SKB TECHNICAL REPORT 86-29

Quantitaive estimates of sedimentation rates and sediment growth in two Swedish lakes

Sverker Evans

Studsvik Energiteknik AB, Nyköping

October 1986

SVENSK KÄRNBRÄNSLEHANTERING AB

SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO

BOX 5864 S-102 48 STOCKHOLM

TEL 08-665 28 00 TELEX 13108-SKB

QUANTITATIVE ESTIMATES OF SEDIMENTATION RATES AND SEDIMENT GROWTH IN TWO SWEDISH LAKES

Sverker Evans

Studsvik Energiteknik AB, Nyköping

October 1986

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

Information on KBS technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01) and 1985 (TR 85-20) is available through SKB.

STUDSVIK ENERGITEKNIK AB

STUDSVIK/NP-86/42

1986-10-11

Sverker Evans

QUANTITATIVE ESTIMATES OF SEDIMENTATION RATES AND SEDIMENT GROWTH IN TWO SWEDISH LAKES

ABSTRACT

In order to form the basis for release scenarios of radionuclide dispersion in a lake ecosystem that gradually is silting up to become agricultural land, sediment budgets were performed for two Swedish lakes. The yearly load of sedimenting material was measured *in situ* during a two-year period using sediment traps. The net sediment growth, integrated over a longer time period, was on the average 2 - 4 mm y^{-1}. Resuspension showed to be the single most difficult factor to assess in the budget calculations, and was assumed to contribute 50 - 80 % of the sediment catch. For the two lakes under study, Lake Trobbofjärden and Lake Sibbofjärden, the silting up of the lake basins will occur within 1 500 - 3 000 years and 2 200 - 4 500 years, respectively.

LIST OF CONTENTS

			Page
1	INTRODUCTION		1
2	MATERIAL AND METHODS		3
	2.1	Collection of sedimenting material	3
	2.2	Collection of suspended material	3
3	RESULTS		4
	3.1	Contents of suspended material	4
	3.2	Seasonal variation in sediment load	4
	3.3	Yearly gross sediment load	4
	3.4	Resuspension	6
	3.5	Primary production	8
	3.6	Sediment budget calculations	10
		3.6.1 Lake Trobbofjärden	10
		3.6.2 Lake Sibbofjärden	11
	3.7	Areas of erosion and accumulation	12
4	DISCUSSION		14
	4.1	Design and trap efficiency of sediment collecting device	14
	4.2	Resuspension	14
	4.3	Sediment growth - comparison with adjacent areas	16
	4.4	Sediment growth versus age	16
		4.4.1 Experience from varved lake sediments	16
		4.4.2 Experience from radio-logical dating	17
		4.4.3 Experience from sediment trap measurements	17

5 CONCLUSIONS 19

ACKNOWLEDGEMENT 20

LIST OF REFERENCES 21

FIGURES

TABLES

APPENDIX - Description of the vegetation in Trobbo- and Sibbofjärden during the summer 1985

1 INTRODUCTION

The uptake of dissolved element species by particulate material suspended in the water column is one of the major routes of removal of dissolved species from the water. The net flux of particles from water to sediments is of importance for chemical and geochemical processes in the water as well as in the sediment and may be a significant factor controlling the exchange of elements between water and sediment. Monitoring the sedimentation cycle is thus one important step in assessing the flux rates of elements in the water column. This investigation is a part of a project with the ultimate aim developing a dynamic model for the long-term behaviour of radioactive elements which reach a lake or bay that undergoes a gradual change to agricultural land (Sundblad, 1986). Two sites in middle Sweden, Lake Sibbofjärden and Lake Trobbofjärden, have been chosen as suitable areas for performing site-specific element budget calculations and subsequent release scenarios (Figure 1).

Lake Sibbofjärden is a Baltic bay that, due to the progressive land uplift, has gradually changed toward limnic conditions and which at present only has a narrow connection with the sea. Lake Trobbofjärden also constitutes a former bay that in 1955 was separated from the Baltic Sea by means of a flood-gate.

In this report the yearly load of sedimenting material in the two lakes is assessed using sediment traps. Although some aspects of studies on sedimentation rates with the aid of sediment traps have been criticized (Kirchner, 1975), their use represents a useful technique for examining the flux of material to the bottom in limnic and marine environments (Zeitschel, 1965, Steele and Baird, 1972; Webster and Paranjape, 1975; Bloesch et al, 1977).

The deposition and resuspension of particulate material is evaluated using site-specific data on run-off, amounts of suspended matter in the water and sediment catches in the traps. Values on the pelagic primary production are assessed using values from Swedish lakes. The magnitude of sedimentation is compared with results from adjacent lakes and estuarine environments. The sediment growth and the time periods required for the silting up of the two lake basins are assessed.

2 MATERIAL AND METHODS

2.1 Collection of sedimenting material

Sediment traps suspended in the water column were used to collect data on the downward flux of particulate material in Lake Sibbofjärden and Lake Trobbofjärden. Plexiglass cylinders with a height of 500 mm and a diameter of 69 mm, i.e. a H/D ratio of 7.25, were held in position by wire, anchor and subsurface floats (Figure 2, 3). The cylinders were deployed in duplicate at 2, 5 and 8 m depth in Lake Sibbofjärden and at 2 and 4 m depth in Lake Trobbofjärden. The distance from the deepest located traps to the bottom was 1 m at both localities.

In order to minimize the risk of significant loss by decay, the traps were visited approximately every 10th day during the summer months and during every 2nd week during autumn and spring. During the ice-covered period, when the sedimentation rate was at its lowest, the sedimenting material was collected at about monthly intervals. The collected material was transported to the laboratory where dry weights and ash-free dry weights were determined. The contents of combustible organic matter were estimated by weighing the dry samples before and after ignition at 540^{o}C.

2.2 Collection of suspended material

The content of suspended matter in the water was recorded by centrifugalizing 2 l water samples which were collected at the same times as the sediment traps were visited.

3 RESULTS

3.1 Contents of suspended material

The contents of suspended particulate material in Lake Trobbofjärden and Lake Sibbofjärden are shown in Figure 4. The average content was 7 $\pm$ 3 mg l^{-1} and 5 $\pm$ 2 mg l^{-1} dry wt for Lake Trobbofjärden and Lake Sibbofjärden, respectively.

3.2 Seasonal variation in sediment load

The seasonal variation in sedimentation for Lake Sibbofjärden and Lake Trobbofjärden, respectively are shown in Figure 5 and 6. After the break-up of the ice at the beginning of May, phytoplankton production and biomass in- creased rapidly. Runoff of particulate material from the surrounding drainage areas also peaked during this period (B Sundblad, 1986). The sediment load reached maximum in July - September for both areas.

The traps were always run in duplicate in order to assess the variation in sediment load for parallel samples. In Lake Trobbofjärden the average coefficents of variation $\frac{S}{X}$ between duplicate samples at 2 and 4 m depth were 0.20 and 0.14, respectively. For Lake Sibbofjärden, the corresponding figures for the 2, 5 and 8 m depths were 0.24, 0.13 and 0.07, respectively. These figures were assumed to constitute the average variation in the sediment load at the different depth intervals.

3.3 Yearly gross sediment load

All sedimentation rates measured with traps represent gross sedimentation, including both primarily settling material and secondary settling material (resuspension). Figures 7 and 8 show the the mean sedimentation rates and the mean variations as functions of depth for the two lakes. It is assumed that a linear regression describes sufficiently well the relation between the sedimentation rates and the different depths.

The constants a and b of the regression equation $Y = a + bX$ (Y = depth in m, X = yearly deposition in g m^{-2} dry wt) describing the depth-dependent sediment load in Lake Sibbofjärden and Lake Trobbofjärden, respectively, are given below.

	Lake Trobbofjärden	
	a	b
min	-1.46	2.07×10^{-3}
average	-2.22	2.14×10^{-3}
max	-3.04	2.23×10^{-3}
	Lake Sibbofjärden	
	a	b
min	-6.52	8.28×10^{-3}
average	-5.56	9.32×10^{-3}
max	-4.26	9.61×10^{-3}

The regression equations are assumed to be valid for the whole depth intervals of the two lakes.

In order to assess the annual gross sedimentation, i.e. the summed deposition of old resuspended material and new material supplied to the lakes, the areal contribution from the different 1 m depth layers to the total area was calculated from the hypsografic curves made up for the two lakes. The amounts of deposited material within the different depth intervals were summed to obtain the total yearly load (Table 1). The annual gross sediment load in Lake Trobbofjärden was on average 2 700 tons km^{-2} y^{-1} with a range of 500 tons km^{-2} y^{-1}. For Lake Sibbofjärden, the corresponding value was 1 300 tons km^{-2} y^{-1} with a range of 100 tons km^{-2} y^{-1}. The total gross sediment load in Lake Trobbofjärden would then amount to 8 000 tons y^{-1}, compared with 7 600 tons y^{-1} in Lake Sibbofjärden.

Assuming a mean sediment density of 1.2 and a water content of 85 % in the upper sediment layer, the gross sediment growth in Lake Trobbofjärden and Lake Sibbofjärden should amount to 14 - 17 mm y^{-1} and 7 - 11 mm y^{-1}, respectively, which are fairly high values compared to other areas. The water content in the sediment decreases further down and stabilizes around 60 %. Taken compaction into account, the yearly gross sediment growth, integrated over a longer time period, will then amount to 10 - 12 mm y^{-1} in Lake Trobbofjärden and 5 - 8 mm y^{-1} in Lake Sibbofjärden.

3.4 Resuspension

During rough weather conditions an increased resuspension may be expected of already settled material from the bottom to occur (e.g. Webster et al, 1975; Forsskåhl et al, 1982).

The fraction of resuspended material in the sediment catch may increase with increasing fetch and with decreasing water depth. An attempt was made to record any addition of resuspended material to the sediment catches. The ratios of the amounts of material simultaneously trapped at 4 m and 2 m depths were calculated for each time interval in

Lake Trobbofjärden. For Lake Sibbofjärden the corresponding calculations were performed for the 5/2 and 8/5 m ratios. In Lake Trobbofjärden the mean amount of material trapped at 4 m depth was increased by 60 %, compared to the amount trapped at 2 m depth (Figure 9). In Lake Sibbofjärden the mean increase was 60 % and 66 % for the 5/2 and 8/5 m ratio, respectively (Figure 10 and 11). The individual values showed a similar variation with time in both lakes, but no seasonal variation could be detected. The contents of suspended material in the water column were also compared with wind speed data from the Studsvik tower (Figure 12). However, no correlation was found between amounts of suspended material and wind speed, even if a lag time of one week was introduced between the wind data and the contents of suspended matter in the water.

In Lake Sibbofjärden and Lake Trobbofjärden, which both contain very turbid water, the pelagic primary production will not extend deep down. This means no further contribution of newly produced sedimenting material to the deeper situated traps, and the addition of material in these traps may then constitute resuspended material. Measurements of the loss of ignition (L.O.I) of trapped material support this theory.

Data from the 5 m deep site in Lake Trobbofjärden are presented below:

Sediment traps in Lake Trobbofjärden

Date	Depth (m)	L.O.I (%)
860716	2	17.7
-"-	4	15.2
860730	2	14.3
-"-	4	13.1
860814	2	13.5
-"-	4	11.8

Sediment core in Lake Trobbofjärden

Date	Depth (m)	L.O.I (%)
860108	5	9.8

A reduced content of organic matter is recorded in the deeper situated traps which indicates that a larger fraction of resuspended material from the bottom will be mixed with the primary settling material. The increase in sedimentation rate with increasing depth is thus interpreted as a result of resuspension.

3.5 Primary production

Usually only the pelagic primary production is measured, while the contribution by benthic algae and higher plants to the primary production is seldom assessed. Data regarding the production of phytoplankton in Swedish waters are presented in Table 2, expressed as g C $m^{-2}y^{-1}$. The conversion of amount of carbon to amount of material expressed in g dry wt is highly uncertain. However, some guiding principles may be given. The carbon content in sedimenting material constitute about 40 % of the organic content (Oviatt and Nixon, 1975; Kautsky and Evans, in prep). The amount of carbon in the sedimenting material will then contribute 5 - 10 % in both lakes. A production of 100 g C m^{-2} y^{-1} was adopted for both lakes, with a variation of 50 to 200 g C $m^{-2}y^{-1}$ as a reasonable span. This will mean a sediment load of 1 000 - 2 000 g dry wt m^{-2} y^{-1} with an extreme variation of 500 - 4 000 g $m^{-2}y^{-1}$.

However, only a fraction of the yearly primary production will reach the bottom and become embedded in the deposits. In the Baltic Sea as much as 40 to 50 % of the phytoplankton spring bloom reaches the benthos (Hobro, Larsson, and Wulff, 1975). Sedimentation studies showed for the Kiel Bight and the Eckernförde Bight sedimentation rates of 22 to 61 g C $m^{-2}y^{-1}$ (Zeitzchel, 1965; Smetacek, 1980) and for the Eckernförde Bight 31 to 45 g C $m^{-2}y^{-1}$ (Hendriksson, 1976; Iturriaga, 1979). The ratio of sedimentation to primary production was roughly 30 to 40 % (Smetacek, 1980). In the northwestern Baltic proper, the primary production was 130 g C $m^{-2}y^{-1}$ and the sedimentation 40 to 50 g C $m^{-2}y^{-1}$, which constitutes about 35 % of the primary production (Elmgren, Ankar, and Larsson, 1979). In the Gulf of Finland, the primary sedimentation was about 19 g C $m^{-2}y^{-1}$, making up about 25 % of the annual phytoplankton production (Forsskåhl et al, 1982). During the peak production in spring, about 40 % of the primary production was sedimented. During the rest of the productive period, most of the produced matter was decomposed in the water phase.

Observations by Iturriaga (1979) at the Eckernförde Bight, Baltic Sea, confirm that the greater part of the organic content of planktonic organisms is suspectible to rapid bacterial degradation. Golterman (1972) observed that after analysis, algae can lose from 20 to 30 % of their biomass, which is similar to the observations by Iturriaga (1979).

In eutrophic lakes, about 30 % of the pelagic primary production will reach the bottom (I Ahlgren, pers.comm). To sum up, 25 - 50 % of the primary production will settle and this fraction will increase with an increasing degree of eutrophication and with decreasing depth. For the shallow and eutrophic Lake Trobbofjärden and Lake Sibbofjärden, a value of 50 % seems reliable.

3.6 Sediment budget calculations

A sediment budget was developed for the two lakes under study.

3.6.1 Lake Trobbofjärden

Sediment import

The import of material to Lake Trobbofjärden due to upland runoff was estimated to 250 tons y^{-1} (Sundblad, 1986).

Primary production

A mean literature value of 100 g C m^{-2} y^{-1} was adopted for Lake Trobbofjärden. A carbon content of 10 % of the dry material will mean a production of 1 000 g dry wt $m^{-2}y^{-1}$. Assuming that 50 % of the material will reach the bottom, primary production will on average contribute 500 g dry wt $m^{-2}y^{-1}$ or 1 500 tons y^{-1} for the whole lake area.

Sedimentation

According to the data from the sediment traps, the gross sedimentation in Lake Trobbofjärden will amount to 8 000 tons dry wt y^{-1}.

Budget calculations

An imbalance of 8 000 - 1 750 = 6 250 tons y^{-1} will arise when making the sediment budget for Lake Trobbofjärden. If resuspension alone is assumed to be responsible for this large gap in the data, 78 % of the sediment catch will then originate from secondary settling material. Accordingly, the net sedimentation in Lake Trobbofjärden will be 3 - 4 mm y^{-1}. Over a longer time period, taking compaction into account, the net growth is 2 - 3 mm y^{-1}.

3.6.2 Lake Sibbofjärden

Sediment import

The import of material to Lake Sibbofjärden due to upland runoff was estimated to 1 000 tons y^{-1} (Sundblad, 1986).

Primary production

The primary production for Lake Sibbofjärden is assumed to be identical to that of Lake Trobbofjärden, meaning a deposition of 2 950 tons y^{-1}.

Sedimentation

The gross sedimentation in Lake Sibbofjärden amounted to 7 600 tons y^{-1}.

Budget calculations

A deficit of 7 600 - 2 950 = 4 050 ton y^{-1} will arise in Lake Sibbofjärden. With a similar argumentation as for Lake Trobbofjärden, the resuspension will amount to 53 %. The net sediment growth will then be similar to Lake Trobbofjärden or 3 - 5 mm y^{-1}. Likewise, taking compaction into account, the net growth is 2 - 4 mm y^{-1}.

3.7 Areas of erosion and accumulation

The fractions of the total lake area which could be considered as areas of erosion and accumulation, respectively, may be calculated according to the equation given by Håkanson (1981):

$$A_e = 25 \times (\sqrt{A}/\bar{D}) \times 41^{0.061 \times \bar{D}/\sqrt{A}}$$

where

A = lake area (km^2)
$\bar{D}$ = mean depth (m)
A_e = erosion area (% of A)

Accordingly, the erosion area of Lake Trobbofjärden contributes 31 % to the total lake area.

With knowledge of the erosion area, the critical depth of erosion and transportation can be assessed from the relative hyposografic curve (Figure 13). The critical depth is 38 % of the maximum depth or about 2.5 m. Beneath this depth the bottoms may be classified as areas of accumulation, at least according to the equation given above. If so, about 1 750 tons y^{-1} of primary settling material in Lake Trobbofjärden will be focused within an area of 0.9 $km^2 y^{-1}$, meaning a net sediment load of about 1 950 tons km^{-2}.

4 DISCUSSION

4.1 Design and trap efficiency of sediment collecting device

Sedimentation measurements with traps are not free of errors. The main problems are resuspension from the bottom and deficiencies in the sampling technique. Gardner (1980) investigated the efficiency and turbulent effects of various trap designs when used in currents between 4.0 and 9.5 cm s^{-1}. He concluded that cylinders having a height/width ratio of 2.3 most closely approach 100 % trapping efficiency. Generally, under moderate hydrodynamic conditions the use of cylindrical sediment vessels with a height/ width diameter greater than 3 seems to give reliable results (Hargrave and Burns, 1979; Blomqvist and Kofoed, 1981). The traps used in this study fulfilled these requirements. Besides, the suspension device always allowed the traps to be in a vertical position.

4.2 Resuspension

The question arises whether the measured sediment load is truly representative of the transfer of fresh sedimenting material from the water column to the sediments or whether the measurements are distorted by the inclusion of significant amounts of resuspended sediment. Turbulent water transport is strongest in the upper part of the water column and leads to resuspension of particulate material from shallow areas. This resuspended material is mixed with primary settling material, and thus turbulent water movements give rise to increased quantities of material settling in the traps (Young and Rhoads, 1971; Webster et al, 1975; Parmenter et al, 1983).

