#### MONITORING OF CONIFEROUS FOREST ECOSYSTEMS IN The results and the contract of the second o SWEDEN

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A monitoring program is planned for the terrestrial environment around industries in Sweden, which emit acid compounds and heavy metals. Directions for the County Government Boards are being prepared. The paper deals with the present pollution situation in Sweden, based on recent scientific results, the justifications for local monitoring, and the organizing of the monitoring including the parameters suggested.

Four examples from a case study at an oilfired power station illustrate reporting of the data and the difficulties in interpreting the results. The examples are the distribution of a lichen indicator, heavy metal content and phosphatase activity in the moor layer, soil respiration and tree growth.

### PREFACE

Instructions for monitoring of the terrestrial environment around industries are under preparation. The instructions will deal with the effects on ground and vegetation of both acid and metals. The reason for this is together and the effects of those components are difficult to separate. The solubility and toxic effects of the metals are changed with changing acidity.

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Board (SNV) and the instructions are to be published in its PM series. Docent Germund Tyler, the University of Lund, and the author are responsible for the scientific design. The author is the leader of a case study of that acid and metals are often emitted coniferous forest mainly at the oilfired powerstation of Karlshamn, S Sweden but partly also at the sulphite pulp mill of Domsjö and the smeltery of Rönnskär, N Sweden. The intention of the study is to find out the best The project is initiated and directed by the possible terrestrial methods for monitoring.

### BACKROUND

It is a well known fact that the deposition of emissions (RODHE 1971). The heavy metals

acid and sulphur (excess-values) through Pb, Cu, Zn and Ni have been examined in precipitation over Scandinavia has increased herbaria-mosses (RYHLING & TYLER 1969). considerably since the 1950s and that S and It is evident that deposition of those metals SW Sweden and S Norway are worst affected over S Sweden has been increased by (GRANAT 1972). Counted roughly, half of European industry. Today the foreign sources the sulphur deposited in S Sweden comes contribute to our contamination of heavy from adjacent regions in Europe, the rest metals (a good example is Pb), but for many from natural background and Swedish metals the dominant centres of distribution

are Swedish industries (RYHLING & SKÄRBY 1979).

It is no doubt that acute injuries and growth reduction of Swedish forest trees are in Sweden is planned by the author in 1982). soil activity caused by heavy metals, which is proved experimently (TYLER 1977) and shown in local investigations (e.g. TYLER & WESTMAN 1979). That implies worse organic turn over which in turn may result in humus accumulation and acidification. In fact decreasing activity is emphasized in acid forest soils, where the heavy metals moreover are highly available for the trees.

There is hardly no investigation that clearly shows an acidification and impoverishing of the ground caused by acid deposition, because we are in lack of historical references. An acidification and increased leaching is and high nutrient status (spruce on till) in however verified in the middle of Sweden areas with high acid deposition, the during a decade from the beginning of the contribution from the atmosphere is of the 1960s. That is made in the National Forest Survey (Riksskogstaxeringen) which prepares a net of fixed test plots in forests all over Sweden starting 1983. Locally a soil pH lower than normal is established at industries (TYLER & WESTMAN 1979). The author has shown that outside the nearest neutralized zone around pulp mills there are uncommonly low pH-alues and low amounts of calcium expressed as per cent of exchange pollutions are responsible for acidification of capacity in the moor layer (hitherto internal report to SNV, in Swedish).

An attempt to calculate the contribution from different sources of acid was made at the Department of science, SNV, 1979. As acidifying processes are treated deposition caused by direct influence of industrial smoke (through fall), humus accumulation, uptake (a summerizing report on local investigations of mineral nutrients into plants, manuring and ditching and as neutralizing processes The effects by changes of the soil are dis- weathering, leaching, liberating of alucussed. Most clear is the inhibition of the minium and SO42--fixations. The calculation resulted in the following conclusions:

In arable land the atmospheric deposition is of less importance in relation to manuring.

In coniferous forest on ground of low nutrient status (pine on sand and flat rocks) the atmospheric contribution of acid is dominating in areas, where it is high. It has increased seven times after the industrialization. The buffering capacity of the ground is low especially where the soil is thin and permeable, and the surface- and groundwater is directly influenced.

