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CHANGES IN WATER QUALITY IN FINNISH LAKES 1965—1982

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At the network of stations on lake deeps, the trends uncovered in water quality in the period 1965—82 have grown clearly in number and statistical significance since the investigation of the period 1965—77. According to the records for 1970—82, however, the increase has come to a stop. The parameter that has changed the most is still electrolytic conductivity, which accounts for 34% of the total trends. It is followed by chloride, alkalinity and sulphur. Of the trends evident in 1965—82, 73 % indicate a deterioration in water quality; the corresponding proportion for 1970—82 is 65 %. Half of this slowing down of the deterioration is due to electrolytic conductivity. The locations of the changes in water quality are shown in Figures 1—10. Cluster analysis has also been employed to examine the changes in water quality at the middle depth in the water column in the periods 1965—70 and 1977—82. The dominant feature appears to be a decrease in the group of stations in a natural condition.

Index words: Water quality, monitoring, lakes.

1. PREFACE

Linear regression analysis was used to uncover possible trends in water quality at the national net of observation stations (160) at deep places in lakes. The computations included observations made in March in 1965—82 at 4 different depth levels: 1 m, 5 m, h = middle depth in the water column, and 2 h — 1 m. The parameters included were oxygen, conductivity, alkalinity, pH, colour, total sulphur, chloride, iron, organic carbon, total nitrogen and total phosphorus (Laaksonen and Malin 1982).

The analysis was employed to pick out series of observation showing a correlation between time and some of the parameters at or above the 95 % confidence level.

2. RESULTS

The total amount of trends indicating changes in the water quality (% of possible trends) has clearly increased with the length of the observation period:

	1 m	5 m	h	2 h — 1 m	Total material
1965—73	13	13	13	8	12
1965—77	20	19	18	12	17
1965—82	21	20	26	19	22
1970—82	15	15	19	16	16
1973—82	10	11	13	11	11

Lasting changes were noted more often in the middle depth of the water column than elsewhere (26%). In the surface water and the epilimnion the number of changes in the wa-

Table 1. The percentage distribution of trends at depth h.

Years	O_2	γ_{25}	Alk.	pH	Colour	S	Cl	Fe	Org. C	N	P	Total material
1965—73	10	47	11	13	10	6	8	7	..	17	4	13
1965—77	9	67	20	14	10	18	15	14	3	12	15	18
1965—82	19	75	30	21	13	26	32	15	14	17	21	26
1970—82	18	49	16	29	8	14	25	6	9	17	16	19
1973—82	20	24	17	19	6	9	19	4	10	6	10	13

ter quality was clearly smaller in the 1970 than earlier.

Besides the number of trends, the proportion (%) of very significant trends has also increased with the length of the observation series:

	1 m	5 m	h	2 h — 1 m	Total material
1965—73	..	..	..	..	36
1965—77	44	52	53	38	47
1965—82	54	58	60	51	56
1970—82	38	46	45	40	42

In the latter part of the series a clear turning-point was reached in the direction of the changes: the proportion of very significant and significant trends was smaller in the period 1970—82 than in 1965—77.

The percentage distribution of the changes at depth h among the parameters shows, among other things, that the most variable parameter continues to be electrolytic conductivity: in the total observation series a trend was evident at three stations out of four (Table 1).

Changes were also shown more often by the values for chloride and alkalinity (one station in three) and sulphur (one in four) than by the other parameters. Changes were observed least frequently in the values for iron and colour.

Comparison of different periods shows a clear decrease in the trends revealing a change (rise) in electrolytic conductivity. Its proportion (%) of all the trends has decreased continuously.

1965—73	34
1965—77	29
1965—82	27
1970—82	23
1973—82	16

In contrast, the significance of oxygen, pH and chloride as indices of changes is definitely increasing.

Examination of the proportion of rising (+) trends (% of total trends shown by the same variable) at depth h (Table 2) shows, among other things, that during the period 1965—82, electrolytic conductivity, sulphur and chloride had mainly rising trends, whereas organic carbon, colour and iron had chiefly decreasing trends. During the last periods the trends for oxygen and pH show a clear downward direction, while alkalinity shows an upward trend. Judging from the records for 1973—82, the increase in the sulphur concentration has begun to level off. Similarly, electrolytic conductivity also seems to have taken a downward turn at some of the stations. The same cannot be said of chloride.