In Cape Cod Bay, Massachusetts, Young and Rhoads (1971) found that the sediment surface layer was frequently resuspended by tidal currents. Traps 80 cm above the bottom at a station 34 m deep indicated a resuspension and resettling rate of 100 g $m^{-2}d^{-1}$, while traps 20 cm above the bottom gave values almost 10 times greater. Webster et al (1975) measured the input of organic matter to the benthos at two sites in St. Margarets Bay, Nova Scotia. They found a significant fraction - 80 % - of the material in the traps to be of inorganic origin, and suggested that much of this material was resuspended bottom sediment. Resuspension is generally supposed to be of little importance at depths greater than 40 m since little turbulent energy is supplied to the water below. However, even at a deep station (70 m) in St. Margarets Bay, the trap placed 5 m above the bottom was affected (Webster et al, 1975). In the Baltic, a trap 1 m above the bottom at a site 25 m deep collected an unknown proportion of resuspended bottom material (Zeitschel, 1965). Yarbro et al (1983) developed a sediment budget for the Choptank River Estuary, which drains into Chesapeake Bay (USA). They suggested shore erosion to be the dominant term in the sediment budget of this particular estuarine system. The amount of sediment eroded from shorelines contributed seven times more sediment than upland runoff. Besides, according to the conclusions by Webster et al (1975), macrophytes give rise to large quantities of organic detritus, much of which during calm weather settles to the bottom. In times of rough weather this material is resuspended, along with quantities of ordinary bottom sediment. The material in suspension now consists of resuspended bottom material enriched with macrophyte and plankton detritus, and it is this mixture that is caught in the sediment traps. This is supposed to occur also in the two shallow lakes under study, which contain large stocks of reeds along the shores, and may explain a high resuspension to occur.

4.3 Sediment growth - comparison with adjacent areas

The gross sediment growth in some Swedish lakes and in different parts of the Baltic Sea are given in Table 3. In general, the sedimentation rate in eutrophic lakes may be about ten times greater than in oligotrophic woodland lakes, and about five to ten times greater than in the Baltic Sea.

4.4 Sediment growth versus age

4.4.1 Experience from varved lake sediments

Varved lake sediments offer unique possibilities for the study and interpretation of the past environment. The undisturbed conditions in general and the absence of a benthic fauna in particular will result in a high degree of preservation of the deposits laid down annually (Renberg, 1981; Renberg and Hellberg, 1982). Mechanical disruption of the surface sediment due to water movement appears to be relatively slight, at least when the bottom is level. On the other hand, in lakes with an undulating bottom, the varves formed are usually of poor quality because water movements and gravitation are able to transport material down towards the deepest parts of the lakes.

The thickness of any varve formed in a lake sediment depends upon the productivity of the lake, the quantity of allochthonous material carried into the lake, the decomposition conditions and upon the degree of sediment focusing and compaction. In a consolidated sediment (>30 - 50 cm beneath the sediment surface), varve thickness will normally vary between 0.2 and 0.8 mm (Renberg, 1986). In the surface sediment varve thickness varies from a few millimetres up to a centimetre, or sometimes even more (Renberg, 1981). The increasing thickness of the varves towards the sediment surface is due to a reduced degree of compaction but is also because more material may settle on the bottom compared with former time periods (Figure 14). This will clearly demonstrate the non-linearity of sediment growth over prolonged periods of time.

4.4.2 Experience from radiological dating

Edberg (1980) calculated the sedimentation rates of three lakes with heavy sediment loads, using ^{137}Cs fallout data. The recent sediment growth was 3 - 5 mm y^{-1} in the shallow parts and 8 - 11 mm y^{-1} in the deep parts of the lakes. A sediment growth of 8 - 11 mm y^{-1} in the deeper parts of Lake Ekoln corresponded to a deposition of 2 800 - 3 400 g $m^{-2}y^{-1}$ dry wt (Håkanson, 1976).

El-Daoushy and Johansson (1983) recorded a sedimentation rate of 0.5 to 1.2 mm y^{-1} in four Swedish woodland lakes using ^{210}Pb as dating method. For the period 1850 - 1978 a mean sediment growth of about 1 mm y^{-1} was calculated. The 0 - 10 cm layer will then represent a period of about 100 years.

4.4.3 Experience from sediment trap measurements

The mean rate of deposition of Lake Ekoln is on the order of 4 - 10 mm y^{-1} (Axelsson and Håkanson, 1975) which means that the layer 0 - 10 cm will, with sediment compaction taken into account, represent a deposition period of approximately 15 - 20 years. In the less eutrofic Lake Vänern, where the mean rate of deposition is 2 - 3 mm y^{-1}, the corresponding figure is approximately 100 - 200 years (Håkanson, 1975).

For Lake Trobbofjärden and Lake Sibbofjärden, a yearly net contribution of 2 - 4 mm was calculated. The upper 0 - 10 cm layer will then correspond to a period of 25 - 50 years.

5 CONCLUSIONS

The following conclusions may be made with regard to sediment growth and the transformation of lakes and bays into agricultural land:

- According to sediment budget calculations based on *in situ* measurements with traps, a major part of the sedimenting material may consist of old resuspended matter. The low organic content of the trapped material supports this interpretation. Against this tells the formation of varved sediments in certain lakes, where the yearly contributions to the sediment load is clearly distinguished. However, the erosion of decaying organic material produced nearshore in lakes with large stocks of rooted vegetation contributes largely to the sedimentation and may explain this discrepancy.
- For eutrophic Swedish lakes, a sediment growth of 3 - 10 mm y^{-1} seems to be a typical value. The calculated net sediment growth of 3 - 5 mm in the two lakes under study falls within this range. Integrated over a longer time period the sediment growth is on average 2 - 4 mm y^{-1}. This is a high value compared to varved sediments where the varve thickness of consolidated sediment is typically 0.2 - 0.8 mm.

For Lake Trobbofjärden, the silting up of the lake basin will occur within about 1 500 - 3 000 years, provided that the present conditions prevail with regard to nutrient status etc. However, human activities may to a large extent control the degree of eutrophication and the subsequent filling up of the basins (e.g. Lettevall, 1973). For Lake Sibbofjärden, the corresponding period should be 2 200 - 4 500 years. Factors affecting the time scale of silting up were given earlier by Sundblad (1984).

ACKNOWLEDGEMENT

The author is grateful to Karin Andersson, Ulla Bergström and Björn Sundblad for discussions and critical evaluation throughout the study. Many thanks to Rune Axelsson, Svante Lampe and Yvonne Stiglund for good collaboration and assistance in the field and laboratory work. Financial support was obtained from the Swedish Nuclear Fuel and Waste Management Co, which is gratefully acknowledged.

LIST OF REFERENCES

AHLGREN, G (1970)
Limnological studies of Lake Norrviken, a eutrophical Swedish Lake. 2.Phytoplankton and its production.
Schweiz. Zeitschr. Hydrologie 32, fasc 2.

ANDERSSON, G
Resultat och erfarenheter från restaureringen av sjön Trummen.
NORDFORSK Publikation 1975:1.

AVNIMELECH, Y, McHENRY, J R and ROSS, J D (1974)
Decomposition of organic matter in lake sediments.
Environ. Sci. Technol. 18, 5 - 11.

AXELSSON, V and HÅKANSSON, L (1975)
The relation between mercury distribution and sedimentological environment in Lake Ekoln. 4. Deposition of sediment and mercury in 1971 and 1972.
UNGI, Rapport 35, Uppsala.

BLOESCH, J, STADELMANN, P and BUHRER, H (1977)
Primary production, mineralization and sedimentation in the euphotic zone of two Swiss lakes.
Limnol. Oceanogr. 22, 511 - 526.

BLOMQVIST, S and KOFOED, C (1981)
Sediment trapping - a subaquatic in situ experiment.
Limnol. Oceanogr. 26, 585 - 590.

COVENEY, M F, CRONBERG, G, ENELL, M, LARSSON, K and OLOFSSON, L (1977)
Phytoplankton, zoplankton and bacteria - standing crop and production relationships in a euthropic lake.
Oikos 29, 5 - 21.

EDBERG, N (1980)
Determination of recent sedimentation rates in lakes by ^{137}Cs. Vatten 1, 35 - 44.

EL-DAOUSHY, F and JOHANSSON, K (1983)
Radioactive lead-210 and heavy metal analyses in four Swedish lakes.
In: Environmental Biogeochemistry (ed. R Hallberg)
Ecol. Bull (Stockolm) 35, 555 - 570.

ELMGREN, R, ANKAR, S and LARSSON, U (1979)
Kustnära mjukbottnars ekologi i Östersjön - ett integrerat benthos - pelagial projekt.
Askölaboratoriet, 1 - 31.

FONSELIUS, S (1972)
On biogenic elements and organic matter in the Baltic.
AMBIO Special Rep No 1.

FORSSKÅHL, M, LAAKKONEN, A, LEPPÄNEN, J-M, NIEMI,Å, SUNDBERG, A and TAMELANDER, G (1982)
Seasonal cycle of production and sedimentation of organic matter at the entrance to the Gulf of Finland.
Neth. J. Sea. Res. 16, 290 - 299.

GARDNER, W D (1980)
Sediment trap dynamics and calibration: a laboratory evaluation.
J.Mar. Res. 38, 17-39.

GELIN, C (1975)
Nutrients, biomass and primary productivity of nannoplankton in eutrophic Lake Vobmsjön, Sweden.
Oikos 26, 121 - 139.

GOLTERMAN, H L (1972)
Mineralization of algae under sterile conditions or by bacterial breaddown.
Verk. int. Verein. theor. angew. Limnol. 15, 544 - 548.

IGNATIUS, H (1958)
The rate of sedimentation in the Baltic Sea.
C R Soc Geol Finl. 30, 135 - 144.

IGNATIUS, H, NIEMISTÖ, L and VOIPIO, A (1971)
Variations of redox conditions in the recent sediments of the Gotland Deep.
Geologi 3, 43 - 46.

HARGARVE, B T and BURNS, N M (1979)
Assessment of sediment trap collection efficiency.
Limnol. Oceanogr. 24, 1124 - 1136.

HENDRIKSSON P (1976)
Abbauraten von organischem Kohlenstoff in Seston und in Sinkestoffen der Kieler.
Bucht. Kieler Meeresforsch (sonderheft) 3, 105 - 119.

HOBRO, R V, Larsson, U and WULFF, F (1975)
Dynamics of a phytoplankton spring bloom in a coastal area of the northern Baltic.
4th BMB symposium, 13 - 18 Oct 1975, Gdansk, 1-9.

HOLMGREN, S (1968)
Phytoplankton and primary production in Vuolep Njakajaure in Swedish Lapland.
Limnologiska institutionen, Uppsala.

HÅKANSON, L (1975)
Mercury in Lake Vänern - present status and prognosis.
SNV PM 562.

HÅKANSON, L (1976)
A bottom sediment trap for recent sedimentary deposits.
Limnol. Oceanogr. 21, 170 - 174.

HÅKANSON, L (1981)
Lake sediments in aquatic pollution control programs: principles, processes and practical examples.
SNV PM 1398 (in Swedish).

ITURRIAGA, R (1979)
Bacterial activity related to sedimenting particulate matter.
Mar. Biol. 55, 157 - 169.

KIRCHNER, W B (1975)
An evaluation of sediment trap methodology.
Limnol. Oceanogr. 20, 657 - 660.

KÖGLER, F C and LARSEN, B (1979)
The West Bornholm in the Baltic Sea: Geological structure and quaternary sediments.
Boreas 8, 1 - 22.

LETTEWALL, U et al (1973)
A book on water - limnology (in Swedish).
Miljökunskap

PARMENTER, C M, BOTHNER, M H and BUTMAN, B (1983)
Characteristics of resuspended sediment from Georges Bank collected with a sediment trap.
Estuarine, Coastal and Shelf Sience 17, 521 - 533.

PIERROU, U (1977)
Svenska vattenkvalitetskriterier. Organiska ämnen.
SNV PM 919.

RAMBERG, L (1976)
Relations between phytoplankton and environment in two Swedish forest lakes.
Scripta Limnologica Upsaliensia No 426.

RENBERG, I (1981)
Formation, structure and visual appearance of iron-rich varved lake sediments.
Verk. Intermat. Verein. Limnol. 21, 94 - 101.

RENBERG, I (1986)
Varved lake sediments and environmental monitoring.
SNV PM 3083 (in Swedish).

RENBERG, I and HELLBERG, T (1982)
The pH history of lakes in southwestern Sweden, as calculated from the subfossil diatom flora of the sediments.
Ambio 11, 30 - 33.

RODHE, W (1956)
Vattenbeskaffenhet och växtplankton i Motala ström vid Norrköpings stads vattenverk, Fiskeby 1954 - 1955. 3. Fytoplanktonproduktionen.
Limnologiska institutionen, Uppsala.

RODHE, W (1958)
Primärproduktion und Seetypen.
Verh.int. Verein. theor. angew. Limnol. 13, 121 - 141.

RODHE, W (1963)
Vattenbeskaffenhet och plankton i Ransaren och Kultsjön. 3. Primärproduktionen.
Limnologiska institutionen, Uppsala.

SMETACEK, W (1980)
Annual cycle of sedimentation in relation to plankton ecology in western Kiel Bight.
Ophelia (suppl) 1, 65 - 76.

STEELE, J H and BAIRD, I E (1961)
Relation between primary production, chlorophyll and particulate carbon.
Limnol. Oceanogr. 6, 68 - 78.

SUNDBLAD, B (1984)
Lake and coastal zone evolution during postglacial time.
STUDSVIK/NW-84/722. SKB TR 84-17 appendix 1.

SUNDBLAD, B (1986)
Recipient evolution - transport and distribution of elements in the Sibbo- och Trobbofjärden area.
STUDSVIK/NP-86/163. SKB TR 86-30, dec 1986.

TOLSTOY, A (1972)
Chlorophyll a and primary production of phytoplankton in two basins of Lake Mälaren (Lilla Ullevifjärden and Ekoln).
Medd. Naturvårdsverkets limnologiska undersökning No 52.

WASSMAN, P (1983)
Sedimentation of organic and inorganic particulate material in Lindåspollene, a stratified land-locked fjord in western Norway,
Mar. Ecol. Progr. Ser. 13, 237 - 248.

WEBSTER, T J M, PARANJAPE, M A and MANN K H
1975, Sedimentation of organic matter in St. Margaret's Bay, Nova Scotia.
J. Fish. Res. Bd. Can 32, 1399 - 1407.

WILLÉN, E (1976)
Phytoplankton in Lake Hjälmaren.
Acta Universitatis Upsaliensis No 378.

WINTERHALTER, B (1972)
On the geology of the Bothnian Sea, an Eperic sea that has undergone Pleistocene Gaciation.
Geological Survey of Finland, Bull 258.

YARBRO, L A, CARLSON, P R, FISHER, T R, CHANTON, J P and KEMP, W M (1983)
A sediment budget for the Choptank River Estuary in Maryland, USA.
Estuarine, Coastal and Shelf Science 17, 555 - 570.

YOUNG, D K and RHOADS, D C (1971)
Animal - sediment relations in Cape Cod Bay, Massachusetts. 1, A transect study.
Mar. Biol. 11, 242 - 254.

ZEITSCHEL, B (1965)
Zur Sedimentation von Seston, eine produktionsbiologische Untersuchungen von Sinkstoffen und Sedimenten der westlichen und mittleren Ostsee.
Kieler Meeresforsch. 21, 55 - 80.

Table 1

Annual gross sediment load in Lake Trobbofjärden and Lake Sibbofjärden. Data for 1985.

	Lake Trobbofjärden			
Depth	Area	Sediment load (tons y^{-1})		
(m)	(km^2)	min	average	max
0-1	0.30	360	450	540
1-2	0.84	1 400	1 650	1 900
2-3	0.45	970	1 090	1 220
3-4	0.42	1 110	1 220	1 330
4-5	0.48	1 500	1 620	1 730
5-6	0.15	540	570	610
6-7	0.36	1 470	1 550	1 620
	3.0	7 350	8 150	8 950

	Lake Sibbofjärden			
Depth	Area	Sediment load (tons y^{-1})		
(m)	(km^2)	min	average	max
0-1	0.20	140	120	160
1-2	0.42	340	300	370
2-3	0.65	600	530	640
3-4	0.90	920	840	990
4-5	0.20	230	210	240
5-6	0.30	370	350	390
6-7	0.65	880	830	910
7-8	0.94	1 370	1 310	1 420
8-9	0.59	920	890	950
9-10	0.53	880	860	910
10-11	0.54	960	930	980
	5.9	7 610	7 170	7 960

Table 2

Pelagic primary production in different Swedish waters. From Pierrou (1977).

Lake	Production g $Cm^{-2}yr^{-1}$	Reference
Koukkelområdet	2-5	A Lundberg (pers.komm)
Kultsjön	ca 20	W Rodhe 1963
Ransaren	<20	"
Nedre Laksjön	12	S Holmberg 1968
Vitalampa	2.9-6.0	L Ramberg 1976
Botjärn	1.6-3.5	"
Erken	100	W Rodhe 1958
Norrviken	300	G Ahlgren 1970
Görväln	ca 100	W Rodhe 1956
Ekoln	125	A Tolstoy 1972
Ullevifjärden	115	"
Hjälmaren	170	E Willén 1976
Vänern	ca 20	A Tolstoy (pers.komm)
Trummen	390→205	G Andersson 1975
Motala ström	150	W Rodhe 1956
Bysjön	290	M F Coveney et al 1977
Vombsjön	450-655	C Gelin 1975
Bothnian Sea	56.6	S Fonselius 1972
Baltic proper	78.0	"
Swedish west coast	ca 90	"

Table 3

Sedimentation rates in some Swedish lakes and in the Baltic Sea

Lake	Trophic status	Mean depth (m)	Sediment growth (mm y^{-1})	Sediment load ($kgm^{-2}y^{-1}$, dw)	Ref
Erken	eutrophic	17	4-10		Axelsson and Håkansson (1975)
Erken	"	17	8-11	2.8-3.4	Edberg (1980)
Norrviken	"	5	8-10		"
Ramsjön	"	2	8-9		"
Vänern	"		2-3		Håkansson (1975)
Trobbofjärden	"	3	14-17*	2.5-3.0	This study
Sibbofjärden	"	6	7-11*	1.2-1.3	This study
Skärvsjön	oligotrophic	5	0.5-1.2	0.04	El-Daoushy and Johansson (1983)
Björken	"	4	"	0.07	"
Väster-Täcksjö	"	5	"	0.12	"
Tussjön	"	4	"	0.04	"
Region of the Baltic					
Bothnian Sea			0.3		Winterhalter (1972)
Gotland Deep			1.0-1.3		Ignatius et al (1971)
Bornholm Basin			0.5-1.5		Kögler and Larsen (1979)
Southern Baltic			2.5	0.5	Zeitschel (1965)
Baltic Sea (average)			0.1-2.0		Ignatius (1958)

* calculated values assuming a sediment density of 1.2 and a water content of 85 %.

