescens
Usnea hirta

C. Epiphytes–epiliths (26)

Alectoria jubata
Anaptychia ciliaris
Buellia alboatra
Caloplaca chlorina
Cetraria glauca
Nephroma parile
Parmelia exasperata
Parmelia exasperatula
Parmelia fuliginosa
Parmelia saxatilis
Parmelia subargentifera
Parmelia sulcata
Parmeliopsis hyperopta
Physcia ascendens
Physcia caesia
Physcia dubia
Physcia entheroxantha
Physcia farrea
Physcia nigricans
Physcia orbicularis
Physcia pulverulenta
Physcia stellaris
Pseudevernia furfuracea
Ramalina farinacea
Ramalina fastigiata
Xanthoria fallax

D. Epiphytes–epigeans (1)

Lepraria incana

E. Epiphytes–epixyls–epiliths (18)

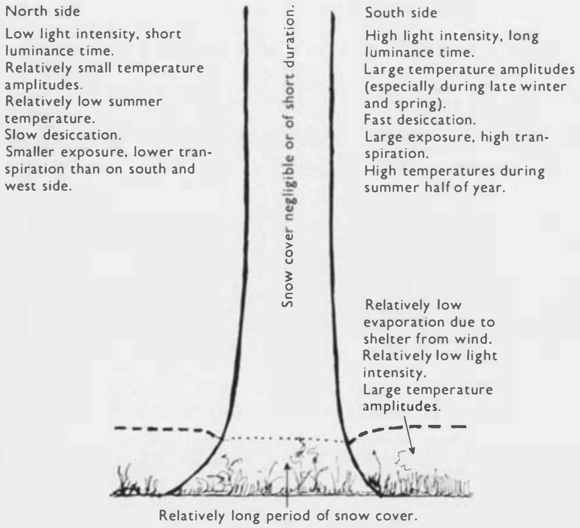
Buellia punctata
Candelaria concolor
Cetraria chlorophylla
Evernia prunastri
Hypogymnia bitteriana
Lecanora conizaeoides
Lecanora Hageni
Lecanora umbrina
Ochrolechia androgyna
Parmelia acetabulum
Parmeliopsis ambigua
Pertusaria amara
Pertusaria globulifera
v. globulifera
Physcia tenella
Ramalina pollinaria
Xanthoria candelaria
Xanthoria parietina
Xanthoria polycarpa

F. Epiphytes–epiliths–epigeans (2)

Cetraria pinastri
Peltigera canina

G. Epiphytes–epiliths–epixyls–epigeans (4)

Cladonia coniocraea
Cladonia fimbriata
Hypogymnia physodes
Hypogymnia tubulosa



These factors become more extreme in the case of isolated trees than of trees in parks or wooded areas.

Fig. 89. Environmental conditions on different parts of a straight tree-trunk.

(1929). Such a classification could possibly give an idea of the ecological amplitude of the different species. A species with a wide amplitude should, it would be reasonable to assume, be able to accommodate itself more easily than others to the conditions in the central parts of the investigation area. However, this does not appear to be the case at all. Among the species in group G, we note admittedly *Hypogymnia physodes* and *Cladonia coniocraea,* which both extend far into the investigated area and are common, but neither *Hypogymnia tubulosa* nor *Cladonia fimbriata* plays a role of any importance. *Lecanora conizaeoides* belongs to group E, while *Lecidea scalaris* has been referred to group A. To this latter group also belongs *Lecanora expallens,* while for example *Lepraria incana* is to be found in group D, *Parmelia sulcata* in C and *Bacidia chlorococca* in A. The species in group C, epiphytes—epiliths, are often plentifully represented in the data, this being probably due to the fact that they are favoured by the selection of stations. Roadside trees and trees in dusty locations obtain an abundant addition of mineral particles, which these species obviously desire (cf. Barkman 1958, p. 102). It seems also as if the most sparsely occurring species belong to groups A and B.

A comparison has also been made between the choice of phorophytes made by the various species. Some interesting information can be obtained from the data. *Bacidia chlorococca* avoids *Fraxinus excelsior; Calicium hyperellum* does not occur on *Tilia* or *Ulmus. Bacidia luteola, Pertusaria globulifera* v. *discoidea* and *Ochrolechia microstictoides* have never been found on *Tilia. Xanthoria parietina, Physcia orbicularis, Ph. farrea* and *Ph. dubia* have never been taken from *Quercus robur.* The fungus *Hysterium pulicare* on the other hand seems to prefer oak, is found though rarely on *Acer platanoides* but avoids other deciduous trees. Although the composition of the lichen flora is tolerably similar on *Acer, Fraxinus* and *Ulmus; Tilia* and *Quercus robur* thus differ, each in its particular fashion, from the others.

As regards kinds of trees other than those dealt with above, it should be pointed out that their number is much less, which means that the results are not directly comparable. However, if we add the stations analysed by Lundström, *Pinus silvestris* appears in comparable numbers, while *Picea abies* is still sparsely represented. As expected, a large number of species are absent on coniferous trees and on such deciduous trees as *Betula* and *Alnus.* On the other hand all the "conifer species" are to be found on the other type of deciduous trees (*Acer, Fraxinus* and *Ulmus*), except the *Parmeliopsis aleurites* (18 stations), *Cladonia flabelliformis* (2 stations) and *Lecanora pinastri* (1 station), all found by Lundström.

If one investigates which species are most frequently present among the various kinds of trees, disregarding their abundance entirely, it will be found that in the present material *Hypogymnia physodes* is the commonest lichen on *Tilia, Quercus robur* and *Betula. Lecanora conizaeoides* is the commonest lichen on *Acer platanoides, Ulmus glabra* and *Aesculus hippocastanum.* On *Populus, Alnus glutinosa* and *Salix* both these species are equally frequent, this being presumably due to the small number of stations of the kinds of trees concerned. *Lecidea scalaris* has the greatest frequency of occurrence among the species found on *Pinus silvestris.*

The distribution pattern on the maps indicates, however, that the result will be quite different if a comparison is made between stations in the transitional zone and stations in the normal area, and if abundance is also taken into account. Such a comparison can be made in Tables VI–XIV for each phorophyte separately.

The tables show that the lichens' choice of substrate is considerably changed in the transitional zone. One reason for this may be reduction of competition as the result of some species having disappeared through desiccation. Those resistant get a chance to colonize even such substrates as are not normally available to them. Another reason may be that the substrate has changed so that it suits species other than those in an unaffected area. What happens is that the *Xanthorion* federation species normally found on some deciduous trees are replaced by those of the *Physodion* federation. In the innermost part of the transitional zone a community of plants appears which is very reminiscent of Barkman's (1958, pp. 363 ff.) *Lecanoretum pityreae*.

In the lichen-free part of the investigated area, no new colonization has been observed, with the exception of what has already been said about *Lecanora conizaeoides*. With the wind's help, however, the central parts of the investigated area are in all likelihood constantly supplied with diaspores from the surroundings. As it appears from Table 7, it is not merely a question of soredia and isidia but also of thallus fragments and spores. The reason why no new colonization takes place may either be that the dispersed units die or lose their germinating power very quickly, or that the substrate is no longer suitable for lichens. A combination of these causes is also conceivable.

Fig. 90. Station 9, old *Populus alba* on Helgeandsholmen islet in the centre of Stockholm. *Lecanora conizaeoides* is growing on the upper side of the trunk.

PHYSICAL NATURE OF SUBSTRATE

A tree trunk offers epiphytic vegetation several different combinations of environmental factors. A comparison has been made in Fig. 89. Geiger (1950, p. 231) says for example regarding micro-climate: "Auch der Baum hat seine 'Wetterseiten', die manchmal am Moos- oder Flechtenbelag hervortreten".

Normally, for example, the north side of the trunk receives a much smaller share of sunlight than the south side. The day temperature in sunshine is therefore not so high there as it is on the south side of the trunk. The maximum intensity of light also occurs at a different time of the day. Krenn (1933), shows however that the south side of the trunk receives its strongest radiation during the spring. Seeholzer (1935) draws attention to the risk of bark damage because of the strong incoming radiation in the early spring when the air temperature is still below freezing point. The bark of *Betula,* for example, but also of species with rough bark, often cracks in the spring owing to the violent variations in temperature. *Xanthoria parietina* can be found in the vicinity of such cracks on *Betula verrucosa* in the comparison area. Similar observations have been made on old *Ulmus* in Djurgården. The temperature amplitude during sunny winter days is probably considerably greater on the trunk's south side than on the north side.

The epiphytes and their substrate desiccate more quickly on the south side than on the north side. The last parts to dry are the strips of moisture which usually occur on the trunk after more or less persistent rain. The appearance of the top of the tree and thus also the kind of tree are of great importance for the trunk's moisture-conditions, both during and immediately after rainy weather.

These factors become more extreme for isolated trees than for trees in parks or woodland.

The conditions at the base of the trunk differ in several respects from those on the trunk. The base, at least in some situations, is protected by snow for a considerably longer time than are the other parts of the trunk. The light intensity is often lower. The temperature climate is probably quite a different one. Evaporation in consequence of wind is also lower than it is for the rest of the trunk. It is principally the algal vegetation that reacts towards these differences in the environment (Lehtsaar 1963), but the epiphytic moss vegetation (Sjögren 1961) and the lichens also do so. Du Rietz (1945 *a*, p. 148) describes for example *Cetraria pinastri, Parmeliopsis ambigua* and *P. hyperopta* as tolerant of snow, while certain *Parmelia* species, for example, are stated to be sensitive to snow.

In well-developed epiphytic vegetation, especially on spruce, the finer boughs are also overgrown with lichen—a circumstance that makes it possible to draw certain conclusions regarding the speed of colonization and growth. For practical reasons, however, this investigation has been concentrated on trunk-dwelling epiphytic communities. An account follows below of some of the physical conditions prevailing with respect to the substrate.

As regards its hardness and thickness, the epiphytic substrate varies greatly in different species of trees. In many kinds of trees the bark also changes considerably as the tree ages. At many stations in the investigated area it has been noted that the normally hard bark of the oak (containing sclereids, "stone cells") and the likewise usually rough basal part of birch bark have been loose. The usually medium-hard barks of lime, maple, elm and alder also sometimes noticeably show slight desquamation. With regard to pine bark, see p. 14. At certain stations, for example in Kungsträdgården Park, lime bark also seems to be pitted; this has not been observed outside the heart of the city. The bark at the base of the trunk seems always to be looser than the rest of the bark.

The structure of the bark seems to have only a limited effect on the lichens' powers of colonizing the phorophyte in the natural landscape. In the urban landscape, however, it plays some part. Beschel (1958, p. 83) considers for example that glabrous bark becomes less colonized than normally in areas where any factor has an inhibiting effect. Birch in the transitional zone of the investigated area is often still bare for example when most other deciduous trees have epiphytic vegetation, and this confirms Beschel's observations. With regard to the colonizing capacity of the mosses, see Sjögren 1961, and others.

Primarily, however, the structure of the bark is of importance for the water-containing capacity of the substrate.

With regard to the distribution of ages among the phorophytes, reference should be made to the table on p. 20.

The inclination of trees is of importance for the development of the epiphytic flora (see for example Sjögren 1961, pp. 87 and 88). On inclined trees with a smooth bark, part of the rainwater runs from the upper side down the sides and collects in drops on the underside. Young trees in age group 1–2 therefore have lichens on the underside of the trunk also. When the bark becomes older and furrowed, the rainwater often follows the furrows down the trunk, and the underside remains dry or receives considerably less precipitation than the upper side. Lichen vegetation on these trees is more or less concentrated on the upper side. The upper side desiccates more thoroughly and is exposed to stronger light than the other parts of the trunk. Horizontal branches on old oaks, for example, in the transitional zone can have a relatively abundant vegetation of *Hypogymnia physodes* even when the trunk is quite bare. The fact that the epiphytes prefer the upper side of the trunk is presumably due to several cooperating factors such as light and moisture, and cannot be explained merely by the water factor.

In the course of field work, strongly inclined trees have been avoided as much as possible.

Sharply inclined trees occur only in station No. 9 (Fig. 90). Slightly inclined trees occur in the stations included in Table 11. Other stations have more or less vertically growing trunks, which makes them more comparable with respect to influences derived from their environment (see also the table on på 21).

Different sides of a tree's trunk receive varying quantities of energy through radiation from sun and sky. Fig. 91 and 92 have been drawn up after Ångström 1958, and show a comparison between inward radiation and illumination on (*a*) a horizontal surface and (*b*) vertical surfaces exposed to different points of the compass. The total inward radiation from sun and sky during one year on a horizontal surface amounts in Stockholm to 76,000 (gram-)calories per cm^2. A southward-facing vertical surface receives 61,000, an eastward-facing one 52,000, a westward-facing one 47,000 and finally a northward-facing vertical surface in Stockholm receives 25,000 calories per cm^2 and year. The values admittedly refer to flat smooth surfaces, but they nevertheless give a clear indication of the enormous differences in climate that prevail on different sides of a tree trunk.

During the summer the trunk usually receives its maximum illumination only in the morning and evening, while the foliage prevents insolation in the middle of the day. This also means that the northern side of the trunks in moderately dense park and woodland areas is maximally warmed only during the morning and evening hours. This is true mainly of trees in parks and plantations, but also of isolated trees whose crowns are relatively low-lying or in which downward-hanging boughs screen the trunk. In the table on p. 22 an attempt has been made to express the exposure of the phorophyte. This gives some indication of the admission of light to the trunk, but disregards effects such as those coming from hanging branches, etc. The flow of light is at its greatest in the autumn and spring when the trees are bare. The process outlined does not refer to the conifers. As far as *Pinus silvestris* is concerned, the differences between the seasons are less, as the top of the tree often begins at such a great height above ground level that it does not affect its own trunk, and the influence from surrounding pines also hardly varies according to the prevailing season.

The importance of moisture for epiphytic vegetation is emphasized by Sjögren (1961, p. 86) and others. Mosses colonize trunks in a special order.

Table 11. *Distribution of lichen vegetation on inclining phorophytes in the investigated area.*

Station	Kind of tree	Age	Inclining towards	Remarks
2	Salix babylonica	6	E	Algae on N side
9	Populus alba	6	N	*Lecanora conizaeoides* on E, S, W side
64	Pinus silvestris	5	SE	4 lichen sp. + algae on upper side
116	Betula verrucosa	6	S	6 lichen sp. + algae on upper side
118	Fraxinus excelsior	5	N	2 lichen sp. + algae on upper side
120	Alnus glutinosa	5	NW	2 lichen sp. + algae on S side
123	Acer platanoides	3–4	S	15 lichen sp. on upper side
142	Salix fragilis	3–4	S	8 lichen sp. + algae on upper side
187	Acer platanoides	5	S	5 lichen sp. + algae on upper side
221	Acer platanoides	6	SE	Algae on N side
222	Salix babylonica	6	S	*Lecanora conizaeoides* + algae on upper side
313	Acer platanoides	3–4	W	*Lecanora conizaeoides* + algae
320	Salix sp.	6		6 lichen sp. + algae on upper side
327 *b*	Salix sp.	6		6 lichen sp. + algae on upper side
396	Populus alba	7		2 lichen sp. + algae
425	Acer platanoides	6		20 lichen sp.
486	Ulmus glabra	3–4		Algae over whole of trunk

Note. Most of the stations are in the transitional zone.

Young trunks have moss communities resistant to dryness, which change from mesohygrophile to hygrophile with increasing age (Sjögren 1961, p. 87). Barks with a similar capacity for retaining moisture should, if the moisture factor were decisive, show similar epiphytic vegetation. Other factors such as light, wind and dust impregnation, as well as inclination, manifestly play such an important role that the parallelism in the epiphytic vegetation between bark moisture and the groups of kinds of trees concerned is only a weak one (cf. Barkman 1958, p. 43).

Moss vegetation often retains moisture for a long time, and the bark beneath the moss becomes looser and also retains moisture longer than normally (Sjögren 1961, p. 88). Something similar has been observed under coverings of *Parmelia sulcata* on *Fraxinus excelsior, Ulmus glabra* and *Acer platanoides.* Most lichens, however, probably have a limited influence on the moisture conditions of the bark. Algal vegetation on the tree trunks is neatly zoned according to the moisture conditions (Schmidt 1927, Lehtsaar 1963). While the genuine aerial algae on tree trunks, for example *Pleurococcus viridis,* do not absorb rainwater, or absorb it in only to an insignificant extent, the *Prasiola crispa* of the trunk bases sucks up water very quickly. If the quantity of precipitation is small, the trunk covered by algae remains dry, but the parts on which there are no algae become moist, like the lower part of the trunk's base.

Curiously enough, lichens in the inner part of the transitional zone are not found particularly often in or adjoining the rain- or water-tracks of the trunks, which could be expected if moisture were the decisive factor. On the other hand it is possible to observe lichens on the upper side of large branches in the tops of otherwise lichen-free trees. The irregularity in the substrate's moisture conditions probably becomes evident in the composition of lichen vegetation on a trunk, even if there are no investigations to show this. Atmospheric humidity, however, has an equalizing effect, and moreover all other factors (not least, pH) also operate in different directions, so that it is probably difficult to isolate the importance of substrate moisture. Yarranton (1967) shows that the distribution of certain lichens follows the "microrelief" of the bark.

On single trunks, however, water seems to play an important role as a transporter for diaspores. *Hypogymnia physodes, Parmelia sulcata* etc. occur often for example in more or less vertical strings on trunks. This phenomenon has frequently been interpreted to mean that lichens can only survive in these tracks because of the dryness of the city climate, for example. Another interpretation is that the supply of diaspores from already established thalli higher up on the trunk or in the top of the tree is greater in these tracks than it is on other parts of the trunk.

While the snow is melting, the bases of the trunks sometimes remain moist for several weeks. However, it has not been possible to observe any positive effect on lichen vegetation for this reason.

In rainy weather quite large quantities of water can be transported along the trunk. The trunk flow is great in trees with acute branch-angles, and less in trees with horizontally extended or hanging branches such as spruce, for example. B. Nihlgård

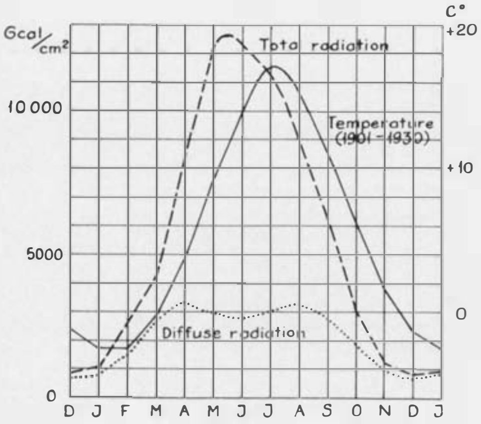


Fig. 91. Total and diffuse radiation (in gcal/cm²) and monthly mean temperature (1901–30) in Stockholm. (After Ångström 1958.)

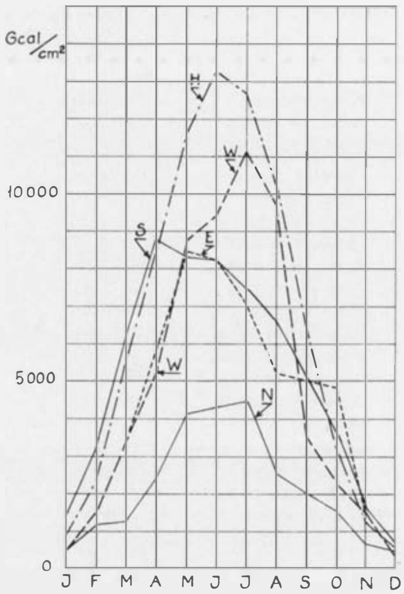


Fig. 92. Total inward radiation in gcal/cm² on a horizontal surface (H) and on vertical surfaces towards different points of the compass (S = south, W = west, N = north, E = east) in Stockholm. (After Ångström 1958.)

has orally informed me that he has found the following values for trees in woods (investigations made in the south of Sweden):

Fagus silvatica in winter > 30 %, in summer, light rain (< 10 mm) 7 %, heavy rain (15–25 mm) 16 %. *Picea abies,* light rain 0 %, heavy rain 5 % stem flow. Barkman (1958, pp. 64 ff.) discusses the water factor and gives the following values for stem flow: *Fagus silvatica* 12.8 %, *Acer platanoides* 5.9 %, *Quercus robur* 5.7 %, and *Picea abies* 1.3 % (after Ebermayer 1897, quoted by Hilitzer 1925). It is obvious that the water-absorbing capacity of the bark plays an important part. The development of the top is also of importance. The reason why some conifer lichens (belonging to *Parmelietum furfuraceae*) are usually lacking on spruce is explained by Barkman by the weak stem flow, which seems to be a rather far-fetched explanation, however.

