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Hällristning
Fiskare från
bronsåldern

Rock carving
Bronze age
fishermen

MEDDELANDE från
HAVSFISKELABORATORIET LYSEKIL Nr 262
INSTITUTE OF HYDROGRAPHIC RESEARCH
GÖTEBORG SERIES No 7

THE BALTIC ENTRANCE PROJECT: MEAN VALUES AND TIME DEVELOPMENT OF PARAMETERS MEASURED AT THE GF-SECTION IN THE NORTHERN KATTEGAT 1975 - 1977.

BY

BODIL THORSTENSSON

October 1980

1 Utförande institution/Rapportutgivare (namn, adress, telefon)

Fiskeristyrelsen
Hydrografiska Laboratoriet
Box 2566, 403 17 Göteborg

☐ PROJEKTBESKRIVNING
☐ TITELBLAD-RAPPORTER

2 REF

PR

3 Datum: 80 10 10

4 Ärendebeteckning(Diarienr)

5

6

7 MI projektnr

8 Projekt

☐ 1 Uppläggning ☐ 2 Komplettering ☐ 3 Avslutat

9 MI rapportnr

10 Inrapportör

11 Kontraktnr

12 Startår

13 Slutår

14 MI projektnr (i förek fall)

15 Finansierande organ

SNV FO-nämnd, kontrakt nr 7-182/74-78

16 Projektets/Rapportens titel och undertitel

The BALTIC ENTRANCE PROJECT: Mean Values and Time Development of Parameters measured at the GF-Section in the Northern Kattegat 1975-1977

17 Projektledare/Rapportförfattare

Thorstensson, Bodil (författare)
Svansson, Artur (projektledare)

18 Sammanfattning av projektet/rapporten (ange gärna målsättning, metod, teknik resultat m m)

In the three main chapters are presented a) review of the total means 1975-1977, as well as of the individual years, b) quarterly means and c) time development at station GF 4 respectively. The parameters treated are temperature, salinity, density, oxygen, total phosphorus, phosphate, total nitrogen, nitrate, nitrite, ammonia, total organic carbon and current (measured by pendulum device).

I de tre huvudkapitlen presenteras a) översikt över totalmedelvärden 1975 - 1977 samt årsmedelvärdena individuellt för de tre åren, b) kvartalsmedelvärden och c) tidsutvecklingen av några parametrar på några mätdjup på stationen GF 4. Behandlade parametrar är temperatur, salthalt, oxygen, total-fosfor, fosfat, total-kväve, nitrat, nitrit, ammoniak, totalt organiskt kol och vattenström (mätt med pendelmätare).

19 Sammanfattningen skriven av: Författaren

20 Förslag till nyckelord

Y, hydrografi, Kattegatt, temperatur, salthalt, oxygen, närsalter, TOC, strömmar

21 Klassifikationssystem och klass

22 Indexterm

23 Bibliografiska uppgifter

Meddelande från Havsfiskelaboratoriet, Lysekil nr 262
IHR Göteborg Series No 7

24 ISSN

25 ISBN

26 Hemligt: ☒ Nej ☐ Ja, jämlikt ... paragraf ... § sekretesslagen

27 Språk: Eng.

28 Antal sidor: 20s+25f

29 Pris

30 Rapporten beställs hos

Se ovan 1.

THE BALTIC ENTRANCE PROJECT: MEAN VALUES AND TIME DEVELOPMENT OF PARAMETERS MEASURED AT THE GF-SECTION IN THE NORTHERN KATTEGAT 1975 - 1977.

BY

BODIL THORSTENSSON

NATIONAL BOARD OF FISHERIES, SWEDEN

INSTITUTE OF HYDROGRAPHIC RESEARCH

P.O. BOX 2566

S-403 17 GÖTEBORG, SWEDEN

CONTENT

Page

CONTENT

1. INTRODUCTION

The Baltic Entrance Project started in 1974 and ended in 1977. During this period of time a section of 10 stations Göteborg - Frederikshavn (Fig. 1) was surveyed 75 times, mostly by the rescue vessel "Ulla Rinman", but a few times by the research vessels "Argos" and "Thetis". Automatically recording Aanderaa current meters were also used (Möller 1981) and the daily measurements at the lightvessel "Läsö" were supplemented with total phosphorus determinations (Lööf 1979).

Lööf and Thorstensson (1980) have described the section work methods and equipment as well as the quality of measurements expect for the pendulum current determinations, which will be taken up by Möller (l.c.). Lööf (l.c.) also compared Light Vessel (L/V) measurements with section data mostly in relation to sampling frequency.

One of the main purposes of the project was to determine the transport of phosphorus and nitrogen through the section. Total mean transport values have been presented by Szaron (1979).

Svansson (1975), Thorstensson (1978) and others have described features of the northern Kattegat hydrography. From current measurements made during one hundred years at light vessels we know that as an average the surface layer is moving towards the Skagerrak. Deeper down measurements made in this project have shown that there is a counter-current in the eastern part of the section. In the western part of the section, however, there seems to be a counter clockwise circulation from surface to bottom round the island of Läsö (Szaron l.c.). As the water is flowing northward near Denmark, such a circulation implies two flows in the channel between Läsö and the Danish Mainland, one northwards and one southwards.

2. REVIEW OF THE TOTAL MEANS 1975-1977, AS WELL AS MEANS OF THE INDIVIDUAL YEARS 1975, 1976 AND 1977.

2.1. TEMPERATURE

The total mean values of temperature, based on the measurements made 1975-1977 (Fig. 2), range between 8.1°C and 8.9°C in the surface layer above 20 m depth. The temperature at station GF 4 were for the individual years at the surface 9.09°, 7.21° and 9.45 °C and at 70 m 7.04°, 6.28° and 6.98°C respectively. The 1976 annual mean value at both these depths was lower than the 1975 and 1977 ones.

Comparison was made with mean values calculated from daily measurements of temperature at the light-vessel Läsö (see also Lööf 1979). These means were at the surface 10.1°, 9.0° and 9.2°C for the three consecutive years respectively.

2.2. SALINITY

Fig. 3 shows the 1975-1977 means. The isohalines are inclined with salinities increasing towards Denmark at every depth. The surface salinity increases from 21.2 to 25.5 ‰ S.

The salinities at depths beneath 10 m were in 1976 higher than the 1975 and 1977 ones. At 70 m the GF 4 salinity was in 1976 34.79 ‰, but only 34.56 in 1975 and 34.53 in 1977. Below 20 m depth the changes were smaller than in the surface layer. The vertical salinity gradient is usually largest at 10 m depth.

In the upper 10 meters there was a continuous salinity increase during the three years. The values at GF 4, 0 m, were 21.89, 22.16 and 22.52 ‰ S for the three years respectively. At the western-most station the increase from 1975 to 1977 was almost 3 ‰.

There was also an increase of the surface salinity at the light-vessel Läsö from 23.3 ‰ in 1975 to 24.3 ‰ in 1977 (Lööf 1979). But from 20 m depth downwards the highest mean values of salinity were found in 1976. At Bornö Station this increase trend is found at all depths. At all the three stations, GF 4, Läsö and Bornö the 1975 salinities were lower than the 1976 and 1977 ones.

2.3. DENSITY (AS SIGMA-t)

If density is expressed in kg/m^3 then Sigma-t is density minus 1000. The mean values 1975-1977 (Fig. 4) show variations between 16 and 27 units of Sigma-t. Density increases from east to west in the same manner as salinity.

2.4. OXYGEN

Fig. 5 shows the 1975-1977 mean values of oxygen concentration expressed in ml/l (Multiplication by 1.43 gives results in mg/l). The values show an observable decline from the years 1975 and 1976 to 1977. GF 4 concentrations were for the three years at the surface 7.62, 7.70 and 7.28 ml/l and at 70 m 6.11, 6.12 and 5.82 ml/l respectively.A slight oxygen increase was observed in the 1975-1977 means from the Danish to the Swedish coast, e.g. from 7.34 to 7.61 ml/l . Low values at the Danish side will be discussed in Ch. 2.10.

In order to calculate oxygen saturation, temperature and salinity have to be used in addition to the concentration values. For 1975-1977 the lowest annual mean value of oxygen saturation (Fig. 6) was 88 % at 70 m at GF 4. At the observation position Fladen (N 57°11.5′, E 11°40′) 86 % at 70 m in 1975 and 78 % in 1977 were found. At the surface the mean saturation was 105 %. The oxygen saturation also decreased slightly from 1975 to 1977 in the same manner as the oxygen content.

A horisontal study shows that there was a small increase to the east. An exception of this is station 3 from 15-20 m and further down. This seems to be an area with less good water exchange conditions.

2.5. TOTAL PHOSPHORUS

From the annual mean values, 1975-1977 (Fig. 7) it can be seen that the concentrations of total phosphorus were about the same from surface down to 20 m, 0.65 µgat/l. Further down there was a continuous rise to about 1 µgat/l. Outside Göteborg and more pronounced off Frederikshavn, also an increase was found. The surface water outside Göteborg had a higher concentration of phosphorus than the more saline water at 5 m depth. This can be explained by the transport by non-saline water from the Göta River. The input from the Göta River is about 1 200 ton P / year (ICES 1978). Minima were found at GF 4 and GF 5.

The values of total phosphorus from the discrete years were higher in 1975 and lower in 1976 than the total means for 1975-1977. The high mid-depth and bottom water values at the Danish side will be discussed in Ch. 2.10. A comparison between measurements at GF 6 and the light-vessel Läsö shows small differences, smaller that 0.05 µgat/l, (Lööf 1979).

2.6. PHOSPHATE

The concentration of phosphate in 1975-1977 (Fig. 8) ranged from 0.20 µgat/l at the surface to 0.6 - 0.8 µgat/l near bottom, except for the two stations outside Göteborg, where the amount of phosphate at the bottom was smaller, e.g. 0.4 µgat/l.

Also phosphate was similarily to total phosphorus higher in 1975 than in the two other years, especially in the surface layer down to 20 m depth.

2.7. TOTAL NITROGEN

The mean values at the different depths from the three individual years did not differ much from each other. The mean values for 1975-1977 (Fig. 9) varied between 13 µgat/l and 18 µgat/l.

The Tot-N levels was in contrast to phosphorus highest in 1977. High concentrations were found near the coast with the maximum value at the surface outside Göteborg.

2.8. NITRATE

Fig. 10 shows 1976-1977 means only as these analyses were not made on a regular basis until 1976. The NO_3 values down to 20 m were lower in 1976 than in 1977, but at 30 m depth and downwards opposite conditions were found.

The mean values range from 1.5 µgat/l to 6.5 µgat/l. Outside Göteborg the surface values were somewhat higher than at other stations.

2.9. NITRITE

Analysis of nitrite was not made on a regular basis until 1976. Fig. 11 shows the 1976-1977 means. A distinct higher level is apparent in 1977 in comparison with the preceding year. This was also the case with Tot-N and NO_3 (0-20 m particularily), though the differences were not of the same magnitude. The 1977 nitrite values at the surface were three times higher than those in 1976, 0.15 and 0.05 µgat/l respectively. At some depths the concentration was as high as 0.46 µgat/l.

2.10 AMMONIA

Measurements of ammonia started on a regular basis first in 1976. This parameter generally shows large variations. Ammonia values were like total nitrogen, nitrate (0-20 m depth) and nitrite higher in 1977 than in 1976. Almost all of the 1977 values are at least twice as high as those in 1976, the highest 1977 value being 1.8 µgat/l. The layer 0-10 m had ammonia concentrations between 0.7 and 0.8 µgat/l.

It is apparent from the mean values in 1976-1977 (Fig. 12) that the two stations close to Frederikshavn have high mid-depth concentrations of NH_4. There are similar trends in the distribution of the other nutrients and Tot-P, but also in salinity and density (Fig:s 3 and 4) which points at a hydrodynamical explanation. Alternatively runoff from agricultural fertilization may be responsible for the extreme values.

2.11. TOTAL ORGANIC CARBON (TOC)

There were only small variations between the different years of measurement. The total mean values 1975-1977 (Fig. 13) ranged between 3.5 mg C/l at the surface and 1.6 C/l near bottom. The highest concentration was found outside Göteboeg. The isoline for 2 mg C/l is found at 15-20 m depths.

2.12. CURRENT MEASURED BY PENDULUM DEVICES. (Haamer 1973)

Figures 14 and 15 show the 1975-1977 means in simplified form. Most apparent is the great westerly component (Fig. 15). Only at few positions there were currents flowing straight perpendicular to the section (small y-component) i.e. out of or into the Baltic.

The three years are rather similar in respect of currents. But a more detailed study reveals some differences. The most apparent ones were found at GF 4 and GF 5. The 1976 directions differed somewhat from the 1975 and 1977 ones. At GF 5 the directions at 10, 15, 20 and 30 m were in 1976 almost towards south instead of to WSW as in the mean. At GF 4 some depths show more easterly flowing currents than westerly ones.

Total means of these currents for 1975-1977 as well as of current multiplied by chemical parameter concentrations have been worked by Szaron (1979).

3. QUARTERLY MEANS

3.1. CALENDAR OR SEASONAL QUARTERS

As the GF data are too few to allow a subdivision into a monthly means discussion, a division of four equal parts of the year was chosen instead. As the seasons winter, spring, summer and autumn are defined by means of air temperature limits, different at different places,see e.g. Ångström (1946), it is more convenient to divide the year into four equal parts. Quarter I of the Calendar Year comprises January-March, etc. In order to adjust the subdivision more into "oceanographic" seasons it might be better to choose Quarter A as December-February, Quarter B March-May etc.