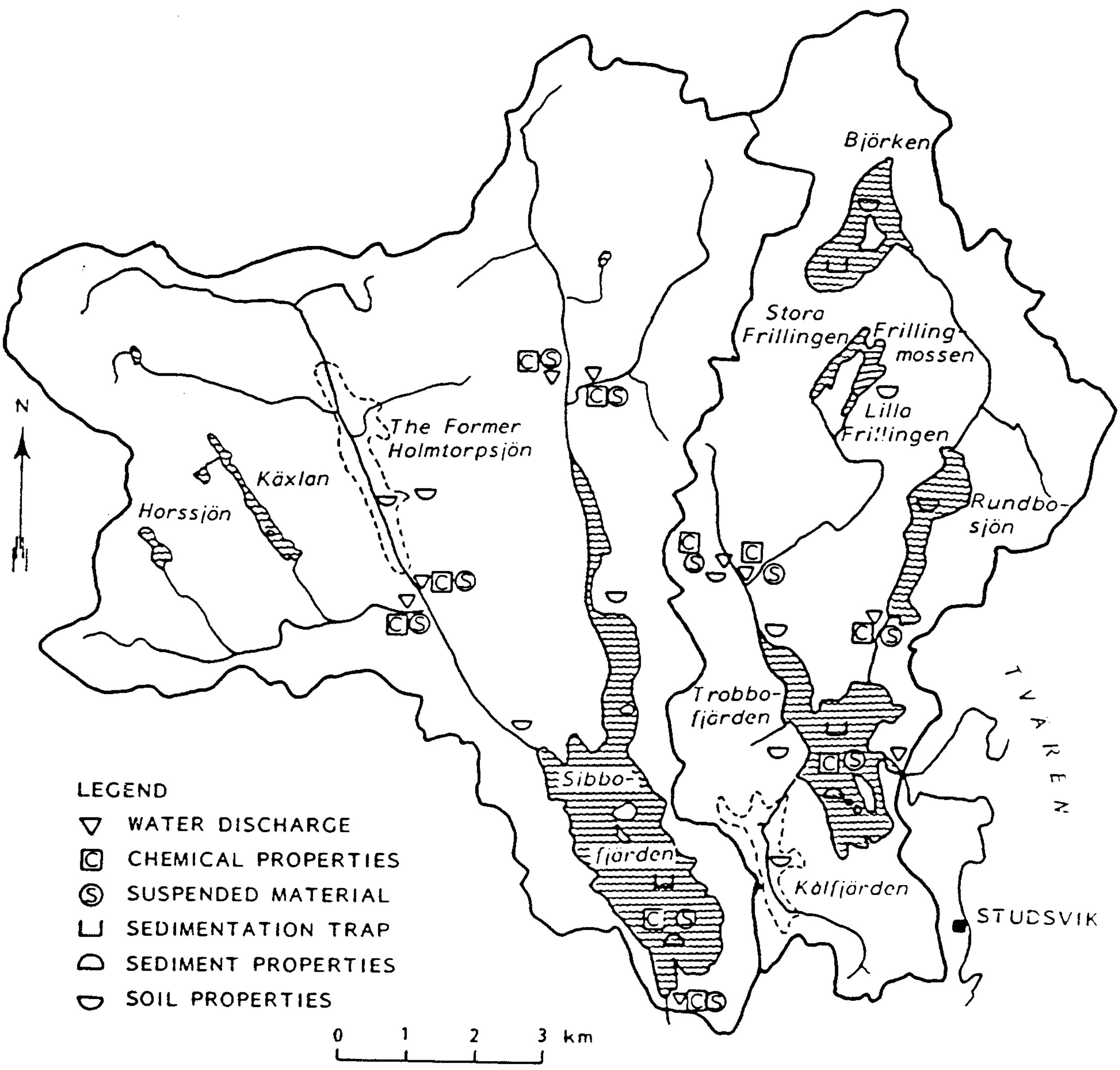


Figure 1. Lake Trobbofjärden and Lake Sibbofjärden.

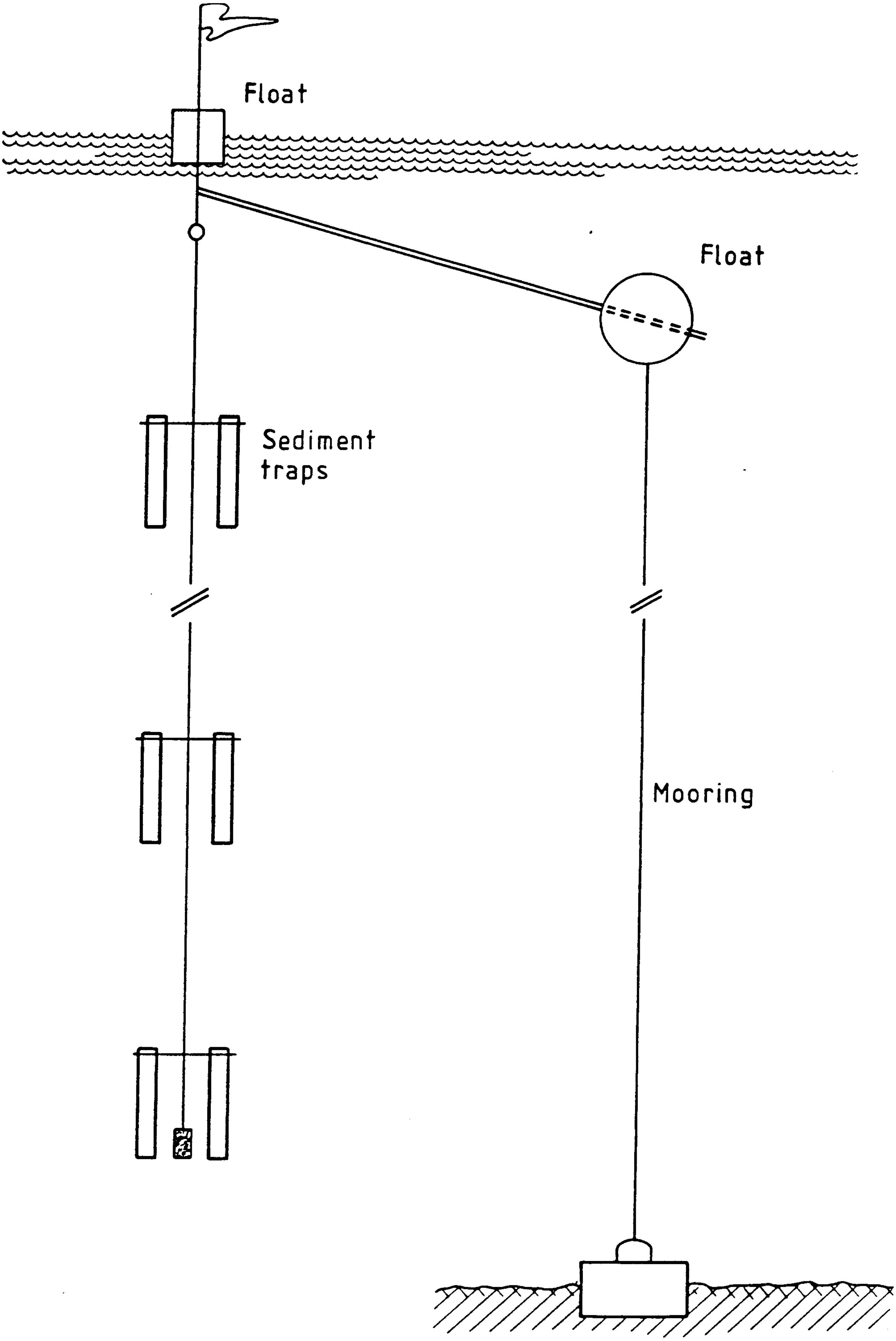


Figure 2. Suspension device of the sediment trap.

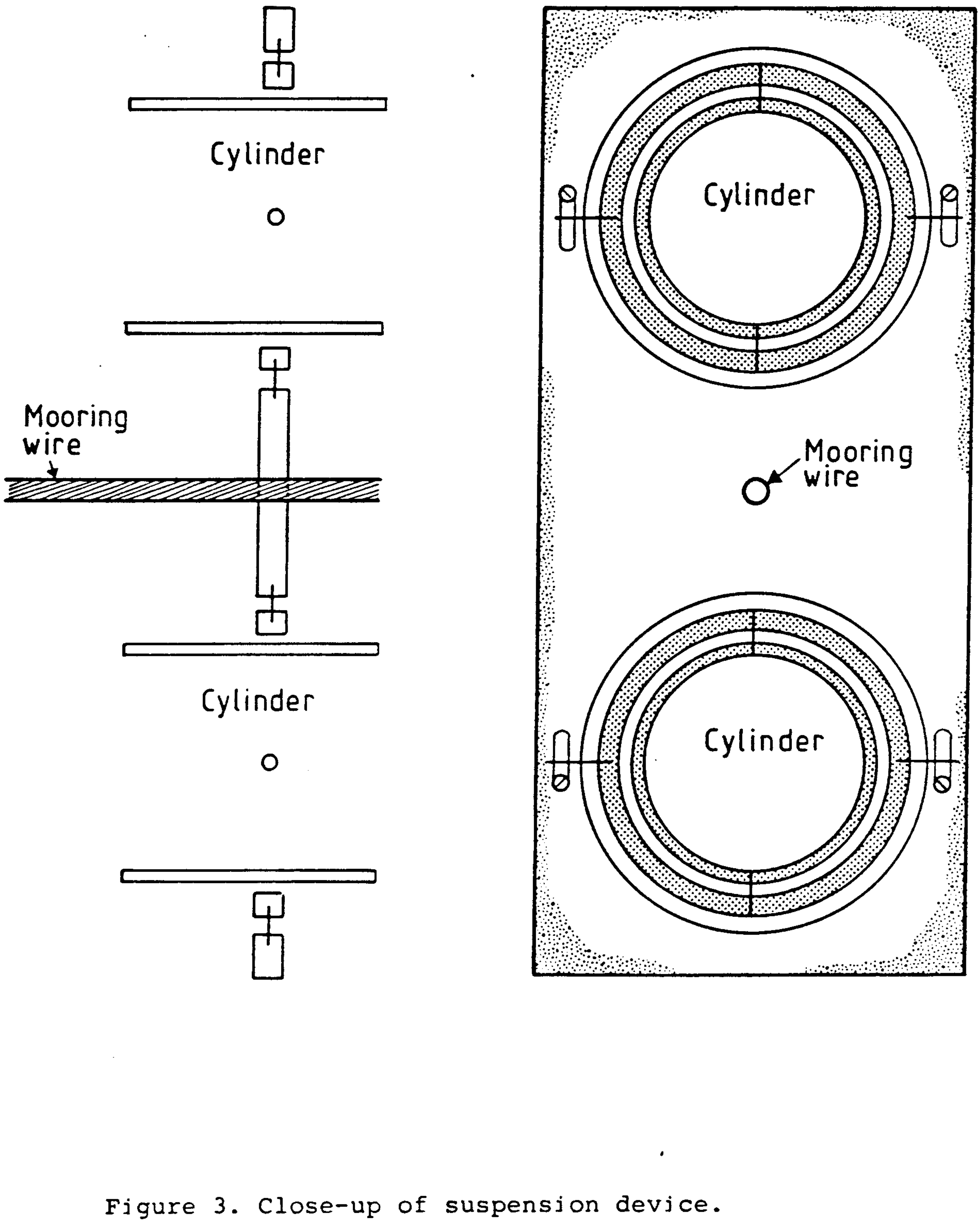


Figure 3. Close-up of suspension device.

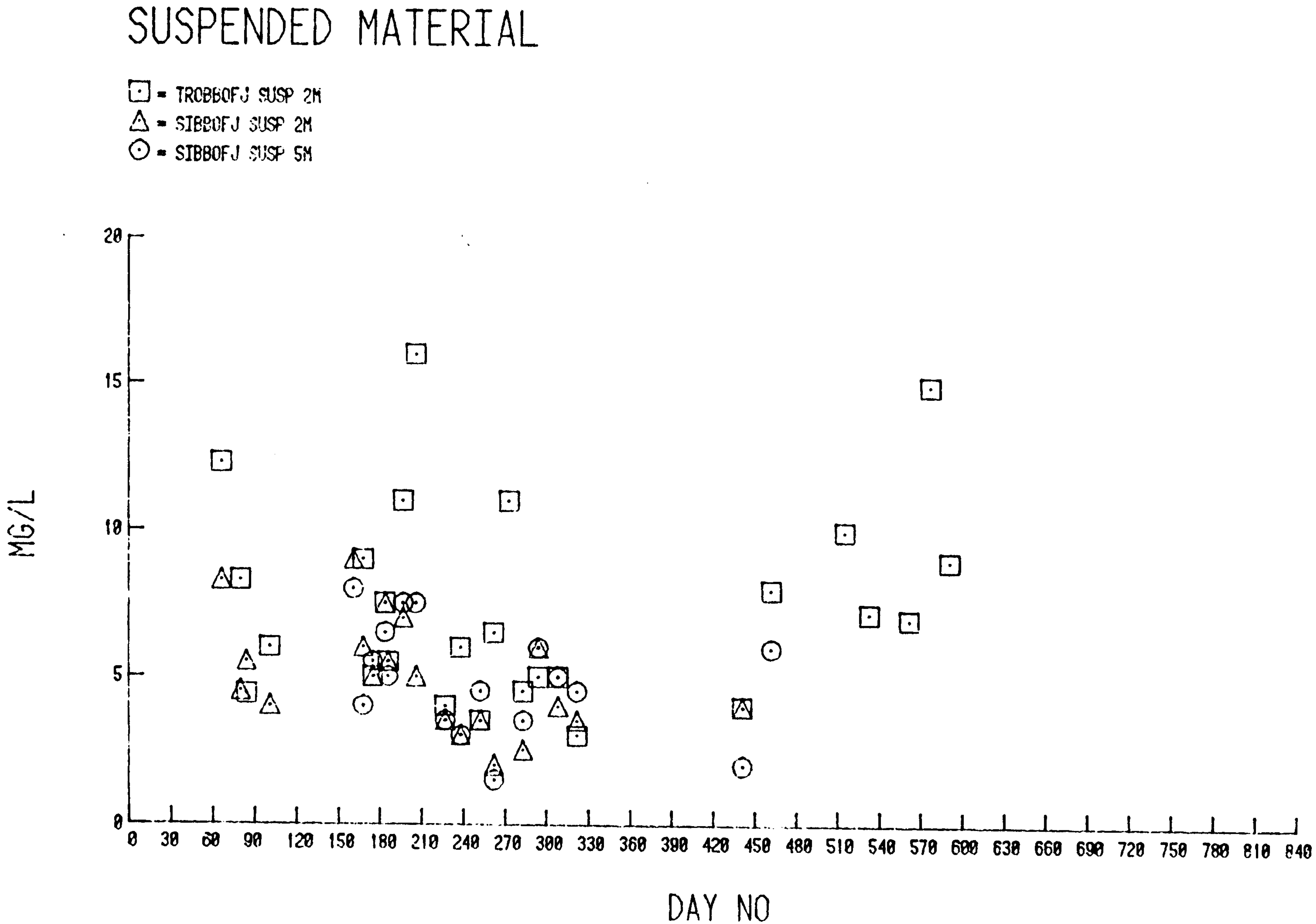


Figure 4. Contents of suspended particulate material in Lake Trobbofjärden and Lake Sibbofjärden.

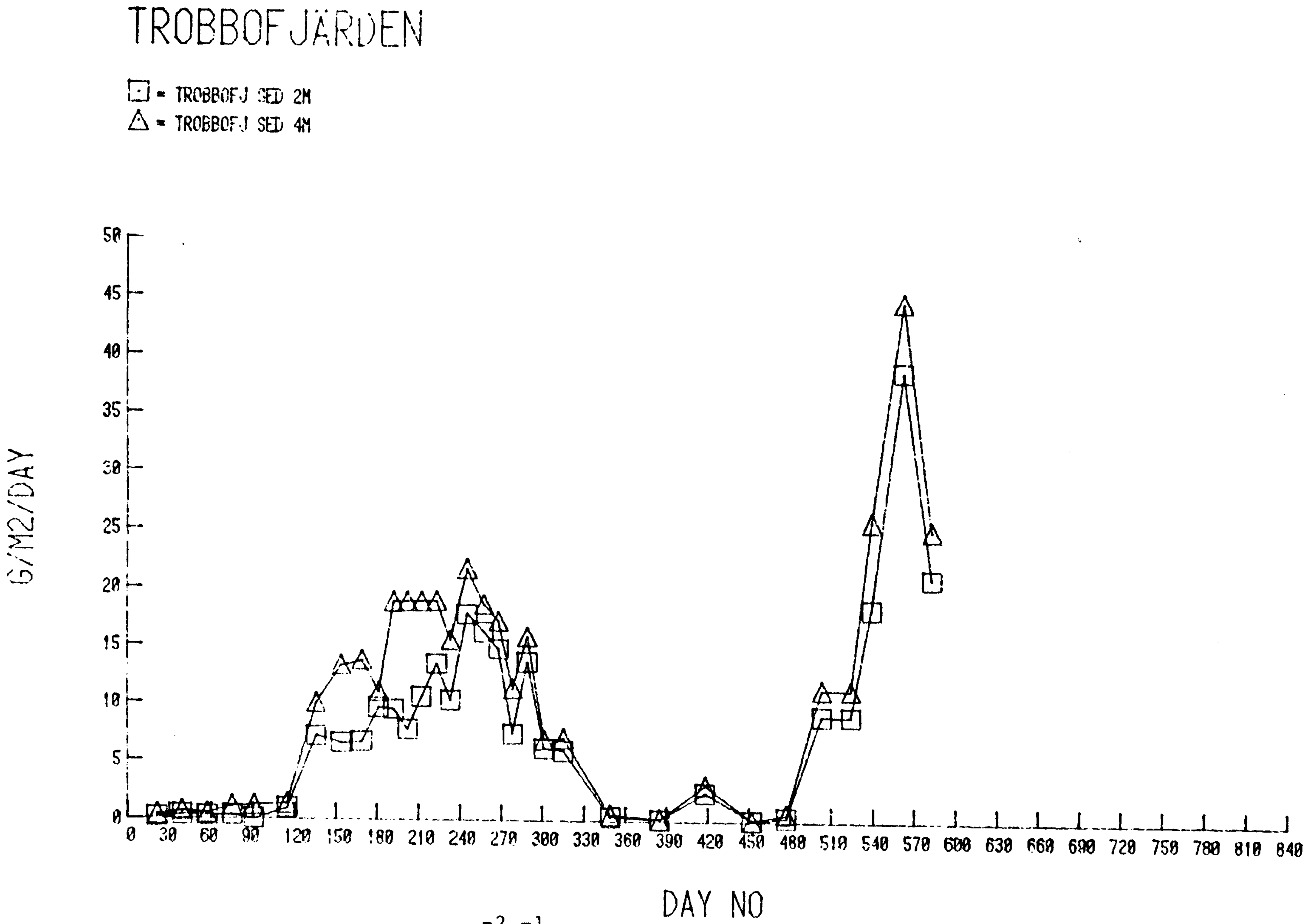


Figure 5. Sediment load (g $m^{-2}d^{-1}$ dry wt) at 2 m and 4 m depth in Lake Trobbofjärden.