In coniferous forests on ground of medium same order of size as nutrient uptake and humus accumulation. Changed land use may give a higher contribution of acid than the atmospheric deposition during the first 10 years. Manuring of forest ground has occasional acidifying effects, while felling is of lasting import. Utilizing of the whole tree may give around half of high atmospheric contribution. It is evident that not only air the ground. This fact must be considered in monitoring programs.

# THE AIM OF MONITORING PROGRAM

The aim may be summarized in three parts: 2. To follow up the long-term changes. 1. To document in time and space the extent and degree of the influence of the environment that is caused by the industrial activity.

- 3. To control continuously the observing of the directions that are valid for the industrial activity.

# **JUSTIFICATIONS FOR LOCAL MONITORING**

Detailed practical instructions are missing. environment. Terrestrial monitoring is thereair quality, but not for the terrestrial soil are going on.

They exist for parts of water environment and fore neglected in vain serious changes of the

The terrestrial environment is a very complex system. If the components of the PMK-Land) is highly debatable for local emissions are ever known, we know too little about their synergistic and antagonistic every polluted area. Without consequent use effects. Every source of emission is unique of standarized methods we can not even concerning the proportions of the emitted substances and the character of the surroundings.

to make evolutionary predictions except very rough ones from general future models. Evolution takes one of many possibilities at every step.

Because of the unique character of every source and every area it is difficult to compare to other studies and make conclusions. Thus the reference function in the regional

terrestrial monitoring in Sweden (the project purpose. The best reference lies just outside compare diffetent measure series from the same area.

Consequently the only way of monitoring To that background it would be hazardous is to follow the development in each area by measuring with standardized methods. What we measure are some key processes in the biological system which are compared to contents of important pollutants of the area. To manage this, detailed instructions are required, which are to be followed now and 50 years later.

# ORGANIZING OF THE MONITORING WORK

The extent of a monitoring program is dependent on the type and size of emission, the choice of type of nature and the choice of measure-parameters fitting to that type.

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#### Emissions

The actual types of sources are those emitting sulphur, fluoride and heavy metals. The size, that is the amount of emission per period, usually per year, gives some information about what is meaningful to measure. Injuries to vegetation may be dependent on the frequencies of high contents in the air during short periods. Such information is, however, nearly always missing, even from old industries.

# Type of nature.

The types of nature are arable land and 2. A standard program applied to all forest. The types must not be too hetergenous. Hitherto we have worked with forest on moor cover. We prefer either dominance of spruce forest or pine forest of shrub lichen type on sand or rough till. Its is important to have knowledge of geology and climate as key maps of the area to avoid heterogenity. One has to consider the climatic coast-inland gradients and the situation of

the highest coast line. Reference data must be distributed at the same distances from the coast as the head material.

#### Parameters

The parameters are of two types; those which illustrate the quantity and distribution of the substances emitted and those which describe the effects. They must be practical to handle, and rather not too time consuming or expensive. The effect-related parameters shall give a comprehensive picture of the changes of the ecosystem. The soil measurements are limited to some key processes.

Table 1 shows parameters suggested. They are divided into three levels of ambition:

1. A base program, only containing content-related parameters, preferably applied to small emittents.

medium sized or big emittents.

3. An additional program applied to big industries (in Sweden e.g. planned coal power stations or metallurgic industries with emission of high quantity and extension). This program is more expensive and to some extent more difficult to accomplish.

Table 1. Suggested parameters the end of the state of the sta 1=Base program 2=Standard program 3=Additional program

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	Heavy metal deposition measured in	1,2	nitrat-N and nitrit-N under controlled conditions	
2.	Heavy metal content in the soil	1,2	11. Ureas activity; that is the ability of the	
3.	Content of S or F in epiphytic lichen	1,2	soil to split urea, measured under	
4.	Mapping of epiphytic indicator lichens	1 (?) 2	controlled conditions 3	
5.	pH in the soil	2		
6.	Soil respiration measured as CO2 -yield		Some additional parameters are discussed:	
2	under controlled conditions		12. Soluble Al, measured as leaching into ly-	
7.	Phosphatase activity, that is the activity of		simeters	
	the soil to split organic phosphorus, me-		13. Mapping of fungi; occurrence of fruit	
	asured under controlled conditions	2	bodies of big fungi in the forest.	
8.	Content of soluble H, Na, K, Ca and Mg		14. Decomposing of organic material in litter	
	in the soil	2	bags.	
9.	Tree-production; measured as diameter		15. Changes of pigments in needles and lea-	
	growth, shoot length and variations in		ves.	
	needle weight	2 (?) 3	16. Changes of the photosynthesis in lichens,	
10.	Mineralization of nitrogen in the soil;		needles etc.	
	transformation of organic N to NH4-N,		17. The N/S-quotient of the needles.	