If the number of trends showing a decrease in oxygen, alkalinity and pH is added together with the number showing an increase in the other parameters, the result, expressed as the percentage of the total trends, may give a somewhat better picture of the possible deterioration (or amelioration) in the water quality:

	1 m	5 m	h	2 h — 1 m	Total material
1965—73	67	79	75	69	73
1965—77	77	80	76	64	75
1965—82	77	79	67	68	73
1970—82	65	65	65	67	65
1973—82	61	61	62	61	61

The column for the total material indicates, for example, that three trends in four still show a deterioration in water quality. The records for the last observation period, however, show a change of direction; the number of trends indicating deterioration is clearly decreasing. In the period 1965—82, the deterioration can be seen to be coming to a stop at the surface and in the epilimnion, whereas it is already clearly decreasing at the middle depth. The change for the better will not be confirmed until later in the surface and epilimnion, and will last become evident in the hypolimnion.

Almost half of the improvement in the water quality discernible from the period 1965—

Table 2. The proportion of rising trends at depth h.

Years	O_2	γ_{25}	Alk.	pH	Colour	S	Cl	Fe	Org.C	N	P
1965—73	56	97	11	60	69	56	77	50	..	81	33
1965—77	73	97	13	45	81	76	76	70	0	68	46
1965—82	48	96	31	42	25	80	75	50	9	56	45
1970—82	45	92	56	35	38	73	67	30	36	63	42
1973—82	9	92	71	23	10	53	77	33	6	44	44

77 onwards appears to be due to the change in electrolytic conductivity, whose proportion (%) of the trends indicating deterioration is:

1965—73 45
1965—77 37
1965—82 37
1970—82 33
1973—82 25

With time, the acid precipitation presumably becomes unable to dissolve large amounts of cations from the soil (Järvinen and Haapala 1980). The quality of the runoff is undoubtedly also changing.

3. CLUSTER ANALYSIS

General trends were also sought by examining the distribution of the means for 1977—82 — from the middle depth (h) — among five classes created by grouping the means for 1965—70 (Table 3).

Comparison of the proportions of the observation stations in the 1960s and 1970s reveals changes mainly from groups 1 and 2, i.e. the least disturbed waters (Table 4). The directions of the changes are mainly the same which were observed previously in 1971—77 (Laaksonen 1982): they represent a loss of purity rather than an increase in pollution. Evidence of change was found especially in shifts in the distribution of the values for electrolytic conductivity and total nitrogen.

Table 4. Percentage distribution of the observation stations among the groups in the 1960s and 1970s.

		Groups 1	2	3	4	5
		%				
O_2	1965—70	38	23	17	15	7
	1971—77	32	25	21	16	6
	1977—82	29	26	22	17	6
γ_{25}	1965—70	20	41	24	10	5
	1971—77	11	39	35	9	6
	1977—82	10	31	40	12	7
Alkal.	1965—70	19	42	31	6	2
	1971—77	16	59	17	6	2
	1977—82	13	52	22	10	3
Tot.N	1965—70	15	34	40	9	2
	1971—77	1	45	39	13	2
	1977—82	2	28	52	17	1
Tot.P	1965—70	51	26	12	7	4
	1971—77	52	27	16	4	1
	1977—82	46	34	14	6	0
Tot.S	1965—70	19	44	26	7	4
	1971—77	17	42	31	7	3
	1977—82	16	40	36	5	3

Table 3. Classes formed by cluster analysis based on means of observations made on lake deeps in 1965—70.

		Groups 1	2	3	4	5
O_2 sat.	%	>81	81—73	72—61	60—33	<33
γ_{25}	mS m^{-1}	<3.3	3.3—4.9	5.0—8.1	8.2—13.7	>13.7
Alkal.	mval. l^{-1}	<0.10	0.10—0.16	0.17—0.29	0.30—0.62	>0.62
Tot.N	mg l^{-1}	<0.2	0.2—0.4	0.5—0.7	0.8—1.5	>1.5
Tot.P	μg l^{-1}	<11	11—24	25—54	55—137	>137
Tot.S	mg l^{-1}	<1.7	1.7—3.1	3.2—6.4	6.5—12.8	>12.8

4. THE CHANGES IN DIFFERENT RIVER SYSTEMS

Figures 1—10 show the locations of the changes in the quality of the water revealed by electrolytic conductivity, alkalinity and pH, and by the concentrations of chloride, total sulphur, organic carbon and oxygen.

