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CRITICAL OXYGEN CONCENTRATIONS OF FINNISH LAKES

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Data on oxygen concentrations in Finnish lakes are available in the water quality register from about 17 000 observation sites during the period 1961–1980. Observations were made in March-April in 8 500 sites. Of the lakes investigated one quarter contained totally or nearly totally oxygen depleted water in the bottom layers at the end of the winter season. Of the low-oxygen observation sites (0_2 < 11 % of saturation), over half contained low-oxygen water to a level of less than 21 % of the height of the water column.

Index words: Oxygen, lakes, monitoring, water quality.

The aim of this study was to determine the generality and distribution of near or complete oxygen depletion in Finnish lakes in March-April during the period 1961–1980. The objects of the investigation were those observations in which the oxygen concentration was below 11% of the saturation value. The data was supplied mainly by the water authorities and is contained in the water quality register of the Water Research Office, which in July 1981 contained data from 465 252 water samples. Data on observed oxygen concentrations in lake waters were available from 16 969 observation sites. Of these, 8 504 samples (~50 %) had been taken in March-April.

When the number of observation sites is reduced by 10 % to eliminate sampling from different parts of the same lake, it becomes possible to refer to individual lakes instead of observation sites. On this basis, the oxygen concentration was measured in 20–28 % of Finland's 55 000–75 000 lakes, and the concentration at the end of the winter season was measured in 10–14 % of the lakes.

Oxygen concentrations below 11 % of the saturation value were recorded at least once in 2 353 of the observation sites examined in March-April (>5 m deep sites in Fig. 1). On the basis of the 10 % reduction in numbers referred to above, a total of 2 118 of the lakes investigated, i.e. 28 %, had at least on occasion a severe disturbance in the dissolved oxygen level: In one lake out of four the bottom water layers were either totally or nearly totally oxygen depleted at the end of the winter season, with the result that the return of phosphorus from the bottom silt was sifnifi-