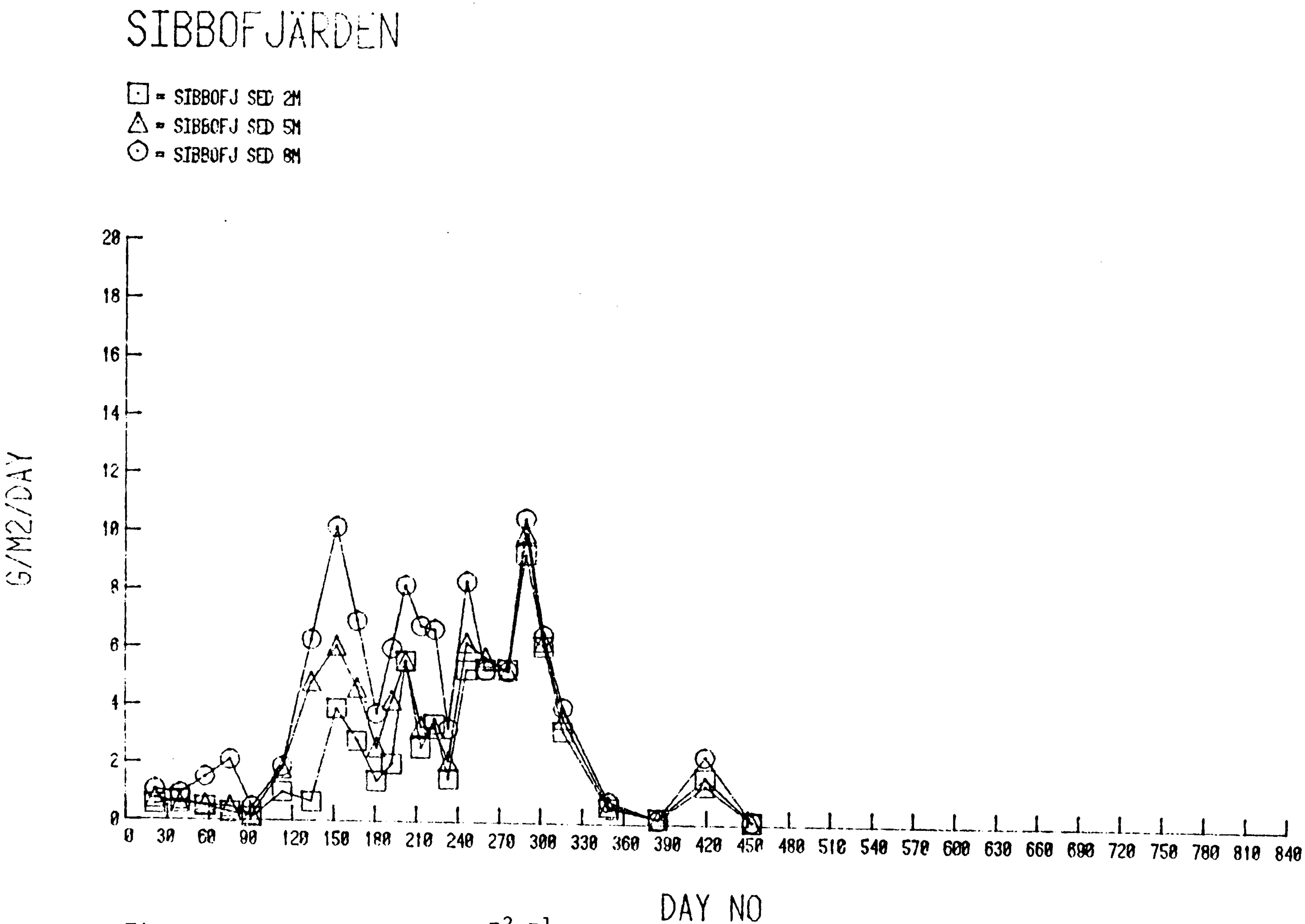


Figure 6. Sediment load (g $m^{-2}d^{-1}$ dry wt) at 2 m, 5 m and 8 m depth in Lake Sibbofjärden.

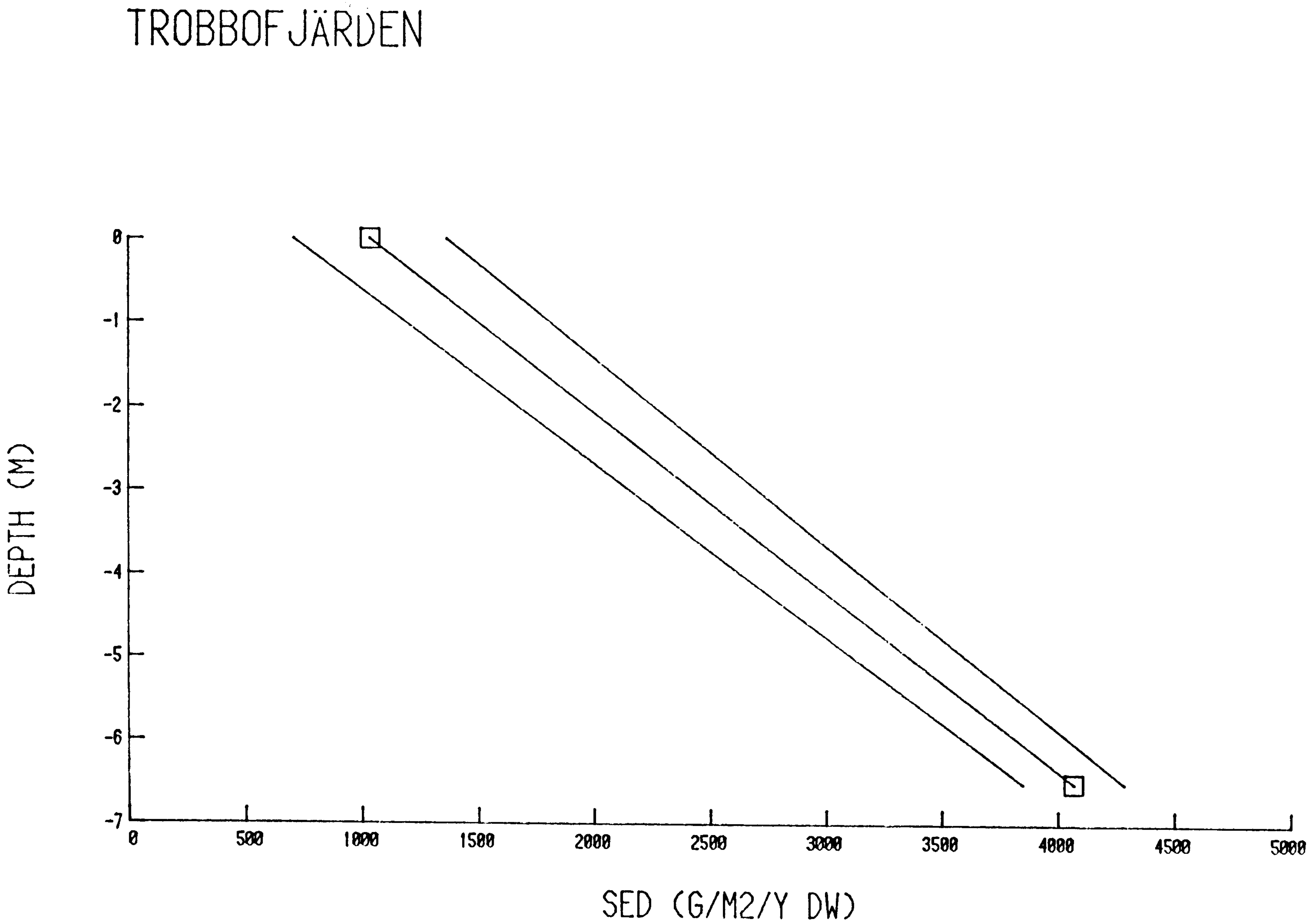


Figure 7. Sediment load versus depth in Lake Trobbofjärden.

SIBBOFJÄRDEN

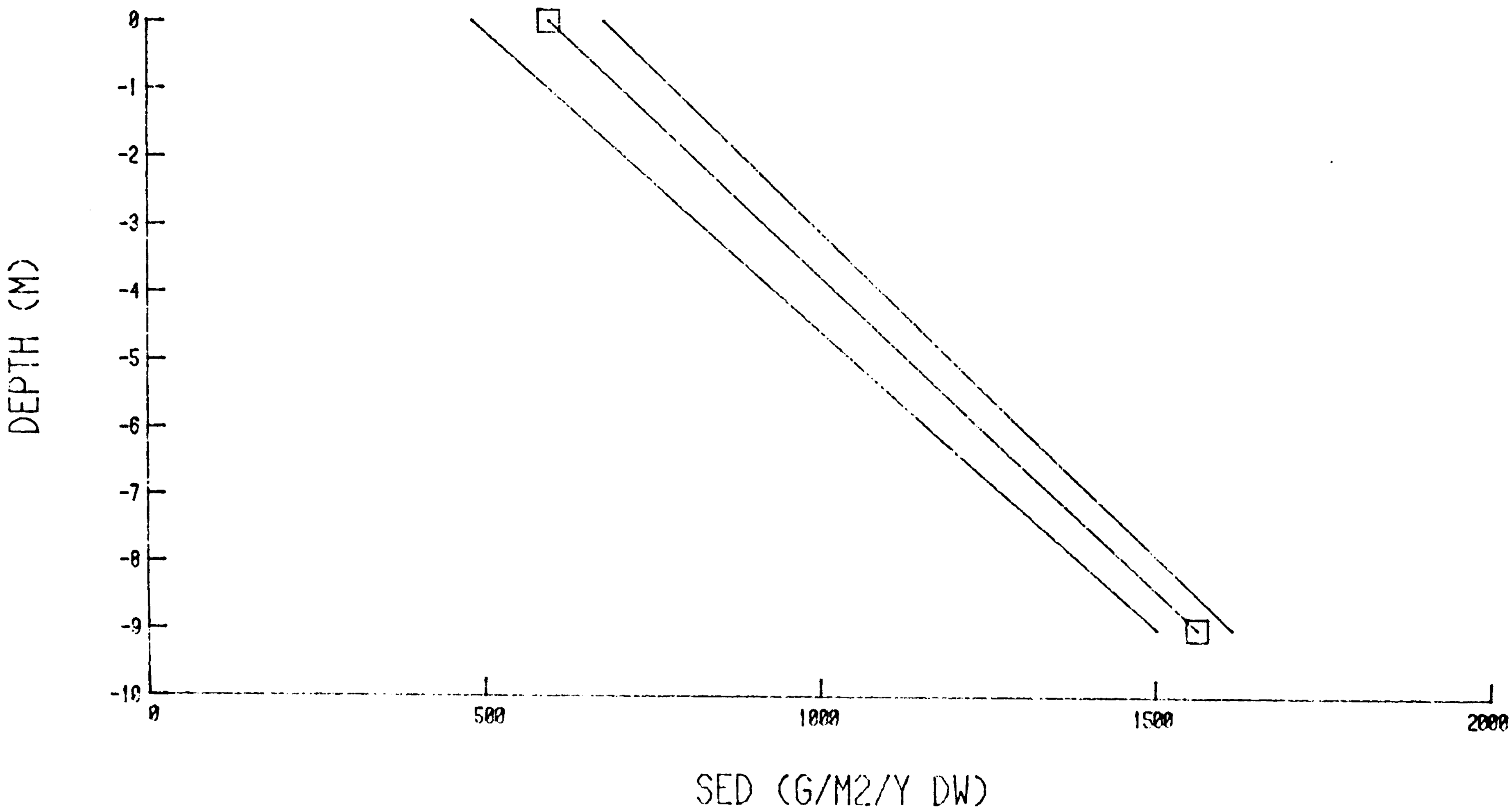


Figure 8. Sediment load versus depth
in Lake Sibbofjärden.

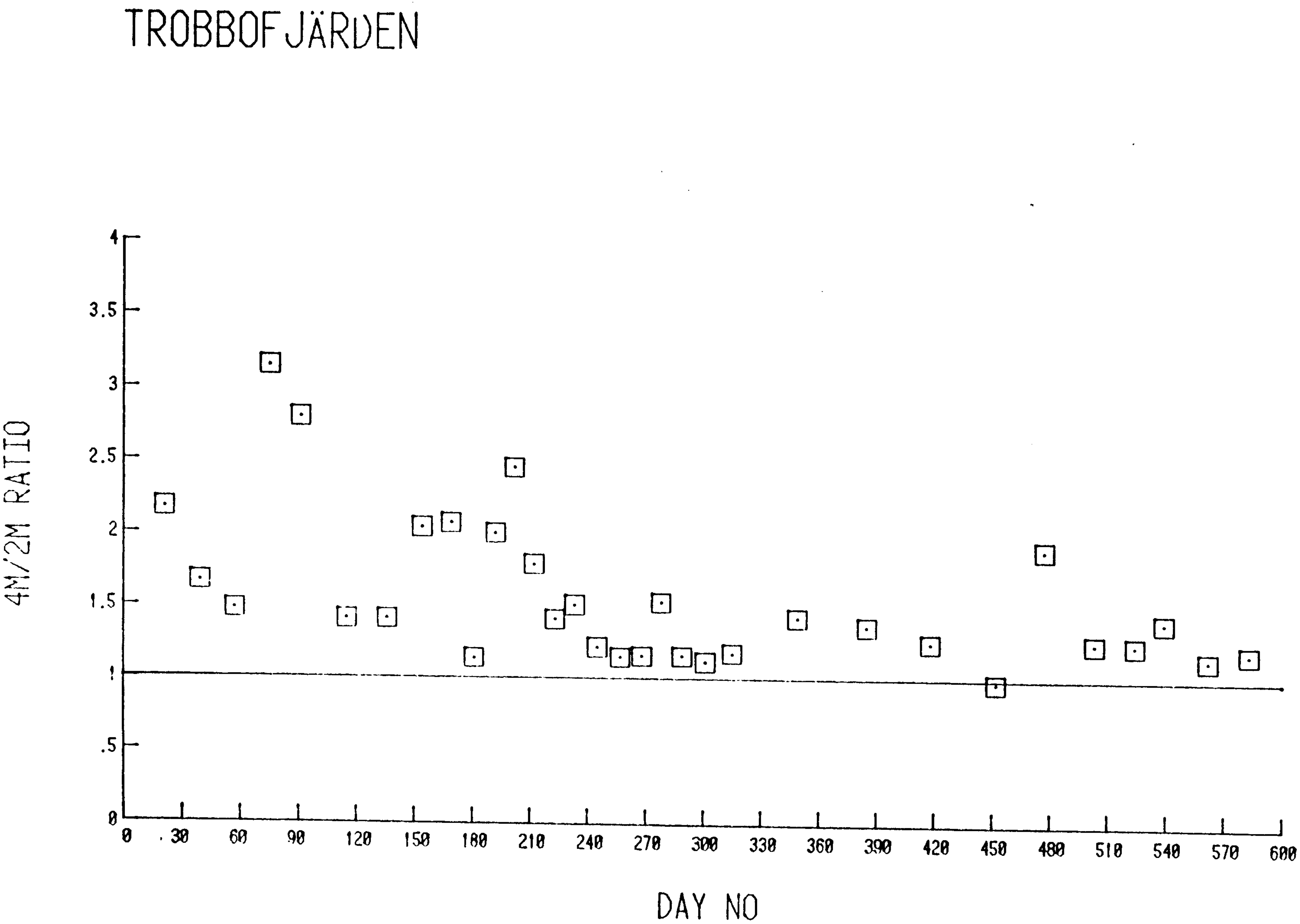


Figure 9. Mean ratios of amounts of material trapped at 4 m and 2 m depth in Lake Trobbofjärden.

