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NOTES ON THE GROWTH OF SCOTCH PINE IN UTSJOKI IN NORTHERNMOST FINLAND

BY

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INTRODUCTION

In a previous paper (1948) I have described the various growth phenomena in Scotch pine (*Pinus silvestris L.*), i.e. the annual variations in growth and thickness, growth in height and length, needle growth and intensity of flowering.

In July 1949, I had the opportunity of spending a week in the Utsjoki valley in northernmost Finland (about 69°30'N. lat.). Part of the time was devoted to collecting data concerning the above mentioned annual variations in the growth of pine, mainly as supplementary notes only to check the accuracy of my earlier work on the same subject. No increment borings were made in 1949. Dr. *Peitsa Mikola* has allowed me to use his original rough radial growth series for Utsjoki, collected in 1946. I express my sincere gratitude for this aid.

Helsingfors, January, 1956.

I. H.

I. GENERAL REMARKS ON THE DURATION OF THE VARIOUS GROWTH PHENOMENA OF THE PINE IN NORTHERNMOST FINLAND

The growth of the pine starts in Utsjoki in early June or late in May, when the first signs of awakening are seen on the buds, i.e., a slight bending back of the outer scales of the buds and a slow disappearance of the thick resin layer. In the middle of June, sometimes a little earlier, the elongation of the shoot is visible. The elongation process is more or less completed in early and mid-July. The elongation seems to be markedly faster in Utsjoki than in South Finland (compare H 1947b[1]). When the elongation of the shoots starts there is always enough water in the ground in the northern forests. Sometimes, as in 1945, there is still snow on the forest floor when the buds start their emergence.

Radial growth (growth in thickness) starts in the end of June and conti-

[1]) The expressions H 1947b, H 1948, etc., refer to the author's previous papers.

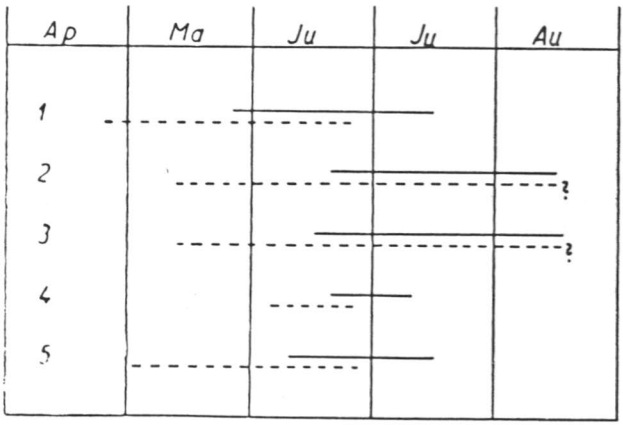

Fig. 1. Approximate duration of different growth processes in Utsjoki in northernmost Finland. The dashed line marks the approximate duration of the same growth processes in southernmost Finland. 1=elongation of the annual shoot. 2=growth in thickness. 3=growth of the needles. 4=approximate date for pollination. 5.=swelling of the 1-year cone.

nues until mid-August. It seems to be slower in August than in July. This is one reason why we can use the simple July mean temperature as a fairly good indicator of the climatic conditions during the time radial growth is in process.

The needles are just visible on the new shoots in the middle of June. At the end of June the tips of the new needles are green, but only 1—3 mm long. They continue to grow until mid-August, and in years with a very warm August probably longer. One would expect a certain correlation between needle growth and growth in thickness.

In northernmost Finland the flowering of the pine, i.e. the pollination, takes place in the end of June and begin of July. The small brown female cones of the previous season start swelling in the middle and end of June and grow slowly to »green cones» until about the middle of July. The process is finished at about the same time as the elongation of the shoot. — Compare Fig. 1.

II. GROWTH IN THICKNESS

The growth in thickness of the trees is more sensitive to changes in the summer climate at the polar limit of the forests than farther south. The growth season is short and unfavourable; the effect of the weather in the beginning of the summer, for instance, cannot be neutralized during the same growth season. There is according to several investigators (compare EIDE 1926, ERLANDSSON 1936, H 1940, GIDDINGS 1941, H 1948 and the recent inventory of the tree-ring literature by GLOCK 1955) a satisfactory correlation between

growth in thickness of conifers and the mean temperature of July in the north. Compare, however, also MORK 1941.