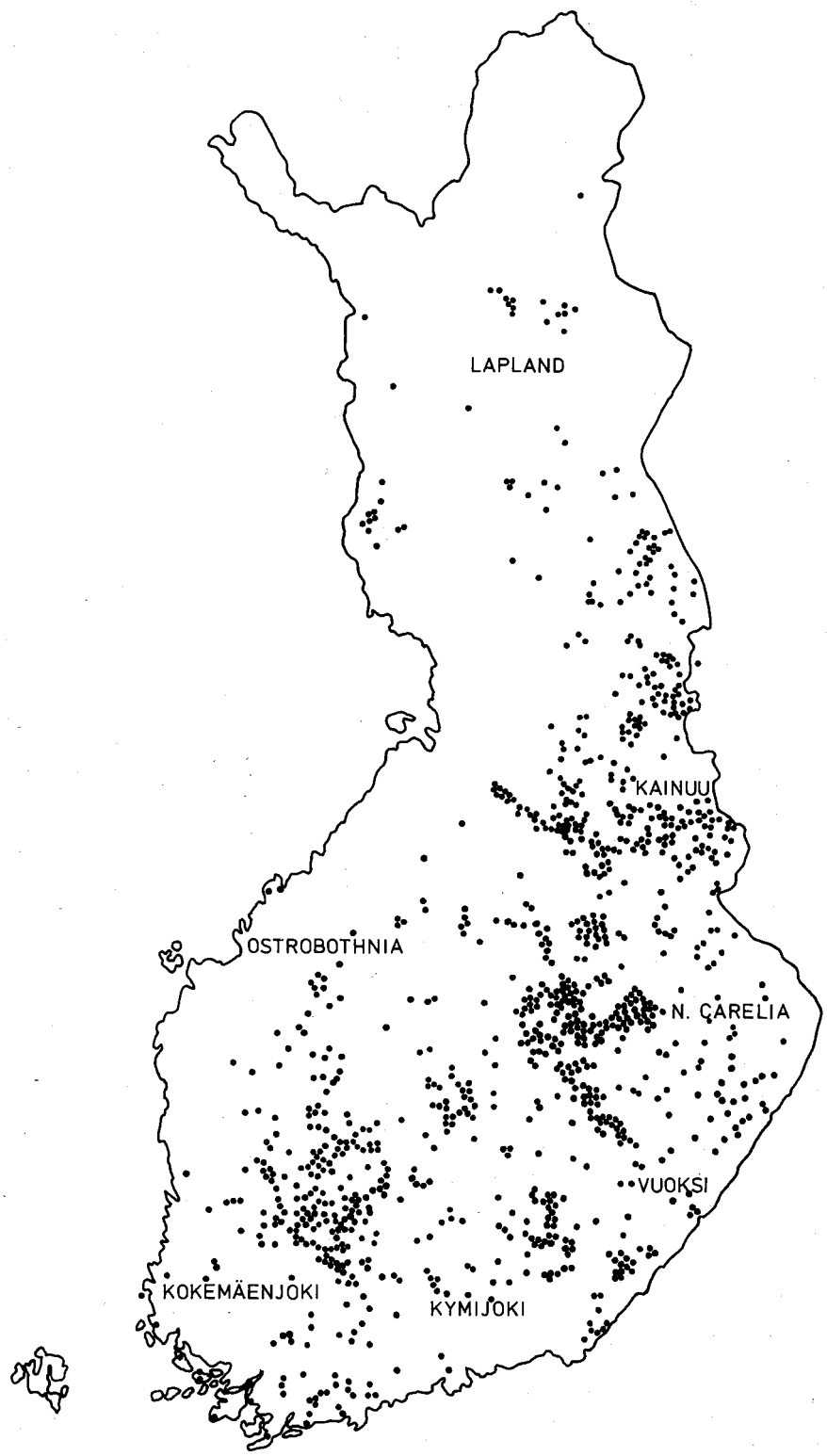

Fig. 1. Lake ($\geq$5 m deep) observation sites at which oxygen concentrations of <11 % of saturation were measured in March-April during the period 1961–1980.

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The occurrence of low-oxygen lakes (0_2<11 % saturation) varied considerably in different areas of the country (Fig. 2). The greatest frequencies of occurrence were in the river Kokemäenjoki watercourse (38 %) and in Ostrobothnia (35 %), while the minimum frequencies were in the river Kymijoki watercourse (21 %), particularly in its southern part (18 %), in the most northern region of Lapland (19 %) and in Northern Carelia (20 %). In other regions the occurrence varied between 24 and 31 %. It is apparent that the generality of low-oxygen lakes is to a large extent due to natural factors, but the effects of human activities are in certain regions also clearly discernable.

The oxygen concentration in the lake waters was observed in March-April during the period 1961–1980 on only one occasion in 6 301 of the lake sampling sites. Of these, the percentage containing low-oxygen water was 23 % (1 444), which is slightly lower than that calculated for the whole data (28 %).

Oxygen deficiency was observed in 576 sampling sites (24 %) more than once and in 1 777 sites (76 %) only once. Of the latter, 1 444 cases (61 %) were investigated on only one occasion, while a total of 1 548 expeditions were made on the remaining 333 sites, representing a mean of 4-6 visits per site. In 78 % of these visits oxygen deficiency (0_2 < 11 % of saturation) was not observed, i.e. the percentage (22 %) of sites with oxygen deficiency was almost the same as in the sites examined on only one occasion. The thickness of the oxygen-deficient water layer as such did not appear to necessitate follow-up visits, but rather oxygen levels near to the critical level and possibly also the depth of the observation site.

A total of 4 889 sampling expeditions were made in March-April to the 576 observation sites at which oxygen-deficient water was observed on more than one occasion, i.e. a mean of 8.5 visits per site. In 58 % of these visits oxygen deficiency was observed. The monitoring interest of the water authorities is in the first place confined to larger bodies of water showing definite signs of changes. Thus the observation frequency of oxygen deficiency is significantly greater than in the single observations of the survey investigation (23 %).

The distribution of the lake observation sites on the basis of the thickness of the oxygen-deficient layer is clearly biased towards the less thick layers. Thus over half (52 %) of the observation sites belong to groups in which oxygen-deficient water accounts for less than 21 % of the height of water column, and only 7 % of the sites had oxygen-depleted water for over 70 % of the height. In the regional examination (Fig. 3) the lakeland area, with deeper lakes than in the remainder of Finland on average, differed to its advantage from the rest of the country. The performance of the study, however, has the result that oxygen deficiency in a shallow lake almost always covers a considerable proportion of the height of water column.