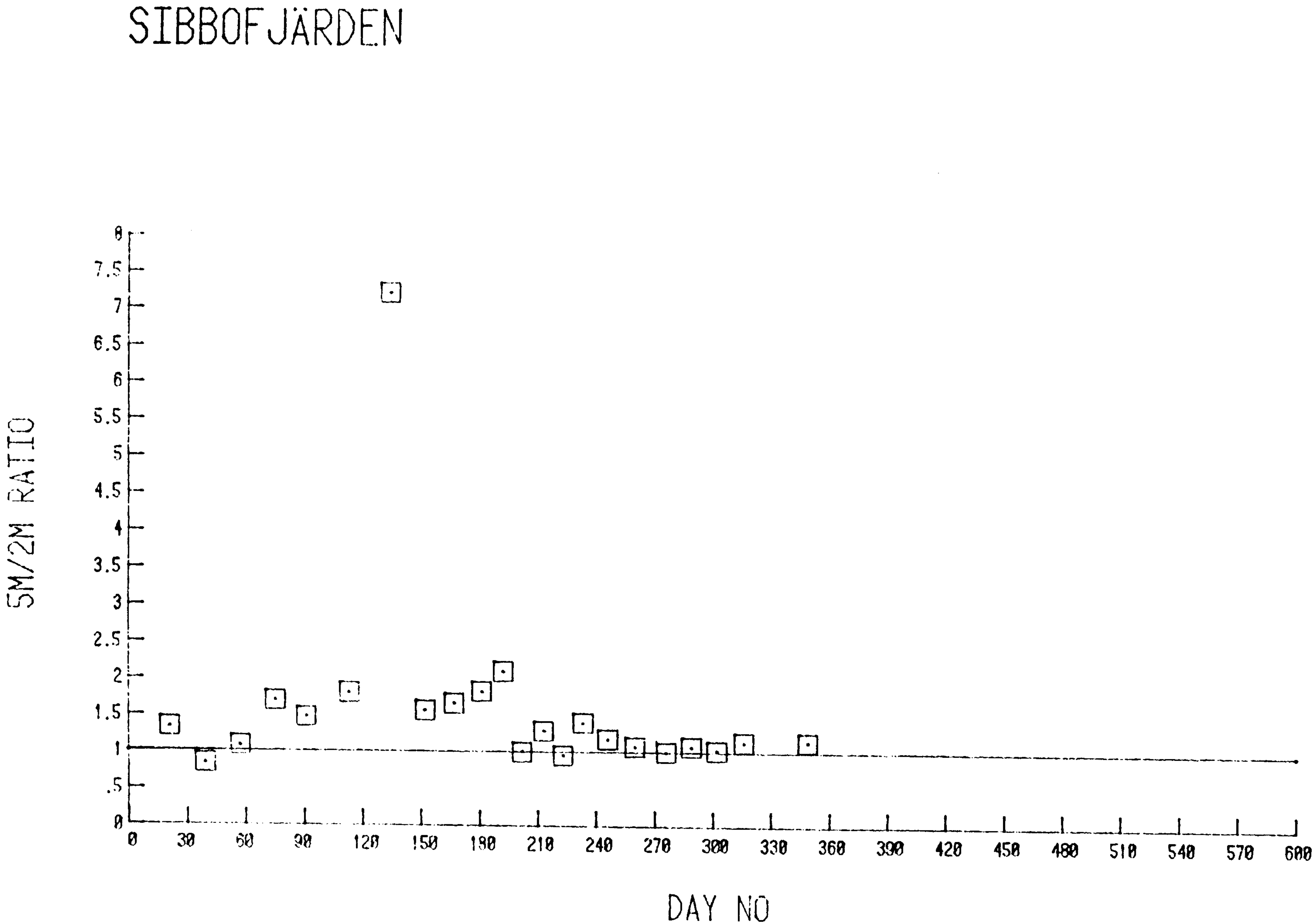


Figure 10. Mean ratios of amounts of material trapped at 5m and 2 m depth in Lake Sibbofjärden.

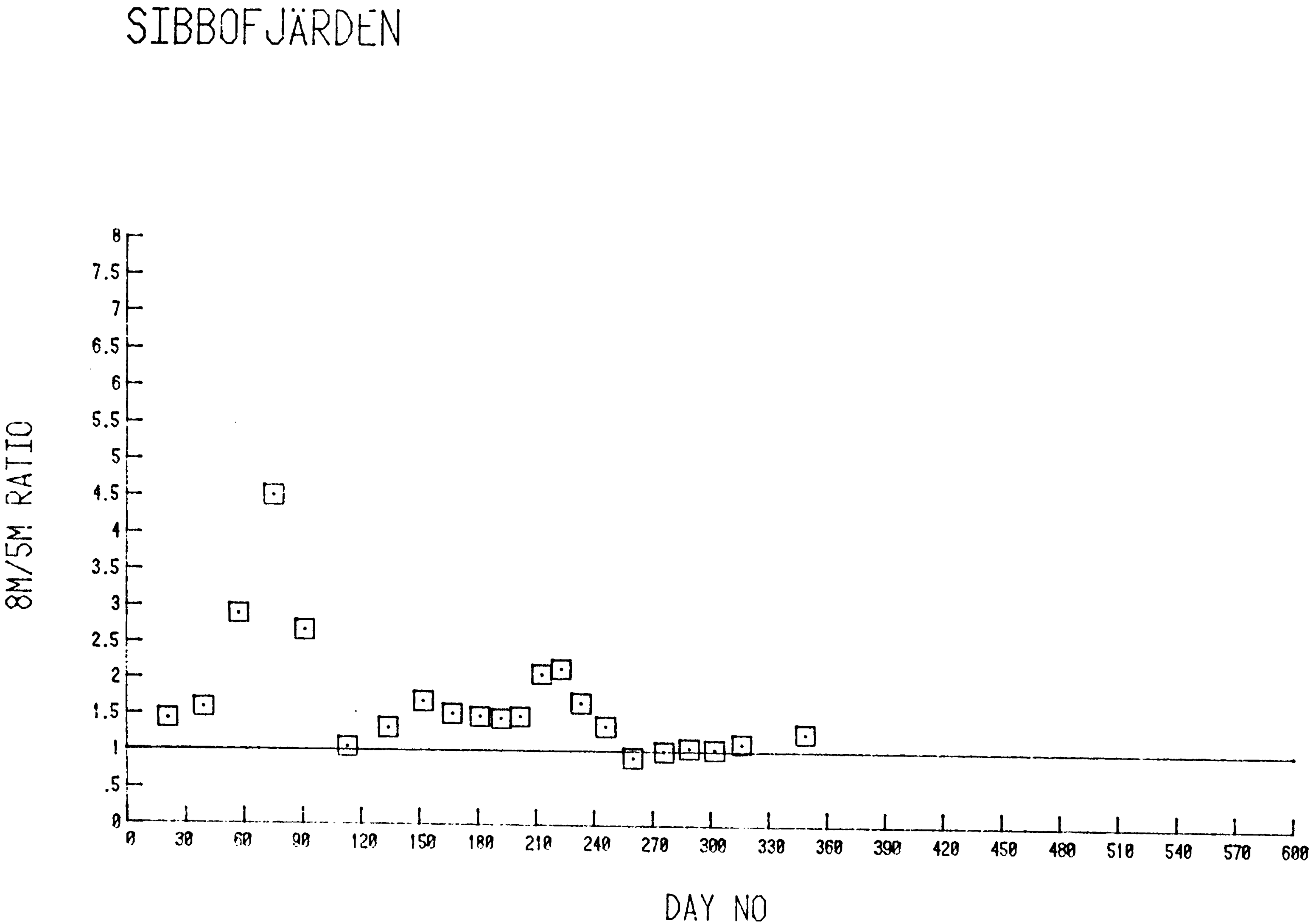


Figure 11. Mean ratios of amounts of material trapped at 8 m and 5 m depth in Lake Sibbofjärden.

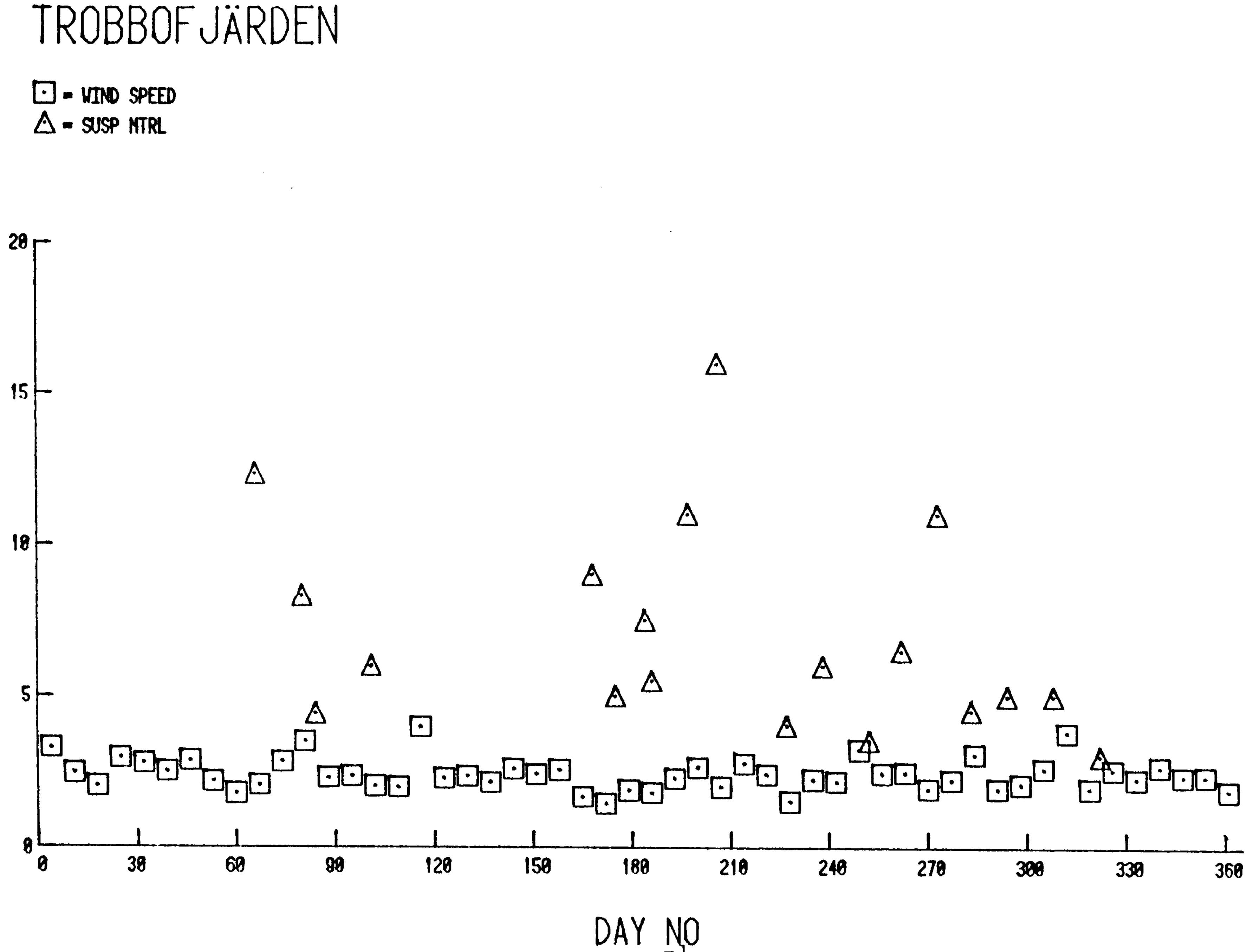


Figure 12. Contents of suspended material (mg l^{-1}) in Lake Trobbofjärden and wind speed data from Studsvik tower (m s^{-1}, weekly mean values, 10 m height). Data from 1985

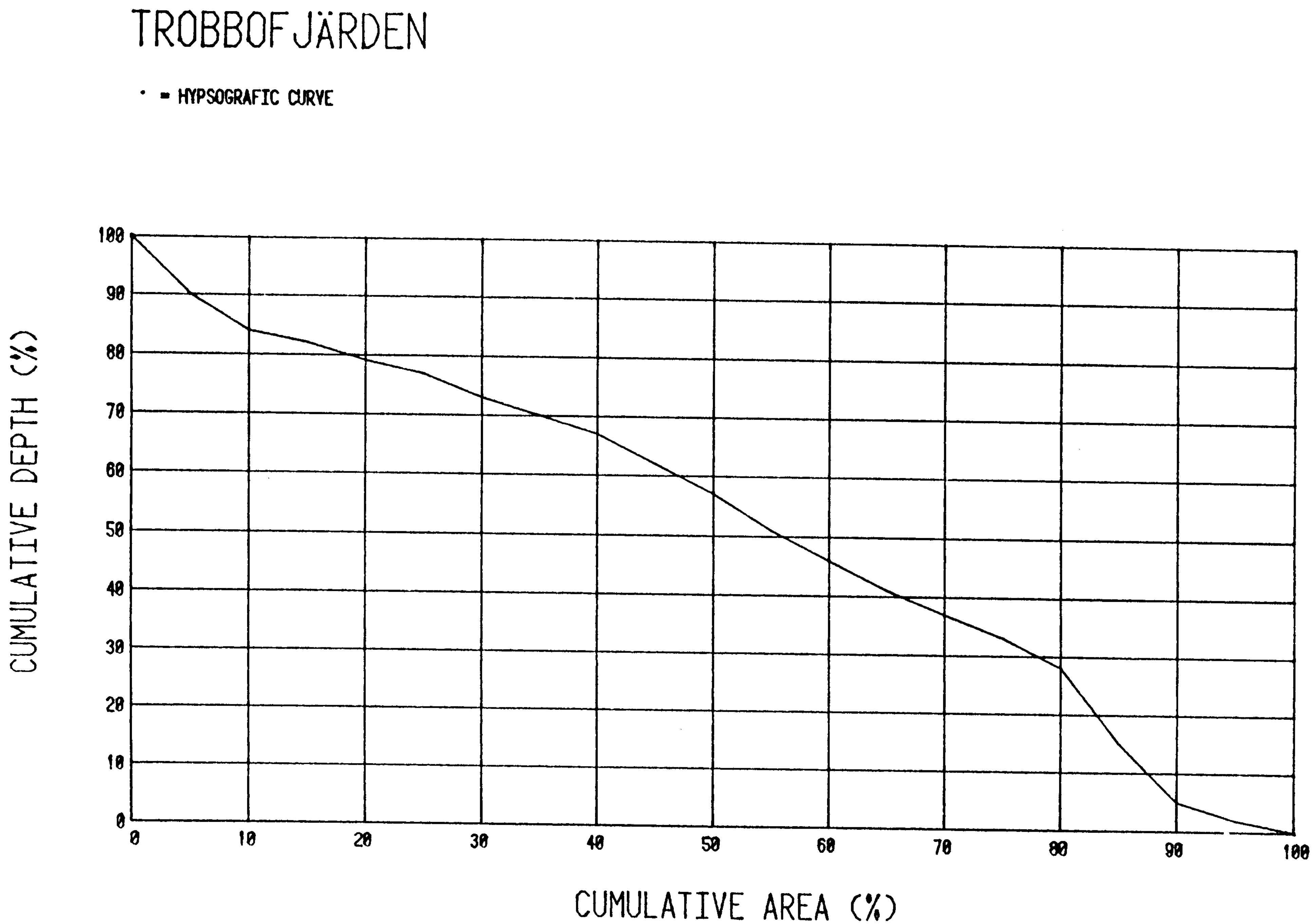


Figure 13. Relative hypsografic curve for Lake Trobbofjärden.

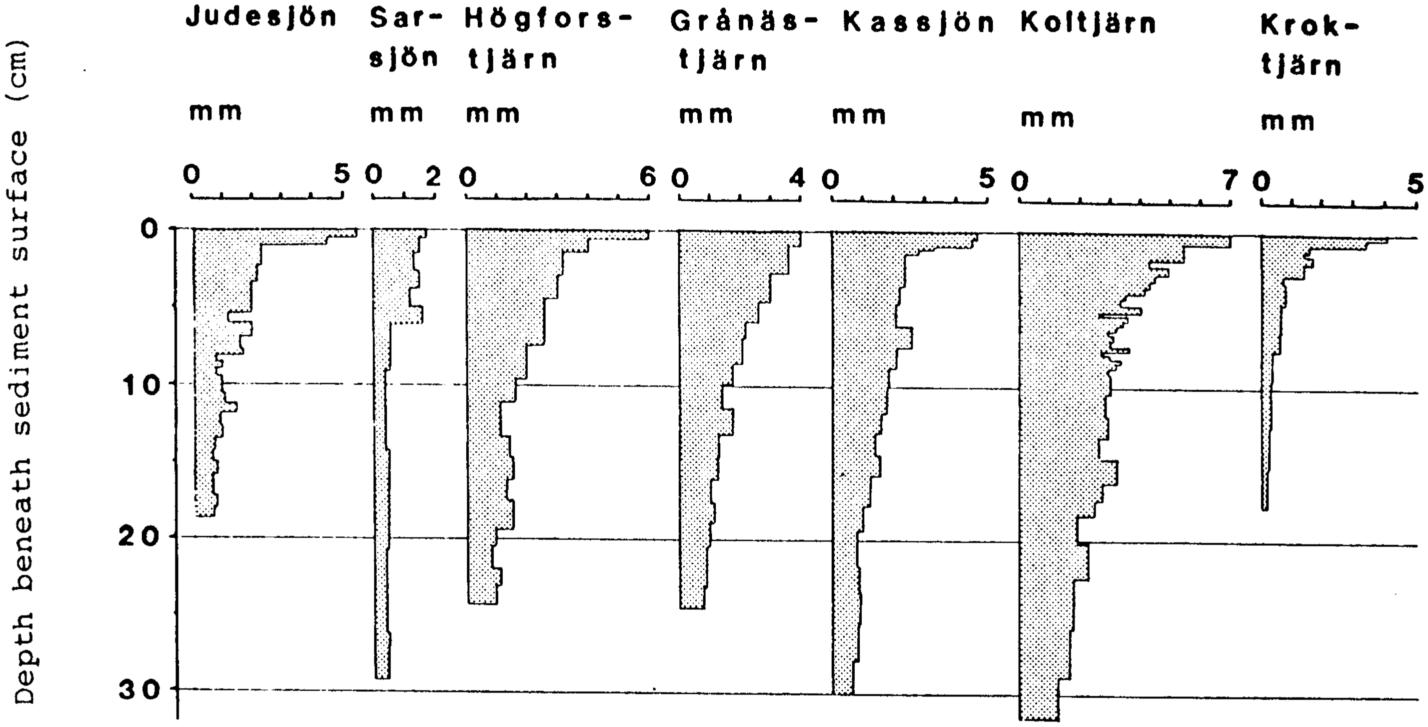


Figure 14. Graphs showing the increase in varve thickness toward the sediment surface in seven Swedish lakes. From Renberg (1981).

1986-12-03

Per-Olof Agnedal
Carina Gummesson

DESCRIPTION OF THE VEGETATION IN LAKE TROBBO- AND SIBBOFJÄRDEN DURING THE SUMMER 1985

ABSTRACT

In the summer 1985 a mapping of the vegetation was performed in Lake Trobbofjärden and Lake Sibbofjärden, which are situated on the coast near Studsvik.

The study has shown that a decrease in salinity and perhaps also in flow through has influenced the composition of species and also the abundance along the shoreline. Regarding the reed it is difficult to conclude whether the factors mentioned are of any importance.

In the summer 1985 a mapping of the vegetation was performed in Lake Trobbofjärden and Lake Sibbofjärden, which are situated on the coast near Studsvik.

Lake Trobbofjärden has been since 1955 shut off from the Baltic Sea by a weir which prevents brackish water from entering. Lake Sibbofjärden has however an open connection with the Baltic, so brackish water can press in at high water level in to the Baltic.

The topography of the two bays is presented in Figures 1 and 2.

One can assume that the two bays have had the same chemical and biological conditions before the weir was built. From the chemical point of view the chloride content of the water in Lake Trobbofjärden has decreased from 2 000 mg/l to the present level of about 30 mg/l. For the surface layer of the sediment the chloride concentration in the pore water has decreased from about 2 000 mg/l (which is the present concentration in that layer in Lake Sibbofjärden) to 50 mg/l. At about a depth of 50 cm in the sediment the Cl-concentration is 2 900 mg/l which is the same as that of Lake Sibbofjärden at the same depth.

The field work was done by Carina Gummesson, who also performed the estimation of the density of Phragmites communis.