Tree-ring studies in regions between the northern forests and the forests near the step or the semidesert do not show the same high coefficients for the relation growth/climate as do similar studies farther north or farther south. Investigators in such intermediate regions tend to underestimate the influence of the climate on the annual variations in growth (compare DOBBS 1951). On the other hand, dendrochronologists from the semiarid regions in USA have earlier overestimated the value of tree-rings as climatological tools (compare GLOCK 1941 and 1955, H 1949).

If tree-rings are used as climatological tools in one way or other, *we must be sure*, for instance, *that two scientists working independently of each other in different years and with different methods, but in the same area, obtain the same result* regarding the annual variations in growth. Therefore I have ventured to compare Dr. *Peitsa Mikola*'s radial growth series and my own from the same area, i.e. Utsjoki.

Dr. Mikola's increment core material, collected in 1946, consists of 155 cores from five pine stands, three from the Kevu valley and two from the Utsjoki valley. The stands were of the dominant type in the area: sparse pine forest with a ground vegetation of *Empetrum hermaphroditum* and *Cladina spp.*, growing on stony slopes or sandy terraces.

The material in H 1948 consisted of 148 cores taken in the summer of 1939 and 1940 from pines growing scattered on the *Empetrum-Cladina* »semitundra» or in the mountain birch region in the Utsjoki and Kevu valleys. The trees were of various diameter and age classes (compare HUSTICH-ELFVING 1944); only the period 1890—1939 was used.

The material used by Dr. Mikola and by myself thus differed in character. It was selected in a different way, but was of approximately the same size and from more or less the same area, compare MIKOLA 1950 and H 1948. Both series represent mean values of original measurements.

In Fig. 2 the two series are compared.

The correlation coefficient between Dr. Mikola's and the series for 1939-40 from H 1948 is, for the period 1890-1939, $r = 0.92 \pm 0.022$.

Thus, we have obtained for the two tree-ring series collected by different scientists a very significant correlation coefficient. We can safely state that with remarkable precision the pines in Utsjoki follow one and the same pattern in their growth in thickness. Dr. Mikola's series show a lower mean value for the radial growth than my own series. This is largely due to the fact that his trees are from forest stands, my cores from scattered trees, which usually display greater growth in thickness than trees growing in more or less closed stands.



Fig. 2. Comparison of growth in thickness of pine trees in Utsjoki. a=the »standard series» in HUSTICH-ELFVING 1944. b=MIKOLA'S series of 1950, see the text.

The »double checking» made above, i.e. the comparison of the tree-ring series taken by Dr. Mikola and by myself, illustrates rather well in my opinion the value of tree-ring measurements as chronological tools. There seems to be, as was mentioned earlier, a good correlation between the July temperature and the radial growth. We can assume that the annual variations in the width of the tree-rings in the northern forests, also, to some extent, reflects the annual variations in the summer temperature. But before doing so we must get to know more of the growth processes and learn, for instance, to distinguish the »lag effect» (compare HUSTICH-ELFVING, l.c.).

How many cores or trees should a dendrochronological material comprise? Usually less than 100 trees or cores are used. The reason is obvious: the detailed routine work involved in such investigations makes it impossible for a single worker to work through a bigger material for a careful tree-ring analysis. Team work of the kind recently published by EKLUND (1954) can embrace thousands of cores. We must, however, remember that a large body of material drawn from wide areas, eliminates local differences and cannot be used as an indicator for local dendrochronological or climatological purposes. Compare the use and misuse of mean climatic values for large areas, and, on the other hand, values of local meteorological stations only. Compare also HUBER 1943.

The two series compared above comprised 155 and 148 cores respectively.

Such a material, selected by the authors themselves in the field in a comparatively small area, gives, as has been shown above, an accurate idea of the annual growth variations. A still smaller material can give a satisfactory picture of the variations in growth in an area where there is strong »minimum factor» such as the summer temperature in northernmost Finland or the water supply near the forest limit to the semidesert.

In H 1948 several series collected in 1945 and comprising only 4-22 trees were compared with the standard series of 1939-40. The correlation between the series of 22 trees and the standard series was $r = 0.89 \pm 0.035$, but even smaller series showed a coefficient of 0.80.