The water content and water capacity of the bark have been investigated by several researchers (see literature in Barkman 1958, p. 72), and different methods have been used for the purpose. In the present work, interest has been mainly concentrated on determining whether there are any perceptible differences in water capacity and water-containing capicity between different phorophytes and within the same kind of tree in different parts of the area now concerned. The bark lay in dry laboratory air (RH 20 % ± 3 %, + 21 °C ± 1 °C). Weighing proceeded so long that a constant weight was obtained. The variations within each kind of tree are large, and it has not yet been possible to ascertain any reliable tendency regarding possible changes in water capacity etc. in the investigated area. As far as differences between different kinds of trees are concerned, the variations between the different kinds of trees are also too large for it to be possible to indicate any reliable tendency. In order to obtain a correct picture of the importance of water capacity, attention should also be paid according to Barkman (p. 73) to the thickness of the bark.

The water content in the bark changes according to the height above the ground, and becomes constant above a height of about 1.5 metre (Billings and Drew 1938, quoted by Barkman, p. 73). According to Barkman, this fact is reflected in the epiphytic vegetation. The water content, however, is liable to great changes because of variations in evaporation as the result of rising temperature, wind, etc.

According to the wind diagram, Fig. 77, the south-west, west and south side of the trunks, in that order, are most exposed to the wind. The north and south-east sides are much less exposed. Further protected are the north-east and north-west side, while the east side is the best protected (half as exposed as the south-west side). It would be reasonable to assume that this would be of importance for both temperature and moisture.

It is often asserted that lichens in cities are mainly found on the north side of trunks and that this is due to the moisture conditions (Rydzak 1953–1959 *b*, Natho 1964, etc.).

There are recordings from 51 stations in the transitional zone that lichen vegetation is limited

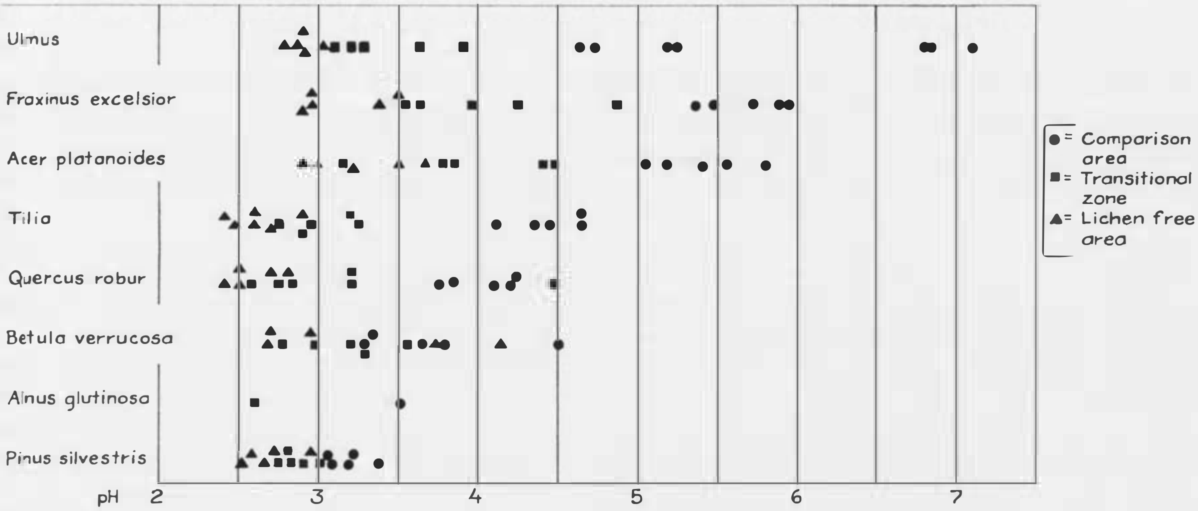


Fig. 93. pH values in bark extract from comparison area, transitional zone and licken-free zone. In *Pinus* there is well-developed lichen vegetation in the case of a pH value of 3.0–3.5, while *Fraxinus* is already lichen-free if the pH value is 3.5.

to one side of the trunk. In four cases it has been noted that the lichen flora is more abundant on the south side than on the other sides or that it occurs there only. At 29 stations (i.e. about 53%) the lichen vegetation is limited to the north side of the trunk, but at practically all 51 stations there are lichens on the northern half of the tree, if the western and eastern positions are included. Whether this is due to the moisture conditions or not has not been investigated. Trees with smooth bark seem to have lichen vegetation more concentrated on the trunk than trees with rough bark. However, the scantiness of the data makes it impossible to express a definite opinion on that point. It should also be noted that the trees concerned are mostly in the more central parts of the investigated area. In the agricultural landscape there is seldom any perceptible scarcity of lichen on the southward-facing side of the trunk.

In some cases the lichen vegetation has been concentrated on a certain part of the trunk, usually the base and parts of the trunk near the base. 7 such notes have been made, 4 of them on *Quercus*. In 4 cases lichen vegetation has appeared only on root-collars. All 4 notes refer to *Quercus*. In two cases, the lichen vegetation was concentrated on the upper parts of the trunk and in the crown of the tree. Cases in which the trunk was free from lichen but in which the crown had lichen vegetation were not noted, but it has been observed on several occasions that such cases exist.

CHEMICAL NATURE OF SUBSTRATE

Barkman (1958, pp. 95 ff.) gives a specification of the bark's chemical composition. Beschel (1958, p. 83) says that it is primarily the pH conditions that are of interest, and that they are more important than the presence of certain ions. Barkman (1958, p. 107) gives a detailed bibliography of works dealing with pH investigations of bark with or without epiphytes. In Sweden Sjögren (1961) has dealt with questions relevant to this subject in recent years. No chemical analyses of bark have been undertaken in the present investigation. However, I have investigated the pH of the bark on phorophytes in the comparison area, in the transitional zone and in the lichen-free part of the investigated area. All the trees are more or less affected by dust.

The samples of bark have been collected at a height of 1–1.5 metres above ground level. One and the same sample includes bark from different sides of the trunk and from moisture-tracks as well as from dry parts. Samples have been taken from middle-aged to older trees, i.e. the age-groups that are predominant in my data. When the bark was collected, efforts were made to obtain slices of bark that were as thin as possible. This was easy as far as *Pinus silvestris* was concerned, and in many cases also e.g. *Tilia* and *Fraxinus* but it was always difficult in the case of *Quercus robur*.

The samples collected were allowed to dry in air for at least 24 hours in the laboratory. The bark was then ground, and three sub-samples each of 2.0 grams were taken. Twice its volume of distilled water was added to each of two of these samples. The third sample was placed in a drying oven for 24 hours at +105°C. The two wet samples were left in a mixing apparatus for 24 hours. After this period the samples were taken out, the sample from the drying oven allowed to cool in an exsiccator and then weighed, while the wet samples were tested for their pH value.

The pH determination was made electrometrically with a glass electrode, a Beckman Zeromatic pH Meter being used. As a buffer solution for pH 4, a biphthalate buffer (pH 4.00±0.02 at 25°C) was used and for pH 7 a phosphate buffer (pH 7.00±0.02 at 25°C) both of P–H Tamm make. The pH determination was made direct in the bark suspension without previous filtration. The result is shown in the Fig. 93.

Sjögren 1961 (p. 102) discusses the difference in pH for samples of small and large pieces of bark respectively. He says that samples of small pieces of bark (< 1 cm^2) show a lower pH value than samples of larger pieces of bark. He also considers that these latter samples show better agreement with pH in bark in natural conditions. By pulverizing the samples one would obtain slightly incorrect pH values (Hale 1955, quoted by Sjögren 1961, p. 102). Sjögren's pH values for bark are all also higher than the values published here; this may partly be due to the size of the pieces of bark, but also and primarily because Sjögren's investigation area is on an island with a base of limestone bedrock, while the area now in question is a primary rock area with moraine and clay soils.

If we compare instead Du Rietz's (1945 *a*) stated colorimetric pH values, we find such good agreement that Hale's fears seem rather exaggerated. Du Rietz states (p. 148) for pine bark extract a pH of 3.4–3.8, for spruce bark of 3.85, for dust-free birch bark of 4.1–4.3, for alder bark of 4.2–4.6 and for oak bark of 3.6, occasionally of 4.3–4.8. Dust-protected ash bark has a pH of 6.4–5.3–5.0, maple of 6.9–6.1, and lime of 5.6–4.8. The values for maple and lime are from stations affected by salt water (Jungfrun island in Kalmar Sound) which give a higher pH than for inland stations. For elm bark from Vårdsätra outside Uppsala, he states a pH of 5.4–5.3 (cf. also e.g. von Krusenstjerna 1945, p. 239; Barkman 1958, p. 108; and Beschel 1958, p. 87).

Gilbert (1965, p. 44) states from Newcastle that pH from the rich barks is reduced to a level that is more typical for the most acid conifers. As the lowest value for *Fraxinus excelsior* he states 3.4, and for *Acer pseudoplatanus* 3.1. He also points out that these values for the pH of the bark are not too low for lichen to be able to grow there. *Pinus silvestris*, whose pH is normally in the region of 3.4, has 4–5 species of lichen at distances of 19 km from the centre of Newcastle. A difference between Stockholm and Newcastle is that bark in the central parts of the former city obtain considerably lower pH values than in the latter location. In Newcastle, the pH in the centre of the investigated area is even higher than it is 4 km farther away. Gilbert explains this by the fact that the trees become sootier in the centre and that soot has a pH of about 6. One has the impression that the Stockholm air is considerably freer from soot than that of Newcastle when one has stayed for a time in both places. The greater exposure to sea salt in Newcastle may be of some importance, too, possibly increasing the pH values. (In Stockholm, spray from the sheltered brackish straits to the east is a negligible factor.)

As the same sampling technique has been used throughout for all the samples taken in this investigation, the values are probably mutually comparable.

It is true of all the different kinds of trees in the investigation (see fig. on p. 105) that the bark has a lower pH—in some cases a considerably lower pH—in the transitional zone than in the normal zone. The reduction in pH is proportionally greater for trees which normally have a high pH, than for trees with a low pH. Trees like *Acer, Tilia, Ulmus* have a pH on the bark corresponding to the normal values for "trivial" deciduous trees like *Betula* and *Alnus* and for conifers. The lichen vegetation also changes from a more or less typical *Xanthorion* federation in the periphery of the investigated area to a mixture with less *Xanthorion* spp. and more and more inclusions of *Physodion*, the more deeply one penetrates into the transitional zone.

The lichen-free or almost lichen-free part of the investigated area has a pH so low that it seldom occurs in nature. For comparison it may be stated that Barkman's (1958, p. 108) absolutely lowest measured pH value is 2.9 and refers to a *Quercus* growing near a canal in Leiden (p. 111). He believes that the low value is due to hydrogen sulphide from the canal.

In the innermost part *Physodion* is replaced, as already pointed out on p. 85, by a *Lecanora conizaeoides* community. The *Lecanoretum pityreae* described by Barkman (1958, pp. 363–365) is strongly reminiscent of this community. Barkman describes it as "the strongly acidi- and toxitolerant counterpart of the *Lecanoretum carpineae*. Both are pioneers on smooth bark, but unlike the latter the present association mainly occurs on very acid bark, in the Netherlands on *Betula pubescens, Fagus*, young *Larix, Hippophaë, Ligustrum, Crataegus* and *Myrica*, occasionally on *Picea*. On rich-bark trees like *Fraxinus* and *Ulmus* it is usually replaced by *Lecanora expallens* both in the Netherlands and England (Laundon, l.c.)." Barkman says later (p. 364): "Yet the association is neither xerophilous nor acidiphilous. I also found it in damp stations . . ." and "In towns the *Lecanoretum pityreae* is found on various trees with subneutral bark".

The statement that the association is not xerophilous is interesting, but the evidence that it is not acidiphilous either seems rather weak, since very likely the "subneutral bark" in the cities is probably no longer subneutral but made acid as the case is in Stockholm. Magnusson (1930, p. 476) stated already that there are few lichens that can stand up to air pollution so well as *Lecanora conizaeoides.*

The results of the pH investigations in Stockholm seem to show clearly that the pH of the bark alone makes lichen vegetation next to impossible in the central parts of the investigated area. The only exception is *Lecanora conizaeoides* which in the present habitat amplitude seems not to be affected by air pollution or the pH of the substrate. There are grounds for assuming that acidification is still continuing, and the older values are therefore not comparable with the newer ones. The speed of acidification is probably affected by the buffer capacity of the bark, its dust impregnation etc.

BUFFER CAPACITY IN SOME EPIPHYTES AND THEIR SUBSTRATES

As well as bark samples (see p. 105) a number of specimens of lichens and mosses have been collected for pH determination from the normal area. The samples have been tested in the same way as the bark samples, with the exception that they have been finely divided by hand.

If we compare the loss of liquid in different samples after 24 hours at a temperature of +105°C, we find that the values vary somewhat. Inequalities in the RH of the laboratory air are probably one of the reasons for this. Thus the air-dry samples contain somewhat different quantities of water, which means a source of error when they are weighed out.

The pH value of the distilled water also varied during the testing period within quite wide limits. A comparison has been made (Fig. 94) to show whether the pH of the sample was affected by that of the distilled water. As the figure shows, any such effect hardly seems to exist. See also Fig. 100.

The buffer capacity of the investigated lichens and mosses is shown in Figs. 95–98. The investigation was carried out by adding 0.1 mole NaOH and 0.1 mole HCl respectively to two samples, each of 2.0 grams, which had been provided with twice their volume of distilled water and shaken for 24 hours. The pH was determined directly in the suspension after 10 minutes' stirring. In certain cases it proved difficult to make a reading, as the value stabilized very slowly. This is particularly true of *Xanthoria parietina, Parmelia acetabulum, Ramalina fraxinea* and *R. farinacea.* At the commencement of the experiment, the pH was measured for every tenth of a millilitre, later for every millilitre until 10 millilitres of the base and of the acid respectively had been used. The method of procedure was partly obtained from Hesselman (1926, pp. 251 ff.).

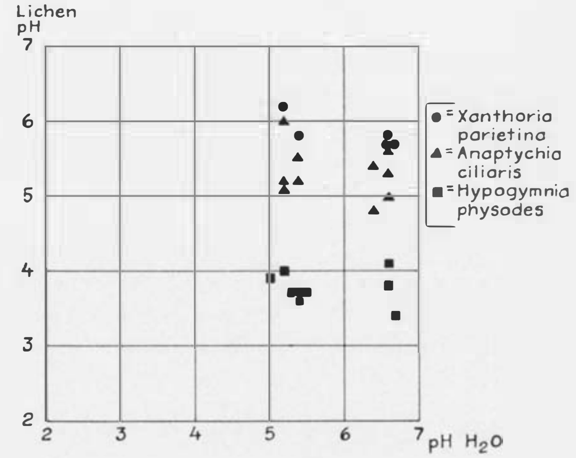


Fig. 94. Relationship between pH values in some lichen suspensions and the distilled water in which the lichen sample has been suspended.

It has also proved interesting to ascertain the extent to which the pH of the epiphytes and the phorophytes agree. Fig. 99 gives an idea of this. Epiphytes and bark are from the same locality and were investigated separately. Surprisingly enough, lichens and mosses seem to be relatively independent in relation to the substrate.

Coker (1967) has investigated how buffer capacities and ion exchange in the bark of *Acer pseudoplatanus* are affected by different influences of sulphur dioxide. He finds that both fall, generally speaking, in accordance with the degree of pollution.

In this investigation, I measured the buffer capacity of bark samples of *Acer platanoides, Alnus glutinosa, Betula verrucosa, Fraxinus excelsior, Pinus silvestris, Tilia* and *Ulmus.* Five samples of each were taken from the comparison area, the transitional zone (primarily from the inner and central parts) and from the lichen-free area in Stockholm.

Figs. 101–108 show the buffer capacity determined in the way previously mentioned. The more closely the curve approaches that of distilled water, the weaker is the buffer capacity. *Betula* bark differs clearly from other kinds of bark. Its buffer capacity is very small. For all the samples, the buffer capacity for acid is less in the transitional zone than it is in

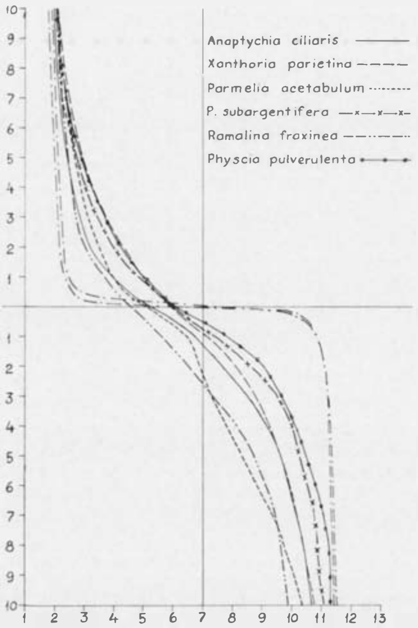


Fig. 95. Buffer capacity in some epiphyte lichens. The curve for the two different grades of distilled water used has also been included.

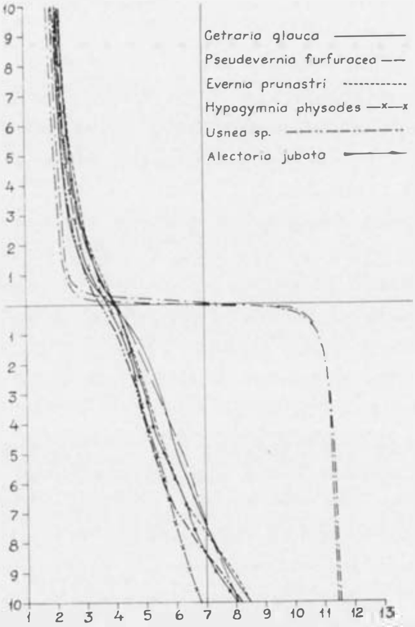


Fig. 96. Buffer capacity in some epiphyte lichens. The curve for the two different grades of distilled water used has also been included.

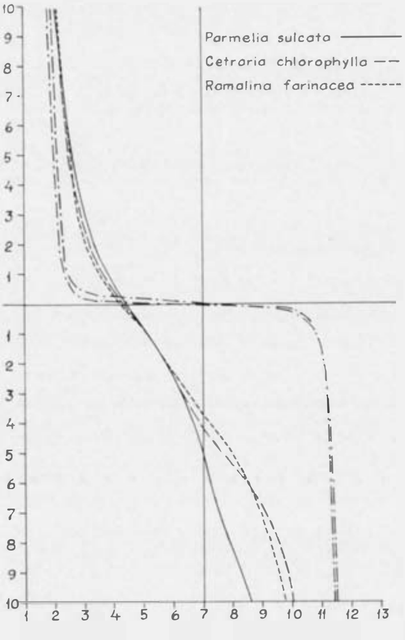


Fig. 97. Buffer capacity in some epiphyte lichens. The curve for the two different grades of distilled water used has also been included.

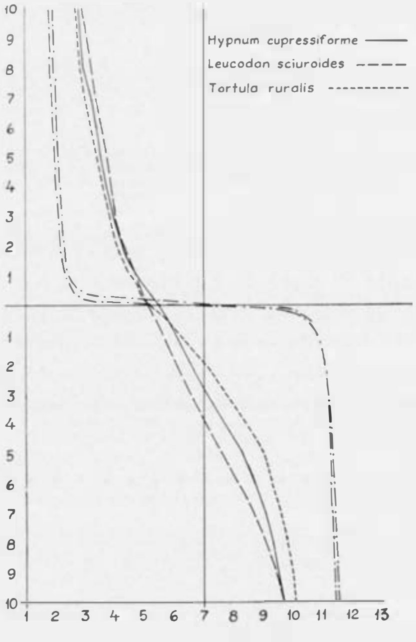


Fig. 98. Buffer capacity in some epiphyte mosses. Distilled water curves included.

the comparison area. As far as the alkaline side is concerned, the dispersion is greater in the transitional zone than in the comparison area. For all phorophytes, the bark in the transitional zone obtains a greater buffer capacity against alkaline substances than in the comparison area. This tendency is strengthened in the lichen-free area. The buffer capacity of *Betula* bark is affected only slightly by the environmental conditions in the transitional zone. If we also take into consideration the values from

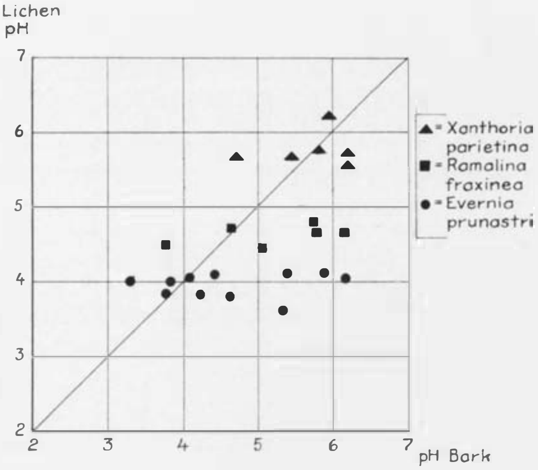


Fig. 99. Relationship between pH in some epiphyte lichens and their substrates.