The mapping was carried out by rowing along the shoreline. The vegetation both above and below the water surface was recorded with about 200 m distance between observation points and the names of the plants are according to Krok-Almquist (1).

At places where the shore was out of reach on account of belt or reed which was too broad, possible shore vegetation was not noted.

The stations are numbered and marked on a map. Figure 1 and 2. Moreover the abundance of species at each station is illustrated on a map by points of various size, Figure 3 - 4.

In order to estimate the density of the reed the number of straws per 1/4 m^2 was counted, by placing a frame of that size just inside the edge of the reeds. The depth at each station was recorded and it coincides mostly with the extension of the reed. Each one of the stations are marked on maps (Figures 5 and 6).

The extension of the vegetation of the reed and of the floating leaves has partly with the aid of airphotos been marked on a map. The precise width of the reed has however not been measured.

The intention of the performed mapping of the vegetation was to investigate whether the decrease in the salinity of the water and also a decrease in flow through the bay might have caused any changes in the composition and number of species. The changes which might have occurred would therefore also occur in a bay if it were cut off from the sea by land elevation and its water would change to fresh water.

The difference between Lake Trobbofjärden and Lake Sibbofjärden is clear from the fact that the number of species per station is greater and that the same species is found at many more stations in Lake Trobbofjärden than in Lake Sibbofjärden (Figure 7).

Species which have their occurrence in saline of brackish water are missing in Lake Trobbofjärden but are found in Lake Sibbofjärden. The density of the vegetation is much higher in Lake Trobbofjärden than in Lake Sibbofjärden apart from the upper part of Lake Sibbofjärden which is very similar to some parts of Lake Trobbofjärden.

The lower flow through Lake Trobbofjärden might also be a factor which can by decreasing the erosion along the shore line increase the density of the vegetation. The profile of the shore in Lake Sibbofjärden is generally steeper than in Lake Trobbofjärden with the exception of the western shore line which mainly consists of steep rock.

In Appendix 1 the species found are noted and also in which bay they occur. For each species there is also a number indicating the number of stations where the species has been found.

In the two bays species in all have been found of which, only in Lake Trobbofjärden and only in Lake Sibbofjärden.

It has, however, to be kept in mind that when performing an inventory only one time during the vegetation period, some species can be overlooked. This would however be the case for both the investigated areas.

The investigation of the density of reed showed that the number of stations with straws from 41 to 120 per m^2 is higher in Lake Sibbofjärden than in Lake Trobbofjärden and that there are also stations with more straws per m^2 in Lake Sibbofjärden, see Figure 8.

CONCLUSION

The study has shown that a decrease in salinity has influenced the composition of species in such a way that species common in brackish water have decreased in Lake Trobbofjärden and a decrease in flow through the abundance along the shoreline. Regarding the reed it is difficult to conclude whether the factors mentioned are of any importance.

REFERENCE

1 KROK-ALMQUIST: Svensk flora 25:e upplagan

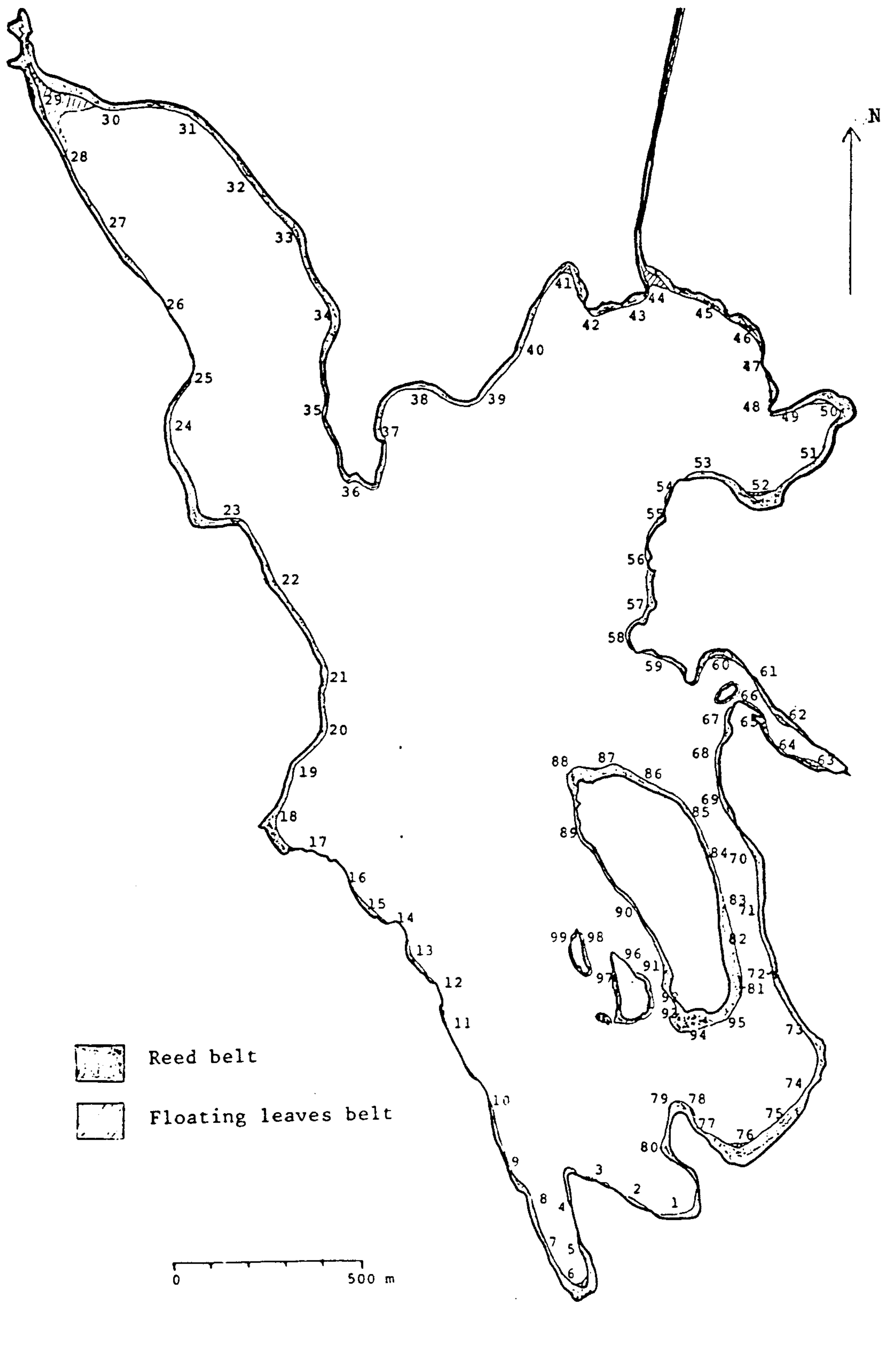


Figure 1 Station number of plant mapping (Trobbofjärden)

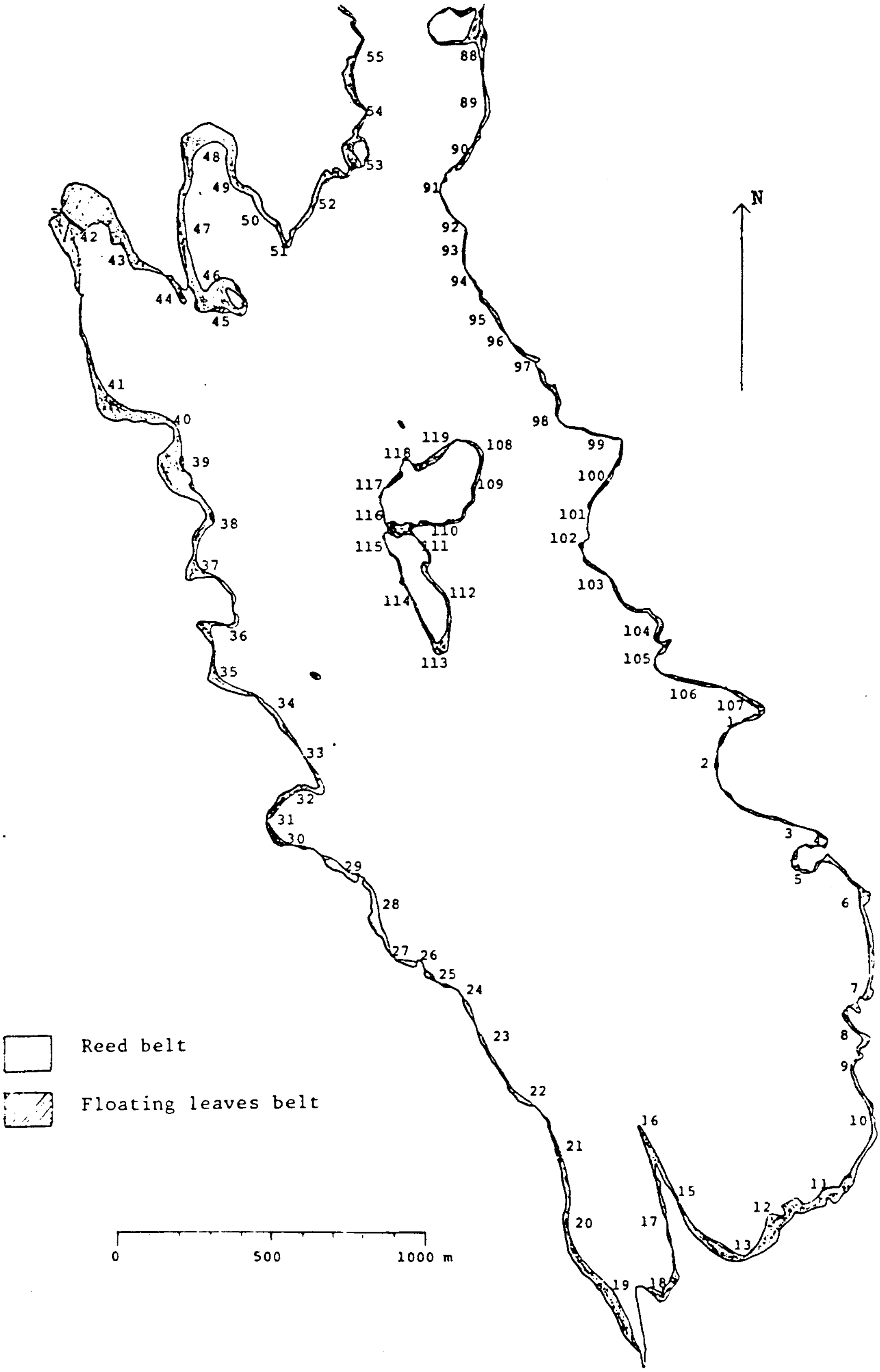


Figure 2A Station number of plant mapping (Sibbofjärden)

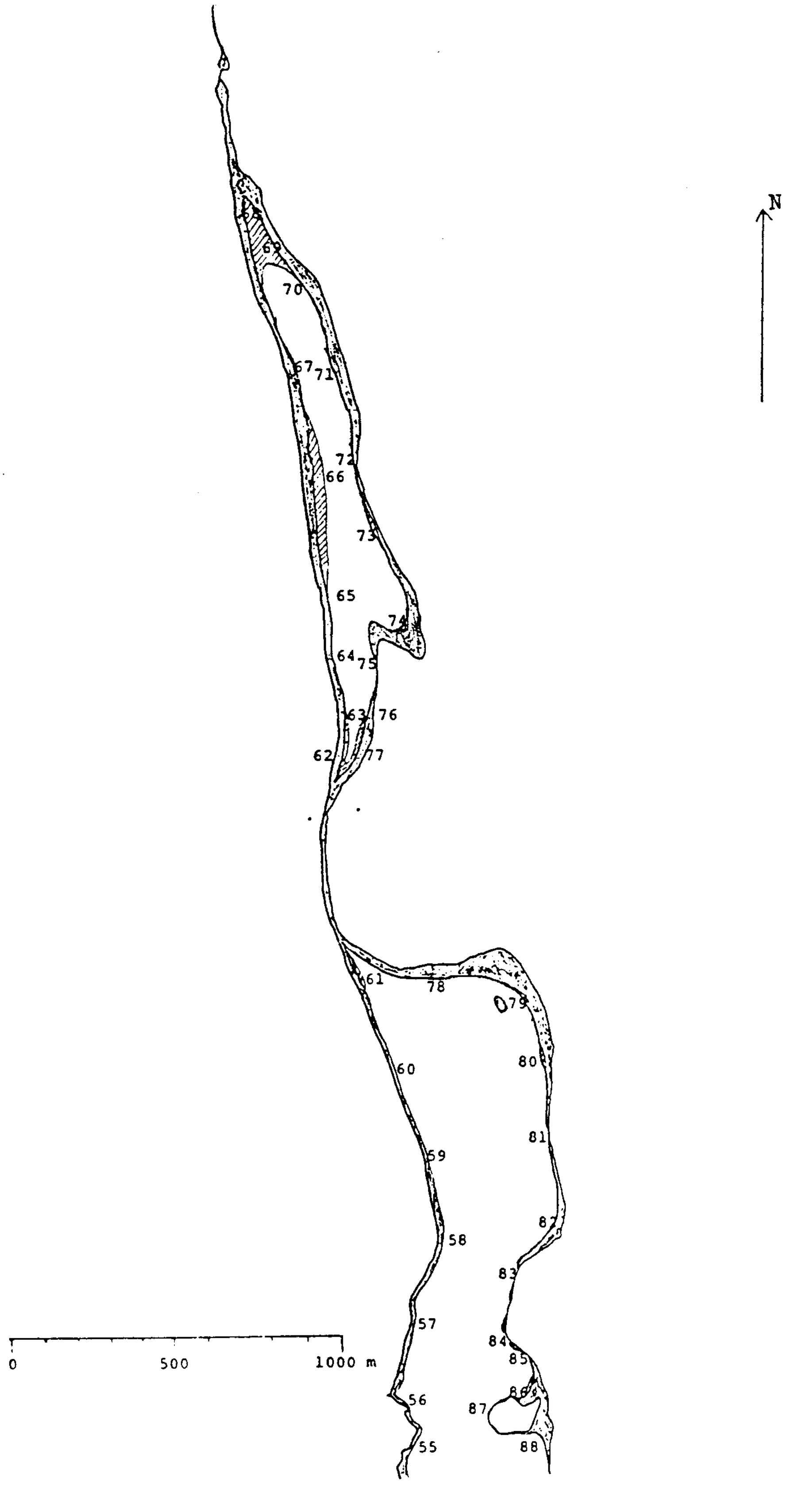


Figure 2 B Station number of plant mapping (Sibbofjärden)

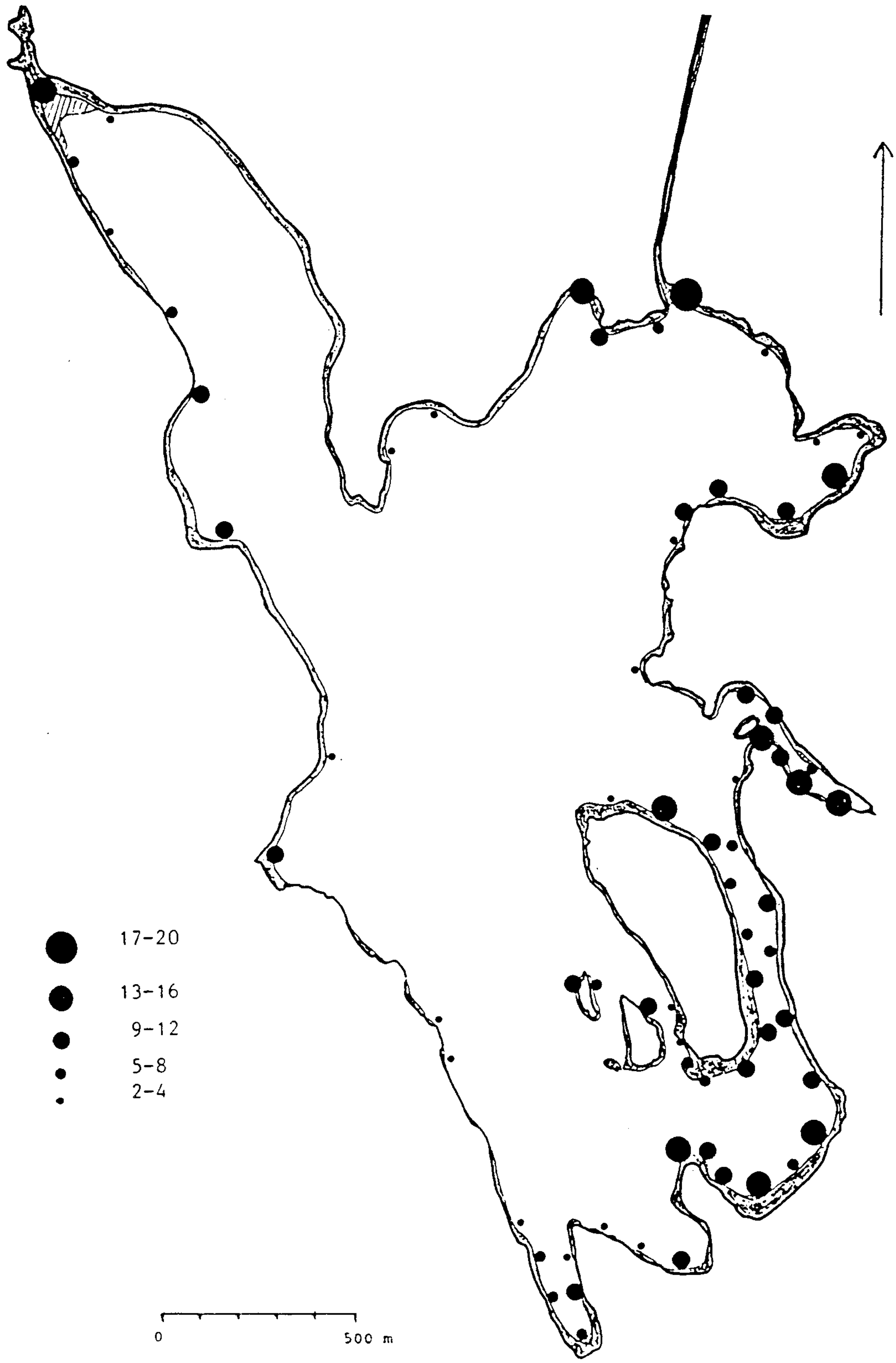


Figure 3 Abundance of species. Number of species in relation to the size of the point (Trobbofjärden).