#### THE TEST

# Pilot study

study which gives a rough idea about the only 15-20 % of the SO<sub>2</sub> and metal affected area. At an already established particles (Cr only < 5 %) are deposed industry this can be done at c. 10 stations within the 50 km border, but the yearly each in the dominant and least dominant wind directions and perhaps some directions border relative to the maximum. tions between. The best and most simple parameters to be used are mosses and lichens (nr 1, 3, 4 in table 1), at old sources, also metals in humus.

There is a rough rule about the relation between the height of the chimney and the extention of the affected area in the dominant wind direction:

Affected area Chimney max 10 km 50 m " 20 "  $50 - 100 \, \mathrm{m}$ ca. 50 km or more 100 m

But in this scheme both the quantity of emissions and climatic factors are missing. At the smeltery of Rönnskär, N Sweden, for instance, we must go at least 100 km to reach the background (TYLER & WEST-

MAN 1979). At calculations for planned power stations in S Sweden It is appropriate to begin with a pilot PERSSON et al (1979) have shown that deposition is 10-20 times lower at the

## Head study

When the real or hypothetical area affected is roughly known, and the type of nature and parameters are chosen the documentation can begin. Then the revisions are to be made at fixed intervals.

Two types of test systems are proposed: The first type is a transect, preferably in the dominant wind direction with at least 10 fixed test plots distributed along the gradient. The second type is an areal network with 60-90 test plots lying in circle segments with the factory in the

In the first type each plot for soil studies is a square, if possible of 40 x 40 m separate revisions without disturbing each zone is to prefer. These two principles and other. At each test may be needed one, two transect studies and areal studies are to be or more samples consisting of 10-20 combined in the best way in each area.

demands on the homogeneity of the test material. deals with:

Dominant tree species The age of the trees The density of the forest The mosaic of field- and bottom layer The thickness of the moor Humidity Inclination Superficial stones

We cannot even tolerate too great forestry changes on such plots during the avoid extremely big or small trees and use monitoring period. If, for instance, quotients of shoots instead of lengths for thinning has to be done, this must be different years. Parasitic influence has to considered in the results.

In the second type, the areal study, the going on. revision need not be done on the same plot and the demands of the plots need not be so hard as for the fixed plots. The great material allows variation to some extent. On the other hand the great number do not permit time-consuming and expensive

How to place the plots in relation to each other is discussed. Concerning the content-related parameters lichen and indicators a logarithmic distribution with more of plots in the center is to recommend. For biological soil variables a future, in vain the trees now are planted a more arithmetic distribution with an

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or equivalent size, large enough to allow additional represcentation in the middle

subsamples. The number is dependent on In studies of tree growth we need the tolerable variation and the homo- reference material. At a transect study a geneity of the test square (that is tested in corresponding transect is placed outside the case study at present). the affected area. In an areal study the On these plots it is possible to make areas around the affected area may act as rather careful measurements and even the reference material. In both cases we must most time-consuming and expensive of consider the coast-inland gradient. the proposed parameters can be used. On Coastal plots and inland plots must be the other hand we must require high equally represented in head- and reference

plot. Otherwise the local variation drowns For studies of the growth of spruce and the changes that a parameter should show pine with the quotient method we have at a revision. If conclusions about the used 10 trees per plot. That is, however, gradient are required, we also must too small a number to treat the test plot as demand similarities between the plots. The a unity, but merely as part of a polluted demands of test plots in a coniferous forest zone with at least 50 trees. Out of such a material we generally are able to distinguish with statistical significancy a growth reduction caused by pollution of 15-20 % or more. We are now testing how many trees are needed to characterise a stand concerning the effect of air pollution.