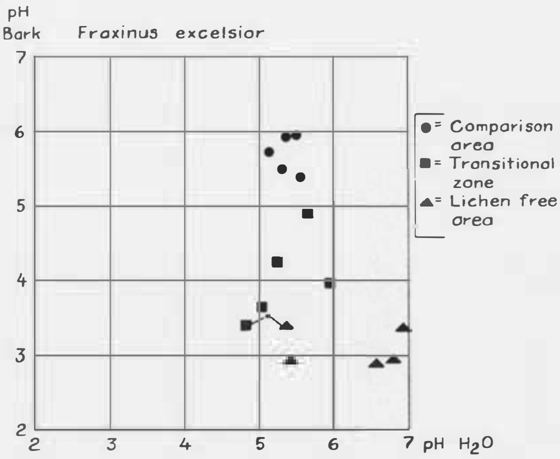


Fig. 100. Comparison between pH in some bark suspensions and the distilled water used.

the lichen-free area, we find that the alkaline buffer capacity of *Betula* bark deteriorates rather than improves towards the City centre.

Pinus silvestris, Tilia, Quercus robur and *Alnus glutinosa* have somewhat similar curves. The buffer capacity of bark from the comparison area is quite high as far as alkaline substances are concerned, rather lower in the case of acid substances. On the acid side, the *Tilia* curve shows the greatest buffer capacity, the *Pinus* curve the lowest. On the alkaline side the situation is precisely the opposite. *Alnus* closely resembles *Pinus, Quercus* resembles *Tilia.* For all these species, the pH of the initial sample does not exceed 4.5.

Fraxinus excelsior and *Acer platanoides* have almost identical curves. This is true both in the comparison area, in the transitional zone and in the lichen-free area. The curves for *Ulmus* show quite divergent and inexplicable values at 3 stations in the comparison area. The three stations are situated in

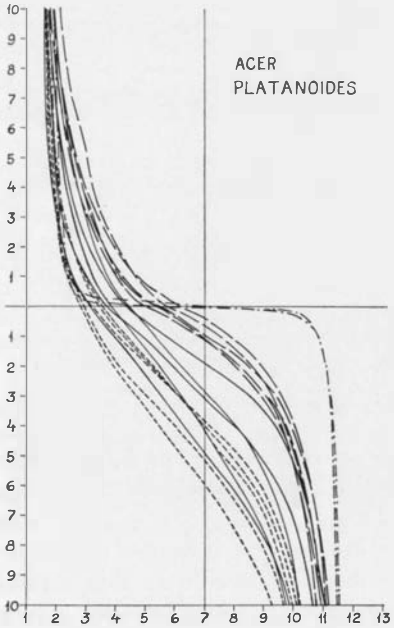


Fig. 101. Buffer capacity in bark samples from *Acer platanoides* in the comparison area — — — from the transitional zone ——— and the lichen-free zone - - - - - -.

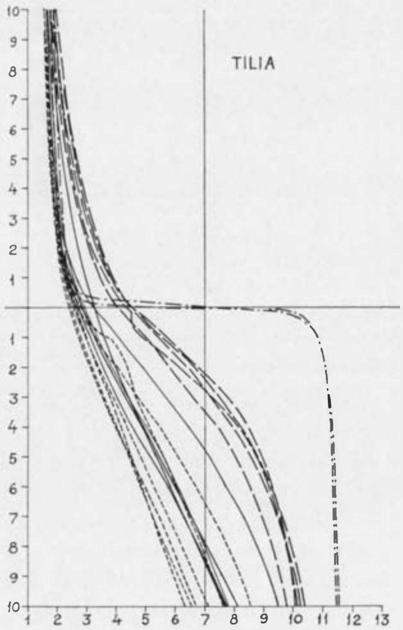


Fig. 102. Buffer capacity in bark samples from *Tilia* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

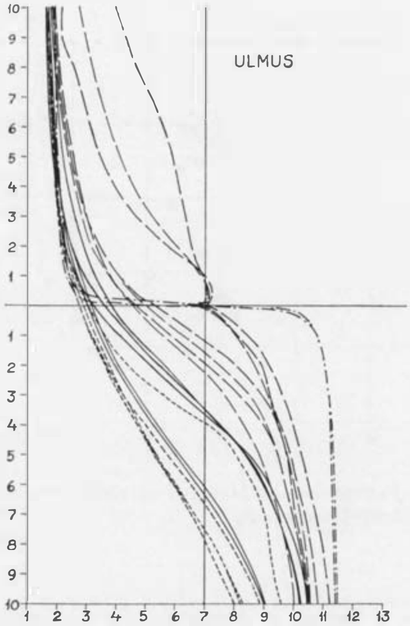


Fig. 103. Buffer capacity in bark samples from *Ulmus* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

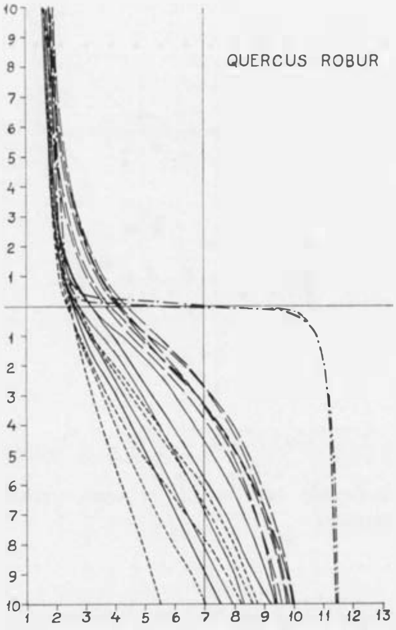


Fig. 104. Buffer capacity in bark samples from *Quercus robur* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

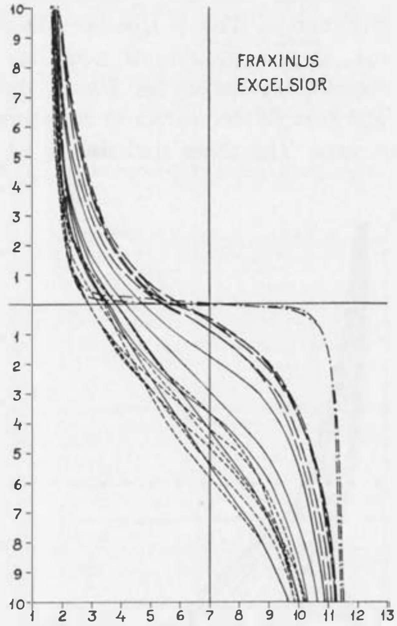


Fig. 105. Buffer capacity in bark samples from *Fraxinus excelsior* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

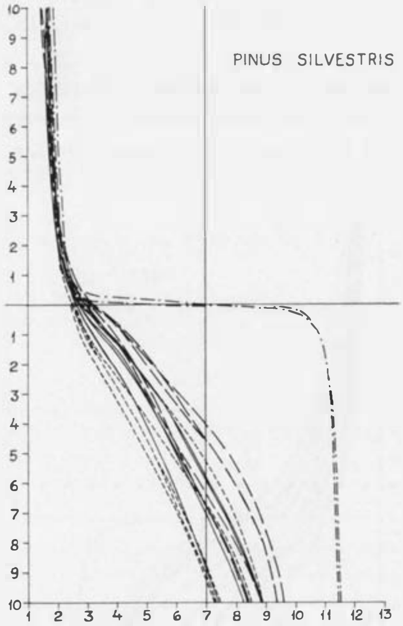


Fig. 106. Buffer capacity in bark samples from *Pinus silvestris* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

different parts of the comparison area, and new samples were titrated from these without any change in the curve having been obtained. If we disregard the divergent curves, the *Ulmus* curves are reminiscent of those of *Acer* and *Fraxinus*, although *Ulmus* shows a greater buffer capacity against alkali in the lichen-free area than the others. Compared with *Tilia*, these 3 phorophytes have a rather lower buffer capacity on the acid side and a considerably lower one on the alkaline side. The curve therefore follows a steeper course.

The phorophytes more or less lose their identity

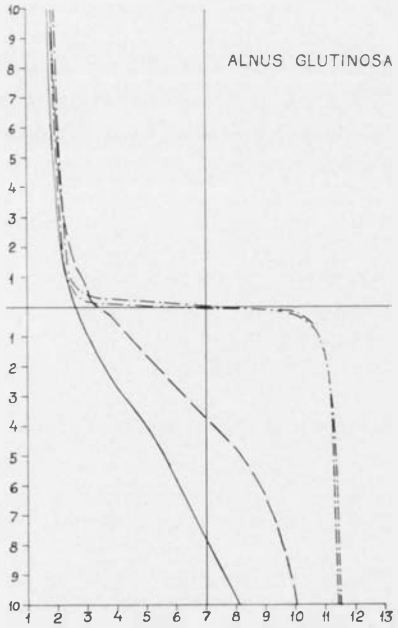


Fig. 107. Buffer capacity in bark samples from *Alnus glutinosa* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

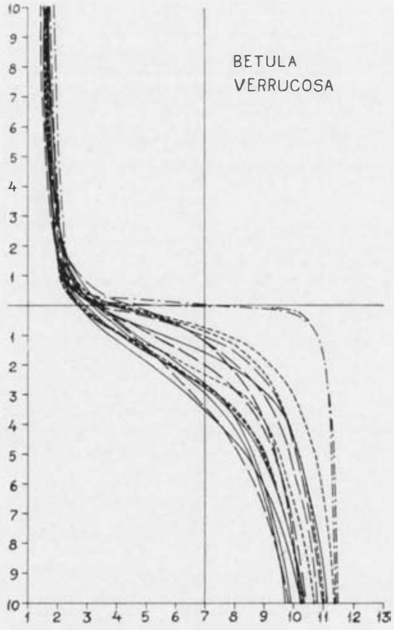


Fig. 108. Buffer capacity in bark samples from *Betula* in the comparison area and from the transitional zone and the lichen-free zone in Stockholm.

as substrates in the transitional zone and in the lichen-free area, *Betula* still forming an exception. For example, the *Acer* curves from these areas are reminiscent to a great extent of the *Pinus* curves from the comparison area. It is interesting that the lichen vegetation also definitely changes in the same direction. The rise in alkaline buffer capacity towards the City centre shown by bark of all species except *Betula,* and involving the greatest change for those barks that are normally substrates for "rich" lichen vegetation is interpreted by me as an accumulation of acid substances in the bark.

A comparison between the buffer capacity of some substrates and some lichens and mosses—all samples from the comparison area—gives the following results. *Evernia prunastri, Parmelia saxatilis, Hypogymnia physodes, Pseudevernia furfuracea, Cetraria glauca, Alectoria jubata* and *Usnea* sp. have titration curves which are reminiscent of the *Pinus-Alnus* curves. However, the buffer capacity is greater in the case of the lichens than in that of the bark.

Anaptychia ciliaris, Parmelia acetabulum, P. subargentifera, Physcia pulverulenta, Ramalina fraxinea and *Xanthoria parietina* have curves reminiscent of the *Acer-Fraxinus* curves.

There is thus an interesting difference in the buffer capacity between the species of the *Physodion* federation and those of the *Xanthorion* federation in the investigated material.

Between these two groups there is a transitional group consisting of *Cetraria chlorophylla, Parmelia sulcata* and *Ramalina farinacea.* In this group the buffer capacity against alkali is rather lower than in the *Pinus* bark, and the course of the curve agrees fairly well with the curves of *Quercus-Tilia.*

Three species of moss were investigated in this way. *Tortula ruralis* was most closely associated with the *Acer* group (though there is only one sample!), *Hypnum cupressiforme* and *Leucodon sciuroides* do not fit into any of the groups. Their buffer capacity against acid substances seems to be considerable. In these cases too, however, only one sample of each exists. The mosses generally seem to have a greater buffer capacity against both acid and alkaline substances than have the lichens. This can perhaps be explained by the possibility that the samples contained dust, or by a higher ionic exchange capacity, but the material is too small for further comments.

If we consider finally the group assignment with regard to the distribution pattern (pp. 23 ff.) we find that the species having curves recalling that of *Pinus* largely belong to the groups 1 A and 2 B. The species with a titration curve reminiscent of *Acer* belong to groups 3 and 2 B, while those which have a "*Quercus* curve" largely belong to group 1 B. (*Ramalina farinacea,* however, to 3).

For the lichens in the "*Pinus* group", the pH falls by one-third to two-thirds of a unit with the addition of 1 ml of acid. (In the case of *Cetraria glauca*, by 1 unit.) For the lichens in the "*Acer* group" the addition of 1 ml of acid leads to a reduction in pH of between 1 and 2 units, and for the "*Tilia* group" finally by between half a unit and 1 unit.

Of the investigated species, it is thus with a few exceptions the species having the lowest buffer capacity for acid substances that disappear first when we proceed from the normal area in towards the lichen-free area. The species occurring in the inner part of the transitional zone have the greatest acid buffer capacity.

IV. MORPHOLOGICAL AND PHYSIOLOGICAL CHANGES IN EPIPHYTES AFFECTED BY SULPHUR DIOXIDE

Introduction

The question of the way in which sulphur dioxide affects the physiology of lichens is to some extent outside the scope of this investigation. As there are even a few researchers (Rydzak, Natho, Klement, and others) who doubt whether lichens are appreciably damaged by sulphur dioxide, some experiments were carried out introductorily in order to investigate the matter. It was also thought desirable to be able to study whether any morphological changes occur when lichens are exposed to pollution.

Morphological Changes

In August and September 1963 a simple field experiment was made in a park area immediately south of Uppsala. The questions to be answered were:

1. Are lichens damaged at all by sulphur dioxide?
2. If they are, what is the appearance of the damaged lichens?
3. How long do such lichens remain on the trunks?
4. How long is it before new lichens colonize the bare trunks?

The experiment was made quite simply by allowing sulphur dioxide to leak out of a steel cylinder and mix with the air. The steel cylinder, which contained 50 kg of SO_2, lay on the ground with its valve pointing towards a *Quercus robur* at a distance of 2 metres. During the course of the experiment the grass vegetation surrounding the valve of the cylinder turned yellow.

Attempts to determine immission by taking air samples for analysis failed, partly because the sampling apparatus failed to function satisfactorily. It was at least clear, however, that the effluxion speed was higher at the beginning of the experiment than at the end, and that the content was therefore higher at the beginning than at the end. The weather was fine during the first week of the experimental period, but mist and fog appeared for several days towards the end. When the cylinder was empty, which took about two weeks, the experiment was discontinued. It was originally intended that it should be followed by field experiments carried out under more closely controlled conditions. For economic reasons, however, these further experiments were never carried out. That a report is given on the experiment despite its shortcomings is due to the fact that it produced some interesting results nevertheless.

The only observable damage to vegetation when the experiment was discontinued was the already mentioned damage to the grass vegetation around the upper part of the steel cylinder. However, approximately a month later clear changes had appeared with regard to the epiphytic lichen flora. The lichen vegetation on the nearby trees showed some morbose changes, but was damaged perceptibly only on the "experimental" tree. *Parmelia sulcata* occurring abundantly on *Quercus robur* had acquired a reddish-violet colour which could be seen from a considerable distance. *Parmelia fuliginosa* seemed corroded and was difficult to identify. *Hypogymnia physodes* had whitened but showed no other changes except that clearly observable brown lobe tips had appeared on some examples. The fruticose lichens *Evernia prunastri* and *Ramalina farinacea* had blackened and curled up in their apical parts.

During the winter the lichens dropped off, primarily from the parts of the trunks facing the source of pollution, and by the spring these parts of the trunk in the case of the "experimental" tree were quite bare. Neither the tree nor the bark seemed to have suffered from the experiment. The lichens that disappeared included *Anaptychia ciliaris, Candelaria concolor, Cetraria chlorophylla, Evernia prunastri, Hypogymnia physodes, Parmelia fuliginosa, P. subaurifera, P. sulcata, Phlyctis argena* (discoloured residues remained), *Physcia entheroxantha, Ph. tenella, Ph. pulverulenta, Ramalina farinacea, R. fraxinea, Xanthoria fallax* and *X. parietina.* Four years after the experiment (i.e. in October 1967) no colonization had yet taken place.

In connection with acute damage caused by ac-

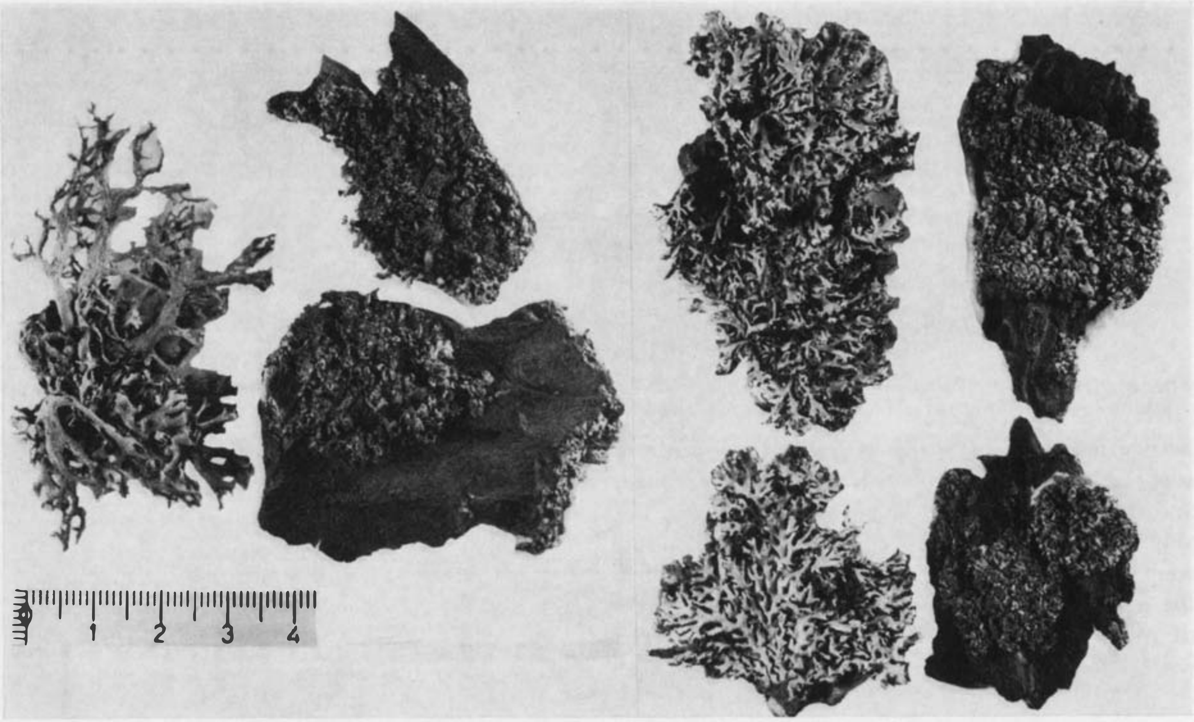


Fig. 109. Pseudevernia furfuracea and *Hypogymnia physodes* from the normal area and the transitional zone in Lundström's investigation.

cidents or errors in industrial establishments I have subsequently observed that *Hypogymnia physodes*, for example, can die and drop off pine bark within a week or so. The thallus loosens first in the distal parts, and the lobes turn outwards at an angle of 90° to the trunk.

Thus no morphological changes apart from the fact that the apical parts of some species blackened and rolled up could be observed in these cases. In the transitional zone of the investigated area, however, morphological changes appear in some species. *Hypogymnia physodes*, for example, turns to a dark steel-grey to greenish-grey in colour, the thallus wrinkles and the thallus edges disappear. In *Parmeliopsis ambigua* and *P. hyperopta* the whole of the thallus is dissolved in soredia. *Pseudevernia furfuracea* becomes strongly isidiose while at the same time the thallus changes from fruticose to almost foliose, i.e. the lobe tips disappear. (See Fig. 109, and Moberg 1966, p. 47.) *Ramalina* and *Evernia* also lose their thallus tips, and frequently nothing remains but some fragments of thallus a centimetre long.