But as we proceed farther into areas where the factors affecting the growth in thickness becomes more and more complex (as in England, Central Europe or Eastern USA), the more and more trees we must use as a minimum amount for a correct analysis. The use of too small a material in regions with a complex relationship between growth and climate probably accounts for a lot of the confusion regarding the value of tree rings as climatic indicators. And, tree-rings should not be used as climatic tools everywhere.

III. GROWTH IN HEIGHT AND LENGTH.

Growth in height of pine is, as was shown by HESSELMAN (1904) and LAITAKARI (1920), more dependent on the temperature of the previous summer than on the temperature of the growth season itself (in Sweden and Finland). This is due to the fact, already indicated above, that the growth in height is an elongation process, the initial cells having been formed during the previous summer.

In 1949 I collected some notes re the annual variations in growth in height; the information is compiled in Table I. Series *a* is from H 1948 (3 young trees, 60-70 years old). Series *b* is a wellgrown pine, 11 m high, 25 cm in d.b.h. and about 75 years old, measured in July, 1949. Series *c* represents the mean values of 12 young pines (15-20 years old), measured in July, 1949.

Table I. Growth in height (in cm) of young pines.

	1948	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26
a	—	—	—	—	15	16	23	12	18	24	26	20	19	28	19	21	13	23	—	—	—	—	—
b	14	12	11	7	8	11	14	13	11	13	16	14	16	18	12	13	18	13	14	22	16	24	27
c	17	18	13	6	9	9	14	8	7	7	—	—	—	—	—	—	—	—	—	—	—	—	—

In Table I, 1935, 1938 and 1942 appear as maximum years. The earlier years are uncertain. Compare H 1948, p. 30. MIKOLA (1950, p. 87, Fig. 30) has 1931, 1935, 1939 and 1942 as maximum years and 1930, 1933, 1936, 1941 and 1943 (45) as minimum years.

However, the growth of young pines is not merely dependent on the climate itself, but also on internal factors. The annual growth of a pine reaches its optimum in the 20—40th year and then slowly decreases. In Utsjoki the growth in height of the trees is rarely undisturbed and occasional measurements do not give an accurate picture. (Series *b* above is a single tree, included here mainly to show the absolute values of growth in height of a wellgrown pine in the area.)

The often disturbed growth in height of pine at its northern limit was the reason why the author (in H 1940) adopted another indicator to illustrate the growth in height, i.e. the growth in length of second order branches (re the concept »second order branches» compare RENVALL 1912). Branches which have already passed their first rapid development, register, as has been shown earlier, the variation of the climatic conditions of the summers, more or less independently of the internal factors. Long annual shoots on such branches almost certainly indicate that the previous summer was a favourable one.

Table II comprises the material in H 1940 and H 1948 (*a-d*) compared with a smaller material of 33 branches (trees) collected in 1949 (*e* in Table II).

Table II gives a rough idea of the annual variations in growth in length of the shoots of pine in Utsjoki. The minimum years are, according to Table II, 1933, 1936, 1941 and 1944, whereas 1932, 1935, 1938, 1942 and 1946 were years with longer annual shoots. There is a good correlation between Table II and Table I as also between Table II and MIKOLA 1950. The Table also illustrates that the mean length of the shoots of second order pine branches in Utsjoki is only 2.5 - 3.5 cm.

Table II. The length (in cm) of the annual shoots of second order pine branches in Utsjoki.

	1949	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31
a	88[1])	—	—	—	—	—	—	—	—	—	—	26	19	19	22	21	16	20	18
b	94	—	—	—	—	—	—	—	—	—	33	39	29	28	34	31	27	35	—
c	25	—	—	—	—	—	—	—	—	30	36	42	30	27	35	32	31	40	37
d	62	—	—	—	—	21	27	33	21	26	30	33	29	26	30	27	24	—	—
e	33	24	29	29	32	24	24	27	34	25	30	31	32	—	—	—	—	—	—
M	24	29	29	32	24	23	27	34	23	29	30	34	27	25	30	28	24	32	28

[1]) Number of shoots included.