The above is valid to grown up trees. On planted, young trees (<15 years) the growth of top shoots are measured. Because of the great variation we must be considered carefully. Method tests are

Lichen studies or moss sampling had better be done in connection to other studies. The great problem is the poorness of the tree lichen communities in S Sweden, which not only has to do with air pollution but also with the darkness in the dense spruce plantations. Naturally regenerated forests are richer in lichens both measured as individuals and species. The few dispersion centra and the acid precipitation will both contribute to the lack of indicator lichens in S Sweden in little thinner.

# THE DATA

A work group with specialists from The County Government Board different institutions are now working out demanded an immediate monitoring routines for storing and processing of monitoring data. All the material is to be stored in such a way that it is possible to quickly receive data from other areas and from earlier investigations at revisions. The principles of the RUBIN-system are proposed.

Statistical treatment is necessary for confirming relations or tendencies. Gradients and changes are best illustrated as distribution maps and diagrams. This paper is ended by some examples from the case study at the oilfired powerstation of Karlshamn. These examples also illustrate the difficulties in interpreting the results.

program. This was done with resources available. The results however showed that some analyses were difficult to interprete because of incorrect technique especially in the sampling. Therefore concerning ground analyses we only made method tests in 1980. The summer 1981 we started complete monitoring program with the parameters 1-9 (table 1). Later other suitable parameters may be added. Method tests go on e.g. at the Inst. of Forest Site Research, Swedish University of Agricultural Sciences, Umeå. A very great problem is the extraction and measuring of available cations. A radically new method built on sensitive instruments is needed.