A series of *Parmelia sulcata* from the comparison area and the transitional zone were sectioned and the result showed that the thickness of the lichen thallus changed in the transitional zone. The thallus of *P. sulcata* (in the comparison area) was normally fairly thick, but in the transitional zone it became very thin in certain cases. Moreover, in the samples coming from the comparison area the thickness increased through the fact that the lobe edges were superimposed in several layers, to a far greater extent than in the case of the specimens from the transitional zone. It would be possible to explain this by the fact that the competition in a closed epiphyte vegetation compels the lichens to grow, so to speak, vertically instead of sideways. When the pressure from an individual growing around it lightens, the lichen can grow laterally instead. A comparison between the growing conditions in the transitional zone in Uppsala (Slottsbacken) and the comparison area gives an indication that this would be the case.

The sections also showed that the algal layer in the lichens in the comparison area was in certain cases twice as thick as and greener than in the lichens from the transitional zone. A fairly large number of brown algal cells occurred in the latter. These observations led to the Warburg experiments which were reported in Pearson and Skye (1965, p. 1601).

Chlorophyll determinations with a spectrophotometer were also carried out, both from the comparison area and from Slottsbacken, Uppsala. The intention was to ascertain whether there was any difference in the chlorophyll content between lichens from the comparison area and from the transitional zone. Each sample of lichen was first ground in fine sand in a mortar with 10 ml of acetone, then with 10 ml of ether and further with 5 ml of acetone. The ether-acetone mixture was filtered once and the acetone washed away with the help of distilled water and a separating funnel. About 5 washings sufficed.

The chlorophyll solution was diluted with pure ether to 25 ml and the extinction of the solution thus obtained was measured in a spectrophotometer. A reading was made every tenth nm between the wavelengths 400 and 700 mμ. To obtain comparative figures for the total chlorophyll content, the formulas used were those in Koski (1950, p. 339). In the comparison area, *Hypogymnia physodes* and *Parmelia sulcata* probably have practically equal contents of chlorophyll a, but the values for the latter species seem to vary more than for the former. However, there was no statistically demonstrable difference in the scanty material if a comparison was made between samples from Slottsbacken, Uppsala, and from the comparison area. *Parmelia sulcata* which during the field experiment had been exposed to sulphur dioxide immission was analysed after the end of the experiment and proved to have noticeably lower values than in fresh condition.

How Sulphur Dioxide Affects Green Plants

The harmful effect of sulphur dioxide on green plants has been studied by a very large number of researchers. Reference is made here only to Thomas (1961), Berge (1963), and Garber (1967) and the literature mentioned by these. Various theories have also been advanced.

It has been possible to show, for example, that relatively high contents of sulphur dioxide disturb the plasma movements in the cell. Not infrequently, plasmolysis occurs. The cell content dissolves and forms a more or less homogeneous mass. Changes in colour occur as a result of the fact that chlorophyll etc. are destroyed. The injurious effects on the chlorophylligerous cells increase if there is an increasing supply of light and a constant immission-concentration (Berge 1963, p. 9).

Berge differentiates between indirect or direct chronic effect and acute effect of sulphur dioxide. In the case of chronic effect, according to him, the normal or complete transference of photochemical energy to carbon dioxide is prevented. Berge (l.c., p. 12) says "dass während des Lichtstadiums die photochemische Energie von ihrem normalen Akzeptor Kohlendioxid abgelenkt und zu einem photooxydativen Angriff auf die Chlorophyllfarbstoffe und auch auf das Zellplasma geführt wird". This deflection would be due to ferriferous compounds in the chloroplast being changed by the sulphur dioxide. He gives no indication as to the nature of this change. According to Berge, the acute effect of sulphur dioxide is to be regarded as a direct acid attack on the plasma.

Rao and Le Blanc (1966) show that lichens that have been exposed for 24 hours to 5 ppm of sulphur dioxide develop a long series of divergences from the normal state. It was ascertained for example that the chlorophyll was bleached in the algal cell (*Trebouxia* was the algal symbiont in all experiments), that a permanent plasmolysis appears and that brown spots occur on the chloroplast. These spots were more numerous in lichens that had been exposed to sulphur dioxide at a higher humidity. It is also shown that chlorophyll a decomposes to phaeophytin a according to the formula:

$$\text{Chlorophyll a} + 2\,\text{H}^+ \rightarrow \text{phaeophytin a} + \text{Mg}^{2+}$$

This experiment was repeated for mosses by Coker (1967). He summarizes his investigations as follows: "The destructive effects of sulphur dioxide pollution on epiphytic bryophytes is seen to be due to chlorophyll degradation and the impairment of cell structure and function through plasmolysis".

The supposition made by Pearson and Skye (1965) after having carried out their Warburg experiments, that "Thus some kinds of lichens may be absent from city environments because of atmospheric pollutants which destroy chlorophyll" thus proves to be a well-founded possibility and applies also to epiphytic mosses.

The fact that the hyphae of fungi are also damaged by sulphur dioxide is shown by McCallan and Weedon (1941) and others in a series of laboratory experiments. Scheffer and Hedgcock (1955, p. 10) state that certain fungi on trees had almost entirely disappeared from an area with air pollution, while they were common outside it. The distribution of *Hysterium pulicare* in the Stockholm area is shown in Fig. 62. The species belongs to group 2 B. Saunders (1966) studies *Diplocarpon rosae* Wolf., a fungus causing blackspot on roses, and finds (p. 113) that "The field survey revealed an inverse relationship between atmospheric SO_2 and infection that is also characteristic of the distribution of some lichens around sources of pollution (Gilbert 1965, Skye 1965). Such lichens have been used as indicators of atmospheric pollution (Skye 1965). It may be possible to use *D. rosae* in a similar manner, and the possibilities of control of blackspot by this toxicant may well be worth studying."

In higher plants respiration increases through the effect of sulphur dioxide, and this can lead to a direct stimulation of dissimilation. Transpiration increases in the beginning but then falls back. Osmosis and permeability are affected, and the far-reaching changes in the structure of the protoplasm affect metabolism in the tissues. The hydrogen ion concentration does not change until the later stages during acute SO_2 immission, this being attributed to the cell sap's buffer capacity. The change in pH brings about coagulation of plasma protein. Experiments with water plants (Thomas and co-workers 1943, 1950, quoted by Berge, p. 15) show that the pH of the medium in which the plants live is of importance. The toxicity of the sulphur dioxide is greater, the lower the pH value of the medium.

Another theory concerning the affect of sulphur dioxide on green plants is put forward by Spálený, Kutáček and Oplištilová (1965, pp. 525 ff.). A study was made of the metabolism of $S^{53}O_2$ in the leaves of cauliflower (*Brassica oleracea* v. *botrytis* L.) and it was found that $S^{53}O_2$ was incorporated as an integral part of the glucobrassicin molecule and was not merely present as a result of sulphate group exchange. In the view of these writers there is therefore reason to assume that sulphur dioxide in polluted air may enter the plants and be incorporated into thioglycosides. It is also said that "Some of the degradation products of such thioglycosides are strongly anti-thyroid and goitrogenic". It is of great interest in this connection that "Some of these breakdown products are known for their bactericidal, fungicidal or herbicidal effect, and may be important in understanding the mechanism of the toxic effect of SO_2 on plants" (l.c., p. 525).

Obviously no full inquiry has yet been made into what goes on in the plant.

Physiological Changes in Lichens and Mosses

Smith (1960, p. 183) says "If *Peltigera* and other lichens possess strong powers of absorption under natural conditions, and if it proves to be generally the case that absorbed substances are utilized at a slow rate, this would suggest certain features about the biology of lichens in nature". As lichens lack special absorption organs, presumably the absorption of nutrients from a water solution takes place over the whole surface of the thallus. The slow rate of utilization of the nutrients is regarded by Smith as a necessary adaptation to enable the lichen to survive long periods of starvation. Smith also points out (l.c., p. 184) that "It is possible that the marked sensitivity of lichens and other epiphytes to atmospheric pollution may be due partly to the possession of highly efficient mechanisms for accumulating substances from very dilute solutions, and partly to the fact that these plants have to rely almost entirely for nutrients on substances carried down in the rainfall from above." He also believes that a similar explanation can be given of the circumstance noted by Gorham (1959) that mosses and lichens accumulate more radioactive substances than angiospermae. (See also Brodo 1964.)

Gilbert (1965, p. 43) shows that the sulphur content of *Parmelia saxatilis* growing on sandstone was 2870 ppm (as S) at a distance of 6 km from the centre of pollution, that at a distance of 14 km the quantity was 695 ppm and that at a distance of 34 km it was 225 ppm. *Parmelia saxatilis* thus contains considerably greater quantities of sulphur in the immediate surroundings of the city than farther away. In the whole profile, the quantities are substantially higher than the species can conceivably need for its metabolism. Physiological activity in the lichen thallus is, as has previously been pointed out, dependent upon a relatively high water content (see also Smith 1962, p. 548), Gilbert (l.c.) considers that this also means that the longer a lichen thallus is moist, the more time the lichen has to oxidize sulphur dioxide to less toxic forms. "By favouring the damper habitats in polluted areas, the lichens will dry out more slowly and be capable of carrying on the conversion for a longer period" (Gilbert 1965, p. 43). It would be reasonable to assume that lichens having a relatively large and rapid water-absorptivity absorb more pollutants than other lichens. If such polutants then accumulate in the thallus (see Smith 1962, p. 549) and if the loss of water is also rapid (see Fig. 110) the lichen thallus, if this theory is really correct, will receive greater quantities of toxic substances than a lichen thallus with slower water-absorptivity and water loss. According to my measurements, the lianoid lichens correspond to the first-mentioned type, while many foliose lichens are more likely to belong to the second category. As previously pointed out, the lichens are active even during a part of the year when the content of pollution in the city air is very high.

Why Lichens?

Is there any reasonable explanation why lichens in particular should be more sensitive to air pollution

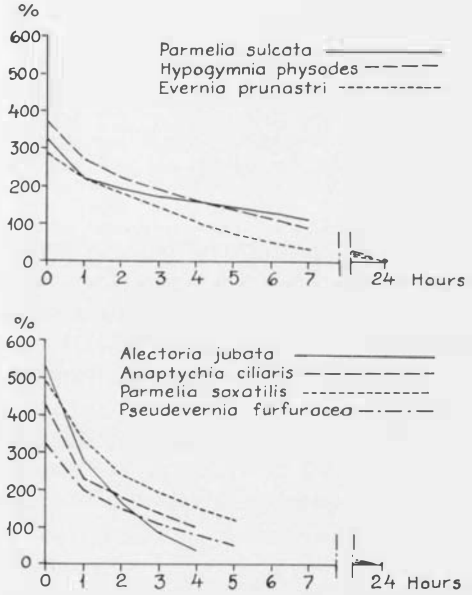


Fig. 110. Some epiphyte lichens' water-absorptive capacity. The curves show that the life form is important for the water economy (note, however, that the material is scanty).

than other plants? In the central parts of Stockholm aerial algae, for instance, grow on all tree trunks if the moisture conditions are suitable. Nevertheless Rao and Le Blanc, for example, assert that it is precisely the algal layer in the lichen that is damaged.

The answer to the question is perhaps to be found in the special living-conditions of the lichens. Smith (1964, p. 249) summarizes the results of his experiments on the nutrition of lichens as follows:

(*a*) "The fact that they live in barren habitats has meant that they have evolved highly efficient mechanisms for nutrient absorption."

(*b*) "They have evolved slow rates of growth so as not to outstrip their nutrient supplies, and so that . . . they can store up food when it is available . . ."

Moreover, for lichens the autumn and spring are the most favourable periods—partly because of the humidity conditions—while summer is sometimes not so favourable. The lichens are thus at their most active when the air pollution is great.

It is primarily in the algal layer that the metabolic activity is at its greatest. The algal layer has also, compared with the medulla, more efficient mechanisms for absorbing nutrients. The medulla, on the other hand, can hold more water and may according to Smith (l.c., p. 250) function as a region of storage. Smith (1960), as mentioned on p. 115, has expressed certain views on the sensitivity of lichens to air pollution.

Drew and Smith (1966) show that *Nostoc* in *Peltigera polydactyla* produces glucose in photosynthesis, and that this leaks rapidly out of the cells and is then absorbed by the fungus. Many other species with blue-green phycobionts may conform to this pattern (l.c., p. 201). Richardson and Smith (1966) examined *Xanthoria aureola* and found that the carbon fixed in photosynthesis by *Trebouxia* moves from alga to fungus mainly in the form of ribitol (l.c., p. 203). In both cases the photosynthetic product was converted into mannitol by the fungus. This substance then accumulates in the thallus. When the phycobiont is directly isolated from the thallus, carbohydrate leaks out of the cells, but it diminishes after a period in culture. The *Nostoc* phycobiont then bears a closer resemblance to cultures of free-living *Nostoc muscorum.* I believe that these experiments show that the alga in the lichen thallus has quite a different communication with its environment than the free-living alga. Its protection against injurious substances which for example are stored in the medulla is considerably less than the protection that the free-living aerial algae have against harmful substances in the air and rainwater. If the degradation products then acquire a fungicidal effect because of the occurrence of sulphur dioxide, injury is caused to both the algal and the fungal component. Saunders' investigation shows that sulphur dioxide as such is harmful to certain fungi and can thus conceivably injure the fungal component direct.

The investigations made by the present author in Stockholm show also that acidification of the substrate finally makes it impossible for the *Xanthorion* federation species to live there. Whether the species of the *Physodion* federation will primarily have to yield because of acidification or because of the toxic effect of sulphur dioxide, has not yet been investigated in full.

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TABULAR APPENDIX

(Tables I–XIV)

Square 1

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
214	6	63	U	1	5	112	010	280	-	-	0
215	6	63	Ae	1	3-4	112	030	389	-	1	1
335	11	63	F	1	3-4	122	020	260	2	15	3
336	11	63	T	1	7	112	032	160	3	29	3
362	6	64	F	1	6	122	040	000	4	14	2
363	6	64	T	1	3-4	111	040	217	-	4	1
364	6	64	A	1	3-4	111	041	110	-	-	0
376	6	64	F	1	5	111	020	350	6	21	3
377	6	64	T	2	3-4	212	022	130	-	11	1
378	6	64	U	1	5	122	0[+]40	159	-	8	1
379	6	64	Q	1	3-4	111	040	129	3	10	2
380	6	64	F	1	6	122	120	347	3	21	2
381	6	64	O	1	3-4	111	031	230	-	15	2
382	6	64	Q	1	3-4	121	032	259	-	7	2
411	8	64	U	1	5	111	032	150	-	12	2
515	9	64	A	1	3-4	111	030	132	-	12	2
519	9	64	U	1	3-4	111	020	297	4	26	3
520	9	64	A	1	6	112	021	139	1	22	2
573	9	65	A	1	5	111	140	007	2	20	2
574	9	65	A	1	5	111	040	186	1	17	2
593	6	66	F	1	5	122	000	284	4	20	3
594	6	66	A	1	7	111	030	115	2	26	2
597	6	66	T	1	5	111	030	179	2	29	3
598	6	66	T	1	3-4	111	020	259	1	3	1
599	6	66	F	1	3-4	121	030	209	3	27	3
600	6	66	Q	1	3-4	111	020	150	1	15	2
601	6	66	F	1	5	121	130	186	4	17	2

[+] earlier 1.

Square 2

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
338	6	64	Q	1	5	121	010	144	-	4	1
339	6	64	Al	1	3-4	112	0[+]10	199	-	6	2
340	6	64	Q	1	5	111	010	000	-	3	1
341	6	64	Q	1	3	111	030	378	-	5	1
342	6	64	Al	1	3-4	122	040	289	-	3	1
343	6	64	Q	1	6	122	000	289	-	2	1
344	6	64	Q	1	7	121	020	000	-	5	1
345	6	64	U	1	6	111	12[++]0	180	-	1	1
347	6	64	Q	1	3-4	111	000	260	-	-	0
349	6	64	Al	2	3-4	121	040	290	-	5	2
360	6	64	A	1	6	111	020	360	1	9	1
361	6	64	U	1	5	111	020	159	2	3	1
365	6	64	A	1	3-4	111	021	169	-	-	0
366	6	64	Ae	1	6	111	022	140	-	-	0
372	6	64	A	1	4	111	010	003	4	10	2
373a	6	64	Pi	1	6	121	000	244	1	3	1
373b	6	64	T	1	7	111	020	236	1	12	2
374	6	64	A	1	6	121	030	130	2	12	2
375	6	64	F	1	5	111	031	157	-	16	2
438	9	64	A	1	6	111	010	350	-	16	2
439	9	64	T	1	6	111	030	259	-	-	0
441	9	64	T	1	6	112	020	139	-	4	1
467	9	64	A	1	4	111	010	170	-	8	2
468	9	64	T	1	6	111	020	100	-	7	2
469	9	64	F	1	5	121	030	010	-	10	2
470	9	64	Pi	1	5	122	000	387	-	3	1
471	9	64	Q	1	3-4	111	030	158	1	10	2
472	9	64	A	1	6	111	020	169	2	17	2
511	9	64	F	1	3-4	112	000	388	1	5	1
516	9	64	Po	1	5	121	030	160	-	16	2
517	9	64	Q	1	7	121	030	389	2	15	2
518	9	64	T	1	6	111	010	149	5	21	2
525	9	64	A	1	3-4	111	022	276	1	14	2
580	5	66	F	1	3	121	003	009	1	13	2
581	5	66	A	1	6	111	030	157	4	7	2
582	5	66	F	1	5	111	030	157	5	20	2
595	6	66	Q	1	6	111	010[+++]	300	1	22	2
596	6	66	U	1	5	111	032	000	-	20	2

[+] earlier 1 [++] the crown is hanging [+++] earlier 3

Square 3

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
509	9	64	A	1	6	121	110	289	3	19	2
510	9	64	F	1	6	122	000	379	4	13	2
512	9	64	A	1	3-4	111	010	165	-	3	1
527	9	64	T	1	5	111	031	005	2	22	2
528	9	64	Q	1	6	121	030	000	2	17	2
529	9	64	A	1	5	111	120	269	1	13	2
530	9	64	Ae	1	5	121	040	180	-	8	1
531	9	64	F	1	6	121	010	000	1	23	3
532	9	64	F	1	6	111	020	009	1	10	1
533	9	64	F	1	3-4	121	030	299	1	15	2
535	10	64	F	1	6	121	110	299	6	17	2
542	10	64	F	1	5	121	000	387	3	17	2
543	10	64	F	1	6	111	010	318	3	19	2
544	10	64	T	1	6	111	010	169	1	15	2
545	10	64	F	1	6	121	010	130	2	19	3
546	10	64	F	1	6	111	031	117	1	23	2
547	10	64	A	1	6	111	130	008	5	33	3
548	10	64	F	1	6	111	020	130	4	29	3
549	10	64	F	1	6	121	010	009	4	21	3
550	10	64	U	1	5	121	020	238	-	26	2
576a	5	66	U	1	6	112	030	153	5	24	3
576b	5	66	B	1	5	122	022	140	2	19	3
577a	5	66	U	1	6	111	032	308	4	36	3
577b	5	66	B	1	5	111	030	367	1	13	3
578	5	66	F	3	2,-3	121	040	209	3	25	2
579	5	66	F	1	5	122	010	164	2	20	3