In the period 1965—82 an increase in the electrolytic conductivity is a common feature in almost all the waters (Fig. 1). It has even begun in the northernmost part of the country, in Lapland. The increase in elecrolytic conductivity has been weakest in the waters below cellulose factories and in lakes in clayey areas on the coast. These areas and Lapland mainly show no increase in the period 1970—82 (Fig. 2).

A rising trend in the chloride concentrations is a common feature in the lakes in the southern part of the country and in the coastal district (Fig. 3). This trend became still stronger in the 1970s.

In contrast to the preceding trends, the changes in total sulphur (increase) are chiefly concentrated in the less polluted upper parts of the river systems of the Vuoksi and the Kymijoki (Fig. 4). The few cases of a decrease in the sulphur values generally occur in the waters below cellulose factories; see organic carbon (Fig. 10).

The values for alkalinity fairly commonly show an increase that is spreading and is not concentrated in any particular area. On the other hand a decreasing trend in alkalinity is clearly concentrated in the middle part of the Kokemäenjoki river system (Fig. 5).

In contrast to the case with alkalinity, a decreasing trend is becoming common in the pH values. This trend is concentrated in the southern part of the Vuoksi river system, above the main basin of Lake Saimaa, and is spreading into the eastern part of the river system and westwards into the system of the Kymijoki (Fig. 6). A rather small group of decreasing trends is still located in the centre of the Kokemäenjoki system. A distinct area with rising pH trends is situated in the northern part of the Vuoksi system; the area extends to the limit of the system in the west, continuing to Lake Päijänne (Fig. 7).

The decreasing trend in oxygen concentrations is also clearly spreading. This has occurred in the northern part of the system of the River Vuoksi, which, according to the 1970—82 series, is the same as the area of the rising

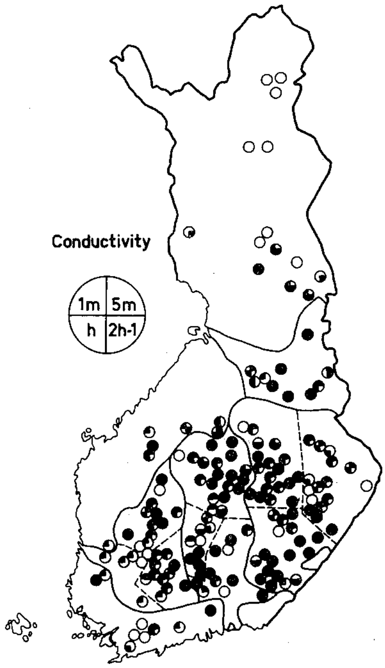

Fig. 1. Increasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◑ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾95 %.

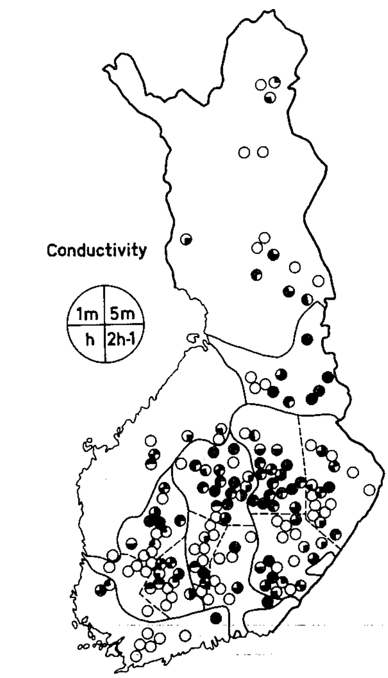

Fig. 2. Increasing trends at observation stations for the main lake deeps in 1970–1982. ◐ = depth 1 m, ◑ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾95 %.

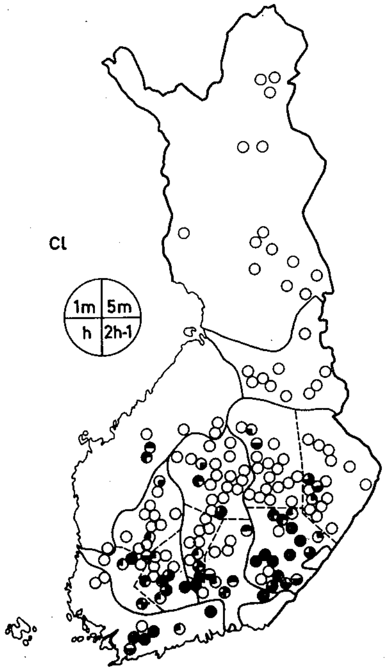

Fig. 3. Increasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◕ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾ 95 %.