# EXAMPLES FROM A CASE STYDY

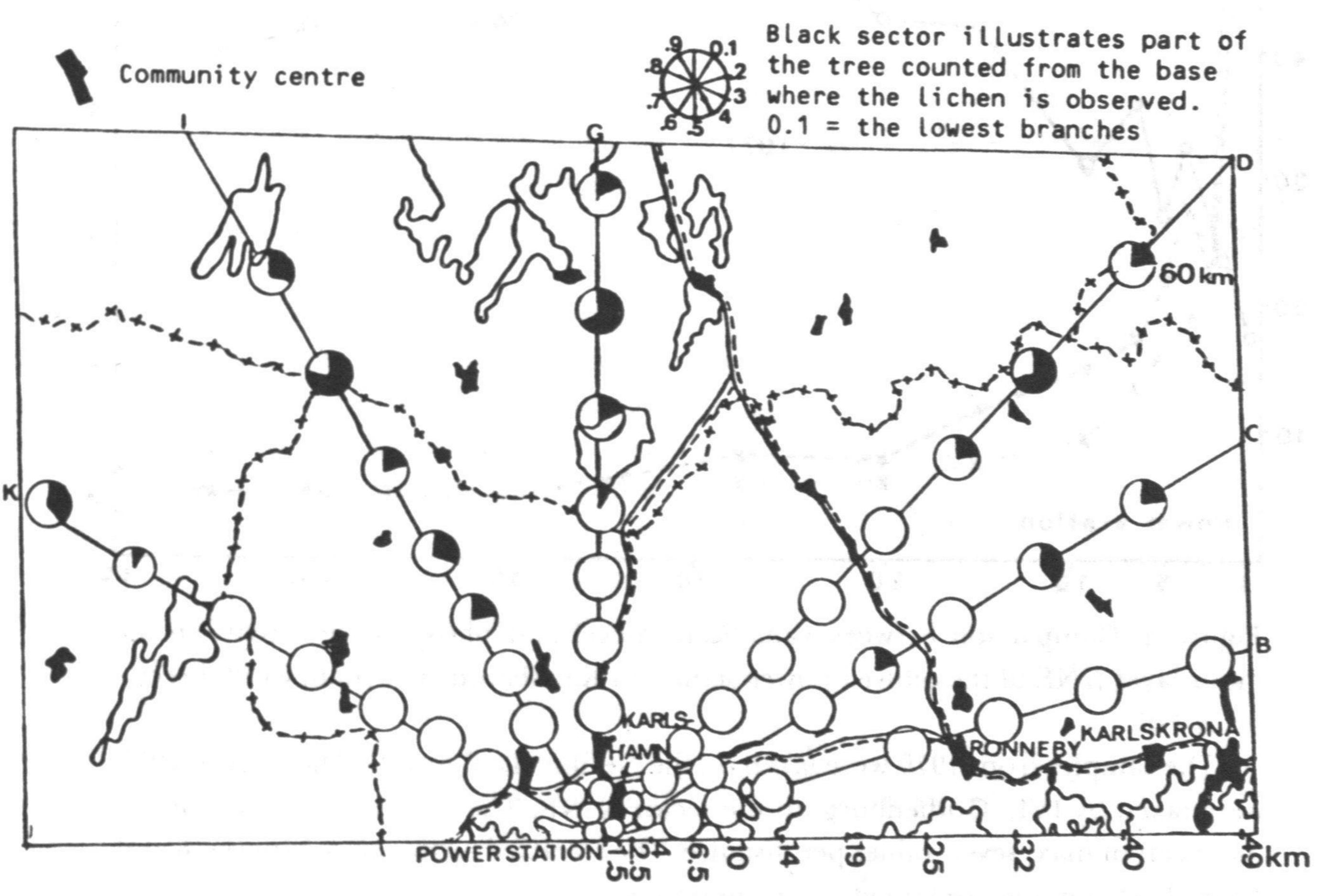


Figure 1. Vertical distribution of Bryoria capillaris on branches of spruce around the oil-fired power station of Karlshamn, July 1980.

Bryoria capillaris (Ach.) Brodo & D. Hawksw. is synonymous with Alectoria capillaris (Ach.) Crombie. In the often used Swedish flora, Svenska växter, Kryptogamer, by B. Ursing (1953) it is called Alectoria implexa (grå tagellav).

It is the most pollution sensitive of all common Swedish conifer lichens. Compared to other lichen parameters used the vertical distribution is less dependent on habitad factors, except air moisture (Westman 1976). Because of the influence from SO<sub>2</sub>, acid rain and probably also heavy metals the lichen occurrence is reduced from the top of the tree. Black sector illustrates the highest level of normal trees in a sample plot up to which it is observed.

The distribution shows a coast-inland gradient. The cause for this may be more air pollution near the coast, more favourable climate in the high inland regions (cold and moist a greater part of the year) and higher frequency of old naturally regenerated forest there acting as dispersal centra. The zone where the lichen species is lacking is however broader around the pollution source, especially in the main north-easterly wind direction.