Square 4

125	9	62	Pi	1	5	122	200	470	1	7	2
126	9	62	Pa	1	5	112	040	477	1	5	1
127	9	62	B	1	3-4	121	030	475	1	7	1
128	9	62	Pi	1	3-4	122	010	270	-	6	1
129	9	62	Q	1	1	221	040	289	1	12	2
130	9	62	B	1	5	111	000	469	4	6	1
131	9	62	Pi	1	3-4	122	001	460	-	6	2
132	9	62	F	1	7	121	110	010	3	18	2
133	9	62	Q	1	3	111	040	269	2	14	2
134	9	62	Q	1	3-4	112	040	379	-	-	-
206	6	63	A	1	5	111	110	159	-	2	1
207	6	63	Po	1	6	112	130	198	-	3	1
208	6	63	Q	1	7	121	030	150	1	9	2
209	6	63	F	1	7	121	030	253	1	7	1
210	6	63	Q	1	5	111	030	398	-	-	-
211	6	63	Q	1	5	121	020	315	-	3	1
212	6	63	Q	1	5	111	020	278	-	4	1
213	6	63	Po	1	5	112	031	298	-	2	1
407	8	64	Q	2	3-4	111	040	390	-	3	1
408	8	64	Q	1	3-4	111	040	264	-	3	1
409	8	64	A	1	5	111	141	109	1	16	2
410	8	64	U	1	5	121	030	264	-	17	2
412	8	64	T	1	5	111	020	350	4	11	2
421	9	64	U	1	5	121	020	118	-	12	2
422	9	64	F	1	6	121	010	383	-	15	2
423	9	64	Q	1	6	111	020	000	-	6	1
424	9	64	A	1	5	112	120	376	2	10	2
					6	111	220	158	-	12	2
425	9	64	A	2							
					6	111	200	158	-	21	3
426	9	64	U	1	6	111	100	380	4	29	3
427	9	64	F	1	6	121	100	360	6	18	2
451	9	64	U	1	3-4	212	030	234	3	6	1
521	9	64	A	1	5	121	020	269	2	27	3
522	9	64	F	1	5	121	121	279	2	25	3

Square 5 A

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
28	6	62	U	2	3-4	111	010	260	-	-	0
29	6	62	B	1	5	111	010	264	-	2	1
30	6	62	A	1	3	121	020	160	-	-	0
56	6	62	Q	1	5	111	030	205	-	1	1
59	6	62	Q	1	7	111	010	000	-	-	0
60	6	62	Q	1	7	221	010	107	-	1	1
61	6	62	U	1	3-4	121	140	204	-	1	1
62	6	62	Q	1	6	111	041	204	-	-	0
63	6	62	Q	1	6	111	030	300	1	7	1
64	6	62	Pi	1	5	121	201	267	-	4	1
65	6	62	U	1	5	111	030	249	-	-	0
66	6	62	A	1	3-4	111	110	260	-	3	1
67	6	62	Q	2	6	111	042	360	-	-	0
83	8	62	Po	1	3-4	112	000	042	-	-	0
84	8	62	Pi	1	6	121	001	264	-	1	1
85	8	62	U	1	2	211	030	399	1	5	1
86	8	62	Pi	1	5	121	021	346	-	-	0
87	8	62	Q	1	5	112	040	335	-	-	0
88	8	62	U	1	5	111	040	104	-	-	0
89	8	62	T	1	3-4	112	020	170	-	-	0
90	8	62	U	1	3-4	111	130	168	-	-	0
136	9	62	F	1	5	111	020	00^{+}8	-	-	0
137	9	62	Ae	1	3-4	111	040	069	-	1	1
138	9	62	Q	1	7	122	020	000	-	4	1
139	9	62	Q	1	7	121	030	030	1	2	1
140	9	62	Q	1	5	121	040	317	-	4	1
141	9	62	Al	1	3-4	122	020	140	-	2	1
142	9	62	S	1	3-4	122	200	177	-	8	1
261	7	63	A	1	3	111	011	286	-	1	1
321	8	63	Q	1	3	111	040	100	-	-	0
322	8	63	Pi	1	5	122	000	265	-	-	0
323	8	63	Pi	1	5	222	000	240	-	-	0
324	8	63	F	1	6	122	030	144	-	2	1
327a	8	63	U	1	6	111	020	133	-	1	1
327b	8	63	S	1	6	121	220	140	-	6	1
328	8	63	T	1	6	111	010	170	-	-	0
329	8	63	A	1	5	111	010	015	-	-	0
330	8	63	U	2	3	121	041	000	-	-	0
331	8	63	T	1	7	111	020	350	-	1	1
332	8	63	A	1	3-4	111	020	101	-	-	0
333	8	63	F	1	6	122	010	386	-	-	0
334	8	63	A	1	5	121	120	300	-	2	1
355	6	64	U	1	7	111	130	000	-	2	1
356	6	64	Q	1	3-4	121	030	230	-	3	1
367	6	64	Q	1	6	121	012	184	-	2	1
368	6	64	T	1	6	111	010	159	-	-	0
369	6	64	T	1	6	122	010	369	-	2	1
370	6	64	T	1	6	122	020	149	-	4	1
371	6	64	T	1	7	212	032	100	-	1	1
413	8	64	Q	1	5	121	020	275	-	2	1
414	8	64	U	1	5	111	040	199	-	1	1

$^{+}$ earlier 4

Square 5 B

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
19	6	62	T	1	5	111	021	224	-	-	0
20	6	62	T	1	5	111	011	342	-	-	0
21	6	62	U	1	5	111	020	247	-	-	0
25	6	62	T	2	3-4	111	030	260	-	-	0
26	6	62	A	1	3-4	111	030	260	-	1	1
27	6	62	Pi	1	3	121	000	286	-	-	0
31	6	62	Ae	1	5	111	020	106	-	-	0
32	6	62	A	1	5	111	010	119	-	-	0
33	6	62	Q	1	6	111	010	118	-	-	0
37	6	62	T	1	5	222	030	200	-	-	0
38	6	62	T	1	5	112	020	240	-	-	0
39	6	62	U	2	6	111	010	220	-	-	0
40	6	62	Ae	2	3-4	111	030	100	-	-	0
41	6	62	Q	1	6	111	031	230	-	-	0
42	6	62	A	1	3-4	111	020	270	-	-	0
43	6	62	Ae	2	5 ,3-4	111	010	360	-	-	0
44	6	62	U	2	5	121	020 010	356	-	-	0
45	6	62	T	2	5	111	030	360	-	-	0
46	6	62	Ae	1	3-4	121	030	265	-	-	0
47	6	62	Ae	2	5	111	030	247	-	-	0
51	6	62	U	2	3	111	041	117	-	-	0
52	6	62	F	2	3-4	121	040 030	189	-	-	0
93	8	62	T	1	5	111	030	200	-	-	0
94	8	62	Ae	1	6	111	020	238	-	-	0
95	8	62	A	1	5	111	030	213	-	-	0
96	8	62	T	1	3-4	111	020	230	-	-	0
97	8	62	T	1	3-4	111	020	210	-	-	0
98	8	62	A	1	6	111	020	070	-	-	0
99	8	62	T	1	3-4	111	041	310	-	-	0
100	8	62	U	1	6	121	021	365	-	1	1
101	8	62	A	1	3-4	211	031	360	-	-	0
102	8	62	A	1	6	111	040	320	-	-	0
103	8	62	T	1	6	111	020	350	-	-	0
104	8	62	T	1	3-4	111	020	250	-	-	0
105	8	62	U	1	6	111	040	250	-	-	0
106	8	62	U	1	4	121	020	240	-	-	0
107	8	62	U	1	5	111	030	360	-	-	0
108	8	62	U	1	3-4	111	030	374	-	-	0
109	8	62	F	1	3-4	122	010	360	-	1	1
110	8	62	U	1	5	111	030	339	-	-	0
111	8	62	U	1	6	111	010	257	-	-	0
112	8	62	U	1	5	121	020	296	-	-	0
113	8	62	Ae	1	6	111	030	250	-	-	0
114	9	62	T	1	7	212	040	169	-	-	0
115	9	62	F	1	3-4	122	040	386	-	1	1
116	9	62	B	1	6	122	210	379	6	6	1
117	9	62	F	1	3-4	121	010	299	-	2	1
118	9	62	F	1	5	112	210	150	-	2	1
119	9	62	A	1	3-4	111	020	285	-	2	1
120	9	62	Al	1	5	111	1^{+}20	299	-	2	1
121	9	62	A	1	3-4	111	010	240	1	7	1
122	9	62	U	1	6	121	010	230	-	5	1
123	9	62	A	3	3-4	112	200	350	2	15	2
124	9	62	U	1	6	111	040	286	1	1	1
135	9	62	F	1	6	121	040	059	-	-	0
150	5	63	F	1	5	121	010	211	-	-	0
151	5	63	A	1	5	111	120	210	-	-	0
152	5	63	T	1	5	111	030	210	-	-	0
153	5	63	A	1	5	111	010	240	-	-	0
154	5	63	T	1	3-4	111	021	100	-	-	0
155	5	63	T	1	5	111	021	113	-	-	0

$^{+}$ The trunk is divided into two

5 B (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
156	5	63	U	1	6	111	000	105	-	-	0
157	5	63	U	1	6	111	000	104	-	-	0
158	5	63	A	1	5	111	031	350	-	-	0
159	5	63	A.p.	1	3-4	111	022	261	-	-	0
160	5	63	A.p.	1	3-4	112	022	241	-	-	0
161	5	63	T	1	3-4	111	031	270	-	-	0
162	5	63	U	1	5	111	021	297	-	-	0
163	6	63	U	1	5	111	131	380	-	-	0
164	6	63	Q	1	3-4	111	012	362	-	-	0
165	6	63	Ae	1	3-4	111	030	200	-	-	0
166	6	63	Ae	1	3-4	111	020	244	-	-	0
167	6	63	Ae	1	3-4	112	030	207	-	-	0
168	6	63	T	1	5	112	110	200	-	-	0
169	6	63	Po	2	6	112	032	160	-	-	0
170	6	63	U	1	3-4	122	030	398	-	-	0
171	6	63	U	1	6	111	020	346	-	-	0
172	6	63	Po	1	6	112	031	100	-	-	0
173	6	63	Ae	1	3-4	111	010	247	-	-	0
174	6	63	U	1	6	111	010	100	-	-	0
175	6	63	U	1	3-4	111	032	000	-	1	1
176	6	63	T	1	5	111	010	020	-	-	0
177	6	63	A.p.	1	6	111	020	010	-	-	0
178	6	63	Ae	1	6	-	031	010	-	-	0
179	6	63	Po	1	6	112	031	010	-	-	0
254	7	63	Pi	1	5	222	010	254	-	-	0
255	7	63	F	1	5	111	010	260	-	2	1
256	7	63	Pi	1	5	222	002	283	-	-	0
257	7	63	A	1	7	111	030	200	-	3	1
258	7	63	F	2	3-4	121	032	240	-	2	1
259	7	63	U	1	6	111	030	307	-	3	1
260	7	63	Q	1	3	121	040	343	-	1	1
325	8	63	S	1	6	111	210	110	-	1	1
326	8	63	Ae	1	5	112	031	110	-	-	0
348	6	64	T	1	3-4	111	040	119	-	4	1
350	6	64	A.p.	1	3-4	111	040	359	-	4	1
351	6	64	Ae	1	3-4	111	040	364	-	1	1
352	6	64	U	1	6	121	000	343	-	11	2
353	6	64	T	1	6	112	000	269	-	8	1
354	6	64	T	1	6	111	000	282	-	4	1
357	6	64	A	1	3-4	121	020	244	-	13	2
358	6	64	T	1	4	111	000	266	-	4	1
359	6	64	T	1	6	111	000	267	-	3	1
440	9	64	A	1	6	111	011	230	-	8	1
499	9	64	T	1	6	111	020	260	-	1	1
500	9	64	A	1	5	111	030	264	-	3	1
501	9	64	Ae	1	6	112	020	150	-	-	0
502	9	64	A	1	5	212	030	170	-	2	1
503	9	64	A	1	6	121	000	269	-	-	0
504	9	64	A	1	5	122	010	275	-	-	0
505	9	64	A	1	3	121	020	209	-	-	0
506	9	64	A	1	3-4	111	030	350	-	1	1

Square 5 C

1	6	62	S	1	6	121	010	214	-	-	0
2	6	62	S	1	6	121	230	210	-	-	0
3	6	62	T	2	3	212	012	270	-	-	0
4	6	62	T	2	3	212	012	260	-	-	0
5	6	62	T	2	3-4	112	012	360	-	-	0
6	6	62	T	2	3-4	212	020	150	-	-	0
12	6	62	A	1	6	111	110	210	-	-	0
13	6	62	U	1	6	111	021	263	-	-	0
14	6	62	T	1	6	112	010	218	-	-	0
15	6	62	U	1	3-4	111	010	247	-	-	0
16	6	62	U	1	6	121	011	330	-	-	0
17	6	62	T	1	5	112	030	240	-	-	0
18	6	62	A	1	6	111	110	230	-	-	0

5 C (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
143	5	63	A	1	6	111	120	218	-	-	0
144	5	63	Q	1	5	111	010	260	-	-	0
145	5	63	A	1	6	111	110	368	-	-	0
146	5	63	F	1	6	121	020	364	-	-	0
147	5	63	Ae	1	3-4	121	031	300	-	-	0
148	5	63	T	1	6	111	000	300	-	-	0
149	5	63	U	1	6	121	020	330	-	-	0
189	6	63	S	1	6	121	030	100	-	-	0
190	6	63	T	1	5	212	020	117	-	-	0
191	6	63	T	1	4	111	030	130	-	-	0
192	6	63	T	1	4	212	010	140	-	-	0
193	6	63	Ae	1	5	111	030	250	-	-	0
194	6	63	T	1	6	111	020	116	-	-	0
195	6	63	U	1	5	111	010	147	-	-	0
196	6	63	U	1	5	111	010	150	-	-	0
197	6	63	Po	1	6	112	130	157	-	-	0
198	6	63	T	1	5	111	012	180	-	-	0
199	6	63	A	1	6	111	030	210	-	1	1
200	6	63	T	1	5	212	010	220	-	-	0
201	6	63	T	1	5	211	010	120	-	-	0
281	8	63	T	1	5	111	04^{+}0	305	-	-	0
282	8	63	T	1	5	212	020	150	-	-	0
283	8	63	Q	1	6	121	030	230	-	-	0
284	8	63	Po	1	6	121	021	110	-	-	0
285	8	63	Q	1	6	121	020	310	-	2	1
286	8	63	Q	1	6	121	020	260	-	2	1
287	8	63	Q	1	3-4	122	020	264	-	-	0
288	8	63	Q	1	5	121	030	200	-	2	1
289	8	63	A	1	3	111	040	170	-	-	0
290	8	63	U	1	6	111	130	140	-	-	0
291	8	63	U	1	5	111	020	145	-	1	1
292	8	63	A	1	3-4	112	020	107	-	1	1
293	8	63	Ae	1	3-4	222	030	160	-	-	0
294	8	63	Ae	1	3-4	222	030	160	-	-	0
295	8	63	T	1	3	111	020	100	-	-	0
296	8	63	T	1	3-4	111	031	130	-	-	0
297	8	63	T	1	3-4	111	020	110	-	-	0
298	8	63	T	1	3-4	111	020	110	-	-	0
299	8	63	Q	1	6	121	020	360	-	1	1
300	8	63	T	1	5	212	020	150	-	-	0
346	6	64	A	1	3	111	040	180	-	-	0
393	7	64	A	1	5	111	040	370	-	-	0
507	9	64	Q	1	5	122	142	000	-	1	1

$^{+}$The lower branches hanging

Square 5 D

53	6	62	Q	1	3-4	111	020	200	-	-	0
54	6	62	Pi	3	3-4	121	011	300	-	-	0
55	6	62	Pi	2	3-4	122	000	388	-	-	0
57	6	62	Q	2	3-4	111	010	370	-	-	0
58	6	62	Pi	3	6	121	010	380	-	-	0
68	6	62	Q	3	5	111	030	394	-	1	1
69	6	62	U	1	3-4	121	141	009	-	1	1
70	8	62	Q	2	6	111	030	000	-	1	1
71	8	62	Q	1	6	111	010	000	-	-	0
72	8	62	Q	1	6	121	140	007	-	-	0
73	8	62	F	1	3-4	-	0-2	299	-	12	2
74	8	62	U	1	6	112	130	366	2	14	2
75	8	62	A	1	6	111	000	386	2	7	1
76	8	62	U	1	6	121	040	364	-	6	1
77	8	62	F	1	6	111	021	388	1	4	1
91	8	62	S	1	5	121	020	100	-	7	1
92	8	62	S	1	5	121	030	057	-	8	1
383	6	64	Q	1	6	121	022	377	1	22	2
384	6	64	Q	1	3	121	240	350	-	2	1

5 D (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
385	6	64	T	1	4	111	$02^{+}2$	309	-	-	0
386	6	64	Q	1	6	111	001	188	-	6	1
387	6	64	Q	1	6	121	020	111	-	4	1
388	6	64	Q	1	3-4	121	020	290	-	4	1
389	6	64	Q	1	5	112	010	170	-	-	0
390	6	64	A	1	3	111	020	000	-	-	0
391	6	64	U	1	6	111	020	236	-	-	0
392	6	64	A	1	3-4	111	010	180	-	1	1
420	9	64	A	1	3-4	111	130	229	-	4	1
429	9	64	U	1	5	121	040	259	-	-	0
430	9	64	Q	1	6	121	010	270	-	1	1
431	9	64	Q	1	7	111	000	209	-	5	1
433	9	64	A	1	6	121	110	190	-	-	0
434	9	64	Q	1	6	111	011	290	-	2	1
450	9	64	T	1	6	111	012	001	-	-	0
456	9	64	A	1	4	111	031	160	-	6	1

+ the lower branches hanging

Square 5 E

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
9	6	62	Po	1	6	221	240	100	-	1	1
22	6	62	T	1	3-4	212	030	147	-	-	0
23	6	62	T	1	3-4	212	030	145	-	-	0
24	6	62	T	2	3-4	111	011	250	-	-	0
34	6	62	T	4	6	111	020	168	-	-	0
35	6	62	Po	4	6	112	040	156	-	-	0
36	6	62	T	2	3-4	212	030	260	-	-	0
48	6	62	T	1	3-4	122	011	237	-	-	0
49	6	62	U	1	4	121	130	330	-	-	0
50	6	62	T	2	6	111	000	320	-	-	0
78	8	62	A	1	3	111	020	396	-	-	0
79	8	62	Al	2	6	111	010	380	-	1	1
80	8	62	S	1	6	221	021	300	2	6	1
81	8	62	U	4	5	111	040	300	-	-	0
82	8	62	U	2	3-4	111	020	280	-	-	0
203	6	63	A	1	5	111	100	105	-	-	0
204	6	63	T	1	6	111	030	153	-	-	0
205	6	63	U	1	6	111	010	158	-	-	0
233	6	63	U	1	6	111	000	277	-	-	0
234	6	63	T	1	5	112	010	273	-	-	0
235	6	63	T	1	6	111	030	270	-	-	0
236	6	63	U	1	6	111	120	264	-	-	0
237	6	63	T	1	4	212	010	215	-	-	0
238	6	63	T	1	4	212	010	259	-	-	0
239	6	63	T	1	5	212	031	209	-	-	0
240	6	63	U	1	5	111	130	358	-	1	1
241	6	63	Po	1	6	222	040	000	-	-	0
242	6	63	T	1	6	212	130	275	-	-	0
243	6	63	U	1	6	111	000	194	-	-	0
244	7	63	A	1	6	111	011	000	-	1	1
245	7	63	U	1	6	111	011	274	-	-	0
246	7	63	U	1	5	112	002	240	-	1	1
247	7	63	U	1	3-4	111	020	279	-	-	0
248	7	63	F	1	6	121	000	217	-	1	1
249	7	63	U	1	6	111	130	242	-	-	0
250	7	63	U	1	5	111	020	237	-	-	0
251	7	63	F	1	5	121	020	399	-	-	0
252	7	63	F	1	7	121	012	389	-	5	1
253	7	63	F	1	7	111	011	006	-	-	0
277	7	63	A	1	6	111	030	362	-	3	1
280	7	63	U	1	6	122	031	396	-	-	0
301	8	63	T	1	4-5	111	$01^{+}0$	266	-	1	1
302	8	63	T	1	5	111	010	366	-	1	1
303	8	63	F	1	6	121	012	355	-	4	1
304	8	63	U	1	6	111	042	250	-	-	0
305	8	63	F	1	6	111	010	208	-	-	0
306	8	63	A	1	5	111	010	260	-	1	1

5 E (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
307	8	63	A	1	6	111	020	217	-	1	1
308	8	63	A	1	5	111	030	370	-	1	1
309	8	63	U	1	6	111	021	000	-	-	0
310	8	63	T	1	5	112	020	178	-	-	0
311	8	63	T	1	6	112	031	179	-	-	0
312	8	63	U	1	6	111	120	005	-	1	1
313	8	63	A	1	3-4	111	$2^{++}01$	116	-	1	1
314	8	63	F	1	5	121	020	130	-	-	0
315	8	63	T	1	6	111	241	019	-	-	0
316	8	63	U	1	5	111	010	170	-	-	0
317	8	63	A	1	3-4	111	040	365	-	-	0
318	8	63	U	1	5	111	230	385	-	1	1
319	8	63	F	1	5	121	100	397	-	-	0
320	8	63	S	1	6	121	220	199	-	6	1
428	9	64	U	1	5	212	140	000	-	-	0
432	9	64	A	1	7	111	020	110	-	-	0
435	9	64	A	1	6	111	040	369	-	2	1
466	9	64	U	1	6	111	022	149	-	-	0