Quarterly means according to both principles, I - IV and A - D were computed. For temperature it is evident that the extremes, i.e. quarters with the highest and the lowest temperatures are found in system I - IV which thereby is a better subdivision system for temperature than system A - D.

As far as phosphate is concerned the differences between the two systems are small. During Quarter III (which corresponds to Quarter C), the concentrations are lowest, and isolines in both systems follow each other closely. There is, however, a distinct difference for the surface layer concentrations during the first Quarter, when the P-values are highest. In December-February the values are 2 tenths higher than in January-March.

In the case of nitrate there is the same situation as for phosphate. The highest value in the first quarter is achieved with system A - D. In the third quarter there is almost the same lowest level in both systems.

Looking at the oxygen diagram for different quarters we find that there is no significant difference between the two divisions of quarters. There also is no reason to choose between the systems as regards ammonia. A quite different kind of parameter, salinity, also did not show any significant difference between the two divisions of quarters.

Due to the rather small differences between systems I -IV and A - D, the former one was for pratical reasons chosen in the following discussion. Fig:s 16-20 concern station GF 4 but there are however no principal differences between the various parts of the GF section.

3.2. TEMPERATURE

In Quarter I there was a continuous increase from 1 °C in the surface to 6 °C at the deepest point of measurement, 80 m. In the horizontal dimension there was an increase from east to west of about one degree.

Quarter II shows in contrast to Quarter I a decline of 2.5 °C from surface to bottom, where the temperature still was 6 °C.

The largest surface-bottom differences, 9.5 °C, was found in Quarter III, July to September, when the surface had a temperature of 17 °C and the bottom, 70 m, 7.5 °C. Opposite to Quarter I conditions there was a decline from east to west.

The most homogeneous cross section was developed in Quarter IV. Here we found the overall highest temperatures, at bottom, almost 9 °C. There was a cooling going on, starting at the surface and moving downwards. At 0 m the temperature was almost 9 °C, while maximum 10.5 - 11 °C was found at 20 m depth.

3.3. SALINITY (FIG. 20)

Quarters I and II are similar to each other with generally the lowest quarterly values of the year at 0 and 5 m depths and the highest at 15 m depth and downwards. This means that during the firsthalf of the year the largest change in salinity from surface to bottom was found e.g. 13.6 ‰ at GF 4, where the increase in Quarter I ranged from 21.1 ‰ to 34.7 ‰.

The horizontal change was the same during the whole year independant of the salinity level. That means that the salinity increased from Göteborg to Frederikshavn was between 4 and 5 ‰. In all the quarters there was an area of varying size (GF 4 and GF 5 at 50 m depth always included), with salinity diminishing towards the west, opposite to the general trend. The largest area of irregularity of this kind occured in Quarter II, which was valid also at GF 3 and GF 6 in the layer 10-50 m.

In Quarter IV there were maximum salinities at the surface. At GF 4 the value was 24.8 ‰ S.

3.4 DENSITY (AS SIGMA-t)

The lowest densities were found in Quarter III at 0 m and 5 m depth, due to the high temperatures here in July and August. At GF 4 sigma-t was as low as 15.6 units at the surface.

The highest surface densities occurred in Quarter IV, as expected when the salinity is high and the temperature low. The overall highest density, 27.4 sigma-t units, was found in the Deep Trench (GF 4).

Density showed the same horizontal variations as salinity with higher values at the more westerly stations with almost the same exceptions in Quarters I, II and III at GF 4 and GF 5, 40 m.

3.5 OXYGEN (FIG. 16)

In Quarter I the highest values of oxygen concentration from surface to bottom were found. The surface at GF 4 had an oxygen content of 8.8 ml/l and the bottom water had 6.7 ml/l. These high values can be explained through the low temperature of the water, because cold water can dissolve more gas than warmer water. Probably there also is no oxygen consumption due to plankton decay.

The worst conditions with respect to oxygen occur from July to September. At station 4 there was a content of 6.2 ml/l at the surface and the concentrations decreased to 5.2 ml/l in the bottom layer. This is the only Quarter when we found values smaller than 5.5 ml/l, actually up to 30 m depth. In this quarter also the highest temperatures were found.

The first half of the year had an oxygen saturation that was very satisfactory. For Station 4 in Quarter I the saturation was 104 % at 0 m and still 96 % at 70 m. From Quarter I to Quarter II there was a change because of the beginning primary production. The values down to 40 m increased, but further down there was a weak decrease. This decrease became marked in Quarter III apparently due to decay of sinking organic material. There we find saturation values of 78 % at 70 m at GF 4.

In Quarter III there was a tendency for higher saturation values at more easterly stations. For example, at 30 m depth, there was a 80 % saturation at GF 8 and 91 % at GF 5. Also here the worst conditions at bottom of GF 3 were found (See Ch. 2.4.).

3.6 TOTAL PHOSPHORUS (FIG. 17).

Quarter I shows less difference between surface and bottom water than the other quarters. Most depths have values between 0.8 and 0.9 µgat/l, i.e. almost homogeneity with high concentrations which moreover occur all over the section. Hardly any phosphorus is bound in the plankton. The main part of the depths had lower concentrations in Quarter II. The values of the upper 20 meters diminished further in Quarter III, whereas the minimum levels, 0.4 - 0.6 µgat/l, were found in Quarter II and III. Hereafter phosphorus recirculates to the water after plankton degradation and in the last quarter of the year the concentrations were rising. The values from 60 m and downwards showed a maximum in Quarters III-IV. The decrease from IV to I is probably due to mixing with water of lower concentration.

3.7 PHOSPHATE (FIG. 18)

From Quarter I with a surface concentration of 0.45 µgat/l there was a quick decrease to lower values. This change can be traced to a depth of 50 m in Quarters II - III. The upper 5 meters had a concentration of only 0.1 µgat/l. In the third quarter this limit went down to 15-20 m. At the end of the year there was a rise at all levels. At depths of 70-80 m at GF 4 phosphate varied in a similar way as total phosphorus.

3.8 TOTAL NITROGEN (FIG. 17)

The concentration of total nitrogen shows small differences between the four quarters. The problem is to decide whether the variations are significant or not (Lööf and Thorstensson 1979).

The maximum concentrations were found from January to March as expected, the most frequent values being 16-17 µgat/l. In Quarter III the level was 12-13 µgat/l over the whole section. These values are the lowest ones during the year. The most homogeneous conditions were met in Quarter IV with 14 µgat/l being the most frequent concentration.

3.9 NITRATE (FIG. 18)

From the first quarter with maximum concentrations of 4.1 µgat/l at the surface and 7.2 µgat/l at 70 m at GF 4, the values down to 20 m decreased due to reduction during the next two quarters. From July to September the nitrate concentration at GF 4, 20 m, was only 0.2 µgat/l. The decrease was, however, noticeable even at 70 m depth. Later in the autumn in Quarter IV, there was a quick rise to increased but not maximum concentrations. Opposite to phosphate, NO_3 was at its minimum in Quarter III also at great depths, e.g. 70 m at GF 4.

3.10 NITRITE (FIG. 19)

Nitrite shows the same main variation as nitrate. At Station 4 in Quarter III there were minimum values of 0.05 µgat/l down to 20 m. Hereafter a quick rise occured, so that in Quarter IV we can find the highest value for GF 4 at 30 m, i.e. 0.55 µgat/l. For Quarters IV and I the maximum did not occur near bottom but 10 meters above bottom. Hagström et al. (1976) found NO_2-values of about this magnitude in the Norwegian coastal current (also along Bohuslän) in October 1975.

3.11 AMMONIA (FIG. 19)

This parameter may show irregularities from one measurement to another independant of the season. At GF 4 there were high concentrations, 1 µgat/l, from 30 m and downwards in Quarters II+IV. For Quarter IV the same conditions were found at 0, 10 and 20 m depth. It is to be noted that in Quarter I we had the low concentrations from 30 m and downwards while the maximum in this season was found at 10-20 m.

Looking at the 30 m values at GF 8, it is interesting to notice that, when we find the minimum nitrate concentrations, (in Quarter III), there is a maximum in the ammonia values.

3.12 TOTAL ORGANIC CARBON

Like total nitrogen this parameter showed small variations between the four seasons. There seems to be a minimum in Quarter II with concentrations of 1.5 - 2.0 mg C/l.

Quarters I and III were similar. For both of them most depths had values from 2.0 to 3.0 mg/l. At all stations the level was diminishing from surface to bottom water during the whole year.

3.13 CURRENT MEASURED BY PENDULUM DEVICE

During spring, April - June, the currents were weakest, probably because this period commonly is a period with weak winds.

At the stations off Göteborg, however, the currents were weakest in Quarter IV.

In Quarter II the current direction at most depths at GF 5 was strongly towards east instead of pointing to the west as in the other seasons. The currents at GF 4 had surprisingly different directions in summer and winter. The current was flowing inwards to the Baltic from October to March at all depths (except at 0 m in Quarter IV). In April the current was northgoing at the surface as well as from 40 m and downwards. In July (Quarter III) all depths had northflowing current.

Looking specially at the x-component (Fig. 20 for GF 4) we find that during Quarters IV and I, there were partly strong currents coming from the north all over the Station 4 and at about half of the depths at GF 5 as well as at GF 8. In spring and summer these strong currents were absent and the area of ingoing water diminished. One exception in Quarter III was the strong currents at the surface at GF 8.

Outside the Danish coast, at Stations 10 and 9, there were all the time very strong (10 - 20 cm/s) outgoing (i.e. flowing northwards) currents at 2.5 m and 5 m depths. In all quarters except Quarter II the currents to the north at GF 6 and GF 7 were strong (5 - 15 cm/s) down to 10 - 20 m. Moreover in Quarter III there was an eastern area of outgoing water at GF 3 and GF 4 with strong (more than 10 cm/s) currents from surface to 10 m and at 60 m. In Quarter II these currents had not been developed except at 2.5 m and 5 m depth at GF 3. The currents were strongest from January to March and weakest from April to June.

4. TIME DEVELOPMENT AT STATION 4

4.1. TEMPERATURE, AUGUST 1974 - DECEMBER 1977 (FIG. 21 FOR 10 m DEPTH VALUES).

The temperature minimum at all depths occurred each year at the end of February and the beginning of March. By then the surface had temperatures of 2.5 °C, 0 °C and -1 °C in 1975, 1976 and 1977 respectively. The corresponding values at 70 m depth were 6.5, 5.5 and 4.5 °C. In April the temperatures at the different depths came closer to each other. In May a thermocline usually developes in the Kattegat. After a period with almost isothermal water the temperature of the upper layer begins to rise fast and reaches a maximum of 19 - 19.5 °C in July. The time for maximum temperature comes later with increasing depth and in the bottom water at GF 4 this extreme is reached in October-November.

4.2 SALINITY, AUGUST 1974 - DECEMBER 1977

In the salinity distribution three layers can be distinguished. The first one is the layer down to 10-15 m, which is characterized by very great changes. Below this one there is another layer down to 30-40 m with less than half the variation of the first one. From 50 m and downwards the salinity changes are within a very narrow range.

In the upper layer the highest salinities, 28-31 ‰, occurred in December or January. Also in September or October there can sometimes be short periods with high saline water in the surface layer. - Salinity minimum, 16 ‰, in the surface layer occurred in 1975 in March, in 1976 in February and in 1977 in both May and August. During these periods the bottom water salinity usually reached its highest value. - Each year in April or May there was a decrease in salinity that can be distinguished at all depths starting from the bottom layers.

4.3 DENSITY, AUGUST 1974 - DECEMBER 1977

The strongest density variations were found above 20 m depth. At the surface the density may within two months change from 25 to 13 sigma-t units. The most homogeneous periods were each year found more or less pronounced at the end of the year. In December 1975 this was particularly the case, when the surface water had a sigma-t of 25 units and the water at 70 m depth had a slightly higher value. A similar tendency can be found at the end of September or the beginning of

October, when the density at 70 m depth often decreases simultaneously with a surface density increase. - In some periods during February - October there were low densities at surface. This fact is partly due to higher temperatures, partly to less saline water.

4.4 OXYGEN SATURATION, AUGUST 1974 - DECEMBER 1977, (FIG. 22)

The surface water is unsaturated with respect to oxygen only in the middle of the winter and then only a few percent below 100 %. The period of primary production as estimated from nutrient data, started in 1975 and 1976 in the middle of February and in 1977 at the end of the same month. Remarkable is the fact that the surface water remains at its minimum temperature, 2.5 °C, until the middle of March in both 1975 and 1976. Thus the increase of primary production is not due to an temperature increase but more likely to a solar radiation increase.

Oxygen values exceeding 110 % saturation were not found in 1976. Instead there was an unusual increase to 105 % in November, probably connected with an autumn primary production.

The bottom water (70 m) had its minimum oxygen saturation at the beginning of August in 1975 (71 %) and in September both in 1976 (76 %) and in 1977 (64 %).

At 70 m depth the water never seems to be saturated, the highest percentages being mostly 95-98 % (December - May). The decrease in June is very uniform in all three years.

4.5 TOTAL PHOSPHORUS, AUGUST 1974 - DECEMBER 1977, (FIG. 23)

The variation of the total phosphorus shows only a slight difference from year to year. During February-March there is a sudden 50 % reduction from 1 to 0.5 µgat/l. A minimum occurs in June or July, about 0.3 µgat/l. The total phosphorus concentrations at 70 m varied between 0.8 and 1.1 µgat/l.