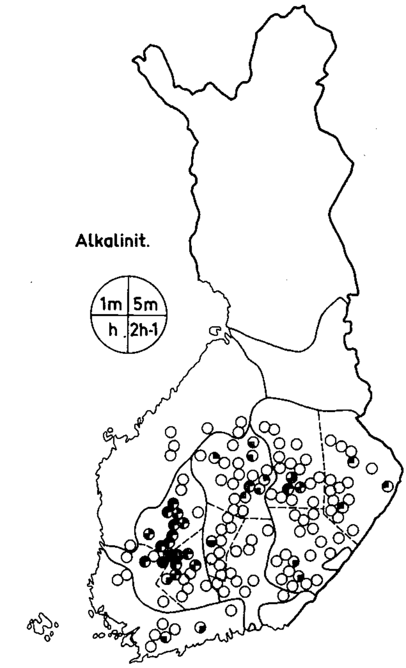

Fig. 5. Decreasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◕ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾ 95 %.

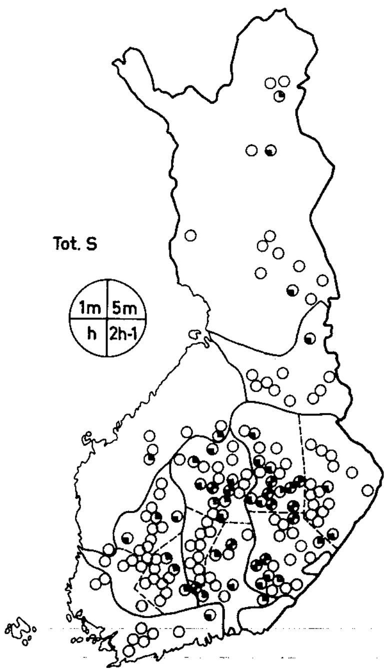

Fig. 4. Increasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◕ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾ 95 %.

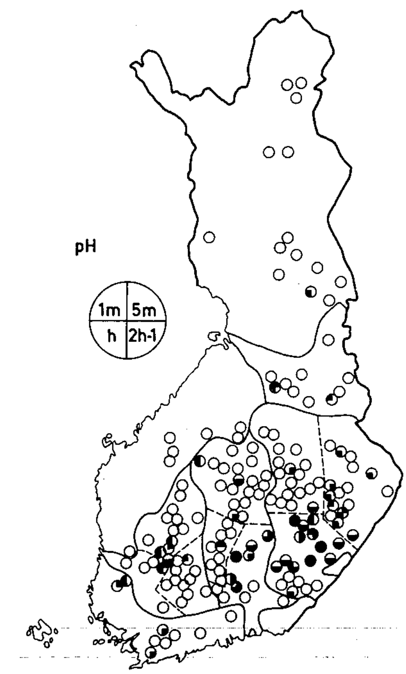

Fig. 6. Decreasing trends at observation stations for the main lake deeps in 1970–1982. ◐ = depth 1 m, ◕ = depth 5 m, ◐ = depth h and ◑ = depth 2h–1. Confidence level ⩾ 95 %.

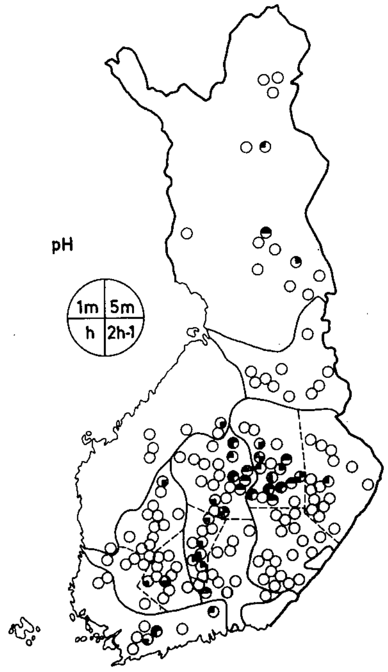

Fig. 7. Increasing trends at observation stations for the main lake deeps in 1970–1982. ◐ = depth 1 m, ◔ = depth 5 m, ◑ = depth h and ◕ = depth 2h–1. Confidence level ≥95 %.