+ the lower branches hanging ++ the trunk divided into two

Square 5 F

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
7	6	62	T	2	5	212	000	150	-	-	0
8	6	62	U	1	6	111	011	120	-	-	0
10	6	62	T	2	5	112	030	100	-	-	0
11	6	62	Ae	1	3-4	112	020	139	-	-	0
180	6	63	A	1	6	111	020	210	-	-	0
181	6	63	A	1	6	121	120	240	-	1	1
182	6	63	A	1	5	111	030	360	-	1	1
183	6	63	Ae	1	6	111	020	250	-	-	0
184	6	63	T	1	4	111	032	210	-	1	1
185	6	63	U	1	7	112	130	240	-	1	1
186	6	63	F	1	5	121	010	360	-	1	1
187	6	63	A	1	5	112	200	360	-	5	2
188	6	63	A	1	6	111	020	280	-	-	0
202	6	63	T	1	6	111	022	360	-	-	0
216	6	63	T	1	6	111	030	217	-	-	0
217	6	63	A	1	4	111	020	280	-	-	0
218	6	63	U	1	5	111	120	000	-	1	1
219	6	63	Ae	1	6	111	030	369	-	-	0
220	6	63	T	1	6	111	031	360	-	-	0
221	6	63	A	1	6	111	210	240	-	-	0
222	6	63	S	1	6	121	210	260	-	1	1
223	6	63	U	1	5	121	020	100	-	-	0
224	6	63	Ae	1	4	111	020	160	-	-	0
225	6	63	T	1	3-4	111	020	316	-	-	0
226	6	63	A	1	5	111	022	305	-	-	0
227	6	63	U	1	3-4	121	041	280	-	1	1
228	6	63	T	1	6	111	101	200	-	-	0
229	6	63	A	1	5	111	030	210	-	-	0
230	6	63	A	1	6	111	030	300	-	1	1
231	6	63	F	1	3-4	121	021	209	-	1	1
232	6	63	T	1	4	111	020	246	-	1	1
262	7	63	Ae	1	3-4	111	020	142	-	-	0
263	7	63	A	1	6	111	020	108	-	-	0
264	7	63	Ae	1	5	111	041	260	-	-	0
265	7	63	U	1	3	111	030	393	-	-	0
266	7	63	F	1	3-4	121	020	360	-	-	0
267	7	63	A	1	3-4	111	020	350	-	-	0
268	7	63	A	1	3-4	111	020	360	-	-	0
269	7	63	A	1	5	112	021	215	-	1	1
270	7	63	Ae	1	3-4	111	030	268	-	-	0
271	7	63	Ae	1	3-4	221	032	275	-	-	0
272	7	63	F	1	5	111	020	338	-	1	1
273	7	63	A	1	7	111	001	302	-	2	1
274	7	63	U	1	5	111	021	299	-	-	0
275	7	63	U	1	5	111	031	113	-	-	0

5 F (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
276	7	63	A	1	6	121	010	110	-	1	1
278	7	63	U	1	6	111	120	370	-	1	1
279	7	63	A	1	4	111	010	389	-	-	0
337	3	64	Q	1	3-4	111	020	346	-	2	1
394	7	64	Ae	1	5	111	020	155	-	-	0
395	7	64	U	1	6	121	010	160	-	3	1
396	7	64	Po	1	7	112	200	270	-	2	1
397	7	64	B	1	5	122	000	369	-	4	1
398	7	64	Q	1	7	112	010	360	4	8	2
399	7	64	A	1	5	111	010	341	-	6	1
403	7	64	A	1	3-4	121	140	340	-	9	2
404	7	64	U	1	7	111	030	140	-	1	1
405	7	64	U	1	6	111	032	107	-	1	1
406	7	64	A	1	3-4	111	022	140	-	1	1
436	9	64	A	1	5	121	030	170	-	-	0
437	9	64	F	1	3-4	121	040	190	-	-	0
444	9	64	F	1	3-4	121	010	199	-	-	0
445	9	64	A	1	4	111	040	354	-	1	1
483	9	64	U	1	5	111	030	267	-	1	1
484	9	64	T	1	5	111	010	112	-	-	0
485	9	64	A	1	4	121	030	116	-	1	1
486	9	64	U	1	3-4	111	230	188	-	-	0

Square 6

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
400	7	64	T	1	3-4	122	040	169	-	5	1
401	7	64	Al	1	7	121	040	259	-	11	2
402	7	64	T	1	5	112	000	289	-	3	1
487	9	64	U	1	6	121	010	369	-	-	0
488	9	64	T	1	3-4	211	030	389	-	-	0
489	9	64	T	1	5	111	000	287	-	3	1
490	9	64	U	1	5	111	010	240	-	11	1
508	9	64	Q	1	3	122	000	286	-	5	2
513	9	64	U	1	6	121	130^{+}	209	-	-	0
514	9	64	A	1	5	122	110	378	-	9	2
526	9	64	T	1	5	222	130	140	4	12	2
534	10	64	T	1	3-4	212	030	158	-	19	2
536	10	64	U	1	3-4	111	030	299	-	12	2
537	10	64	A	1	5	111	012	131	2	19	2
538	10	64	T	1	6	111	010	119	1	14	2
540	10	64	Q	1	3-4	112	030	297	-	2	1
541	10	64	Q	1	3	111	130	248	1	9	1
551	10	64	U	1	5	121	030	320	1	24	2
552	10	64	T	1	5	111	020	349	-	18	2
553	10	64	Q	1	5	111	030	278	1	8	2
554	10	64	Q	1	5	111	020	170	-	17	2

$^{+}$ the lower branches hanging

Square 7

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
452	9	64	Q	1	6	111	030	258	-	13	1
453	9	64	Q	1	3-4	122	020	264	1	14	2
454	9	64	F	1	6	122	040	177	4	22	3
455	9	64	Ae	1	3-4	211	031	120	-	-	0
458	9	64	Q	1	3-4	111	020	254	-	7	1
459	9	64	Al	1	4	121	000	390	-	12	2
460	9	64	Q	1	7	111	000	017	2	25	2
473	9	64	A	1	5	111	020	149	6	19	2
523	9	64	Q	1	6	111	030	190	1	22	2
524	9	64	U	1	7	111	000	009	4	21	3
566	10	64	Q	1	5	111	110	280	1	18	2
567	10	64	F	1	5	121	020	165	2	17	2
568	10	64	F	1	5	121	000	160	1	32	3
569	10	64	F	1	3-4	122	032	153	1	24	2
570	10	64	Po	1	5	111	031	166	1	23	2
571	10	64	Q	1	6	111	120	002	-	19	2

7 (continued)

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
572	10	64	Q	1	3-4	112	031	269	1	14	2
575	9	65	A	1	6	111	030	150	6	28	3
583	5	66	T	1	6	111	020	219	3	24	3
584	5	66	Q	1	5	112	000	389	1	20	2
585	5	66	F	1	5	121	030	168	1	25	3

Square 8

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
415	9	64	Q	1	5	111	140	280	1	10	2
416a	9	64	Q	1	5	121	030	497	1	10	2
416b	9	64	B	1	6	122	200	497	5	10	2
417	9	64	Q	1	3-4	121	020	119	-	6	1
418	9	64	Q	1	5	111	020	279	3	14	2
442	9	64	A	1	5	121	020	340	-	2	1
443	9	64	Q	1	6	111	040	299	-	2	1
446	9	64	A	1	5	122	030	000	-	-	0
447	9	64	A	1	3-4	121	022	124	-	-	0
448	9	64	T	1	7	111	031	270	-	3	1
449	9	64	Al	1	3-4	111	021	170	-	-	0
457	9	64	Q	1	6	111	020	271	-	2	1
461	9	64	Al	1	3-4	112	010	260	-	10	2
462	9	64	Q	1	3-4	112	030	130	-	3	1
463	9	64	Ae	1	3-4	111	040	140	-	-	0
464	9	64	U	1	6	112	000	210	1	17	2
465	9	64	F	1	6	121	010	199	-	-	0
474	9	64	A	1	3-4	111	040	112	2	16	2
475	9	64	U	1	6	121	020	109	-	7	2
476	9	64	Q	1	3-4	111	010	266	1	21	2
477	9	64	A	1	3	111	030	180	-	1	1
478	9	64	A	1	5	111	023	206	-	5	1
479	9	64	Q	1	6	121	131	242	-	13	2
480	9	64	A	1	3-4	111	030	160	-	-	0
481	9	64	Al	1	3-4	111	030	190	-	1	1
482	9	64	A	1	5	111	020	293	-	3	1
492	9	64	A	1	5	121	130	145	-	-	0
493	9	64	Q	1	3-4	121	030	120	-	-	0
498	9	64	A	1	3-4	121	042	380	-	8	1
586	5	66	Q	1	3-4	111	030	240	-	25	2
587	5	66	Q	2	3	111	$01^{+}0$	259	1	22	2

$^{+}$ earlier 3

Square 9

Station	Month	Year	Kind of tree	Number of tree	Age	Appearance of crown	Appearance of trunk	Exposition	Number of moss species	Number of lichen species	Vegetation covers
419	9	64	Q	1	3-4	112	022	114	-	1	1
491	9	64	A	1	5	111	010	355	3	14	2
494	9	64	Q	1	3-4	111	130	186	-	3	1
495	9	64	A	1	3	111	030	129	-	-	0
496	9	64	Q	1	5	121	030	170	1	16	2
497	9	64	F	1	5	121	010	169	2	26	3
539	10	64	Q	1	6	121	030	253	1	18	2
555	10	64	T	1	7	111	030	370	-	9	2
556	10	64	F	1	5	111	030	196	-	14	2
557	10	64	A	1	3-4	111	030	263	-	18	2
558	10	64	F	1	6	111	120	396	1	28	3
559	10	64	Q	1	6	121	000	267	-	14	2
560	10	64	Q	1	3-4	111	030	220	-	22	3
561	10	64	F	1	5	111	020	359	-	18	2
562	10	64	F	1	5	121	020	160	6	18	3
563	10	64	F	1	3-4	111	020	289	1	15	2
564	10	64	F	1	3-4	121	110	389	1	19	2
565	10	64	Q	1	6	111	020	300	1	25	3
588	5	66	U	1	6	122	012	295	3	21	2
589	5	66	A	1	5	121	121	116	2	24	2
590	5	66	T	1	5	111	022	157	1	28	2
591	5	66	F	1	5	121	000	265	4	29	2
592a	5	66	F	1	6	121	030	265	3	17	2
592b	5	66	Al	1	5	111	130	000	-	20	3

VI

Acer platanoides

Station	244	261	269	292	308	313	392	307	181	182	230	306	406	506	26	199	485	477	445	276	119	206	273	334	435	442	502	500	512	482	66	257	277	350	420	187	478	399	456	121	75	440	467	498	403	514	360	581	424	372	515	374	529	357	491	525	123	409	438	474	472	574	557	509	473	573	537	520	589	425	594	521	575	547	
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	9	7	10	10	12	12	13	13	15	14	15	16	16	16	17	17	19	19	19	21	19	22	24	25	26	27	28	33	
Lecanora conizaeoides	1	$1^{1)}$	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3				2	1		3	1	1	3	2	1		2	(1)	2	2	2	3	1	1	1	2	$2^{1)}$	1	1			1			1	1	2			2			1		2	1				1							1	1			49
Hypogymnia physodes																		1			1	1						(2)	(1)		2	(1)		$1^{1)}$	1	1	1	(3)	1	1	$2^{1)}$	1	1	1	2	(3)	$1^{2)}$		2	2	2	3	3	1	2	2	2	2	2	1	2	1	2	(3)		1	1		1	$1^{2)}$	1			2	43
Lepraria incana																			1	1			2							1								2			$2^{1)}$			2	2	2	2					2	2	2	2	1	2		2	1	2		2	2											21
Lecidea scalaris																							2	1	1	2	3	1		3			3	2		3		3	1	2		3	3		2						2			$1^{2)}$			2		2																20
Bacidia chlorococca																													1	1	2			1	1	2				1		1			2				2		1						2			2											2				14
Parmelia sulcata																																(1)							1		$1^{1)}$			1	(2)	(2)	1			3	2	1	3	(2)	3	(2)	2	3	2	3	2	2	2	(2)	3	3	2	1	2	2	1	2	2	3	32
Xanthoria fallax																																	1										$2^{1)}$					1													1		$2^{1)}$			2	1	2	$3^{3)}$						9
Lecanora chlorotera																																			1									(2)							2							2						2						2	2	2	2	2	10
Cetraria chlorophylla																																				1	$(1)^{1)}$				$1^{1)}$	1							1		$2^{3)}$			$(1)^{2)}$			2	2	2	2			2							1				$1^{2)}$	14
Lecanora expallens																																						2			$2^{1)}$	2			1	2							$2^{3)}$			2			2					2	2		2							2	12
Parmeliopsis ambigua																																					$1^{1)}$	(2)				1					2		2		2		2	1		2	2	2	2	2			1	1							1				16
Lecanora subfusca coll.																																					1												1				(1)			1		1		1		1	1			1		1	$1^{2)}$			1	1	1	13
Cetraria pinastri																																							1		$1^{1)}$								1		2							1		1															6
Biatorella moriformis																																							1						1									1										1											4
Buellia punctata																																								2				2		1				2							1		1						1	2				1		2	2	1	12
Physcia dubia																																								2			1									2		1				1	2	3	1	2	2						1	1					12
Xanthoria candelaria																																								(1)																					1														2
Calicium hyperellum																																										1				1													1									1							4
Lecanora umbrina																																											1					1																		2									3
Candelaria concolor																																											1																								1								2
Physcia orbicularis																																											$1^{1)}$					1				1										3			1	2			3	1			1	2	10
Lecanora carpinea																																												(2)			(1)											2		2		1						2		2	1		2	2	10
Physcia tenella																																												(1)								2					2	1			2	3	$2^{1)}$	2	1	2	2	2	2	3	1	2		3	17
Physcia ascendens																																												(1)																		2			1	3		2	2	2	(1)	2	1	1	11
Cladonia coniocraea																																													2				2						2				2															2	5
Parmelia fuliginosa																																													1	1				2			1			2	2	3	2	1			1	1	1		1			2	1	2		2	17
Evernia prunastri																																														(2)				1					(1)	2							2	(2)			2		1	1		3	2	1	12
Candelariella xanthostigma																																															$1^{1)}$			2		2		2		2	2	3		2	(2)	2		2	2	2	2	2	2	2	1	$2^{3)}$	2	3	21
Lecanora sp.																																															1																												1
Parmelia exasperatula																																															1					1					2	2			(1)	1		1	1	2			3	2			2	2	13
Phlyctis argena																																															(2)	1		2		2	1	2	2	2	2		2		2			2	2	3	2	2	1	2	2	3	2	1	22
Xanthoria parietina																																																2				2										3		1	1	2	2	2	2	2	(1)	2	2	2	14
Parmelia acetabulum																																																1														1												1	3
Physcia entheroxantha																																																1		2		2		2	1						3			2	3	2	2	2	2	1	1	2	2	2	17
Lecanora subfuscata																																																	1		2						2	2				2	2		1						2	2	2	2	11
Alectoria jubata																																																	1																						1				2
Physcia pulverulenta																																																		2					1						2	1		2	2	2	2	2	2	2	1	1	2	2	15
Cetraria glauca																																																			2				1	2							2						1						5
Alectoria implexa																																																			1							1																	2
Ramalina sp.																																																				1				1			1		1			1	1			(1)	1	1	(1)				10
Pertusaria amara																																																					3		2						2							2	1			2	2	1	8
Cladonia sp.																																																					1																						1
Parmelia saxatilis																																																					$2^{1)}$																						1
Ochrolechia microstictoides																																																					2														2	2							3
Lecidea efflorescens																																																					2	2	2								2			2									5
Catillaria globulosa																																																							1																				1
Ramalina farinacea																																																							1												1					3	2		4
Ramalina fraxinea																																																							1											2						3	2	1	5
Unknown																																																							1											1									2
Physcia farrea																																																								1									3			2	3	1		2	2	2	8
Ochrolechia androgyna																																																								2								2											2
Lecanora symmicta																																																										1		1															2
Pertusaria globulifera																																																											2									2			2	2			4
Lecanora chlarona																																																												2											2				2
Parmelia exasperata																																																												1		2	1											2	4
Xanthoria polycarpa																																																													1	1					2			1					4
Arthopyrenia alba																																																													1														1
Parmelia subargentifera																																																													(1)				1			1	1	2	1	2	2		8
Physcia aipolia																																																														2													1
Usnea hirta																																																															1											1	2
Pseudevernia furfuracea																																																															2												1
Candelariella vitellina																																																															$1^{1)}$												1
Bacidia luteola																																																																	1				2				2	1	4
Lecidea olivacea																																																																	1	2	2	2		2	1	2	2	2	9
Lecanora crassula																																																																		2						1		2	3
Bacidia Backhausii																																																																		2					2				2
Bacidia Naegelii																																																																			1								1
Anaptychia ciliaris																																																																			1	1	$1^{4)}$	1	(1)	1	2	1	8
Lecanora Hageni																																																																				2							1
Pertusaria globulifera var. discoidea																																																																				2							1
Opegrapha varia																																																																					1			2			2
Lecanora maculata																																																																					1						1
Lecanora allophana																																																																						2					1
Buellia pharcidia																																																																							2				1
Lecidea quernea																																																																							2		2		2
Ramalina pollinaria																																																																								2	2		2
Rinodina exigua																																																																								2	2		2
Pertusaria coccodes																																																																									2		1
Caloplaca cerina																																																																								1		1
Caloplaca aurantiaca																																																																									1	1
Physcia stellaris																																																																									2	1
Hysterium pulicare																																															2		2			1			2																				3
Trematosphaeria sp.																																															1											1		1								1					1		5
Leptosphaeria sp.																																																				1																							1
Pleospora sp.																																																													1														1
Pohlia sp.																																								1																																			1
Hypnum cupressiforme																																									1						1			2		1	2		2		2			2				2							2	2	1	2	13
Plagiothecium silvaticum																																									1																																		1
Orthotrichum sp.																																																1		1		1													1								1	1	6
Bryum capillare																																																2	2												2														3
Pseudoleskeella nervosa																																																2																	2		2						2		4
Stroemia obtusifolia																																																2																					1					2	3
Pohlia nutans																																																	2											2															2
Leucodon sciuroides																																																		2																	2	1	2						4
Amblystegium serpens																																																		2																									1
Radula complanata																																																							2							2											2	2	4
Ptilidium pulcherrimum																																																							2									2											2
Pylaisia polyantha																																																								2					2				2						2	2	2		6
Brachythecium populeum																																																									$1^{5)}$									$1^{5)}$									2
Barbula vinealis																																																										2																	1
Orthotrichum affine																																																																2											1
Ofthotrichum fallax																																																																	2										1
Brachythecium velutinum																																																																	2	2									2
Brachythecium rutabulum																																																																	2										1
Tortula pulvinata																																																																									2		1
Orthotrichum speciosum																																																																										2	1

1) On the base of the trunk
2) Not found on examination
3) c. ap.
4) Sterile
5) Juvenile