4.6 PHOSPHATE AUGUST 1975 - DECEMBER 1977 (FIG. 24)

The decrease of phosphate in the surface water started in the middle or the end of February from a value of about 0.6 µgat/l and continued fast to less than 0.05 µgat/l in the later part of March. It remained beneath 0.1 µgat/l until the beginning of August.

For all three years there was a more or less pronounced maximum in October. Threafter the concentrations for a short period again decreased to values below 0.1 µgat/l followed by a rise to the winter level in December. At 70 m the phosphate concentrations varied between 0.6 and 0.9 µgat/l. But even here, there were observable decreases during spring and autumn in all three years.

4.7 TOTAL NITROGEN, SEPTEMBER 1974 - DECEMBER 1977 (FIG. 25)

The total nitrogen concentrations at the individual depths followed each other rather well with some exceptions. In 1975 there were large variations, the difference at the surface between minimum in April (8 µgat/l) and maximum in July (25 µgat/l) being 13 µgat/l. The level of the nitrogen content was lower in 1976 than in 1977. Especially during May and June 1976 there were very low concentrations with a minimum of 5 µgat/l. Both these years, 1976 and 1977, had their highest level in February, 17 and 24 µgat/l, respectively.

4.8 NITRATE, FEBRUARY 1976 - DECEMBER 1977

From the middle or the end of February the nitrate values ranged from 5-6 µgat/l to 0.2 µgat/l or less in March (1976) and in May (1977). This low level was held until the beginning of October. The maximum winter concentrations were found in December.

In July there was a minimum at 70 m of 2-3 µgat/l. In 1977 another minimum came in November. The winter level was 8 µgat/l. At 20 m depth we had low concentrations in July corresponding to those in March in the surface water. The increase, however, started at the same time in the beginning of October.

4.9 NITRITE, FEBRUARY 1976 - DECEMBER 1977

The surface water had a rather low nitrite concentration, less than 0.1 µgat/l, from March to October. The winter level was 0.4 - 0.5 µgat/l. As a contrast there was at 70 m the lowest values, 0.1 µgat/l, during wintertime, November-January. During the rest of the year the nitrite concentration was at the higher level of 0.4 - 0.5 µgat/l.

4.10 AMMONIA, FEBRUARY 1976 - DECEMBER 1977

There was a decrease in the surface water with regard to ammonia during March from values of 1 µgat/l to 0.25 µgat/l (1976) or to 0.5 µgat/l (1977). The increase after the summer period started in September. The level of 70 m showed almost the opposite variation. During summer the largest part of the values varied between 1.5 and 3.0 µgat/l. Regarding winter and spring we usually had an average value of 0.5 µgat/l.

5. CONCLUSIONS

This paper contains total, annual and quarterly means of parameters measured at the Göteborg - Frederikshavn section in the period 1975 -1977 (some nitrogen compounds only 1976 - 1977). Here and there in the text are inserted hints of explanation of certain features and trends. But it has not been the purpose in this paper to dig deeper into e.g. the nitrogen cycle, N/P ratio, the autumn oxygen minimum etc. Recently Aertebjerg (1980) showed results from the Danish Belt Project. A comparison between the two sets of data will probably be made in a near future.

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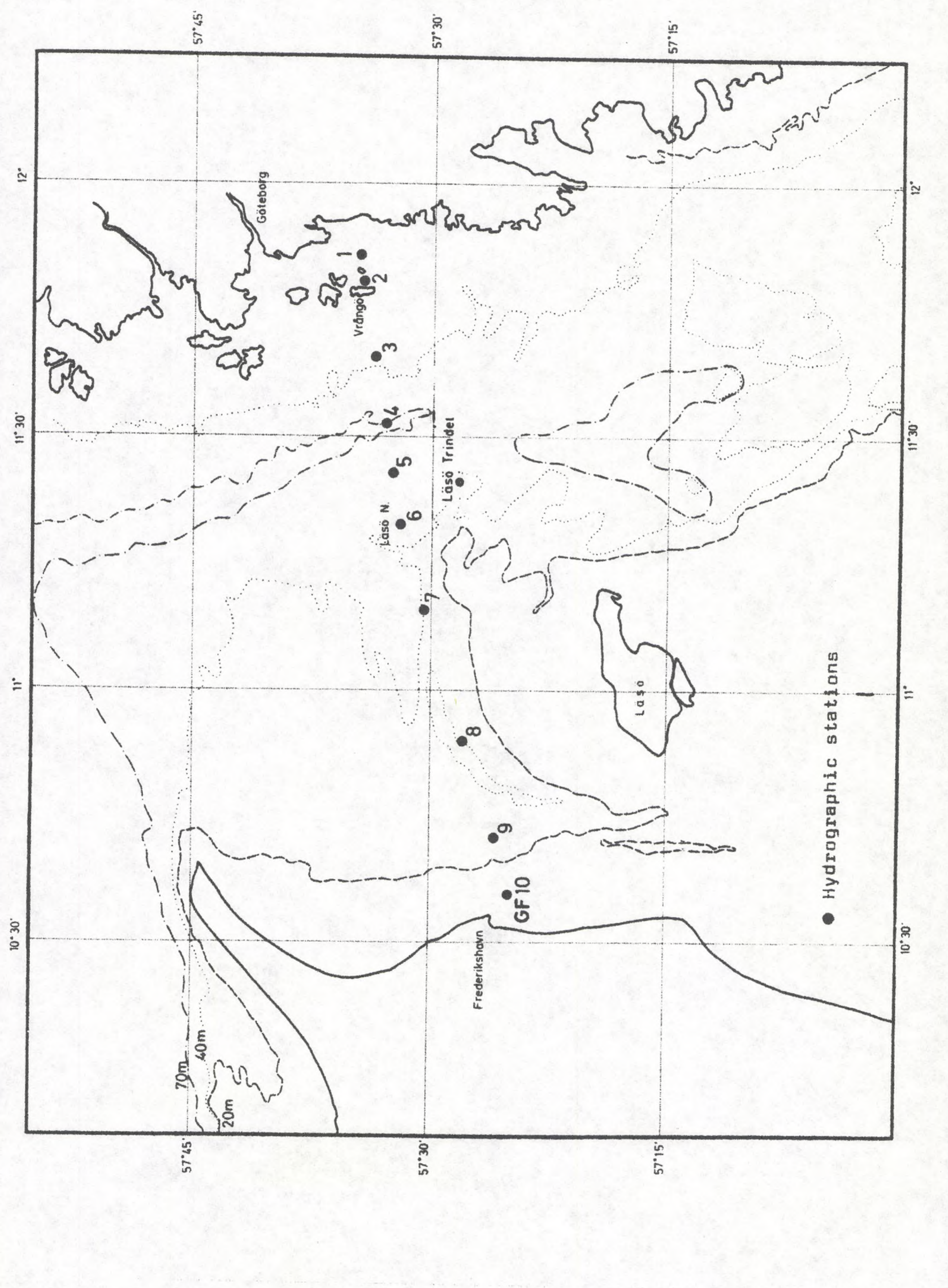
Fig. 1.



57°45'
57°30'
57°15'
12°
11°30'
11°
10°30'
Göteborg
Vrångö
Läsö N.
Läsö Trindel
Läsö
Frederikshavn
1
2
3
4
5
6
7
8
9
GF10
70m
40m
20m
Hydrographic stations

Review of the Temperature (°C) - Mean values 1975 - 1977

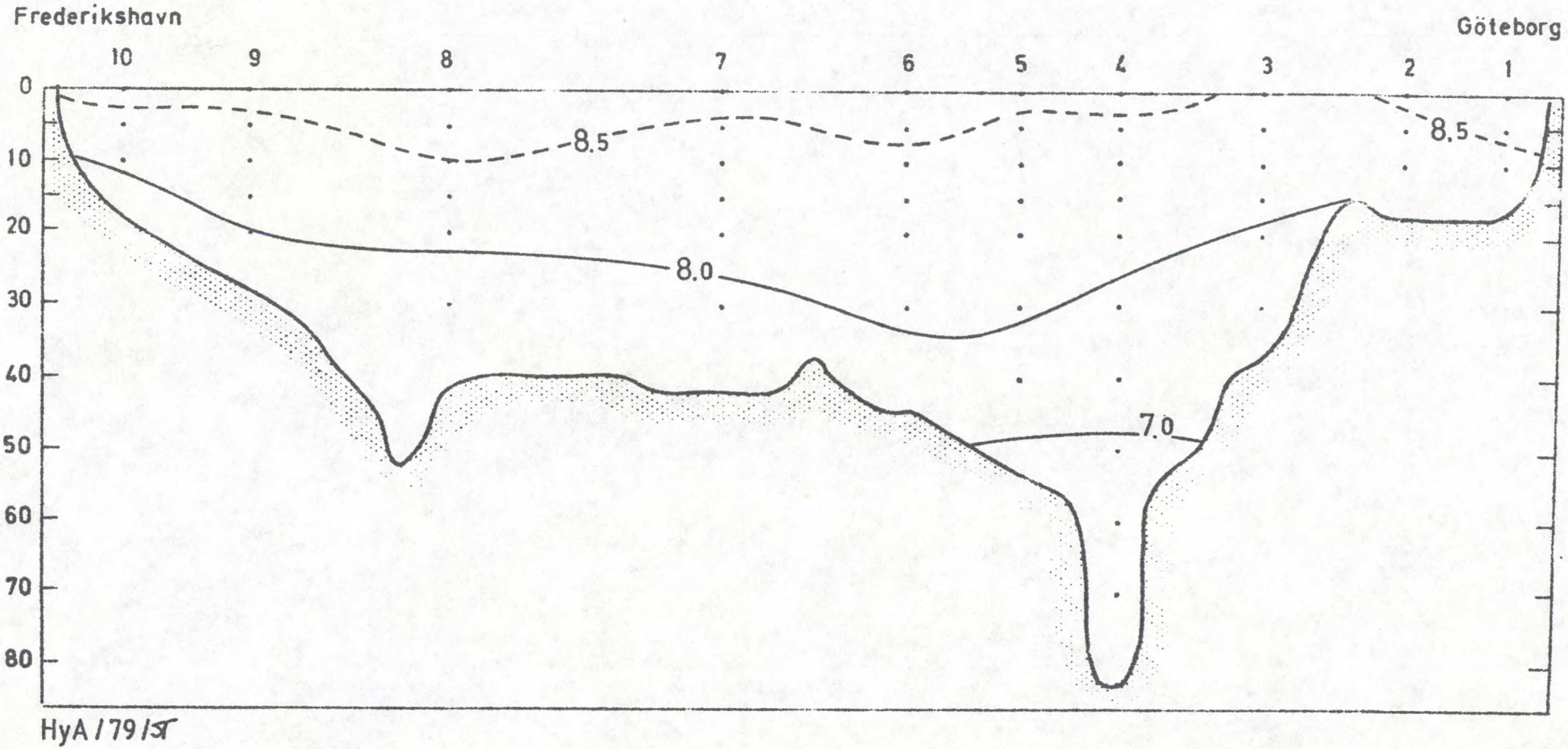


Fig. 2.