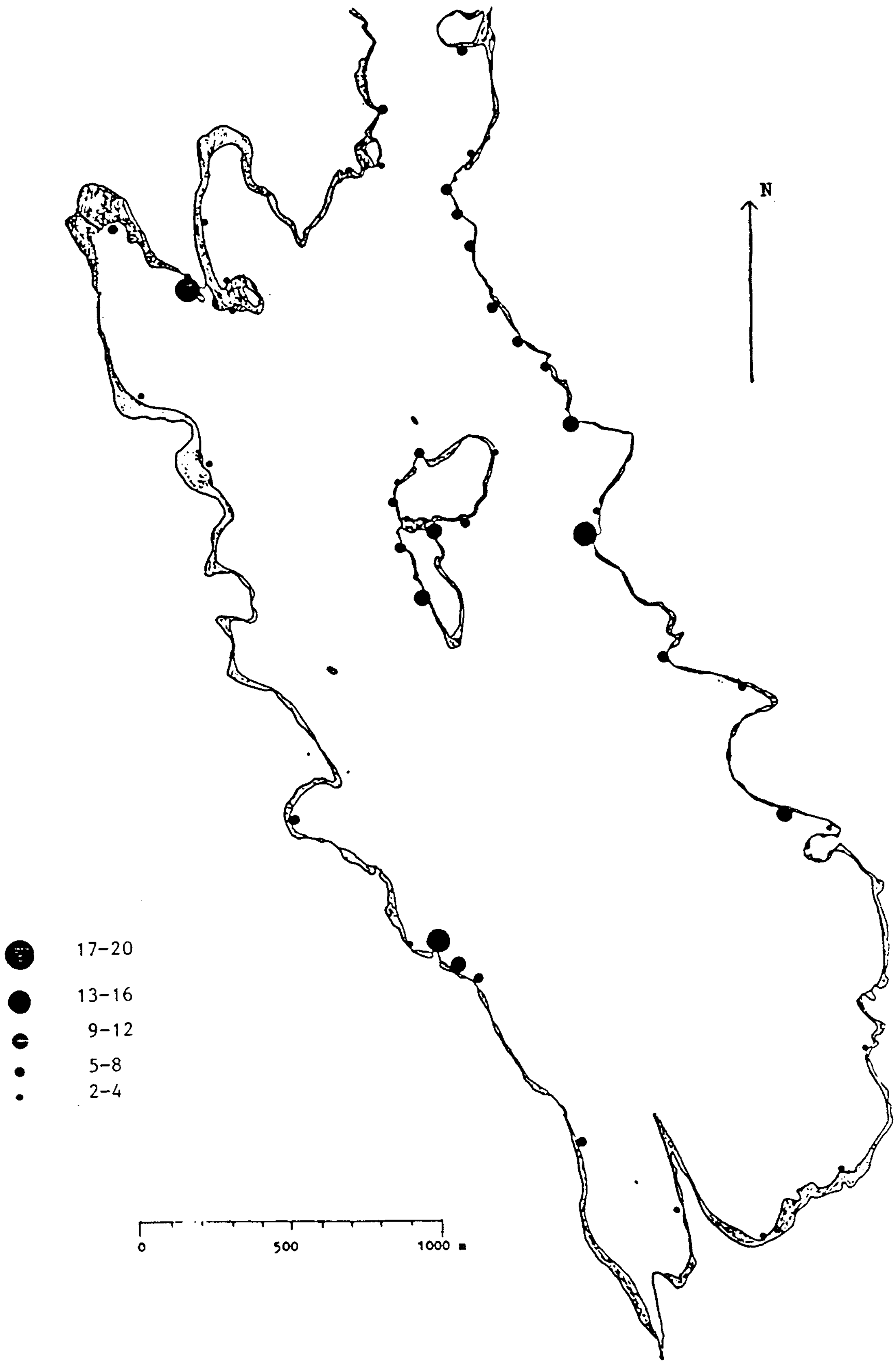


Figure 4A   Number of species in relation to the size of the point (Sibbofjärden)

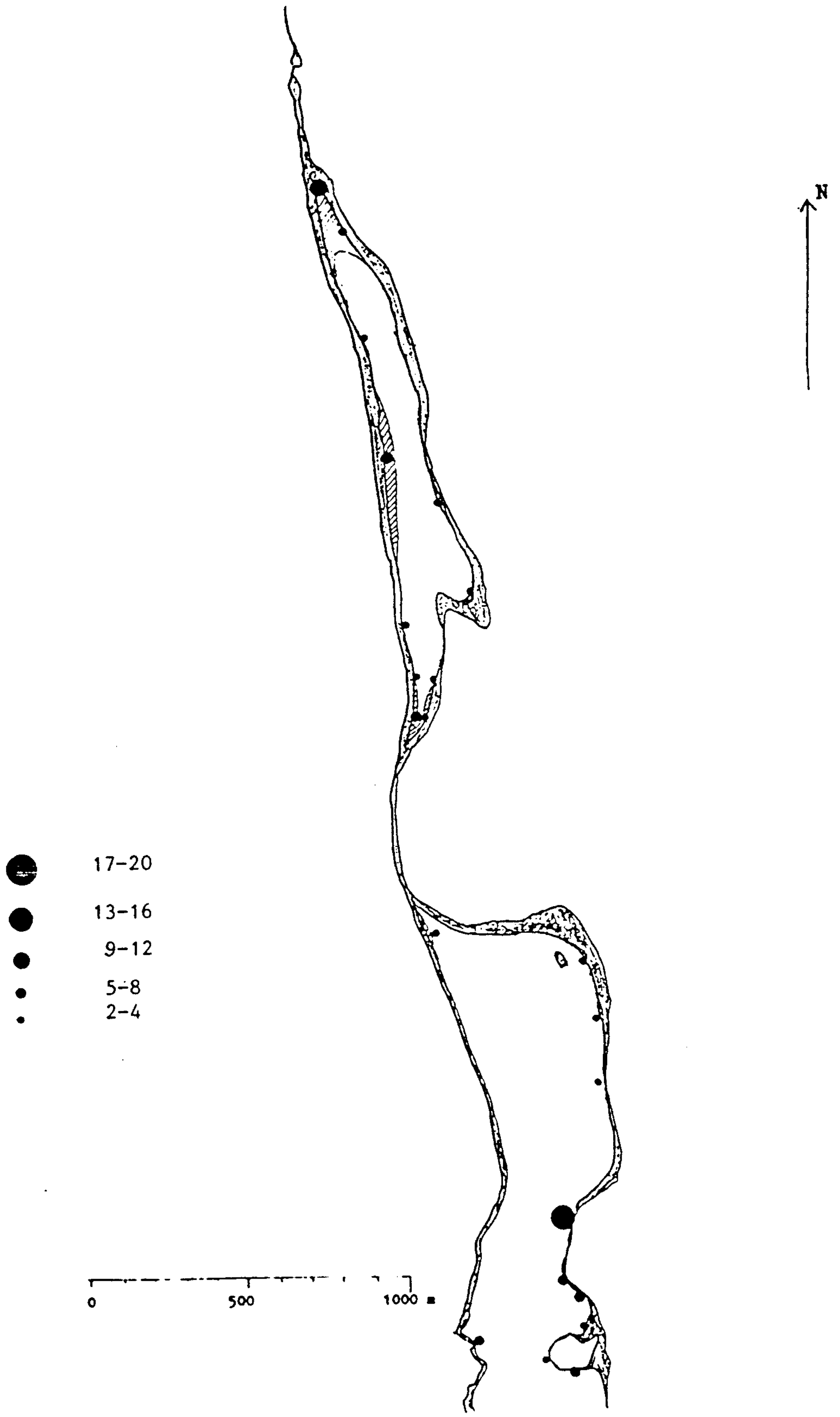


Figure 4B Number of species in relation to the size of the point (Sibbofjärden)

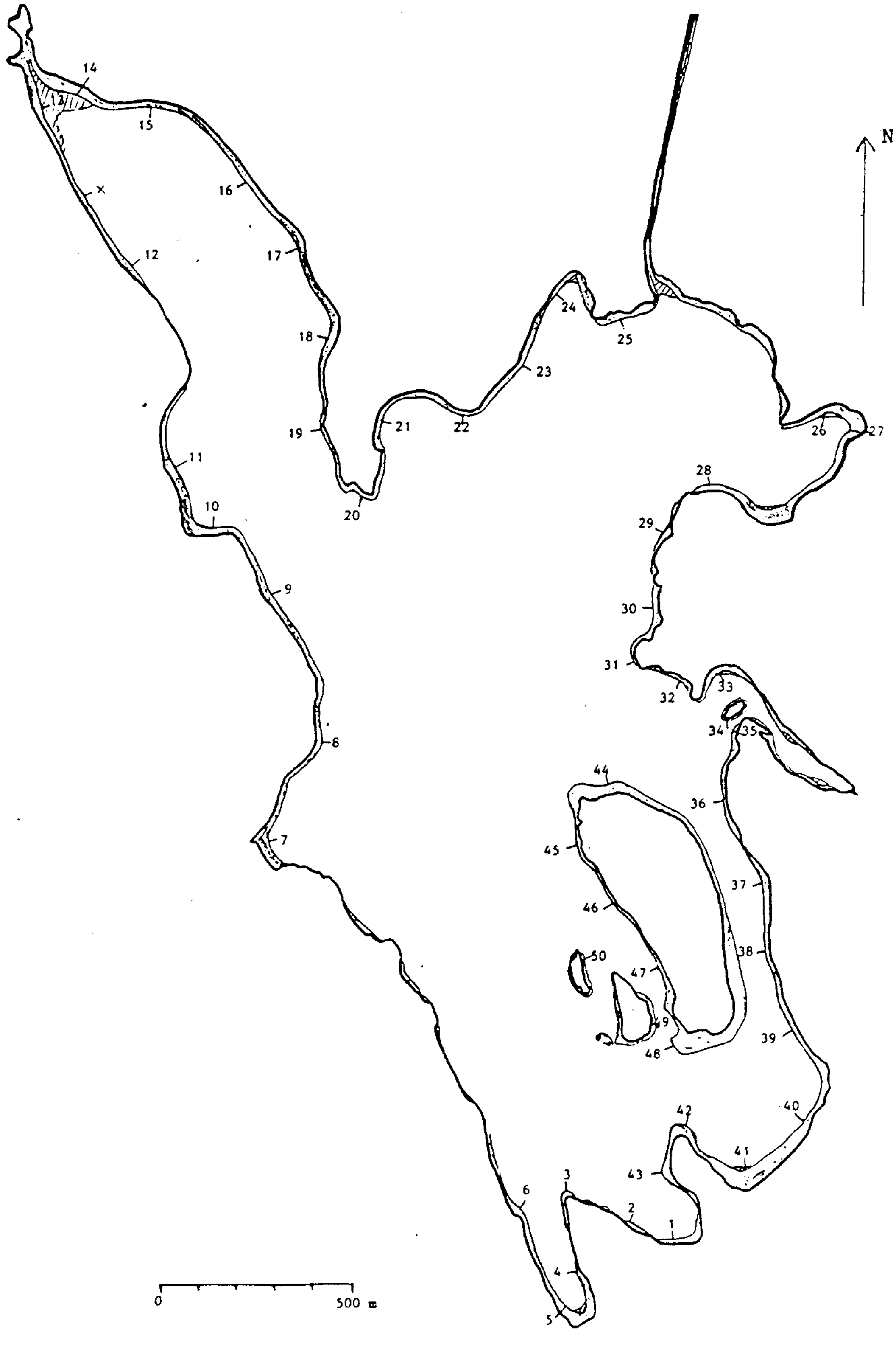


Figure 5 Station number for reed counting (Trobbofjärden)

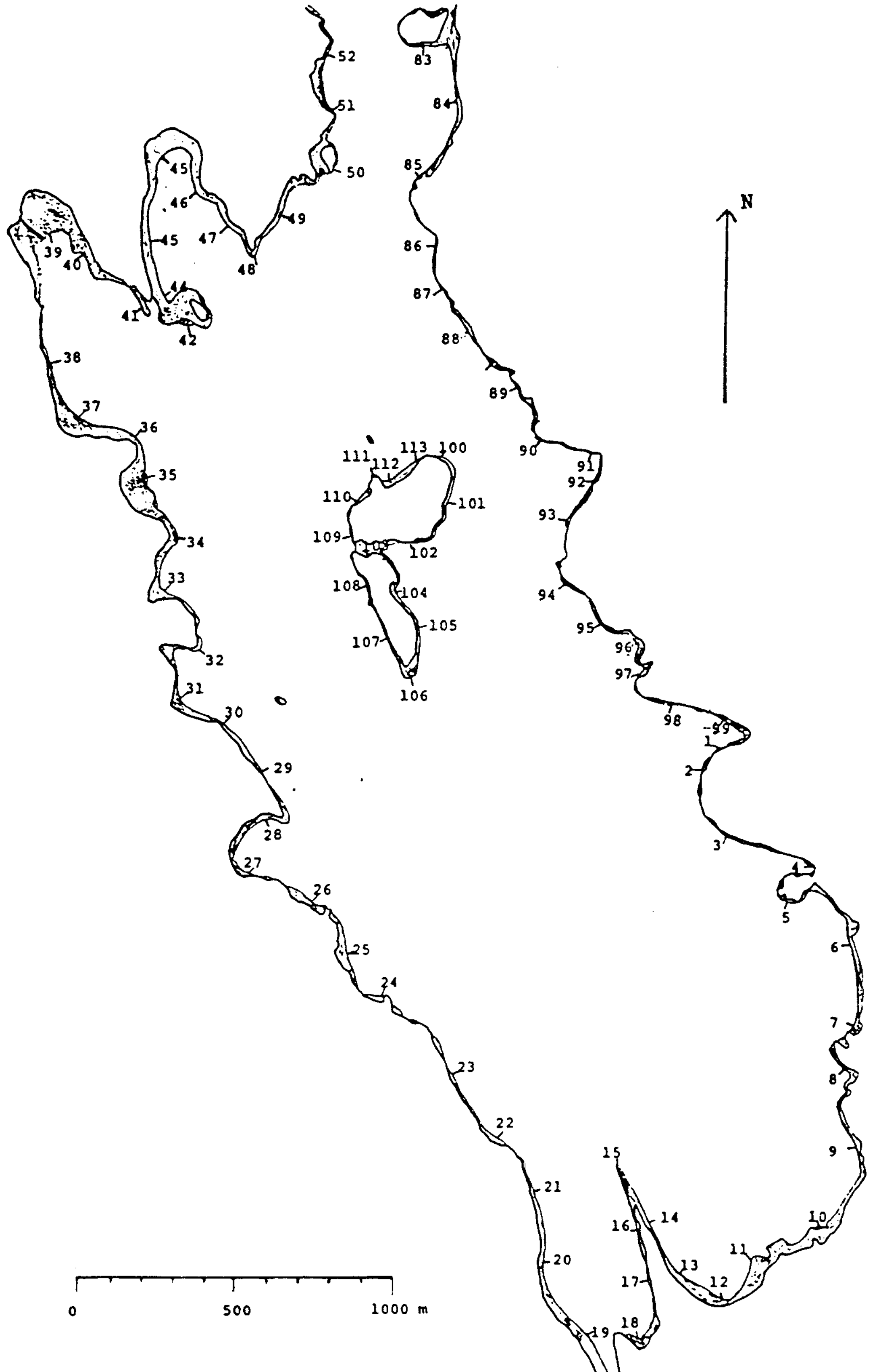


Figure 6A Station number for reed counting (Sibbofjärden)

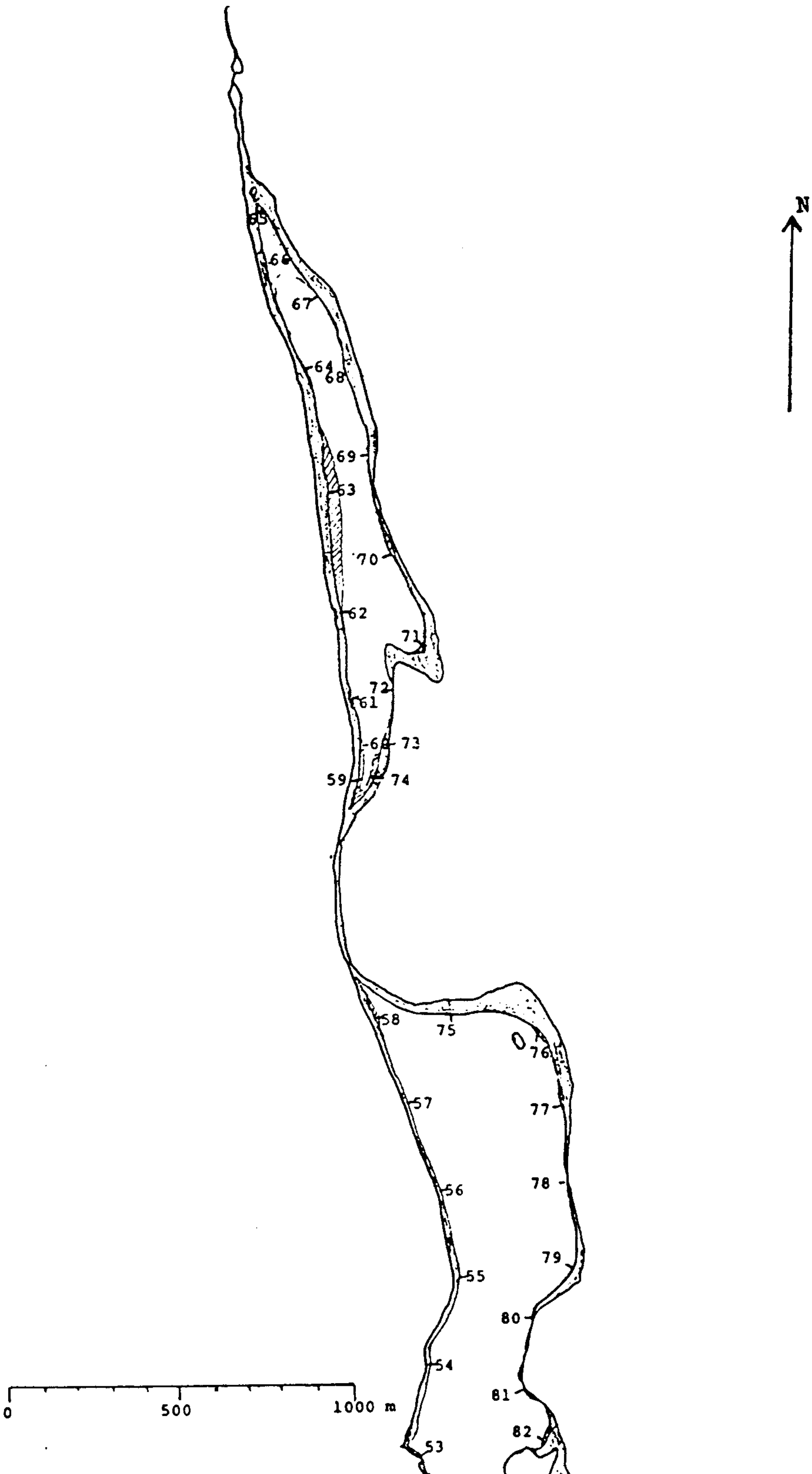


Figure 6B   Station number for reed counting (Sibbofjärden)