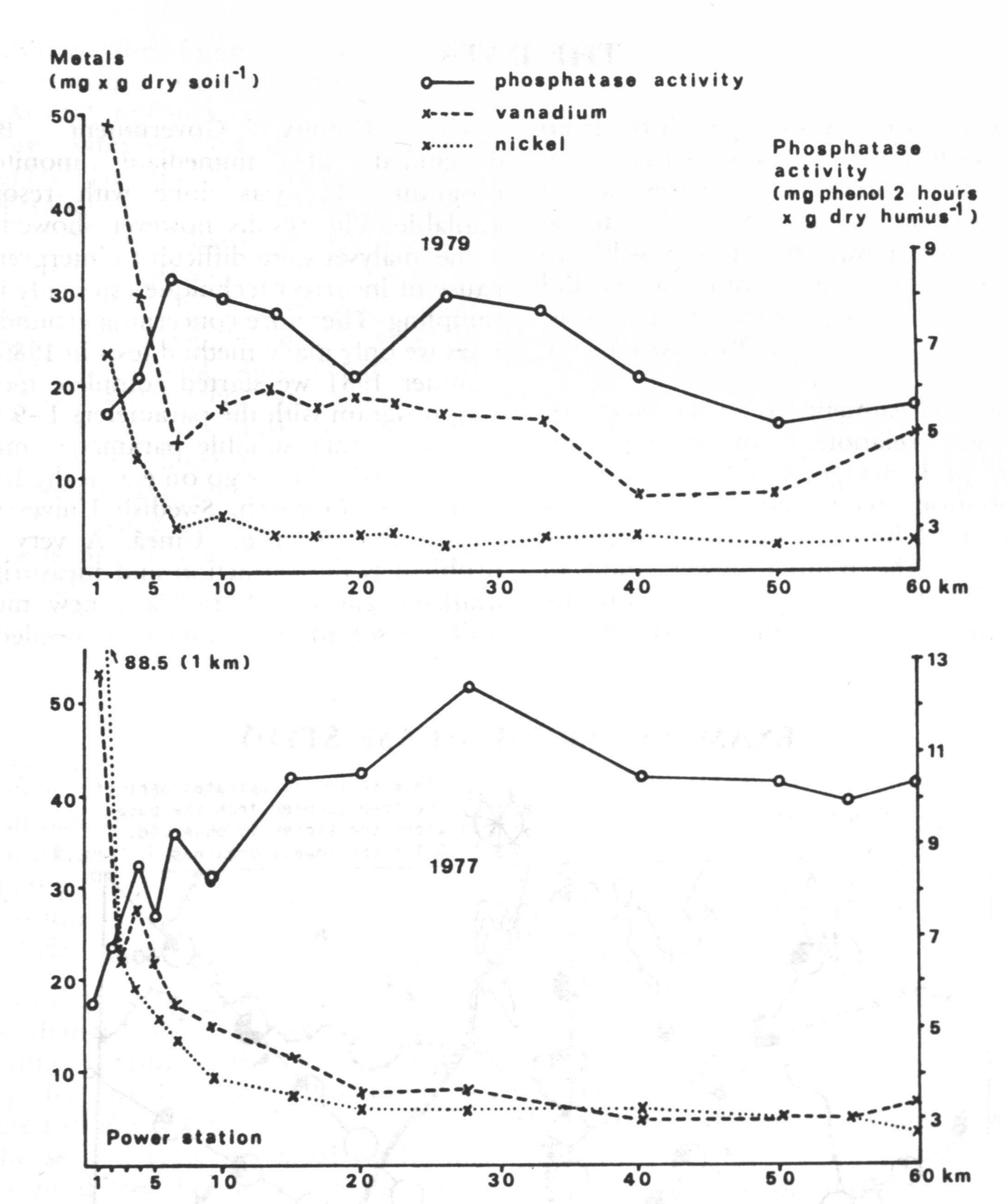


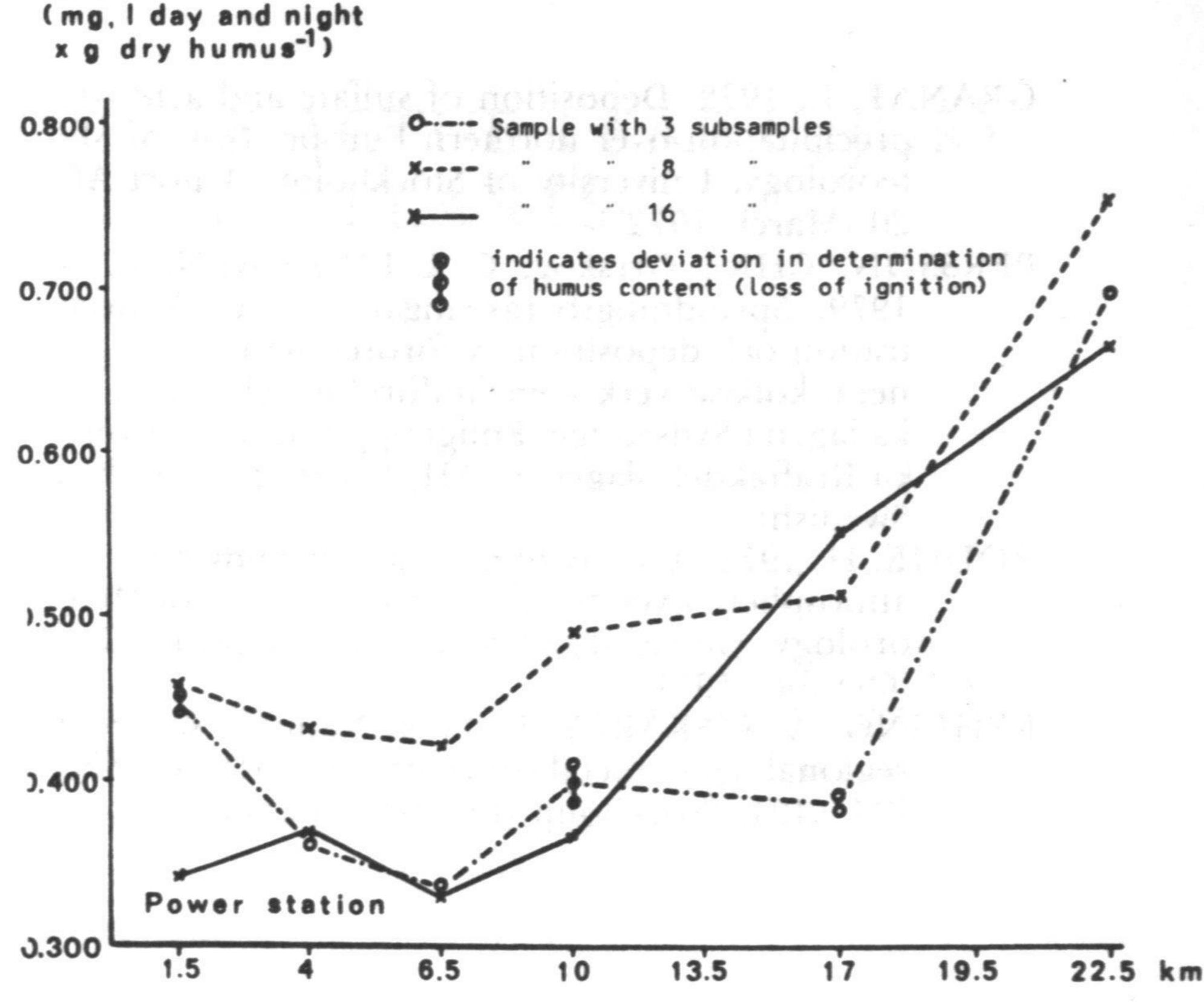
Figure 2. Comparison between vanadium, nickel and phosphatase activity in the moor layer NNE of the oilfired power station of Karlshamn. The main wind direction is NE.