Review of the Salinity (‰) – Mean values 1975 - 1977

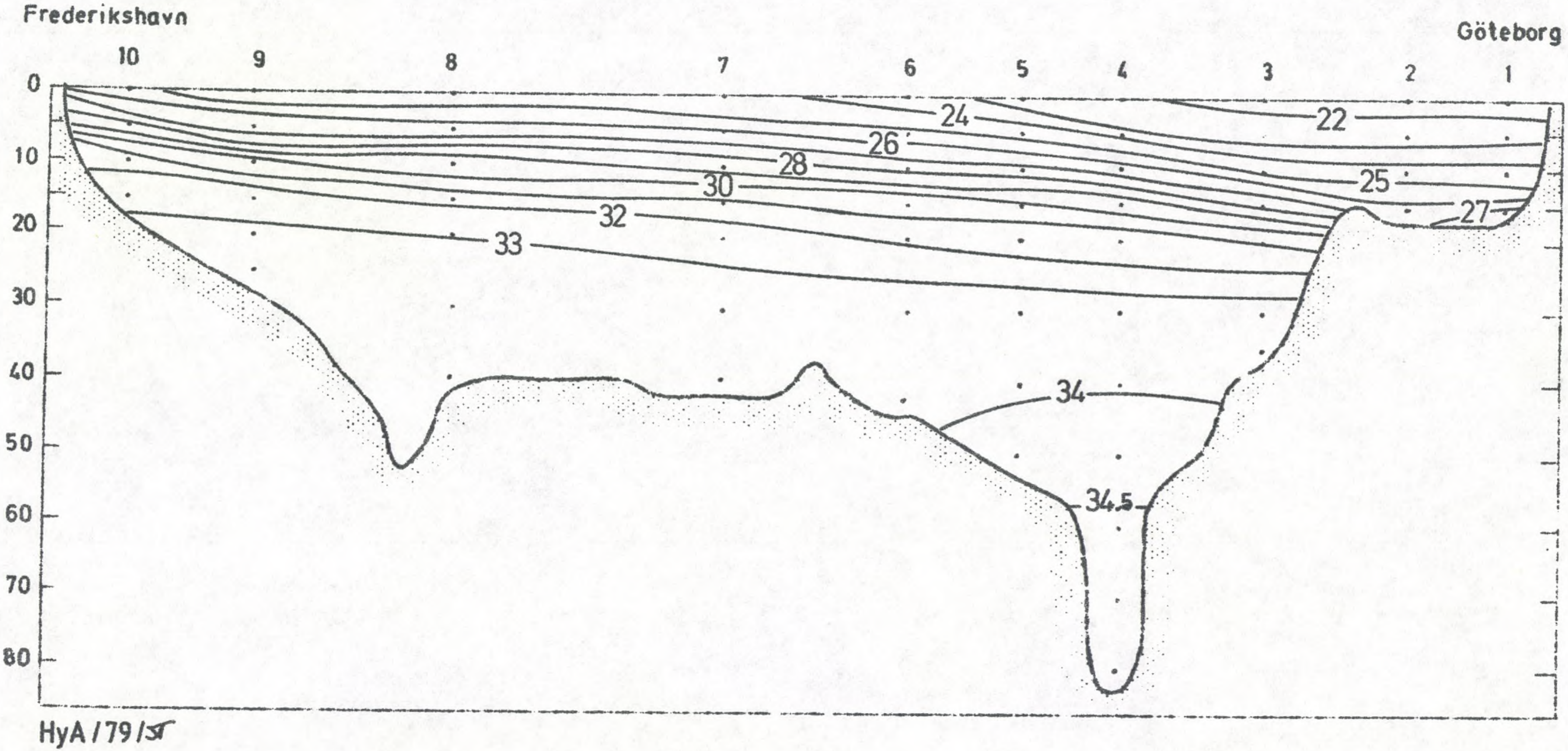
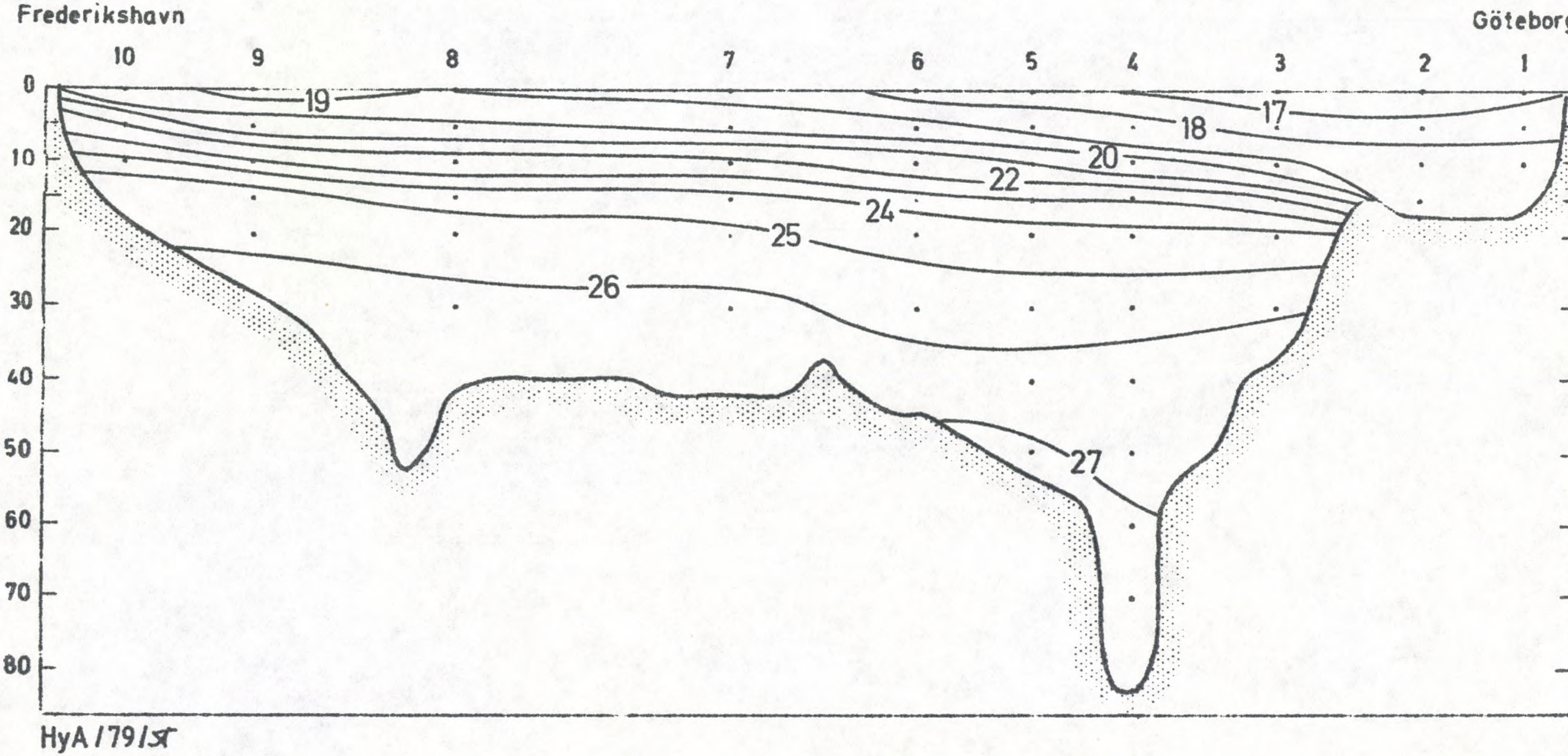


Fig. 3.

Fig. 4.

Review of the Density (Sigma-t) - Mean values 1975 - 1977



Review of the Oxygen (ml/l) - Mean values 1975 - 1977

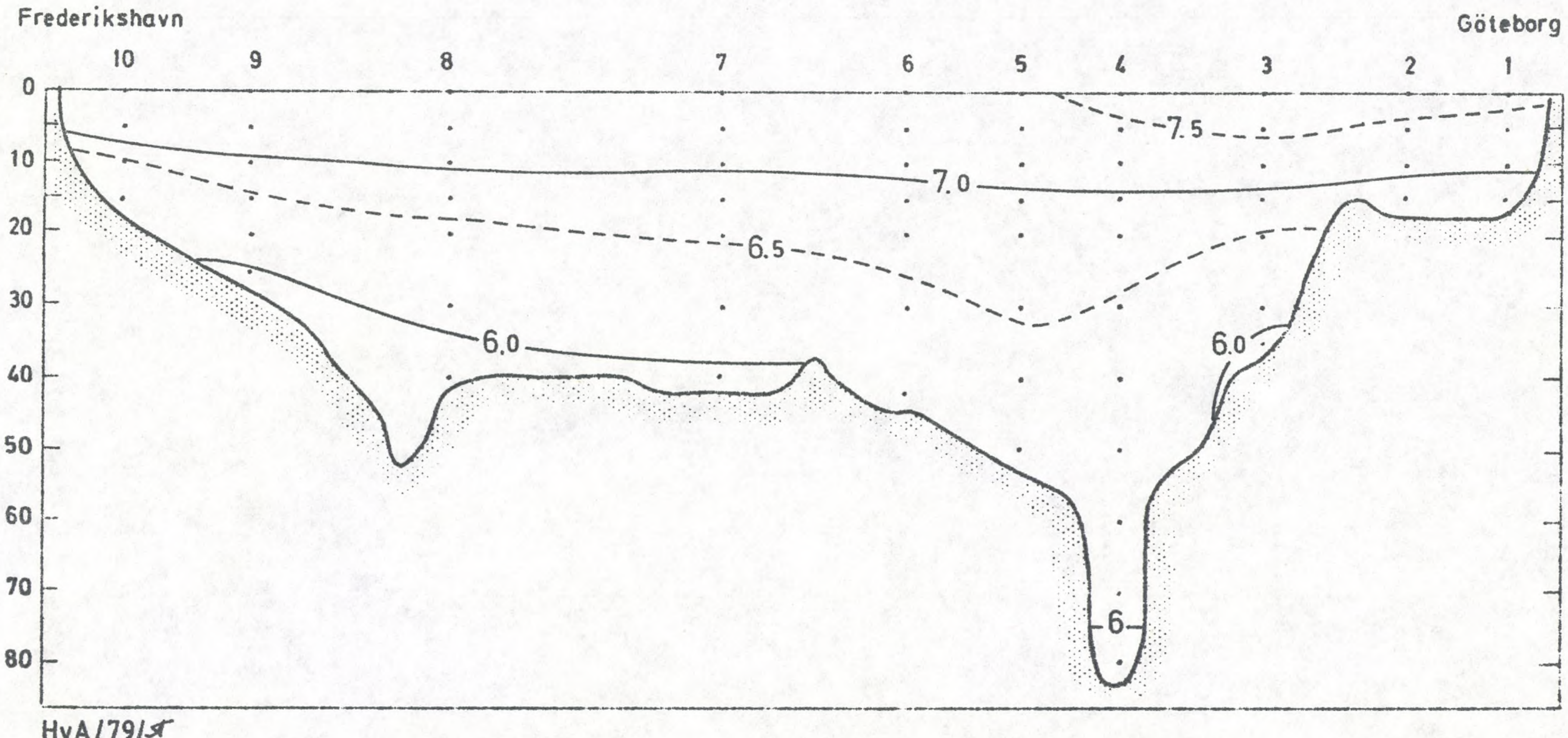


Fig. 5.

Fig. 6.

Review of the Oxygen saturation (%) - Mean values 1975 - 1977

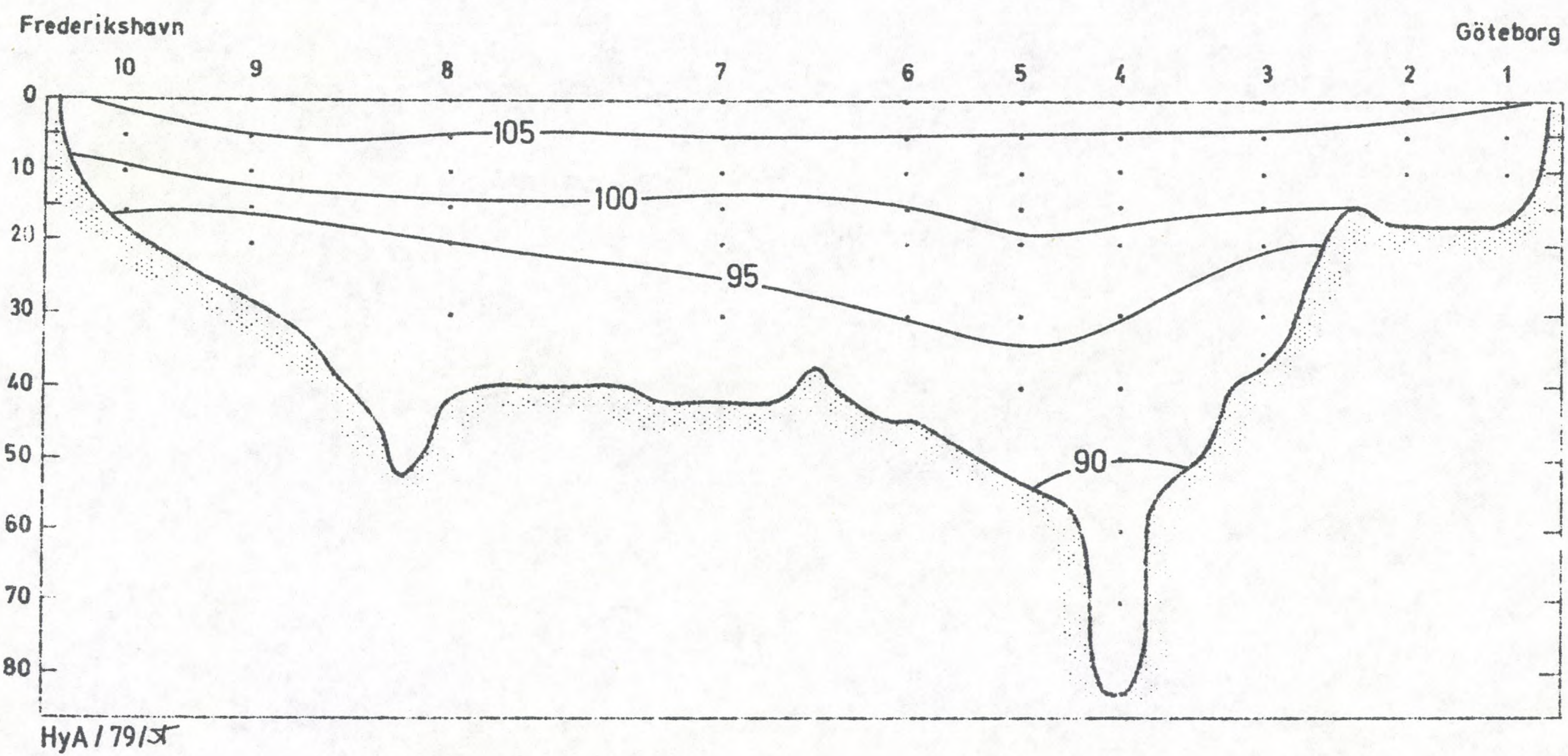
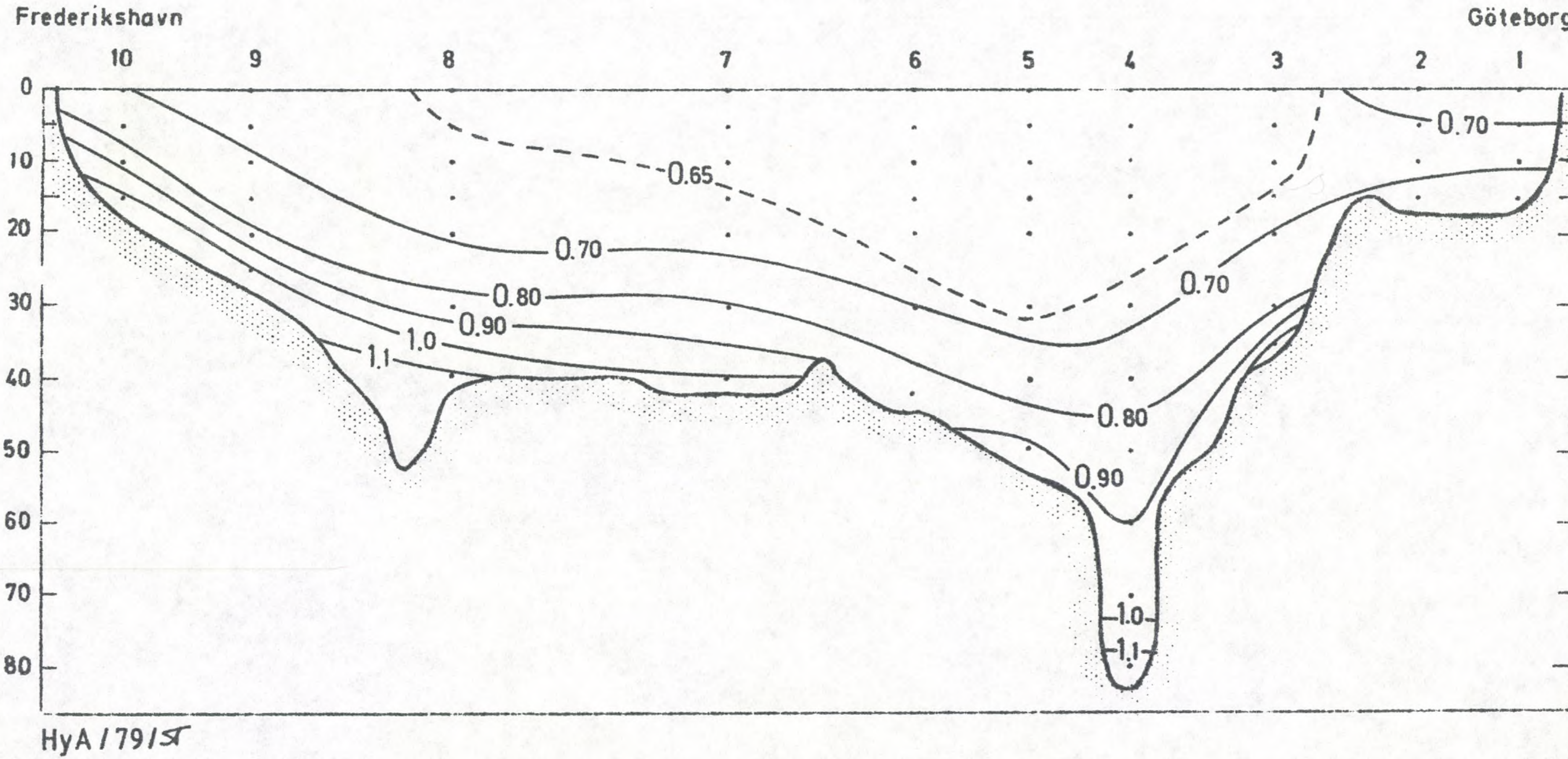