Tilia

Station	184	232	301	302	499	331	371	369	402	448	359	358	370	348	363	354	441	400	489	468	353	555	377	412	598	526	373	538	544	552	534	518	527	583	590	597	336	
	1	1	1	1	1	1	1	2	3	3	3	4	4	4	4	4	4	5	3	7	8	9	11	11	3	12	12	14	16	18	19	21	22	24	28	29	29	
Lecanora conizaeoides	1	1	1	1	1				1 1)	1		1		1				2 1)	1				1	2			1						1		1		2	17
Lecidea scalaris						3		3	1 1)	2	2	2	2	3	2	1	2	3		3	3	3		1		1				1 1)								18
Leprario incana							1	1	2	2			2			(1)	2	2				2				2	2	2		2		2			2			15
Cetraria chlorophylla											1	1 2)	1		2					3	2		1							2	1 2)	1			1	1	2	13
Hypogymnia physodes											1	2	1	1	1	1	2	(2)		3	2 1)	2	1	3		3	2	2	1	3	1	1	1		2	1	2	24
Bacidia chlorococca														1									2	2											1			4
Lecanora subfusca coll.															(1)					1	1									1	1		1				1	7
Phlyctis argena																(1)						2 1)			2	1	2	2	2	1 1)	1	2	1	1	2	1	2 6)	15
Physcia dubia																	2							1				1						1		1		5
Lecanora expallens																		2	1			1	2				2	2		2	2		1		1		2	11
Parmelia sulcata																			(1)	(1)		(1)	1	2	(1)	1	2	(2)	2	(2)	3	(1)	1	1	(2)	2	2	18
Pseudevernia furfuracea																				1	1															1		3
Lecanora subfuscata																				2										2				2		2		4
Parmeliopsis ambigua																					2		1			1				2			1			1	2	7
Alectoria jubata																					1																	1
Cetraria pinastri																					1		1			1				1 1)					1	1		6
Parmelia fuliginosa																						1	1				2	2	2	2	3	2	1		2			10
Pertusaria amara																						1							3	2		2						4
Physcia sp.																						(1)																1
Parmelia exasperatula																							1											1	2	1		4
Physcia tenella																							1								1		1	1	1	1	2	7
Ochrolechia androgyna																								2														1
Lecanora chlarotera																								1							2		1			2		4
Cladonia coniocraea																								1		2 3)			2 3)									3
Evernia prunastri																								(1)				(2)	1 2)	(2)	1	1 2)			(2)	1	2	9
Candelariella xanthostigma																								2	2			1	3	1 1)	1	1	1	1	1	2		11
Lecidea olivacea																										1					1			1		1		4
Lecanora carpinea																										2	2	2			2	2	1	3	1	1	2	10
Lecanora crassula																										1					1							2
Physcia pulverulenta																										1 4)						1		2		1	2	5
Physcia entheroxantha																											1	1	1		1	3	1	3	2	2	2	10
Buellia punctata																											1		2	2 1)	1		2	2	2	2		8
Candelaria concolor																											2							2	1	2		4
Ramalina sp.																											1						1					2
Catillaria globulosa																												3									2	2
Ramalina farinacea																												1	1		1	1		1	(1)			6
Lecidea efflorescens																												2	2									2
Unknown																													1									1
Lepraria candelaris																													2									2
Ramalina fraxinea																													(2)					1			2	3
Pertusaria coccodes																													2			2					2	3
Lecanora chlarona																														2	1							2
Usnea sp.																														1		1						2
Pertusaria globulifera var. globulifera																															1	2			1			3
Hypogymnia tubulosa																																1			2			2
Parmelia saxatilis																																(1)						1
Cladonia fimbriata																																1						1
Ramalina pollinaria																																(1)						1
Cetraria glauca																																1			2			2
Physcia orbicularis																																	1	1			2	3
Parmelia subargentifera																																	1			1	2	3
Bacidia Beckhausii																																	1					1
Physcia farrea																																	1		1	2	2	4
Xanthoria parietina																																	1	1		1	2	4
Xanthoria fallax																																	1			2	2	3
Xanthoria polycarpa																																	1	1		2	1	4
Lecanora Hagenii																																		2				1
Physcia ascendens																																		1		1		2
Physcia caesia																																		1			2 1)6)	2
Lecidea quernea																																		1	1	2		3
Parmelia acetabulum																																		2 5)				1
Anaptychia ciliaris																																		1			2	2
Xanthoria candelaria																																			1	2		2
Alectoria implexa																																			1			1
Usnea hirta																																			1			1
Lecanora sp.																																			1			1
Arthonia radiata																																				2		1
Physcia aipolia																																					2	1
Coniocybe hyalinella																																					1	1
Bacidia Naegelii																																					1	1
Opegrapha varia																																					2	1
Ramalina fastigiata																																					2	1
Pylaisia polyantha																								2 1)										2			2	3
Orthotrichum sp.																								1 1)		1						1	1	1		1		6
Brachythecium velutinum																								2 1)	2													2
Hypnum cupressiforme																								2 1)		2	2	2	2			2	2	2 1)	2 1)	1 1)	2	11
Dicranum scoparium																										2												1
Pohlia sp.																										1												1
Radula complanata																																2						1
Tortula pulvinata																																2					2	2
Amblystegium serpens																																2						1

1) On the base of the trunk
2) Not found on examination
3) In moss
4) Sterile
5) Fertile
6) Not collected

VIII

Ulmus

Station	175	240	291	312	318	404	414	218	490	185	227	327a	69	100	246	124	61	483	345	405	278	355	395	259	361	122	85	76	451	475	378	352	411	421	536	74	410	464	596	588	524	576a	551	519	550	426	577a	
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	3	3	5	5	6	6	7	8	11	12	12	12	14	17	17	20	21	21	24	24	26	26	29	36	
Lecanora conizaeoides	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3								2	2		2		2			1	3	2	2		2		1					2				1	27
Lecidea scalaris																1						2		3		1						1				1												6
Bacidia chlorococca																	1	1									2	2								2	2										2	7
Lepraria incana																			1	1		2	2		2	2		2				2		2			2							2		2		12
Lecanora expallens																					1										2				2	2	2			2	2					2	2	9
Hypogymnia physodes																							2$^{1)}$	1	1$^{2)}$	2		1	(1)		1	3	2	1	1	2	1	(1)				2	1			2	3	18
Phlyctis argena																									(1)									2	2		3	1	1	2	2	1	2	2	2	2	2$^{1)}$	14
Cetraria chlorophylla																										1					1	1	2			1		2					2			2	1	9
Parmelia sulcata																											(1)		1		1	3	2	1	2	2	3	(3)	1	1	1	3	2	1	3	(2)	(2)	19
Candelariella xanthostigma																											(1)			2				3	1	2	3	2$^{1)}$		2	2	1	2	2	2	2	1	15
Physcia tenella																											(2)				1			2		2	2	1	2	1	2$^{3)}$	2	2	2		2	3	14
Physcia pulverulenta																											(2)			1									1	1	2	3	2	2	1	2		10
Buellia punctata																												2				2				2	2		1		2	2	3	2	2	2	2	12
Bacidia Naegelii																												1															2		1			3
Evernia prunastri																													(1)							1		1				2	2		1	2	1	8
Parmelia fuliginosa																													1					2	3		2				3	2	3	2		2	1	10
Physcia dubia																													1	3								1	2			2	1				2	7
Caloplaca chlorina																													1									1						1				3
Xanthoria parietina																														(1)								2	2	1	2	1		3	1	2	1	10
Physcia orbicularis																														3					1			2	3	2	2	2		2		2		9
Physcia nigricans																														1								1						1				3
Physcia caesia																														2																	1	2
Alectoria jubata																															1	1																2
Xanthoria polycarpa																															1		1						1								1	4
Physcia ascendens																																1					2		1	2	2	2		2		1$^{2)}$	3	9
Cetraria pinastri																																1	1	1$^{2)}$		1												4
Lecanora sp.																																1																1
Parmeliopsis ambigua																																	1															1
Biatorella moriformis																																	1	1				1										3
Ochrolechia androgyna																																	1														2$^{1)}$	2
Lecanora subfusca coll.																																	1						1				1	1				4
Lecanora carpinea																																	2				2		1				2		2		2	6
Xanthoria candelaria																																	1						2				2			2		4
Candelaria concolor																																		1														1
Physcia entheroxantha																																		2	2	1	1	1	2	2	2	2	2	2	1	2		13
Ramalina sp.																																			1		1		1	1								4
Lecidea olivacea																																			2					1		2			2		2	5
Parmelia exasperatula																																			1		1		1					2		2	1	6
Parmelia subargentifera																																			1				1		2			2	3	2		6
Parmelia acetabulum																																				2			1									2
Lecanora subfuscata																																					2		1	2					2			4
Lecanora umbrina																																					2											1
Xanthoria fallax																																						2	3		2			2		2		5
Lecanora crassula																																						1					2					2
Anaptychia ciliaris																																								1	2	1		1	2	1	1	7
Lecanora chlarotera																																								2		2	2		1	2	1	6
Bacidia luteola																																								2				1				2
Physcia farrea																																								3	1							2
Coniocybe hyalinella																																								1					1			2
Opegrapha varia																																								2					2		2	3
Pertusaria globulifera var. discoidea																																								3	2		2		2	2		5
Unknown																																								1							1	2
Lecidea efflorescens																																								2								1
Cladonia sp.																																									1					1		2
Ochrolechia microstictoides																																									2			2			1	3
Pertusaria lutescens																																									2		2		2			3
Ramalina farinacea																																									1	2			1	2		4
Ramalina fraxinea																																										3		2	1	2	1	5
Lecidea quernea																																										2						1
Lecidea glomerulosa																																										2					2	2
Physcia aipolia																																										1		1				2
Pachyphiale fagicola																																										3					2	2
Ramalina calicaris																																										2						1
Cetraria glauca																																											1					1
Cladonia coniocraea																																											2					1
Pertusaria coccodes																																											2					1
Lecanora allophana																																												2	2			2
Lecanora maculata																																												2				1
Ramalina pollinaria																																												2		2		2
Pertusaria amara																																													2			1
Buellia disciformis																																													2			1
Lepraria candelaris																																													2			1
Arthopyrenia alba																																													2			1
Catillaria globulosa																																														1		1
Usnea hirta																																														1		1
Catillaria prasina																																															1	1
Lecanora chlarona																																															1	1
Ramalina fastigiata																																															1	1
Candelariella vitellina																																															1	1
Parmelia exasperata																																															1	1
Parmelia saxatilis																																															2$^{1)}$	1
Candelariella luteoalba																																															2	1
Leptosphaeria sp.																																								1								1
Metasphaeria sp.																																								1								1
Pohlia sp.																1$^{4)}$																				1$^{4)}$												2
Hypnum cupressiforme																									1				2							2				2	2	2		2		2	2	9
Amblystegium serpens																									2																							1
Brachythecium populeum																											1$^{4)}$																					1
Pylaisia polyantha																													2									2		2		2		2				5
Barbula vinealis																													2																			1
Brachythecium velutinum																																								2								1
Pseudoleskeella nervosa																																									2			2		2	1	4
Leucodon sciuroides																																									2					2		2
Radula complanata																																									2							1
Orthotrichum speciosum																																										2$^{3)}$						1
Stroemia gymnostoma																																										2						1
Orthotrichum sp.																																										1	1				1	3
Stroemia obtusifolia																																												2				1
Pohlia nutans																																														2		1
Orthotrichum fallax																																															2	1

1) On the base of the trunk

2) Not found on examination

3) c. ap.

4) Juvenile

I Trunk base has considerably fewer species than higher up.

IX

Quercus robur

Station	260	299	56	68	70	507	60	430	139	285	286	288	337	367	343	384	434	540	413	419	340	356	212	330	457	387	211	140	388	462	341	494	407	63	508	458	344	423	138	431	386	443	408	417	382	398	553	208	541	379	416a	418	415	471	479	129	452	133	559	572	453	600	517	381	496	554	539	528	566	571	584	587	476	595	383	523	560	460	565	586	
	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	3	3	4	4	2	4	3	4	4	3	5	3	3	7	5	7	5	6	4	5	6	2	3	6	7	8	8	9	9	10	10	14	10	10	13	12	13	14	14	14	14	15	15	15	16	17	18	17	18	19	21	23	21	23	22	22	22	25	26	25	
Lecanora conizaeoides	$1^{1)}$	1	1	1	2	2			2	3	$3^{1)}$	3	2	1	2	1	2				1	1	$1^{1)}$	2		1	$1^{1)}$	2			1			2	2	1	1		2	1	$1^{1)}$														1		2		1						2			1		2		1			1		1		1		40
Lecidea scalaris							(1)	1	2	1	$1^{1)}$	3	1	1	2			$3^{1)}$	2		3	3	2	3		2		2	1		2			2			1	1	2	$3^{1)}$	$1^{1)}$					2								2	2				1						3	$2^{1)}$		$1^{1)}$										1	1		34
Hypogymnia physodes																1	$1^{1)}$	(1)	(2)	(2)	1	1	$1^{1)}$	(1)	1	1	$1^{1)}$	2	2	(3)	3	2	3	1	(3)	1	$2^{1)}$	1	2	1	$1^{1)}$		(1)	2	3	2	(2)	(3)	$(1)^{2)}$	3	1	(2)	3	3	2	2	$1^{1)}$	3	2	3	3	(2)	1	2	3	(2)	3	(1)	2	2	3	2	3	1	2	2	3	2	2	$1^{2)}$	64
Lepraria incana																							$2^{1)}$	1	2					2			2	2	2	1	2	1		2	$2^{1)}$	1			2	2		1	1		2	1			2		2		2		2	1		2	2	2	2	1	2		1			2	2	2	2	2	2	$2^{1)}$	38
Cetraria chlorophylla																											$1^{1)}$	2	1					(1)		1		1							1	2				2			1	2	2		1		2		1	1			1		1	1	1	3	$1^{1)}$		1	2		2	3	1			27
Pertusaria albescens var. corallina																										2																																																								1
Alectoria jubata																													1																									1				1								1					1	1	1			1					8
Parmeliopsis ambigua																														(2)	1	1			1	1								2	1	2	(2)		(1)	1		2	1	2				2	1	2	3	1	2		1	2	2	1			1	1	2	1	1		1	2	1		32
Bacidia chlorococca																															1	2		2		1												2																	1										2			1	1		9
Lecanora expallens																																	2	2							$2^{1)}$							2								2		2		2		2							2	$2^{5)}$	1	1	2	2	2	2	$2^{5)}$	1	2		19
Lecanora chlarona																																			2																														2							2									3
Pertusaria globulifera var. globulifera																																				3																																							2						2
Xanthoria candelaria																																					$2^{1)}$																											3														2		1	4
Alectoria implexa																																						1																																2							2				3
Lecidea efflorescens																																						2								2						2	2															2	1												6
Parmelia subargentifera																																							2																																			1				1			3
Cladonia coniocraea																																								$2^{3)}$	$1^{1)}$			$2^{1)}$					$3^{1)}$		$2^{1)}$	2		$2^{1)}$				$2^{1)}$	2		$2^{3)}$		2		$2^{1)}$		1								$2^{3)}$			2			15
Calicium hyperellum																																										1	1												1		1		1			1			1	1	1	1				1		2				1	2		14
Pertusaria amara																																											2	$2^{1)}$			(2)				1	3	2		2	3		2	3	2	2	1	2			(2)	2	1	2	2	3	1		3		2		2	2	2	26
Parmelia sulcata																																												(2)	2		(2)	(3)		3		(2)	(2)	1	1	(1)	$1^{1)}$	1	1	(3)	1	(2)	1	2		(1)	2	(1)	2	2	(2)	2	2	1	2	3	(2)	3	2	1	33
Pertusaria globulifera var. discoidea																																												$2^{1)}$												(1)											2													2	4
Ochrolechia microstictoides																																													2			2									1	2		2	2				2		2			1					2					2	11
Evernia prunastri																																													(1)		(1)			1					1		$1^{1)}$		2	(1)	$(1)^{2)}$			1	1	(2)	2	(1)	2	(1)	(1)	1	2	2	1	(3)	1	2	1	1	25
Cladonia fimbriata																																														2												$2^{1)}$					$2^{4)}$								$1^{1)}$	$2^{4)}$									5
Ramalina sp.																																														1		(1)							1	1	(1)	1				1		1					1	(1)	1	1		1	1					1	14
Lecanora crassula																																															2					2																					1			2	1		2		6
Parmelia exasperatula																																															(1)	1																											2				2		4
Phlyctis argena																																															(2)				2		$1^{1)}$			$2^{1)}$		2		2		2	2	1		1	2	2	(2)	1		2		3	1	2		2	2	2	21
Pertusaria leprarioides																																																1																									2								2
Unknown																																																	1						1							1									1	1		1					1		7
Buellia griseovirens																																																	1											2	1				1									1					1		6
Lecanora subfuscata																																																	1											2				2		2			2			2	2			2	2	2		1	11
Lecanora symmicta																																																	1							2																	1			1					4
Lecanora subfusca coll.																																																	1		1	1				1									1								1		1	1	1				9
Lecanora carpinea																																																		2	2		1			2				2		2		2								1	2	2		2	2			1	13
Parmelia subaurifera																																																		1	1																1					1									4
Xanthoria polycarpa																																																		2																												2		1	3
Parmelia fuliginosa																																																		1	3	1					$1^{1)}$	2		2	2		2	2		1	2		2	1	1	3	2	1	2	2	(1)		3	1	22
Physcia tenella																																																		3							1																			2			$2^{1)}$	1	5
Lecidea olivacea																																																			2					2						2		1								2								1	6
Pertusaria coccodes																																																				1			2			2						1		2		2		1					2			1	2	$2^{6)}$	11
Ochrolechia subviridis																																																				1																														1
Cetraria pinastri																																																				1	1	1				1			$1^{2)}$				1		1		1		$1^{2)}$			1	1		1		1		13
Pertusaria pertusa																																																				1																														1
Ramalina fraxinea																																																					(2)																							2		1		1	4
Parmeliopsis hyperopta																																																						2																											1
Caloplaca chlorina																																																						1																											1
Cetraria glauca																																																							1												1	1	2		1		1				1				7
Buellia disciformis																																																								1												1													2
Buellia punctata																																																									1		1											2	3		2	2		2			2	3	9
Calicium Flörkei																																																									1																								1
Lecanora sp.																																																											1																						1
Ramalina farinacea																																																											1	(1)			2			(1)	2						$1^{2)}$			2			1		8
Pertusaria leioplaca																																																												2																					1
Catillaria Griffithi																																																													1																				1
Physcia ascendens																																																													2			1																1			3
Anaptychia ciliaris																																																														1																			1
Ochrolechia androgyna																																																														2			1	2		2	2	1	1	2	1	1	2	2				2	13
Parmelia saxatilis																																																															2						$2^{1)}$			1		1					$2^{1)}$		5
Physcia entheroxantha																																																															2	1											(1)			1	1	1	6
Lecanora chlarotera																																																															$2^{5)}$	1						2						1	2				5
Candelariella xanthostigma																																																															2												1			2	1		4
Pertusaria lutescens																																																															2												2		1				3
Usnea hirta																																																																1			(1)			(1)	$1^{2)}$			1		1	1			1	8
Cladonia sp.																																																																		$1^{4)}$								1						$1^{4)}$	3
Catillaria Ehrhartiana																																																																		2							2								2
Alectoria sp.																																																																				$1^{2)}$													1
Usnea sp.																																																																					1												1
Lecanora maculata																																																																					2				2								2
Parmelia acetabulum																																																																						1							(1)				2
Pseudevernia furfuracea																																																																						2											1
Hypogymnia bitteriana																																																																							1										1
Lecidea quernea																																																																								1										1
Lecidea glomerulosa																																																																								2									1
Parmelia exasperata																																																																									2								1
Rinodina exigua																																																																											2		1			2
Hypogymnia tubulosa																																																																												2	1			2
Xanthoria fallax																																																																													2			1
Bacidia luteola																																																																														2		1
Candelaria concolor																																																																															3	1
Physcia pulverulenta																																																																															1	1
Hysterium pulicare																																										1					2			2		2		2									2				2			2		2	2	2		1	2	1	1	2	16
Trematosphaeria sp.																																													1																																				1
Leptosphaeria sp.																																																											1																					1
Dasyscypha sp.																																																																						1											1
Pleospora sp.																																																																										1							1
Unknown																																																																								1									1
Pohlia sp.									1																																								1																																
Hypnum cupressiforme																																		1												2	1	2			2	2	2					2		2	2		2		2		2	2	2		2			2	2	2		2	2	2	
Orthodicranum montanum																																														2						2																2													
Brachythecium populeum																																														2																																					
Pohlia nutans																																														2																																					
Drepanocladus incinatus																																																		1																																			
Dicranum scoparium																																																		1																																			
Ptilidium pulcherrimum																																																		1				2								2																					
Hypnum cupressiforme f. filiforme																																																				1																				2	2								
Brachythecium valutinum																																																								2																									
Pylaisia polyantha																																																										$1^{7)}$																							
Orthotrichum affine																																																															2																		
Tortula pulvinata																																																																															2			

1) On the base of the trunk
2) Not found on examination
3) On mosses at root collars and trunk base
4) In moss
5) Lecanora chlarotera f. rugosella
6) Pertusaria coccodes var. coronata
7) Juvenile