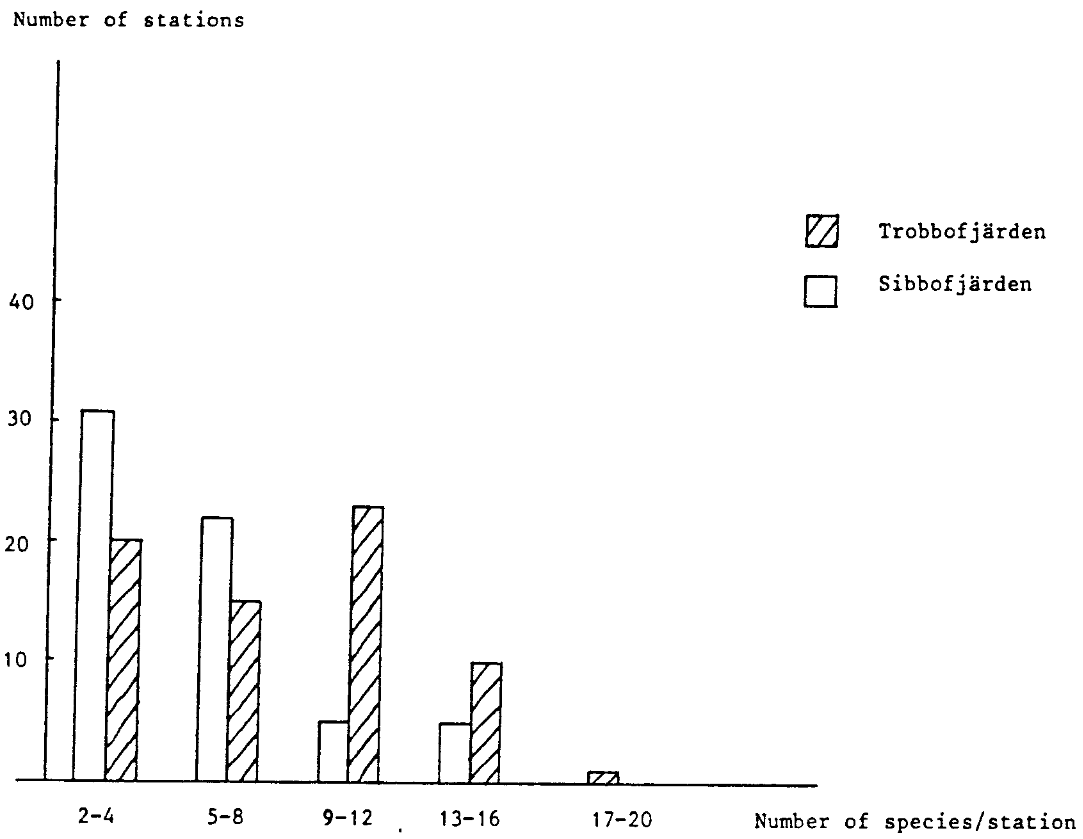
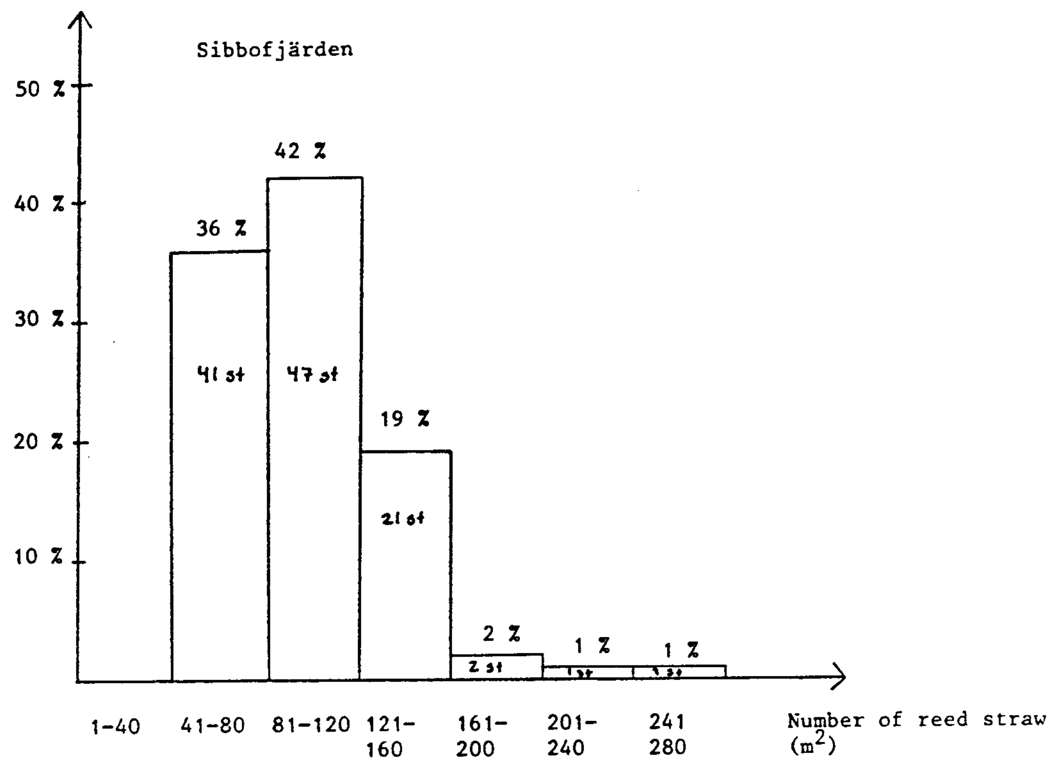

Number of stations
Trobbofjärden
Sibbofjärden
40
30
20
10
2-4
5-8
9-12
13-16
17-20
Number of species/station

Figure 7



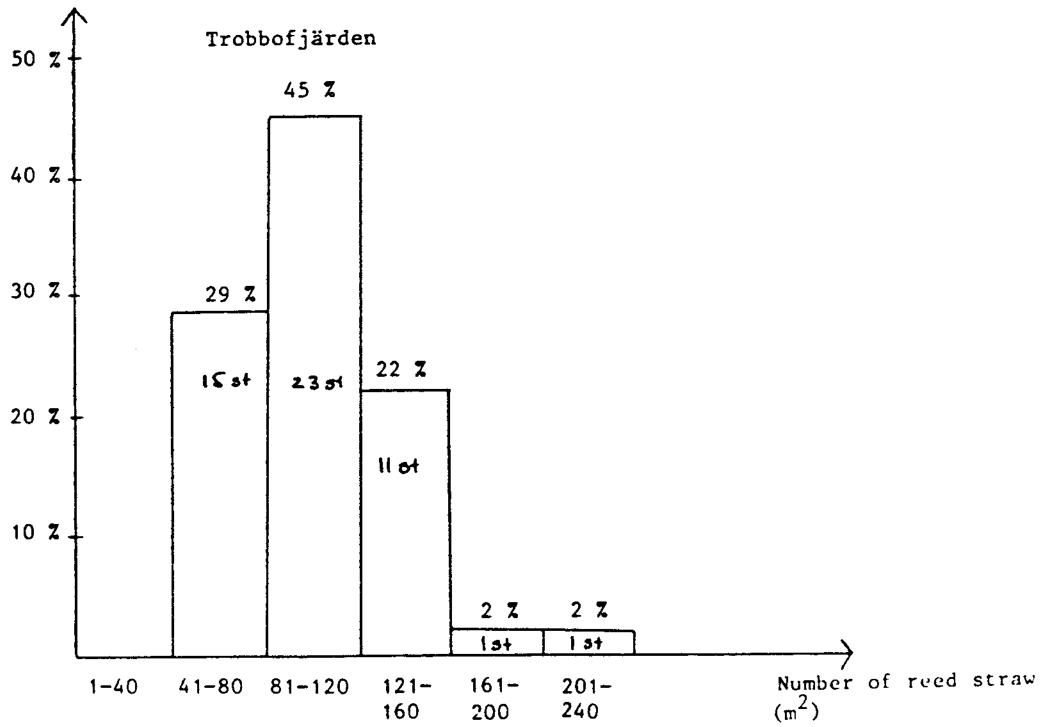


Figure 8 Numbers of stations in percent

	ANTAL LOKALER Trobbofjärden	Sibbofjärden
Lastrea thelypteris T	15	-
Equisetum arvense S	-	1
Phragmites fluviatiles	-	1
Phragmites communis T,S	91	113
Scirpus lacustris S,T	14	29
" palustris S,T	4	14
" maritimus S,T	2	6
Juncus articulates S,T	2	3
" effusus T	2	-
Carex acuta T	9	-
" nigra S,T	1	
" pseudo-cyperus T	20	-
" rostrata T	1	-
" vesicaria T	5	-
" muricata T		
" disticha S	-	2
" canescens T	8	
Agrestis stolonifera S	-	6
Calamagrostis epigejos S	-	6
" lanceolata S,T	4	4
" neglesta S,T	1	2
Glyceria maxima T	1	-
" fluitans T	8	-
Agropyron repens S	-	2
Phalarias arundinacea S	-	30
Typha angustifolia S,T	35	8
" latifolia S,T	15	1
Alisma plantago-aquatics S,T	18	1
Triglochin maritimus S	-	1
Allium oleracesum S	-	1
Rumex crispus S	-	2
" hydrolapatum S,T	33	2
Polygonum dumetorum S	-	1
" amphibium S	-	3
Atriplex latifola S	-	2
Sagina procumbens S	-	
Stellaria palustris T	3	-
Cicuta virosa T, S	42	1
Peucedanum palustre S,T	9	1
Angelica silvestris S	-	7
Epilobium palustre S,	3	1
Lythrum salicaria S,T	4	12
Filipendula ulimaria S	-	9

	ANTAL LOKALER	
	Trobbofjärden	Sibbofjärden
Comarum Palustre S,T	15	1
Potentilla anserina S	-	4
" erecta S	-	2
Cardamine pratensis T	9	-
Caltha palustris S,T	10	3
Ranunculus repens T	1	-
Lysimachia vulgaris S,T	10	14
" thyrisiflora S,T	40	1
Plantago major S	-	10
Solanum dulcamara T	2	-
Stachys palustris S	-	4
Scutellaria galericulata T	5	-
Lycopos Europaeus T	31	-
Myosotis palustris S,T	13	2
Menyanthes trifoliata T		
Galium palustre S,T	10	11
" trifidium T	1	-
Sonchus arvensis S	-	7
Hieracium umbellatum S	-	
Leontodon autumnalis S	-	
Tussilago farfara S	-	1
Nuphar luteum S,T	11	3
Nyphaea alba S	-	19
Potamogeton natans S,T	2	7
" filliformis S	-	6
" gramineus S,T	3	11
" perfoliatus S,T	1	12
Ranunculus peltatus T	3	-
Ceratophyllum demersum S,T	26	1
Hydrocharis morsus-ranae S,T	25	3
Lemna minor S,T	15	2
" polyrrhiza T		-
Fontinalis antipyretica T	1	-
Pleurozium Shebri S	-	1
	-	1
x) Sparganium simplex S	-	1
Utricularia vulgaris S	-	1
Myriophyllum sp S		

List of SKB reports

Annual Reports

1977–78
TR 121
KBS Technical Reports 1 – 120.
Summaries. Stockholm, May 1979.

1979
TR 79–28
The KBS Annual Report 1979.
KBS Technical Reports 79-01 – 79-27.
Summaries. Stockholm, March 1980.

1980
TR 80–26
The KBS Annual Report 1980.
KBS Technical Reports 80-01 – 80-25.
Summaries. Stockholm, March 1981.

1981
TR 81–17
The KBS Annual Report 1981.
KBS Technical Reports 81-01 – 81-16.
Summaries. Stockholm, April 1982.

1982
TR 82–28
The KBS Annual Report 1982.
KBS Technical Reports 82-01 – 82-27.
Summaries. Stockholm, July 1983.

1983
TR 83–77
The KBS Annual Report 1983.
KBS Technical Reports 83-01 – 83-76
Summaries. Stockholm, June 1984.

1984
TR 85–01
Annual Research and Development Report 1984
Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01– 84-19)
Stockholm June 1985.

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01-85-19)
Stockholm May 1986.

Technical Reports

1986

TR 86-01
I: An analogue validation study of natural radionuclide migration in crystalline rock using uranium-series disequilibrium studies
II: A comparison of neutron activation and alpha spectroscopy analyses of thorium in crystalline rocks
J A T Smellie, Swedish Geological Co, A B MacKenzie and R D Scott, Scottish Universities Research Reactor Centre
February 1986

TR 86-02
Formation and transport of americium pseudocolloids in aqueous systems
U Olofsson
Chalmers University of Technology, Gothenburg, Sweden
B Allard
University of Linköping, Sweden
March 26, 1986

TR 86-03
Redox chemistry of deep groundwaters in Sweden
D Kirk Nordstrom
US Geological Survey, Menlo Park, USA
Ignasi Puigdomenech
Royal Institute of Technology, Stockholm, Sweden
April 1, 1986

TR 86-04
Hydrogen production in alpha-irradiated bentonite
Trygve Eriksen
Royal Institute of Technology, Stockholm, Sweden
Hilbert Christensen
Studsvik Energiteknik AB, Nyköping, Sweden
Erling Bjergbakke
Risö National Laboratory, Roskilde, Denmark
March 1986

TR 86-05
Preliminary investigations of fracture zones in the Brändan area, Finnsjön study site
Kaj Ahlbom, Peter Andersson, Lennart Ekman, Erik Gustafsson, John Smellie,
Swedish Geological Co, Uppsala
Eva-Lena Tullborg, Swedish Geological Co, Göteborg
February 1986

TR 86-06
Geological and tectonic description of the Klipperås study site
Andrzej Olkiewicz
Vladislav Stejskal
Swedish Geoloaical Company
Uppsala, October, 1986

TR 86-07
Geophysical investigations at the Klipperås study site
Stefan Sehlstedt
Leif Stenberg
Swedish Geological Company
Luleå, July 1986

TR 86-08
Hydrogeological investigations at the Klipperås study site
Bengt Gentzschein
Swedish Geological Company
Uppsala, June 1986

TR 86-09
Geophysical laboratory investigations on core samples from the Klipperås study site
Leif Stenberg
Swedish Geological Company
Luleå, July 1986

TR 86-10
Fissure fillings from the Klipperås study site
Eva-Lena Tullborg
Swedish Geological Company
Göteborg, June 1986

TR 86-11
Hydraulic fracturing rock stress measurements in borehole Gi-1, Gideå Study Site, Sweden
Bjarni Bjarnason and Ove Stephansson
Division of Rock Mechanics,
Luleå University of Technology, Sweden
April 1986

TR 86-12
PLAN 86— Costs for management of the radioactive waste from nuclear power production
Swedish Nuclear Fuel and Waste Management Co
June 1986

TR 86-13
Radionuclide transport in fast channels in crystalline rock
Anders Rasmuson, Ivars Neretnieks
Department of Chemical Engineering
Royal Institute of Technology, Stockholm
March 1985

TR 86-14
Migration of fission products and actinides in compacted bentonite
Börje Torstenfelt
Department of Neclear Chemistry, Chalmers
University of Technology, Göteborg
Bert Allard
Department of water in environment and society, Linköping university, Linköping
April 24, 1986

TR 86-15
Biosphere data base revision
Ulla Bergström, Karin Andersson, Björn Sundblad, Studsvik Energiteknik AB, Nyköping
December 1985

TR 86-16
Site investigation
Equipment for geological, geophysical, hydrogeological and hydrochemical characterization
Karl-Erik Almén, SKB, Stockholm
Olle Andersson, IPA-Konsult AB, Oskarshamn
Bengt Fridh, Bengt-Erik Johansson,
Mikael Sehlstedt, Swedish Geological Co, Malå
Erik Gustafsson, Kenth Hansson, Olle Olsson,
Swedish Geological Co, Uppsala
Göran Nilsson, Swedish Geological Co, Luleå
Karin Axelsen, Peter Wikberg, Royal Institute of Technology, Stocholm
November 1986

TR 86-17
Analysis of groundwater from deep boreholes in Klipperås
Sif Laurent
IVL, Swedish Environmental Research Institute
Stockholm, 1986-09-22

TR 86-18
Technology and costs for decommissioning the Swedish nuclear power plants.
Swedish Nuclear Fuel and Waste Management Co
May 1986

TR 86-19
Correlation between tectonic lineaments and permeability values of crystalline bedrock in the Gideå area
Lars O Ericsson, Bo Ronge
VIAK AB, Vällingby
November 1986

TR 86-20
A Preliminary Structural Analysis of the Pattern of Post-Glacial Faults in Northern Sweden
Christopher Talbot, Uppsala University
October 1986

TR 86-21
Steady-State Flow in a Rock Mass Intersected by Permeable Fracture Zones. Calculations on Case 2 with the GWHRT-code within Level 1 of the HYDROCOIN Project.
Björn Lindbom, KEMAKTA Consultants Co, Stockholm
December 1986

TR 86-22
Description of Hydrogeological Data in SKBs Database Geotab
Bengt Gentzschein, Swedish Geological Co, Uppsala
December 1986

TR 86-23
Settlement of Canisters with Smectite Clay Envelopes in Deposition Holes
Roland Pusch
Swedish Geological Co
December 1986

TR 86-24
Migration of Thorium, Uranium, Radium and Cs—137 in till Soils and their Uptake in Organic Matter and Peat
Ove Landström, Björn Sundblad
Studsvik Energiteknik AB
October 1986

TR 86-25
Aspects of the Physical State of Smectite-adsorbed Water
Roland Pusch, Ola Karnland
Swedish Geological Co, Lund
Engineering Geology
December 1986

TR 86-26
Modern Shear Tests of Canisters with Smectite Clay Envelopes in Deposition Holes
Lennart Börgesson
Swedish Geological Co, Lund
December 1986

TR 86-27
Hydraulic testing in crystalline rock. A comparative study of single-hole test methods.
Karl-Erik Almén,* Jan-Eric Andersson, Leif Carlsson, Kent Hansson, Nils-Åke Larsson
Swedish Geological Co, Uppsala
*Since February 1986 with SKB
December 1986

TR 86-28
Pressure solution of minerals in quartz-type buffer materials
Mikael Erlström
Swedish Geological Co,
Lund
December 1986