Fig. 7.

Review of Tot-P (µgat/l) — Mean values 1975 - 1977



Review of PO_4-P (µgat/l) – Mean values 1975 - 1977

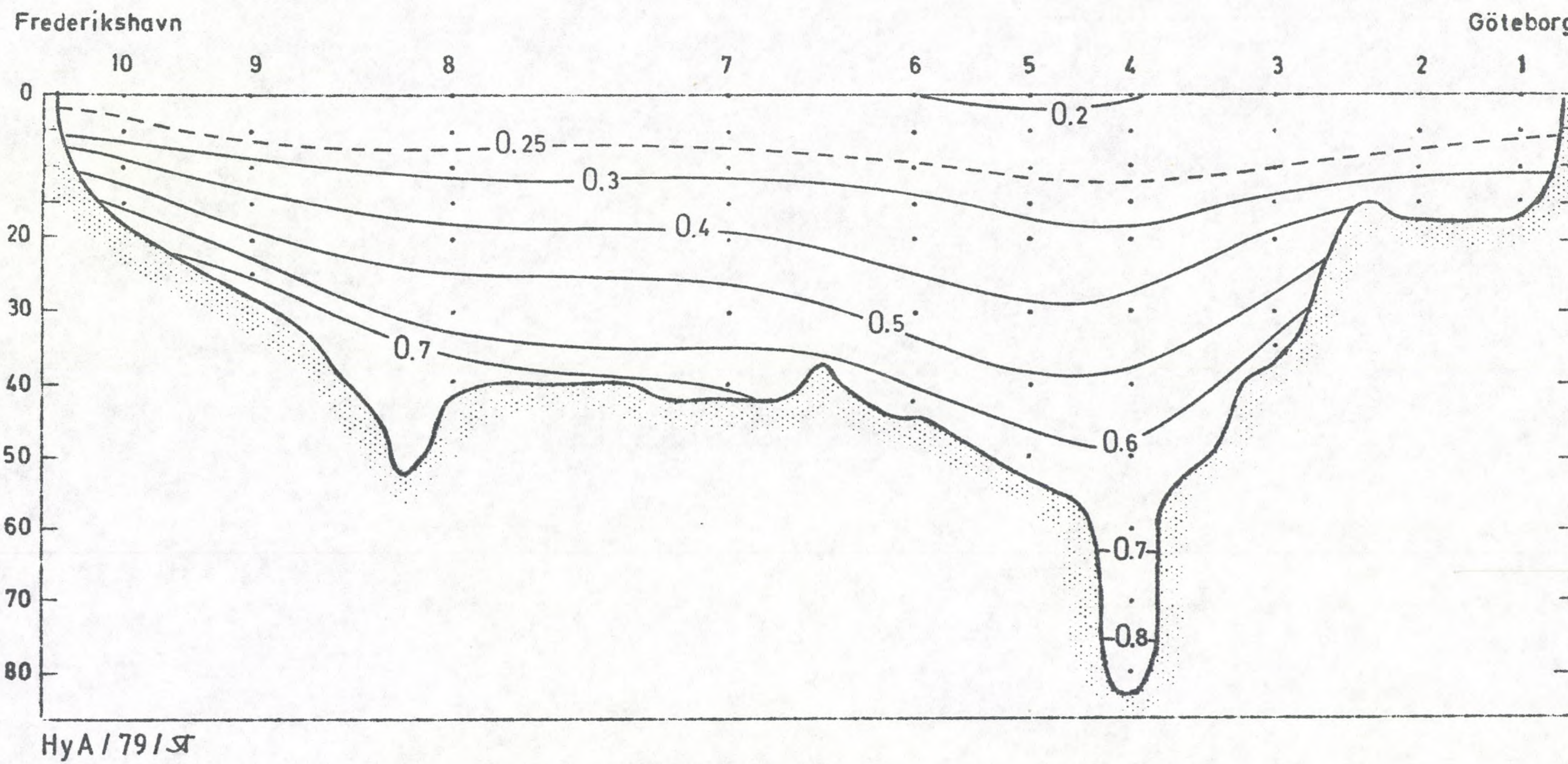


Fig. 8.

Review of Tot-N (µgat/l) - Mean values 1975 - 1977

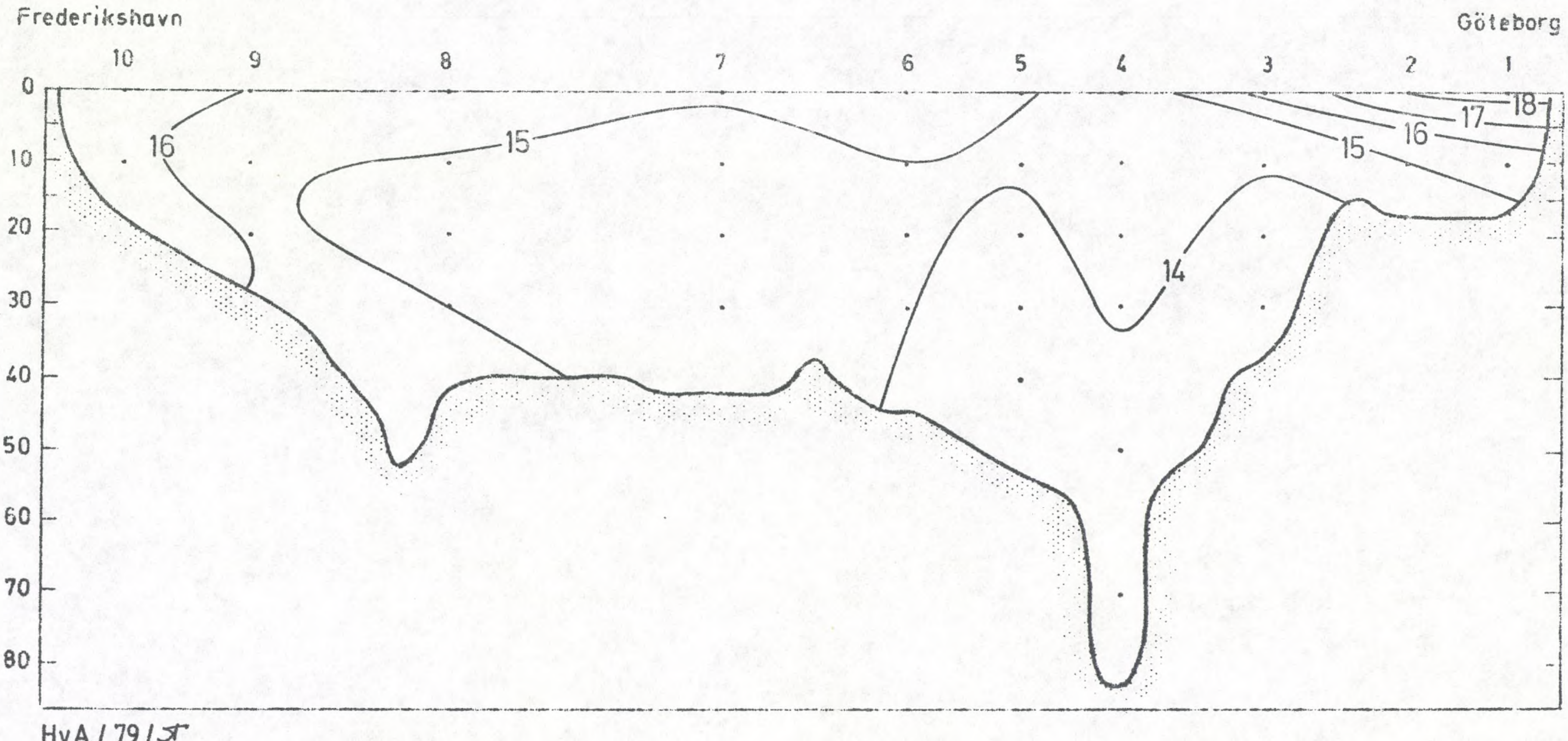


Fig. 9.