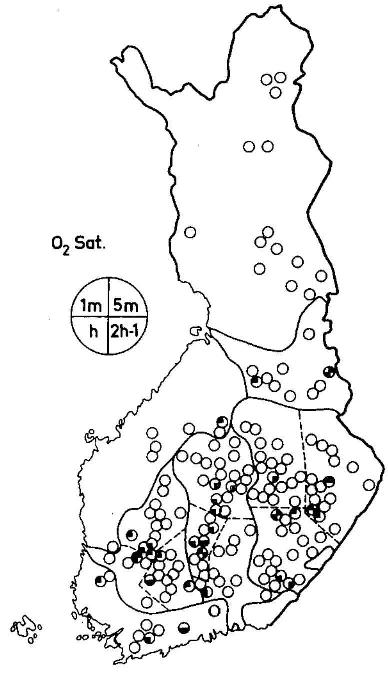

Fig. 9. Increasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◔ = depth 5 m, ◑ = depth h and ◕ = depth 2h–1. Confidence level ≥95 %.

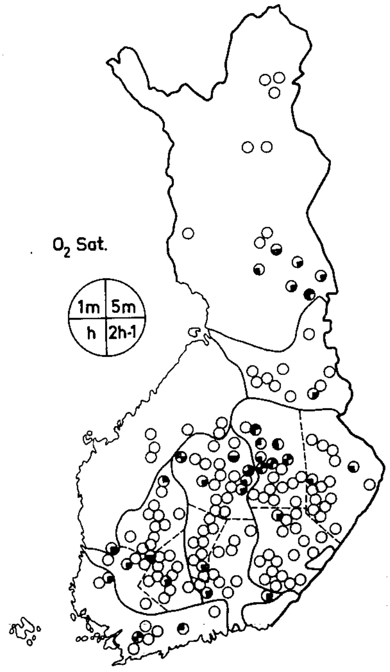

Fig. 8. Decreasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◔ = depth 5 m, ◑ = depth h and ◕ = depth 2h–1. Confidence level ≥95 %.

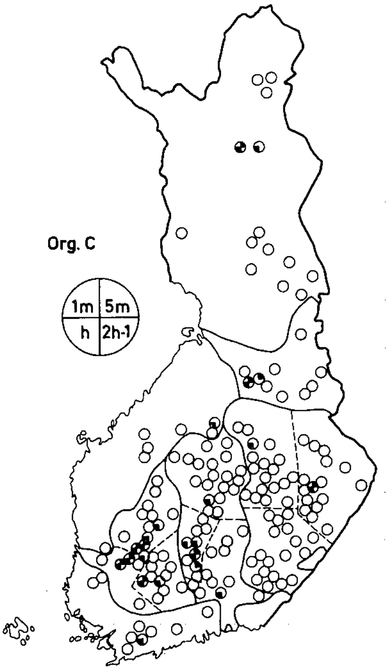

Fig. 10. Decreasing trends at observation stations for the main lake deeps in 1965–1982. ◐ = depth 1 m, ◔ = depth 5 m, ◑ = depth h and ◕ = depth 2h–1. Confidence level ≥95 %.

pH trends, and in many of the regulated lakes in Northern Finland (Fig. 8). Increasing oxygen concentrations are chiefly evident in waters polluted by cellulose factories (Fig. 9), where decreasing concentrations of organic carbon are also observed (Fig. 10). The signs of a recovery have, however, decreased in the records for 1970—82.

LOPPUTIIVISTELMÄ

Järvisyvänneverkolla v. 1965—82 ilmi saatujen veden laadun muutosten (trendien) määrä ja tilastollinen merkitsevyys on kasvanut selvästi edellisestä v. 1965—77 tarkastelusta. V. 1970—82 aikasarjan mukaan kasvu on kuitenkin pysähtynyt. Muuttuvin parametri on edelleen sähkönjohtavuus: 34 % kaikkien trendien määrästä. Seuraavina ovat kloridi, alkaliteetti ja rikki. V. 1965—82 muutoksista 73 % osoittaa veden laadun heikkenemistä; v. 1970—82 65 %. Puolet tästä heikkenemisen laantumisesta aiheutuu sähkönjohtavuudesta. Veden laadun muutokset on paikannettu kuvissa 1—10. Myös ryhmittelyanalyysin avulla on tarkasteltu veden laadun muuttumista syvänteissä vesipatsaan keskikohdalla v. 1965—70 ja 1977—82. Vallitseva piirre on lähinnä luonnontilaa olevien asemaryhmien pieneminen.

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