IV. NEEDLE GROWTH

Table III compares earlier measurements of the needle length with a small series of 32 second order branches (series *e*), i.e. the same branches as in Table II, *e*. The measurements of needle length are the mean values of the two or three longest needles on the annual shoot in question. However, the extremely long needles on the last »short shoots» on the annual shoot are excluded; as a result of a warm August two or four such needles on one shoot show prolonged growth and this makes them useless as a relative measure of the assimilation capacity of the annual shoot. Of course, the number of needles on an annual shoot x their mean length would be a better indicator. The mean length of the pine needles in Utsjoki is 2.5-4.0 cm. The needles usually survive 6-8 years on the pine twigs in this area, rarely longer. In South Finland pine needles usually drop after 3-4 years. Observations in the summer of 1945 showed that at least 3-6 years old needles also take part in the assimilation process (H 1948).

Table III. Needle length (in cm) on second order branches of pine in Utsjoki.

	1948	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33
a	50[1])	—	—	—	—	—	—	—	—	—	36	34	31	29	32	35
b	103	—	—	—	—	—	—	—	—	28	38	38	32	32	39	37
c	31	—	—	—	—	—	—	—	26	28	39	36	29	29	33	32
d	60	—	—	—	29	31	31	38	28	27	33	—	—	—	—	—
e	32	27	31	33	36	28	32	29	35	—	—	—	—	—	—	—
M		27	31	33	36	28	31	30	36	27	28	37	36	31	30	35	(34)

In the needle length series the following years appear as minimum years: 1935, 1940, 1944, whereas 1934, 1938, 1941 and 1945 appear as years with long needles. There is thus no correlation between the length of the annual shoot and the length of the needles on the same annual shoots. There seems to be a certain correlation between radial growth and needle length, see Fig.1 and the synthesis below.

We note that, as in Table II, the supplementary notes of 1949 well confirm the notes in H 1948.

[1]) Number of shoots included; cf H 1948. p. 31.

V. THE INTENSITY OF FEMALE FLOWERING

The flowering intensity of the trees near or at the polar limit of conifers varies considerably from year to year. In »good» years the quantity of inflorescenses on the conifers in those regions is surprisingly high.

Regarding the alternation of ♀ and ♂ flowering and their succession on the annual shoots, compare H 1948.

In 1949, the female flowering of the successive shoots on 32 second order branches (the same as were used for the measurements of shoot length above) was studied, see series *c* in Table IV. For comparison series *a* and *b* from H 1948 are included. In all series the female flowering intensity is given using an index, 1938=100. 1938 was a very prominent »flowering» year in Utsjoki, as has been described in H 1940 and 1948.

Table IV. Female flowering intensity of pine in Utsjoki

	1949	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34
a	160	—	—	—	—	—	—	—	—	54	53	100	38	4	57	26
b	65	—	—	—	—	64	32	84	14	45	55	100	35	12	71	23
c	32	40	44	48	112	8	36	16	64	16	52	44	100	—	—	—	—
	M	40	44	48	112	8	50	24	74	15	50	51	100	36	8	64	24

All series coincide fairly well, in spite of the fact that they were collected during different years. The material is small, but gives, nevertheless, a picture of the marked irregularity in the flowering of the Scotch Pine in Utsjoki. We note minimum years in 1936, 1941 and 1945 and the maximum years in 1935, 1938, 1942 and 1946. A comparison with Tables I and II confirms the author's earlier statement regarding the close correlation of growth in length and flowering intensity. I do not think that the year 1946 exceeded the year 1938 in flowering intensity, in spite of the higher index in series *e*; the marks of flowering and cones of the year 1938 were perhaps in some cases not clear enough in 1949. Also, in 1946 one could not find so many annual shoots with both ♀ and ♂ inflorescenses as in 1938. I also have the impression that younger seedlings showed more female flowering in 1938 than in 1946.

The statement in H 1948 regarding the fact that there are »no years entirely without flowering at the timber line» was confirmed during the trip in 1949. — My data relating to the varying quantity of vegetative buds on the shoots were too small to allow any confirmation or nonconfirmation of the statement in H 1948 that in years with high intensity of female flowering the number of »vegetative buds» at the tip of the annual shoots is also high.