X

Fraxinus excelsior

Station	186	231	272	115	248	109	118	255	324	258	117	303	77	252	511	209	469	532	73	580	510	556	362	563	422	533	335	375	535	567	592a	601	542	564	562	561	427	132	543	545	579	582	593	376	549	380	454	546	531	569	522	578	585	497	599	558	591	548	568	
	1	1	1	1	1	1	2	2	2	2	2	4	4	5	5	7	10	10	12	13	13	13	14	16	15	15	15	16	17	17	17	17	17	19	18	18	18	18	19	19	20	20	20	21	21	21	22	23	23	24	25	25	25	26	27	29	28	29	32	
Lecanora conizaeoides	1	1	1	2	3		2	3	1	1		1	1			1	1		2			1																																							15
Bacidia chlorococca						1							1		1			2						1																																				5
Lecidea scalaris							2	1	1		2	3	2						2			1			1																																				9
Hypogymnia physodes										1				1	(3)	1	3		2	1	2	3		2	3	2		(1) 4)					2	3		2	2												3	1			2			1					1	1	23
Lepraria incana											2	2	2						1		2	2			1											2			2		2							1										2				2	12
Unknown												1												1																																				2
Parmeliopsis ambigua													1		2				(1)	1		3			1										1																									1		8
Cladonia sp.													1																																														1 2)		2
Cetraria chlorophylla														1			3				1 1)	3	(1)		1									1 1)		1 1)		1 1)						1				2				1						1			1 1)	14
Cetraria pinastri														1								1			1																																			1 1)	4
Pertusaria leprarioides															2																																														1
Buellia griseovirens															2						1																																	2				2
Lecanora sp.															1				1								1																																		3
Parmelia subargentifera																1										2	2						1					2	2	2	3	2	3	2					3		3	2	1		3			2	1	18
Candelaria concolor																1																																				2						2		3
Parmelia sulcata																1	2	(2)	2	3	2	(1)	2	3	(3)	3		1 4)	1	(1) 1)	1	1	3	3	2	2	(2)	2	1	2	1	2	3 6)	1	1	3	3	2	1 1)	2	2	1	2	2	2	2	2	(2)	2	43
Physcia tenella																2		1						1					1	1		1	1	1		2	2				1	1	1	1	2		2	1	1		2	2	2	2	1	1	1	1	2	1	28
Physcia ascendens																	2										2	1			1	1				2		1		1	1	2	3	1			1		1	2	2	2	1	1			1	1 1)	1	22
Pseudevernia furfuracea																	2																																												1
Xanthoria polycarpa																	2			1																									1						1			1			1		6
Lecanora carpinea																	2			2		2				2															1		1			2					2	3			1	2			2	12
Cetraria glauca																	2					1											1																										3
Lecanora chlarotera																	2	2								2									2													2	2		2			2	2		1		3	2	2	2	14
Parmelia fuliginosa																		1		3	2	1 3)		3		2		1					1	2			2			1						3		2		1		1		2	3	2	2		1	20
Candelariella xanthostigma																		2					3			2	2	2			2	1	1		2	2	2		1	3	2	1	1	2	3	2	2	2	3	2	2	2 6)	2	2	1	1	2	3	2	32
Physcia pulverulenta																		1					3	2		(2)	2	(1)	3	(2)	2	1	3	(2)	2	2	2	2	(2)	2	1	2		2	2	2	3	(3)	2	3	3	1	1	3	1	2	2	2	3	36
Lecidea olivacea																		3		3			2	2		2			1			2			2	2	2		2	3	1		2		1	1		2		2	2	1	1	2	1	3	2	1	1	27
Phlyctis argena																		2			2	1 1)	1	2	1	2	3	1	2	2	1	2	2	2	2	2	2	2	2	2		2	1	2	1	1	2	2	1	2	2	1	2	2	3	2	3	2	2	39
Ramalina sp.																		1						1		(1)				(1)																				1		1		1					7
Pertusaria globulifera var. globulifera																		1																																		1							2
Lecanora subfuscata																			2	3			2	2					2	2	1	3		2			2	2	2	2		2	2	2	3	1	2	3	2	2			2	2	1	2	2	2	2	29
Bacidia Naegelii																			1														3																												2
Caloplaca chlorina																			1																																										1
Lecidea efflorescens																			2					2										2																							2	2			5
Buellia punctata																				2																													2		2	2	2			1		2	7
Lecanora expallens																				2	2			2		2							2			2			2		1					2		2	2										2		12
Evernia prunastri																				1	(2)											1 3)	(2)		1	2		(1)				2			3	(2)				1		1			2		1	3	15
Buellia pharcidia																				2																								1						1				2				4
Lecanora chlarona																				2		1																																						2
Ochrolechia androgyna																					2				2																															2				3
Cladonia coniocraea																					2 2)																	2 1)																									2
Pertusaria amara																					2			2	2					2				2	2		2	2				3					2	2	2	2			1	2		1			2	17
Peltigera canina																					2 2)																	1 3)																									2
Ramalina farinacea																					(2)								1				1 3)	(2)				2	(1)		3		2			1	1	(2)			1			2		2	1	1	2	17
Lecanora subfusca coll.																							1	1	1	1				1									1				1	1		1	1			1								1	12
Physcia farrea																							1				3		2			1	3		2			1	(2)	1	1	1		2			3		1	1	2		2	1	1			2	2	21
Physcia entheroxantha																							2			2	3	1	3	(2)	2	2	3		2	2	2	2		3	1	2		2	2	2	3	1	3	3	3	1	2	3	1	1	2	2	3	32
Anaptychia ciliaris																							1 1)				3	1	1	(2)	2	2		(1)	3	2		2	1	3	3	2	1	2	3		3	(1)	3	1	2		1	3	2		2	2	2	29
Xanthoria parietina																							2			(1)	3		1	(2)	2	2			3	2	2	2	(2)	3	2	1	3	2	(3)		2	2	(3)	2	2	3	1	2	2	2	1	2	2	31
Xanthoria fallax																							1					1		(2)	2	1			3			2		1		2 6)		3	1		2		2	1	2		1	1			2	1 1)		19
Bacidia Beckhausii																								2																																				1
Buellia disciformis																								1																																				1
Buellia sp.																								1																																				1
Unknown																																																							1				2
Ochrolechia microstictoides																									2																															2	2			3
Parmelia saxatilis																									2																															1				2
Alectoria jubata																									1																								1									2
Physcia orbicularis																											2		1	1	2	2			2	2				1		1		2	1		2	1	1	2	2	2		1	1		1	1	1	22
Physcia aipolia																											2		2		1 5)							2			2				1		1				3	2	3					2	2	12
Arthopyrenia alba																											1		1	1															1													1			5
Lecanora allophana																											2								2	2			2				2					2		2			2						8
Bacidia luteola																											1		1	1	2											2		1	2						2				1	1	2	1		12
Pertusaria globulifera var. discoidea																												3			2	1							3		3				1								1	2	3		3		2	11
Pertusaria coccodes																												2		2											2		1	2	2						1		3	1	2	2	2		12
Physcia dubia																												1										2				1									1	1							5
Ramalina fraxinea																												1	1				1	(1)	2	2	2			1	3		2	2				1 1)	1			2		2		2			2	17
Parmelia exasperatula																												1						2	2								2		2	2					1	1 6)	1						9
Opegrapha varia																													3	2								2	2						1			2	1							2			8
Coniocybe hyalinella																														1	1																												2
Physcia nigricans																															2	1										2							1	1									5
Arthopyrenia fallax																																1																												1
Lecanora crassula																																	2	2																										2
Pertusaria lutescens																																		2						2													2						3
Physcia caesia																																			1								1															2 3)		3
Caloplaca aurantiaca																																				2						(1)				2	2			2				2	2	2			8
Calicium hyperellum																																					1										1											1	3
Usnea hirta																																					1								1													1	3
Ramalina pollinaria																																						2	1						3			1													4
Lecanora Hageni																																						2		2									1												3
Lecanora umbrina																																								2									2												2
Arthonia radiata																																									1						2								1				3
Ramalina fastigiata																																										1												2		2				3
Buellia alboatra																																											2												2				2
Arthopyrenia spaeroides																																											1	1												2				3
Lecanora maculata																																											1												3				2
Parmelia exasperata																																														2													1
Parmelia acetabulum																																															2			2									2
Candelariella vitellina																																																	1												1
Arthopyrenia biformis																																																	1												1
Physcia stellaris																																																		1											1
Xanthoria candelaria																																																			2	3								2
Lecidea quernea																																																				2							1
Lecidea glomerulosa																																																					2			2	2	2		4
Caloplaca cerina																																																					1			1				2
Cladonia fimbriata																																																								2			1
Nephroma parile																																																								2 2)			1
Opegrapha sp.																																																								1			1
Lepraria candelaris																																																										1	1
Metasphaeria grisea																			2																																										1
Pleospora sp.																												1														1		1			1		1				1					1		8
Trematosphaeria sp.																																			1																								1
Unknown																							1																															1	1				3
Hypnum cupressiforme													2		2 3)					2	3		2	2 3)		2 3)			2		2		2	2 3)	2		2			2		2	2	2		1 3)	2	2			2	2				2	2 3)	2		
Pseudoleskeella nervosa																2																					2		2																				2	2		
Orthotrichum speciosum																		2											2													2																			
Mnium cuspidatum																					2														2		2																									
Ptilidium pulcherrimum																					2																																										
Dicranum scoparium																					2																																										
Bryum capillare																							2						2									2																									
Orthotrichum stramineum																							2																																								
Pohlia nutans																							2													2									2															
Leucodon sciuroides																											2				1 7)	2			2				2		2			2	2		2		2						2		2 3)	2		
Tortula pulvinata																											2										2	2		2														2	2				
Orthotrichum sp.																													1	1 7)		1	1		1						1		1	1		1			1			1		1		1		1	
Stroemia obtusifolia																													2			2			2								2	2															
Radula complanata																													2									2																						
Amblystegiella subtilis																														2	2		2								2		2																	
Pylaisia polyantha																																2						2				2	2	2	2																
Brachythecium populeum																																			2			2																							
Orthotrichum affine																																										(2)		2										2						
Orthotrichum pollens																																											2									1 7)							
Amblystegium serpens																																														2													
Orthotrichum fallax																																																			2								
Brachythecium salebrosum																																																				2							
Brachythecium glareosum																																																										2		

1) Not found on examination
2) In moss at base of trunk
3) On the base of the trunk
4) Numbers increase upwards
5) One example overgrown by *Physcia entheroxantha*
6) c. ap.
7) Juvenile

IX

Pinus silvestris

Station	84 373a 64 470 131 128 125
Lecidea scalaris	1 2 1 1[1] 1[1] 1 1 2 2 1 1 2 2 1 3 2 3 3 2 3 2 2 1 2 1 2 3 2 2 1 1 2 2 1 2 3 1[1] 2 2 3 2 2 1[1] 3 3 2[1] 1 3 1 1 2 1[1] 3 2 3 2 2[1] 3 2 3 2 2 2 2 2[1] 3 2 1[1] 2 2 2 1 3 2 2 2[1] 1[1] 2[1] 3 2 2 1[1] 2[1] 2[1] 2 2 3[1] 2
Lecanora conizaeoides	3 3[1] 2[1] 1[1] 3 1 1 2 1 1 2 2 2 2
Hypogymnia physodes	(2) 1 (2) (1) (1) (2) (2) (3) (2) (1)[1] (1) (1) 3 (2) (1) 1 (1) (2) (2) (1) (3) 1 2 2 3 (1) 3 (2) 3 (2) (2) 2 2 (2) (2) (3) (3) (2) (2) 1 (2) 3 3 3 2 (1) 3 3 3 3 2 3 3 3 3 3 (2) 3 3 3 3 3 3 2 3 3 3 3 3 2 3 3 3 3 3 3
Cladonia sp.	1 2[1] 1[1] 2[1] 3 2[1] 1 1[1] 1[1] 1[1] 2[1] 1[1] 1[1] 2[1] 3 1[1] 2[1] 2[1] 2[1] 2[1] 2[1] 2[1] 3 2[1] 2[1] 2[1] 1[1] 2[1] 2[1] 2[1] 2[1] 2 1[1] 1[1] 1[1] 2[1] 2[1] 2[1] 1[1] 2[1] 2[1] 2[1] 1[1] 3[1] 1[1] 1[1] 2[1] 2[1] 2[1]
Lepraria incana	2 2 x x x 2 2 x 2 x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x
Cladonia coniocraea	2[1] x x x x x x x 2 x 2 x 3 x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x
Cetraria pinastri	1 2 1[1] 1 1 1 1[1] 1 2 1 1 1 1 1 1 1 1 1 1 1 1
Bacidia chlorococca	x x x
Alectoria jubata	1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 2
Usnea sp.	1 1 1 1 1 1 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1 1 1
Parmeliopsis ambigua	1 (1) 1 1 1 2 3 3 1 1 (2) 1 (1) (1) (1) 1 1 2 2 1 2 (2) (1) 3 3 1 2 2 3 2 2 2 1 2 2 1 2 1 2 2 2 1 2 2 2 1 2 1 2 2 2 2
Pseudevernia furfuracea	(1) 2 1 (2) 1 (1) 1 1 2 (1) 1 2 2 1 1 2 1 1 2 1 1 1 2 1 2 1 1 2 1 1 1
Cetraria chlorophylla	2 1[1] 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1
Lecanora sp.	1
Cetraria glauca	1 1 1 1 1 1 1 1 1 2 2
Unknown 1	
Ochrolechia microstictoides	x x x x x x x
Parmeliopsis aleurites	2 1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
Cladonia fimbriata	x x x x x x x x x x
Parmeliopsis hyperopta	(1) 1 1
Parmelia sulcata	1
Lecanora subfusca coll.	x x x x x x
Cladonia flabelliformis	x x
Alectoria implexa	1 1 1
Lecanora symmicta	x
Lecanora pinastri	x
Ramalina farinacea	1
Alger	x x 2[1] x x x x 1 2 x x x x x x x x x x x x x[1] x[1] x x x x x x 2[1] x 2[1] x x x x[1] x x x x[1] x x x x x[1] x x x x x[1] x[1]
Pohlia nutans	2[1] x
Ptilidium pulcherrimum	2 x x x x[1] x x x x
Orthodicranum montanum	x
Dicranum scoparium	x
Ptilidium ciliare	x

1) On the base of the trunk

Populus

Station	9	213	396	207	516	570	
	1	2	2	3	16	23	
Lecanora conizaeoides	2	1	3		2		4
Hypogymnia physodes		1		2	3	1	4
Lecidea scalaris			2				1
Parmelia sulcata				2	3	2	3
Lecanora subfusca coll.				1	1	1	3
Cetraria chlorophylla					2[3]	1	2
Parmeliopsis ambigua					2		1
Bacidia chlorococca					2		1
Lecanora subfuscata					2		1
Lecanora chlarona					2		1
Cetraria glauca					2		1
Cetraria pinastri					1		1
Alectoria jubata					1		1
Xanthoria candelaria					1		1
Parmelia exasperata					2[2]		1
Lecidea helvola					1[1]		1
Physcia tenella						3	1
Physcia ascendens						3	1
Physcia entheroxantha						2	1
Physcia pulverulenta						2	1
Physcia orbicularis						2	1
Candelariella xanthostigma						2	1
Xanthoria fallax						3	1
Xanthoria parietina						2	1
Xanthoria polycarpa						1	1
Anaptychia ciliaris						1	1
Phlyctis argena						2	1
Lecanora umbrina						2	1
Physcia nigricans						1	1
Caloplaca aurantiaca						1	1
Caloplaca cerina						1	1
Lecanora Hageni						1	1
Bacidea luteola						1	1
Parmelia fuliginosa						(1)	1
Ramalina sp.						(1)	1
Orthotrichum sp.						1	1

1) On the base of the trunk

2) Overgrown by Hypogymnia physodes and Parmeliopsis ambigua

3) c. ap.

Aesculus hippocastanum

Station	137	215	351	530	
	1	1	1	8	
Lecanora conizaeoides	2	1	1		3
Hypogymnia physodes				3	1
Lecanora chlarona				3	1
Lecidea scalaris				2	1
Parmeliopsis ambigua				2	1
Cetraria pinastri				1	1
Lecanora subfusca coll.				1	1
Lecanora symmicta				1	1
Lecanora subfuscata				1	1

Salix

Station	222	325	80	320	327b	91	92	I 142	
	1	1	6	6	6	7	8	8	
Lecanora conizaeoides	2	1		1	1	2	2	2	6
Hypogymnia physodes			1	1	1	2	1	1	6
Parmelia sulcata			1	1		2	1		4
Cetraria pinastri			1	1		2	1	2	5
Parmeliopsis ambigua			2		1			2	3
Cetraria glauca			2		1		1		3
Cladonia spec.			1						1
Bacidia chlorococca				2		2	2	2	4
Lecanora subfusca coll.				1			1		2
Cetraria chlorophylla					1	2	1	2	4
Lecidea scalaris					1			1	2
Caloplaca chlorina						1			1
Cladonia coniocraea								2	1
Dicranum scoparium			2						1
Orthodicranum montanum			2						1

I) Epiphyte vegetation from ground and approx. 2 metres up on the northern part of the trunk.

XIII

Alnus glutinosa

Station	79	481	120	141	342	349	339	461	401	459	529b	
	1	1	2	2	3	5	6	10	11	12	20	
Lecanora conizaeoides	2		2	2	1	1	1			2	1	8
Lecidea scalaris		1			3	3	3		2			5
Hypogymnia physodes			1		3	2	3	2	2	3	3	8
Lepraria incana				1		2	1	2	2	2		6
Cetraria chlorophylla						1		1		$1^{2)}$	3	4
Alectoria jubata							1			1		2
Lecidea efflorescens							2					1
Parmeliopsis ambigua								2	2	1	2	4
Bacidia chlorococca								1	2	1	2	4
Ochrolechia androgyna								1	2		1	3
Cetraria glauca								1				1
Cladonia coniocraea								2				1
Buellia disciformis								1				1
Ochrolechia microstictoides								2				1
Parmelia sulcata									(2)	1	2	3
Parmelia fuliginosa									2	$1^{2)}$	1	3
Lecanora expallens									2	1		2
Cetraria pinastri									$1^{1)}$		1	2
Calicium Floerkei									1			1
Lecanora chlarona										2	3	2
Lecanora carpinea										1	2	2
Buellia punctata											2	1
Lecidea quernea											2	1
Hypogymnia bitteriana											2	1
Xanthoria polycarpa											2	1
Xanthoria candelaria											1	1
Pseudevernia furfuracea											1	1
Evernia prunastri											1	1
Physcia dubia											1	1
Lecanora umbrina											1	1
Hysterium pulicare											2	1

1) Not found on examination

2) On the base of the trunk

Betula.

Station	29	397	I 116	130	127	416b	577b	576b	
Lecanora conizaeoides	2	3	2		2				4
Hypogymnia physodes	1		1	3	3	3	3	3	7
Lecidea scalaris		2	2	2			2		4
Lepraria incana		2		2	2				3
Cetraria chlorophylla		(1)		1			3	3	4
Parmelia sulcata			2			1		1 1)	3
Parmeliopsis ambigua			1		1 1)	2	2	1	5
Candelariella xanthostigma			1						1
Cladonia coniocraea				2 1)		2		2 2)	3
Lecanora expallens				2					1
Parmelia saxatilis					1	1	2 1)		3
Lecanora chlarotera					1				1
Cladonia sp.					1 3)				1
Pertusaria amara						2			1
Ochrolechia androgyna						2			1
Ochrolechia microstictoides						2			1
Calicium hyperellum						1			1
Evernia prunastri						1	2	1	3
Pseudevernia furfuracea							3	1	2
Cetraria glauca							3	2	2
Alectoria jubata							2	3	2
Usnea hirta							2	2	2
Alectoria implexa							1	1	2
Lecanora subfusca coll.							1		1
Hypogymnia bitteriana							3		1
Parmelia fuliginosa								2	1
Xanthoria polycarpa								2 1)	1
Pachyphiale fagicola								3	1
Parmelia exasperata								1	1
Cetraria pinastri								1	1
Lecanora chlarona								1	1
Physcia dubia								1	1
Physcia tenella								(2)	1
Hysterium pulicare								2	1
Hypnum cupressiforme			2	2					2
Pylaisia polyantha			2						1
Brachythecium velutinum			2						1
Plagiothecium silvaticum			2						1
Mnium cuspidatum			2						1
Orthotrichum sp.			1						1
Orthodicranum montanum				2		2			2
Ptilidium pulcherrimum				2	2	2	2		4
Dicranum scoparium				2		2			2
Brachythecium populeum						2			1
Pohlia nutans						2		2	2
Ceratodon purpureus								2	1

1) On the base of the trunk
2) In moss an base of trunk
3) On root collar

I Lichens occur as small examples

Pris 42: — kronor

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