Review of NO_3–N (ugat/l) — Mean values 1976 – 1977

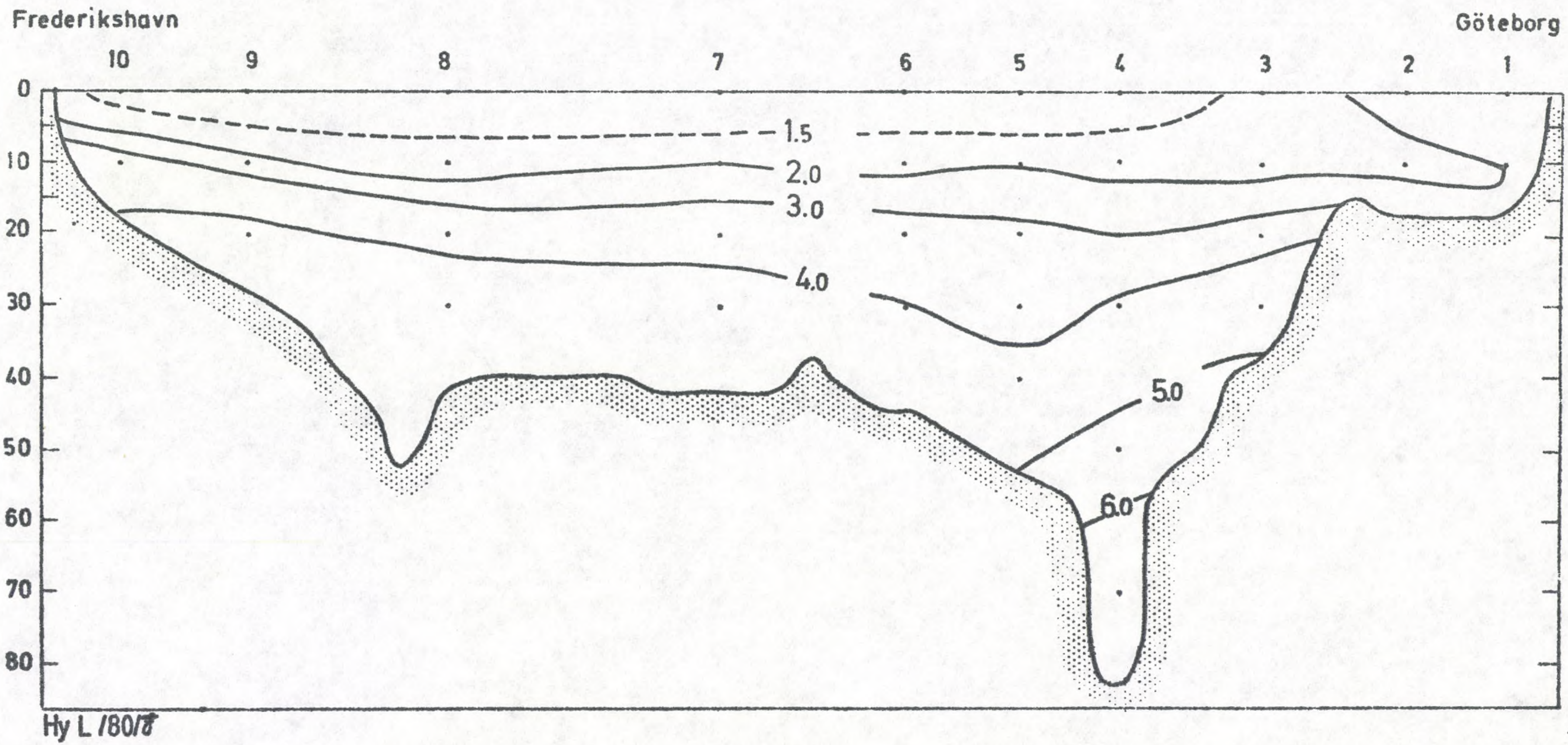
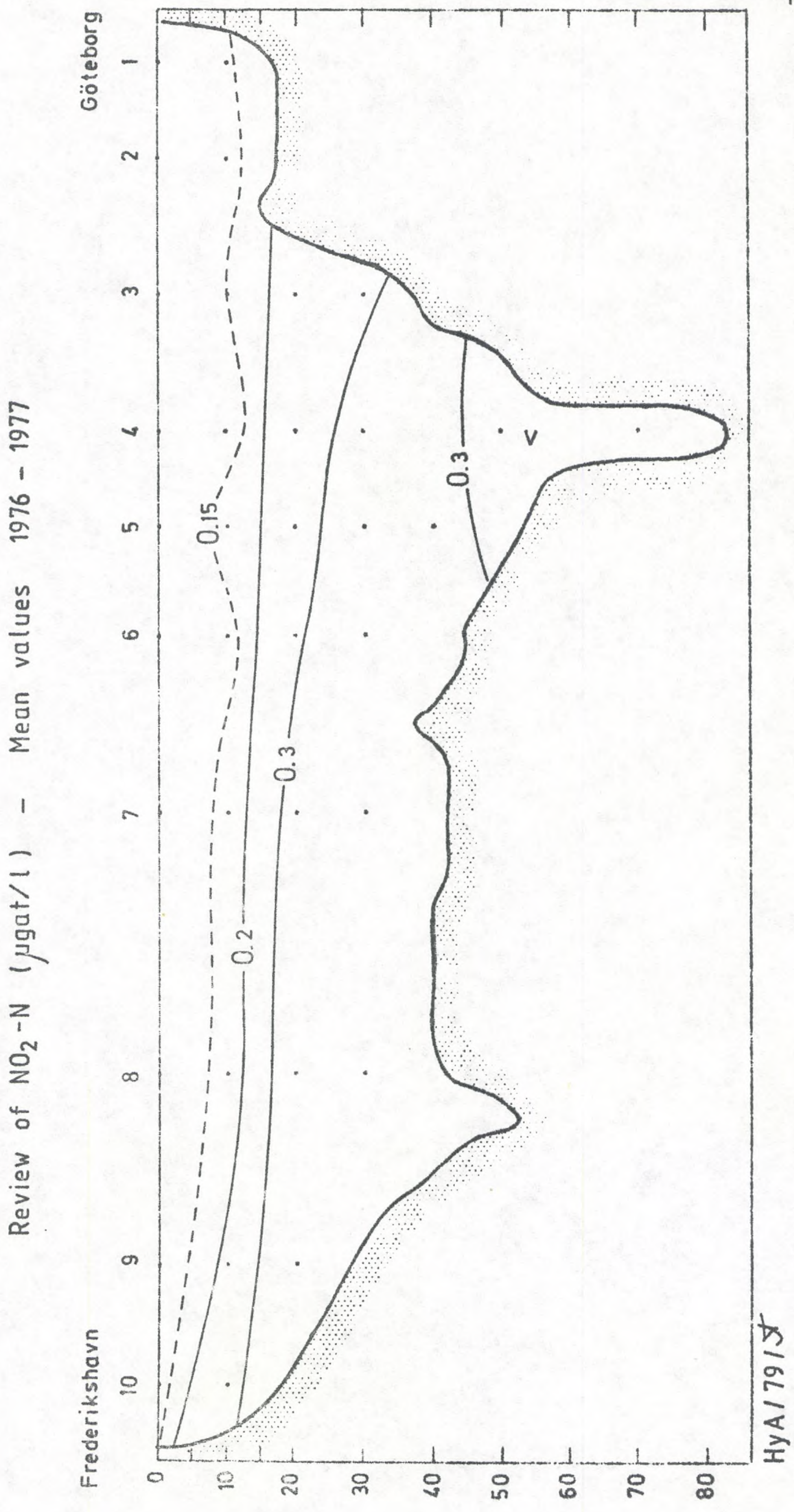


Fig. 10.

Fig. 11.



Review of NO_2-N (µgat/l) - Mean values 1976 - 1977
Göteborg
Frederikshavn
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
0.15
0.2
0.3
0.3
v
HyA/79/

Review of NH_4-N (μgat/l) – Mean values 1976 - 1977

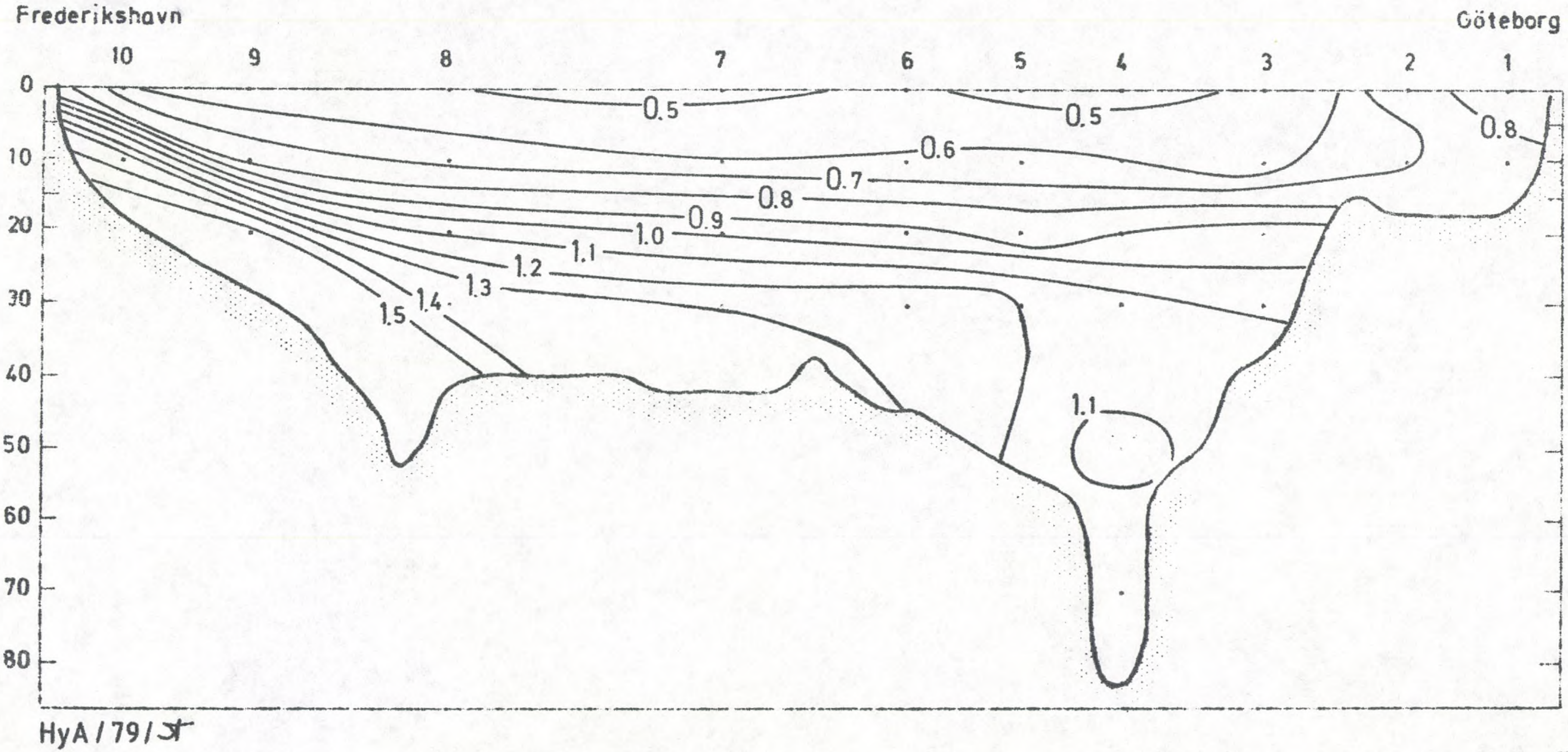


Fig. 12.

Review of TOC (mg C/L) - Mean values 1975 - 1977

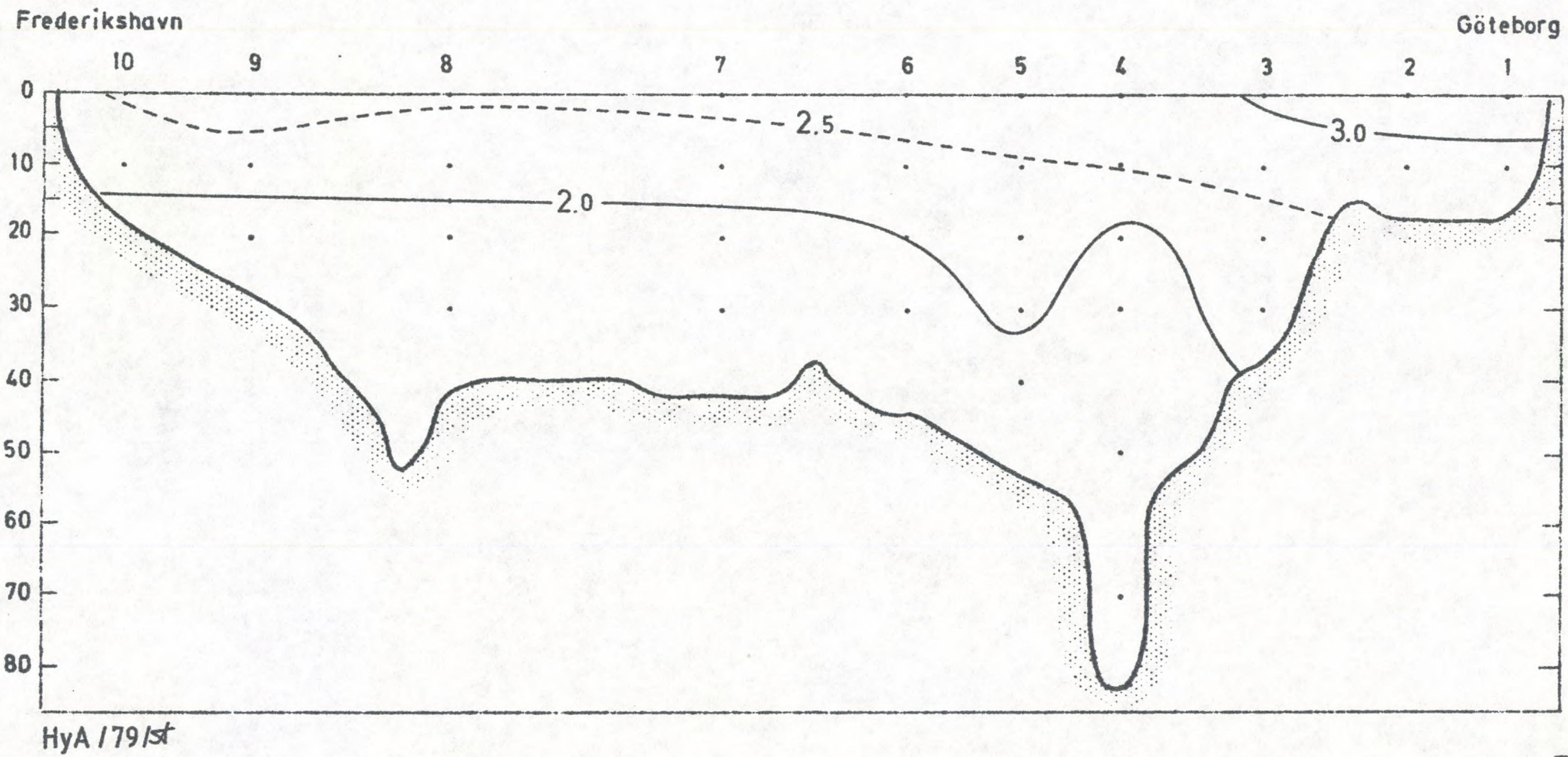


Fig. 13.