The samples from 1979 were taken on the Ne-line (D, figure 1). Those from 1977 were taken by IVL, Gothenburg, in the sector N-NE. The values for that sector are the mean of max. seven values per distance. The standard error varies between 6 and 15 %. Each sample contained three susamples.

Earlier investigations tell us that a content of vanadium of at least twice the background decreases the phosphatase activity. That is what has happened within the 5 km border at the power station. The slow transition towards a more normal backgroud 1977 is eliminated for vanadium and phosphatase 1979. This may be the result of differences in pollution in time and space or differences in sample plots and sampling. The lowered contents of nickel are a little contradictory even if this metal is more easily leached out than vanadium. Method tests have shown, that the values are significantly dependent on habitat factors such as the content of humus, the depth of the sample, the nearness to the trees and the moss cover.

Figure 3. Ground respiration measured as CO2 yield from the moor layer in standardized environment. Samples from line D, NE of the oil-fired power station of 0.600 Karlshamn (see figure 1).

There is a clear tendency to lower respiration values near the source than at great distances. The transect is, 1,500 howerer, too short to confirm the role of the pollution source. The differences between the three parallel samples indicate great variations within the sample plot. 3.400 Method tests have shown that the respiration values are significantly dependent on content of humus and the depth of the sample.



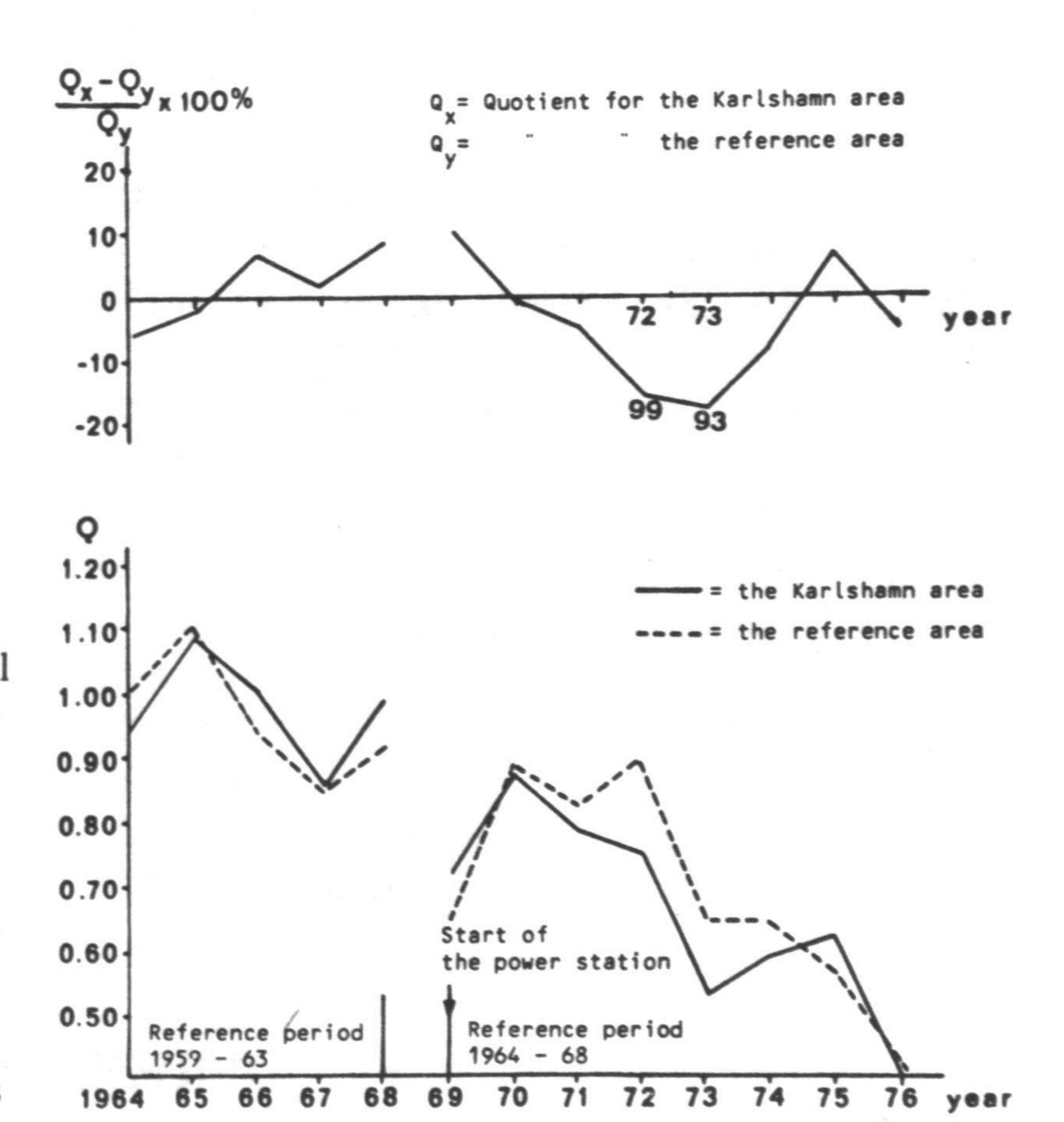
CO2

Figure 4. Results of a pilot study showing changes in the  $\frac{Q_x - Q_y}{2}$  x 100% growth of spruce in a coastal area 1.5-17 km NE of the oil-fired power station of Karlshamn compared to a corresponding reference area 40 km E the power station.

The trees at Karlshamn are 51 distributed on 5 sample plots, the reference trees are 30 on 4 comparable plots. The mean age is 39 and 47 years at breast height, respectively.

Differences in the growth level of the trees owing to genetic qualities or habitat factors are reduced by making growth quotients. For each tree the width of the annual ring for a certain year is divided by the width of the annual rings for a reference period before the start of the power station. Q = the mean quotient for respective area (the bottom picture). The growth in the reference area is 0.80 considered to be normal. A quontient less than normal in 0.70 the Karlshamn area indicates negative effects by 0.60 pollutions from the power station. The difference in growth quontiet between the two areas (the values of the bottom picture expressed as per cent of the normal is illustrated in the upper picture. The figure at the difference curve indicate probability ≥ 80 % according to t-test.

Between 1972 and -74, top years concerning SO<sub>2</sub> emissions from the power station, the spruce trees grew on an average 15 % less near Karlshamn and returned later to normal growth. A Difference less than 15 % is not statistically significant in this material. This is roughly the needles than through changes in the ground.



counted the part of the growth reduction caused by the pollutions from the power station. No forestry actions were reported or observed on the sample plots 1961 to 1976. The difference in tree age may influence the percentage a little but not the main result. The direct reaction of the trees indicate merely influence throught

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