If the investigation is confined to lakes of depth ≥5 m, the number of observation sites decreases by 44 %, from 8 504 to 4 788. This elimination of the shallow waters reduces the number of observations of oxygen deficiency from 2 353 to 1 549, i.e. to 32 % of the number of sites. This figure is slightly greater than that obtained for the whole data (28 %). The percentage of oxygen-depleted waters in the <5 m lakes was 22 %.

The regional distribution of oxygen-deficient observation sites in deep (≥5 m) waters also shows considerable variation (Fig. 4): Lakes are usually shallower in the coastal regions, particularly in Ostrobothnia, and in Lapland, than in the major watercourses and in Kainuu.

If variation in oxygen deficiency is measured according to the criterion of the percentage of sites, on the worst and on the most recently observed year, in which >20 % of the height of water column is deficient in oxygen, it is found that the differences between the two groups of observations are considerable, i.e. 21 % for the whole country (Fig. 5). The greatest variation was in Lapland (36 %) and the smallest in the Kymijoki watercourse (13 %) and in Kainuu (14 %). The difference between the worst and the most recent year was approximately the same in the ≥5 m lakes as in the shallow lakes. On the other hand, within the group of ≥5 m lakes the relative number of lakes in which oxygen deficiency extended to >20 % of the water column fell almost to half (26/33 %) of the corresponding figure for the whole data (48/53 %).

LOPPUTIIVISTELMÄ

Vesihallituksen vedenlaaturekisterissä on vuosilta

1961–1980 tietoja järvien happipitoisuudesta kaikkiaan 17 000 havaintopaikalta. Maalis-huhtikuussa tehtyjä havaintoja on noin 8 500 havaintopaikalta. Tutkituista järvistä todettiin lopputalvella joka neljännessä ainakin kerran lähes tai täysin hapetonta vettä pohjan läheisyydessä. Näistä vähähappisiksi ($0_2 < 11$ % kyllästysarvosta) havaituista havaintopaikoista yli puolet oli sellaisia, joilla vähähappista vettä oli alle 21 % vesipatsaan korkeudesta.

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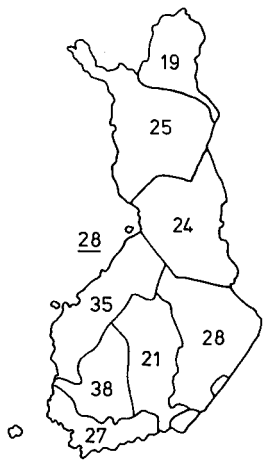

Fig. 2. Percentages of low-oxygen observation sites out the total number of sites investigated in March-April.

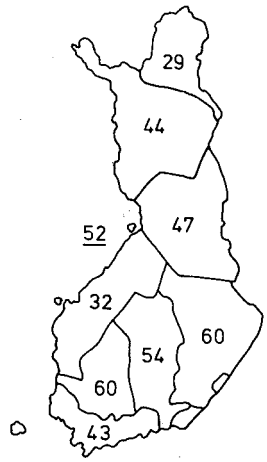

Fig. 3. Percentages of the low-oxygen sites in which oxygen deficiency was observed in less than 21 % of the height of water column.

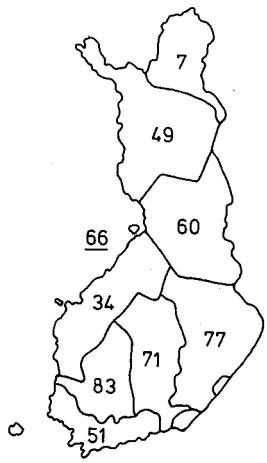

Fig. 4. Percentages of deep (≥ 5 m) observation sites out of the total number of low-oxygen sites.

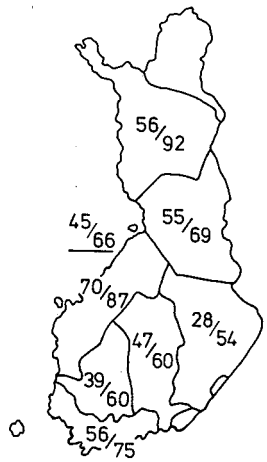

Fig. 5. Percentages of the repeatedly oxygen-deficient sites in which >20 % of the height of water column was deficient on the most recent/worst observation year.