Review of the X-Comp. (Current in cm/s towards 167 degrees)
Mean values 1975 - 1977

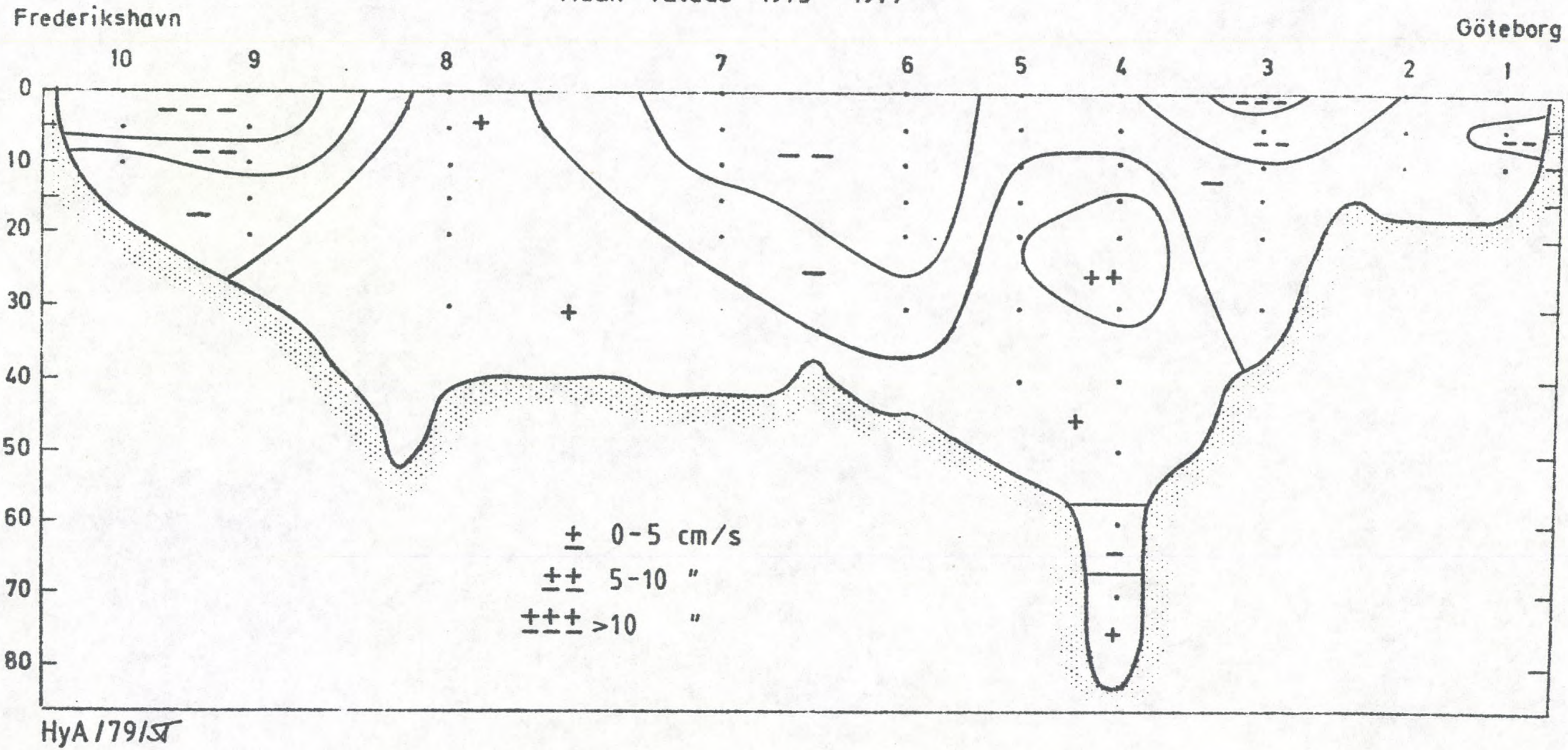


Fig. 14.

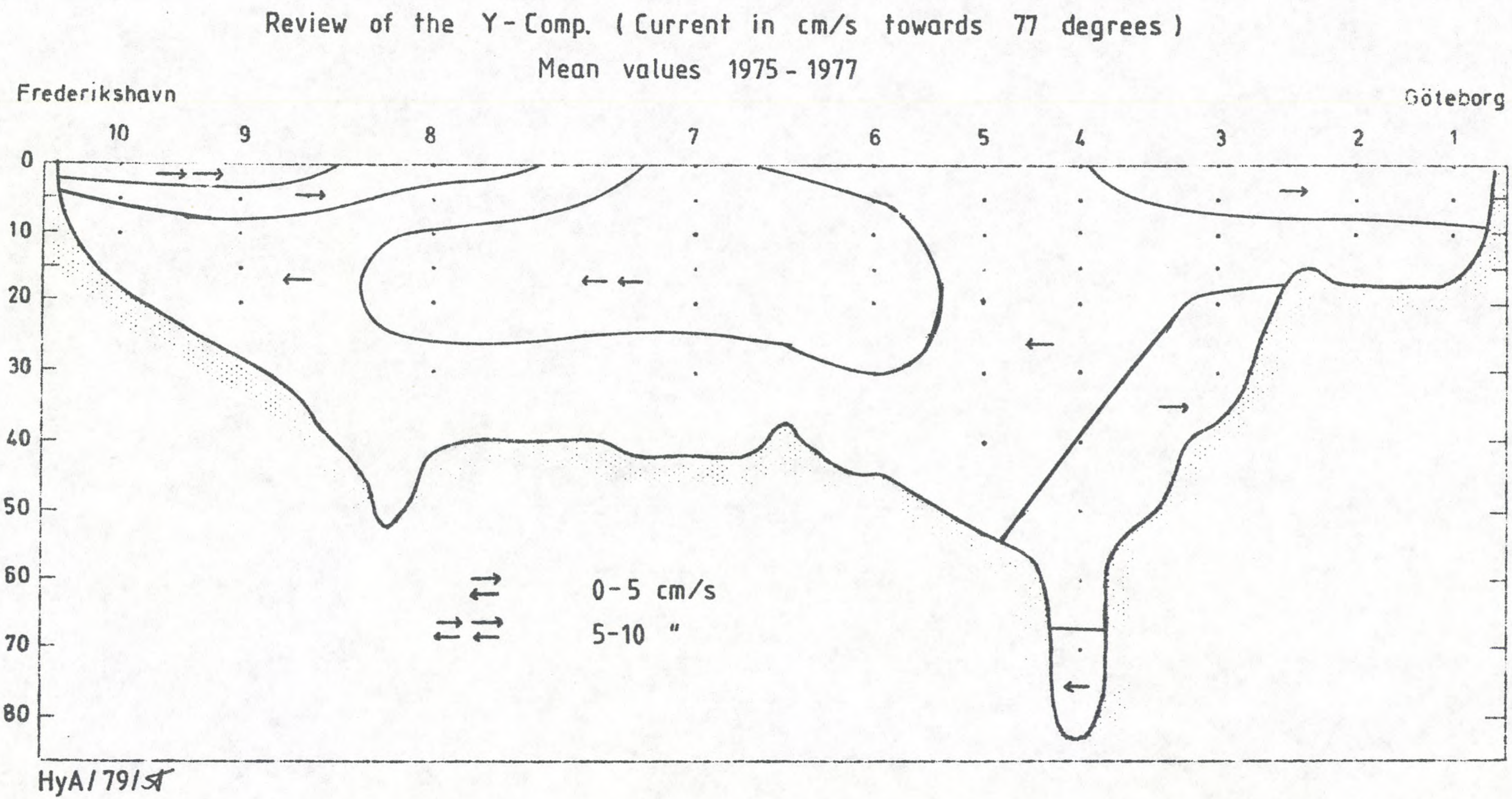
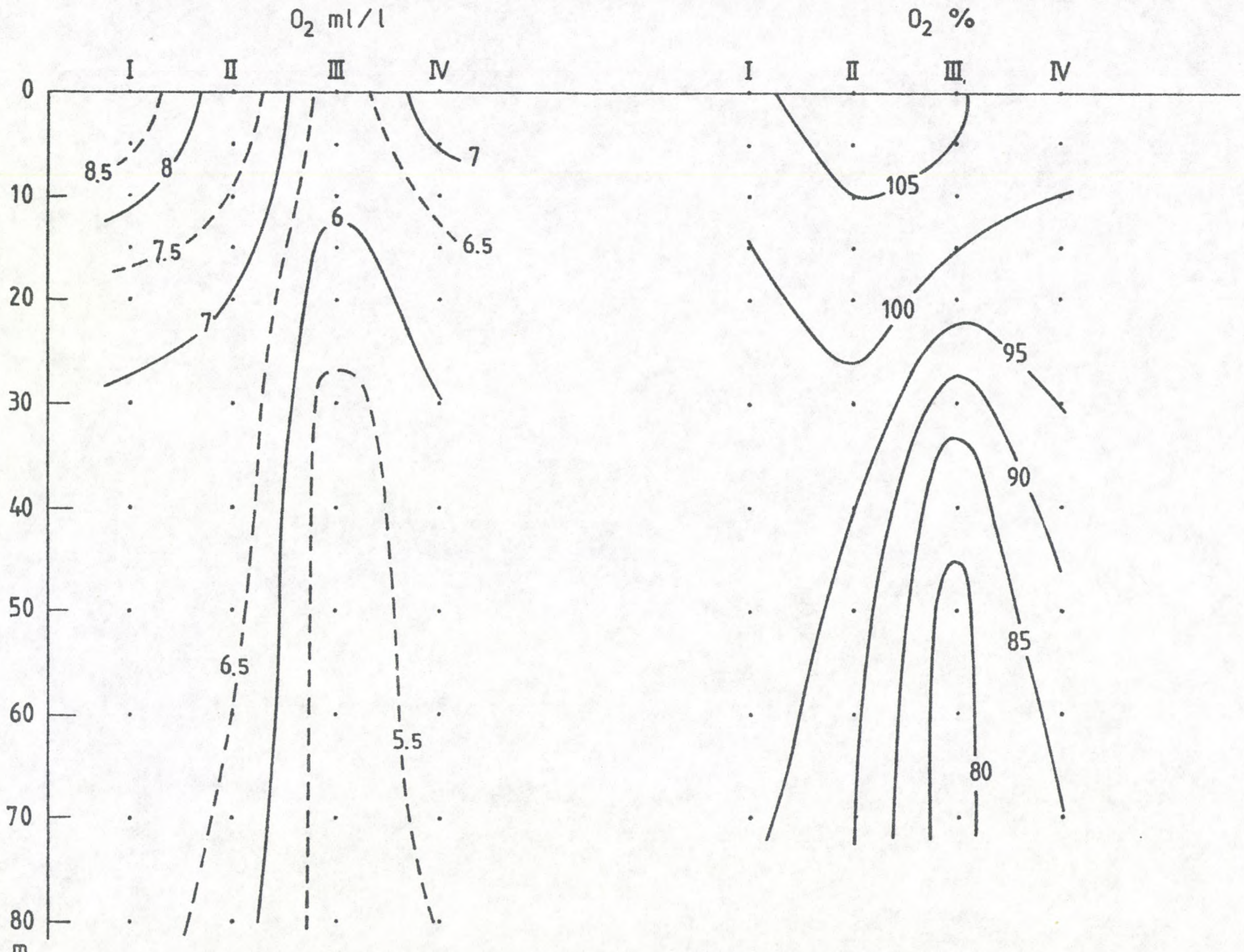

Review of the Y-Comp. (Current in cm/s towards 77 degrees)
Mean values 1975 - 1977
Frederikshavn
Göteborg
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
0-5 cm/s
5-10 "
HyA/79/

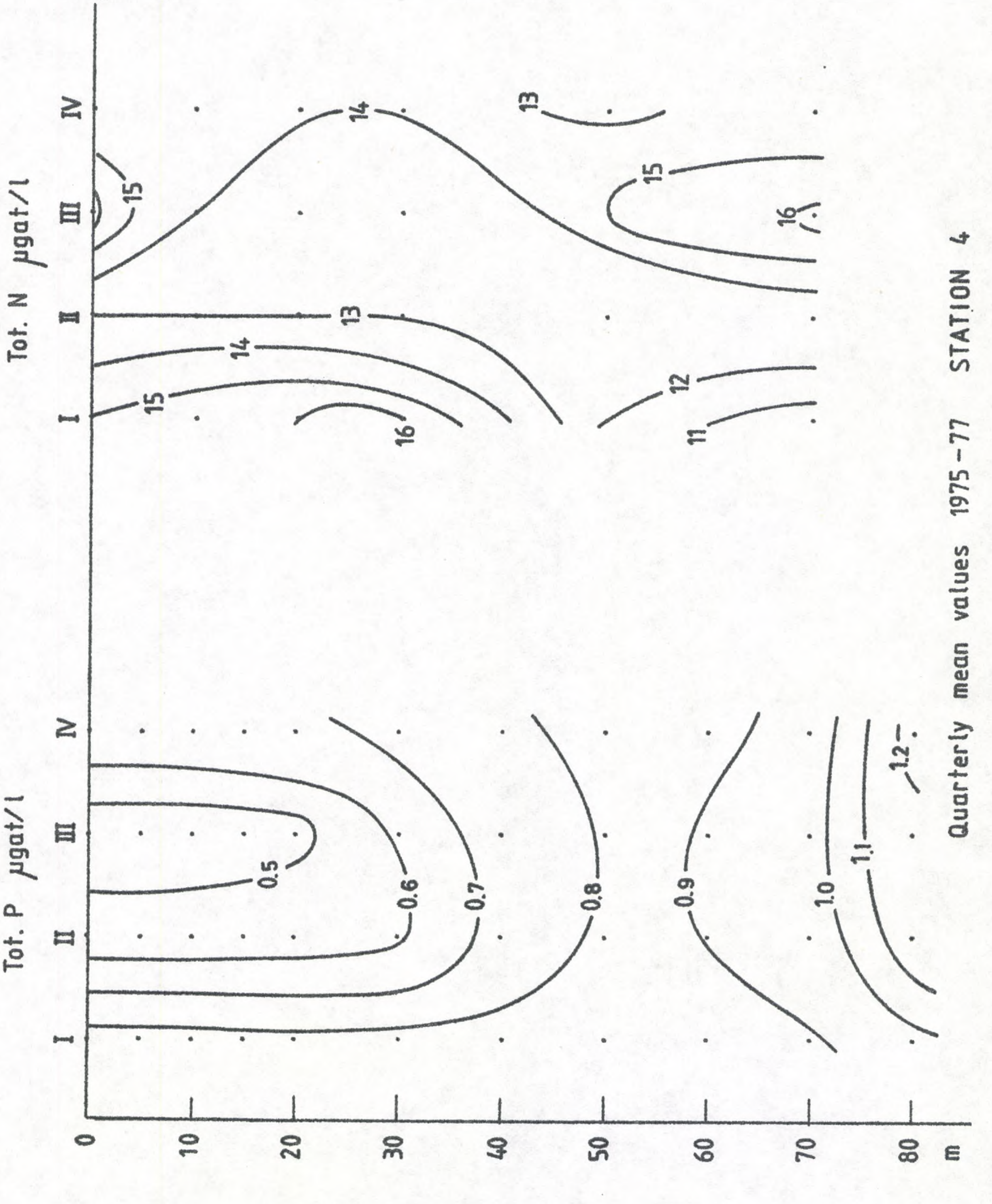
Fig. 15.