VI. SYNTHESIS

The above-mentioned growth phenomena include two physiologically different processes. On the one hand, we have the elongation of the annual shoot, the flowering intensity and the swelling of the 1-year cone. In these growth processes the initial cells are already formed during the previous growing season. On the other hand, we have the growth in thickness and the growth of the needles. Here new cells are formed during the growing season itself. Such growth processes are only rather indirectly dependent on the conditions of the previous summer, including amount of needles, general conditions of the tree, fruit formation (which slows down the radial growth), etc. Fig. 1 roughly indicates these processes.

It is difficult to determine the duration of different growth processes. They start before there are any visible signs to measure. Before growth starts, a chemical mobilisation takes place, as has been shown in H 1947a. In the bud itself biochemically different states prevail during the spring time; chemical changes occur also in the needles. A translocation of nutrients from the needles into the awakening bud seems to take place in early spring, before there are any visible signs of bursting scales, etc. (l. c.). TAMM writes that the conifer needles »act not only as photosynthesizing organs, but also as reserve stores for photosynthases and, to some extent, for nutrients» (1950, p. 20).

The relative length and the amount of needles influences the growth processes in the following years; compare also ORDING 1941. But since the survival on the twigs of needles still capable of assimilation is longer in the north it is probable that the equalizing effect of the varying needle length (i.e. of the varying climatic conditions during the previous years) is greater in the north than in southern parts of the pine region, where the needles survive 3-4 years only.

In his classical paper of 1905 (which I did not know of when I wrote my paper of 1948) BLACKMANN clearly outlined some fundamentals regarding optima and limiting factors relating to growth phenomena. These thoughts are here expanded to cover some differences between the growth phenomena in different regions.

There is a marked difference in the physiology of growth in the northern forests as compared to regions where precipitation is low and the water supply the limiting factor. The elongation processes must mainly depend on the water supply during the early summer. In the north, there is always water enough in the ground (see above). In more arid regions, however, one realizes that the amount of water at the beginning of the growing season is itself of primary importance; in such regions there is always a temperature high enough to allow

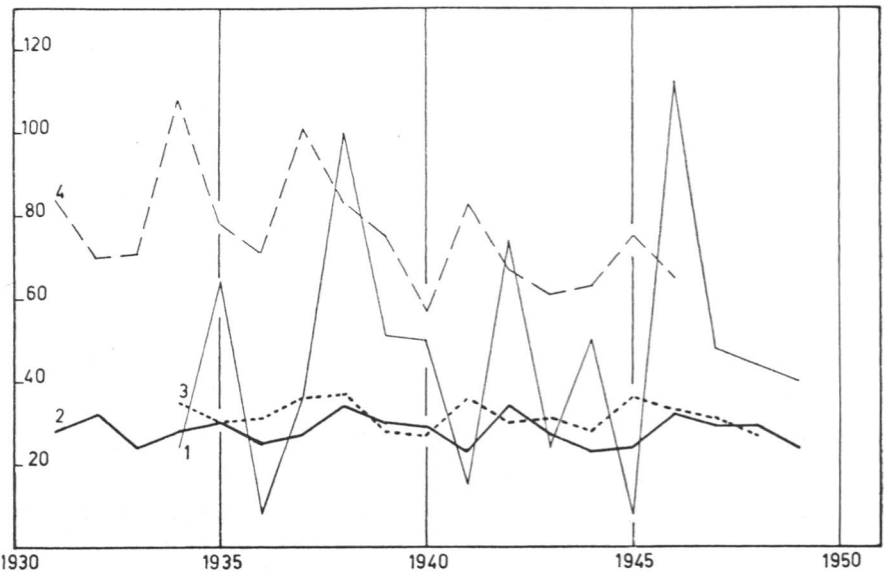

Fig. 3. Comparison of different growth penomena during the period 1931-49. 1=intensity of female flowering, compare Table IV. 2=growth in length of annual shoots, compare Table II. 3=growth of needles, compare Table III. 4=growth in thickness, series b in Fig. 2. according to MIKOLA, see p. 2.

growth processes. Thus, in places where growth is limited by water supply, maxima in growth in height and growth in thickness will occur in the same year, as outlined in H 1948. Therefore, the annual variations in growth in volume of wood will be greater in more arid regions and the trees more liable to extreme changes between good years and bad (i.e. dry) years. In the north, however, temperature is the limiting factor, and the temperature rarely rises so much as to endanger the assimilation process.

This paper gives only some rough account of externally measurable growth processes. For an integration of the growth phenomena by means of a synthetic diagram, the period used in H 1948 (1930-44) can now be slightly prolonged by the new supplementary notes of 1949, presented in Tables II-IV. Fig. 3 combines the data and confirms i.a. the following statements in H 1948:

1. The maximum in the intensity of female flowering coincides with the maximum years for growth in length of the annual shoot.

2. The growth in length and maximum intensity of female flowering sets in during the growing season after the maximum year in radial growth, i.e. one year after a favourable summer.

3. The maximum years of needle growth roughly correspond to the maximum years in radial growth.

It is necessary to point out that we are here operating in an area with extreme conditions for tree growth in general and in an area where temperature represents the limiting factor. Also, our rough measurements illustrate only the external happenings. The biochemical processes in the growth tissues and their dependence on certain climatic factors are beyond our reach.

LITERATURE

BLACKMANN, F. 1905. Optima and limiting factors. Ann.Bot. 19.

DOBBS, A. 1951. A study of growth rings in trees. Forestry 24.

EIDE, E. 1926. Om sommarvarmens inflydelse på årringbredden. Medd.fr. Norske Skogsforsøksv. 2. Oslo.

EKLUND, B. 1954. Årsringbreddens klimatiskt betingade variation hos tall och gran inom norra Sverige 1900-1944. Medd.fr.Stat. Skogsforskningsinst. 44, 8. Stockholm.

ELFVING, G. 1944. See Hustich and Elfving 1944.

ERLANDSSON, S. 1936. Dendrochronological Studies. Data 23. Stockholm.

GIDDINGS, J. L. 1941. Dendrochronology in Northern Alaska. University of Arizona Bull. XII, 4.

GLOCK, W.S. 1941. Growth Rings and Climate. Bot.Review 7. Lancaster.

—»— 1955. Growth Rings and Climate. Ibid. 21.

HESSELMAN, H. 1904. Om tallens höjdtillväxt och skottbildning somrarne 1900-03. Medd. fr.Stat.Skogsförsöksanst. 1. Stockholm.

HUBER, B. 1943. Über die Sicherheit jahrringchronologischer Datierung. »Holz» 6, 10—12. Berlin.

HUSTICH, I. 1940. Tallstudier sommaren 1939 i Enare och Utsjoki. Acta Soc. F.Fl. Fenn. 62. Helsingfors.

—»— 1947a. Anteckningar om tallen I. Till tallskottknoppens fysiologi. Mem.Soc.F. Fenn. 23. Helsingfors.

—»— 1947b. Anteckningar om tallen II. Några fenologiska observationer. Ibid.

—»— 1948. The Scotch Pine in northernmost Finland. Acta Bot. Fenn. 42. Helsingfors.

HUSTICH, I. and ELFVING, G. 1944. Die Radialzuwachsvariationen der Waldgrenzkiefer. Soc. Scient. Fenn. Comm. Biol. IX, 8. Helsingfors.

LAITAKARI,E. 1920. Tutkimuksia sääsuhteiden vaikutuksesta männyn pituus- ja paksuuskasvuun. Acta Forestalia Fenn. 17. Helsinki.

MIKOLA, P. 1950. Puiden kasvun vaihteluista ja niiden merkityksestä kasvututkimuksissa. Comm. Inst. Forest. Fenn. 38, 5. Helsinki.

MORK,E. 1941. Om sambandet mellem temperatur og vekst. Medd. fr. Norske Skogforsøksv. 8. Oslo.

ORDING, A. 1941. Årringanalyser på gran og furu. Medd. fr. Norske Skogforsoksv. 25, 2. Oslo.

RENVALL, A. 1912. Die periodischen Erscheinungen der Reproduktion der Kiefer an der polaren Waldgrenze. Acta Forestalia Fenn.I Helsinki.

TAMM, C.O. 1955. Studies on Forest Nutrition. I. Seasonal Variation in the Nutrient Content of Conifer Needles. Medd. fr. Stat. Skogsforskningsinst. 45, 5-6. Stockholm.

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