Quarterly mean values 1975 - 77 STATION 4

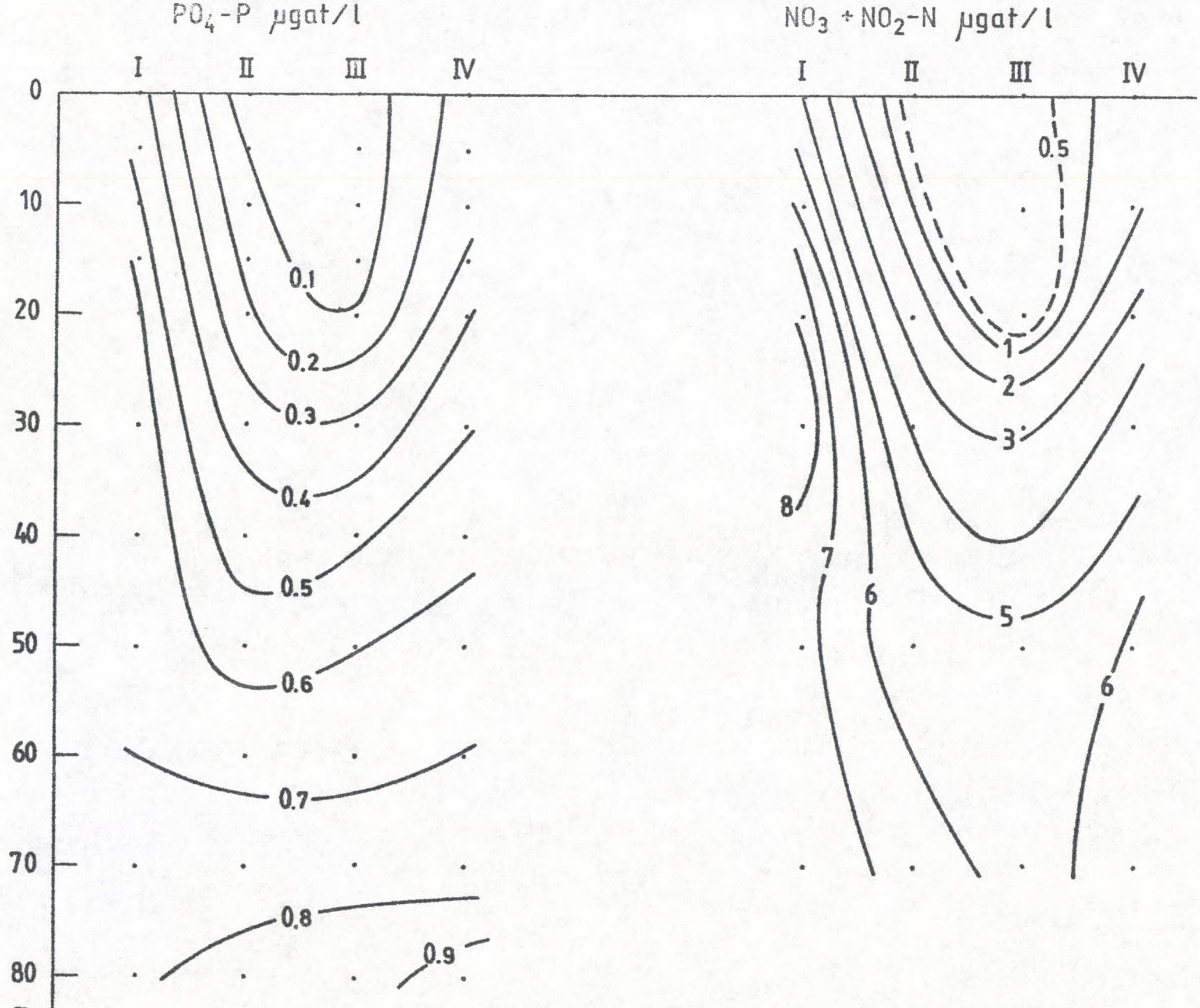
Fig. 16.

Fig. 17.



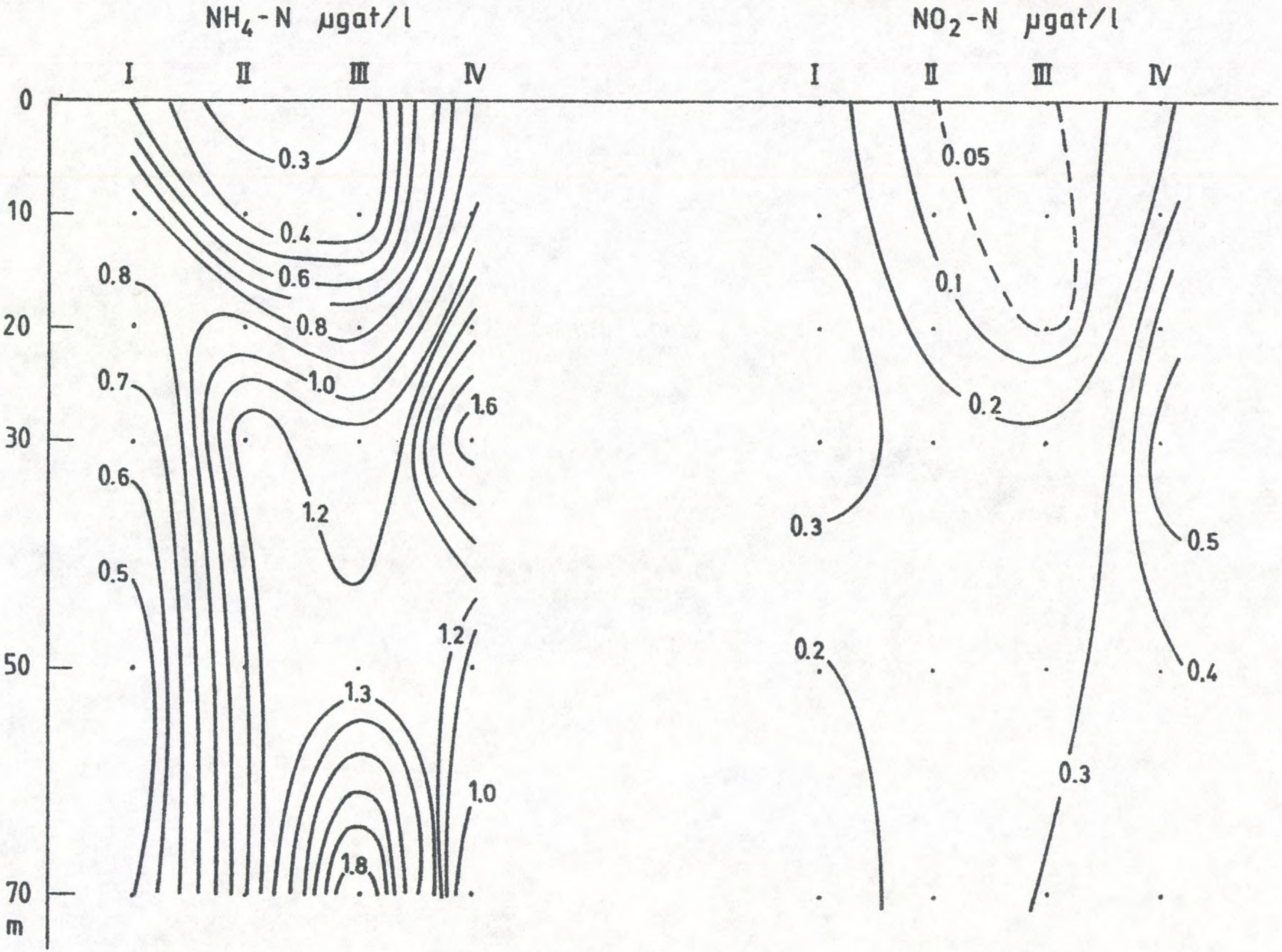
Tot. P µgat/l
Tot. N µgat/l
I
II
III
IV
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
11
12
13
14
15
16
0
10
20
30
40
50
60
70
80
m
Quarterly mean values 1975 - 77 STATION 4

Fig. 18.

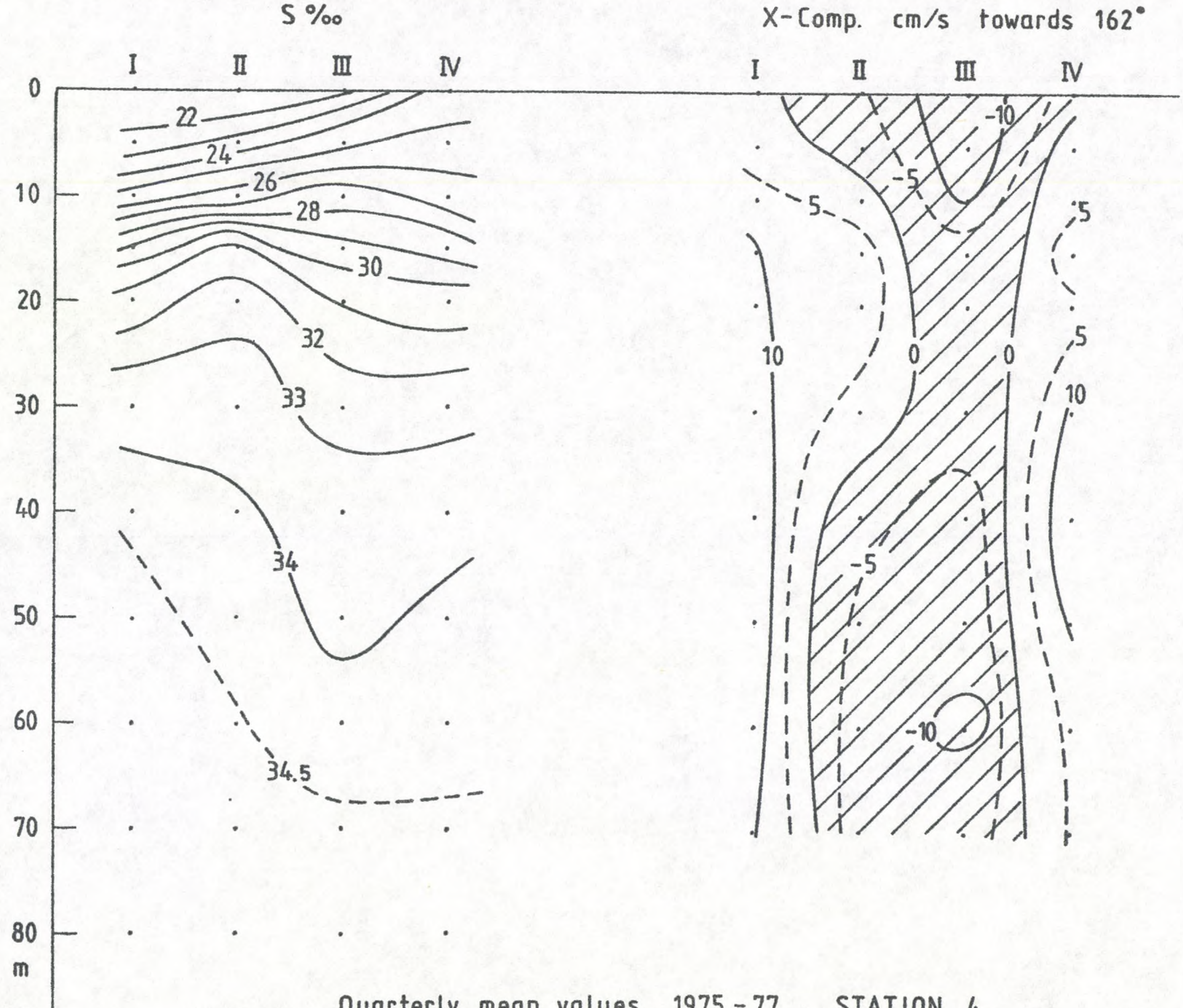


Quarterly mean values 1976 - 77 (PO$_4$-P 1975-77) STATION 4

Fig. 19.



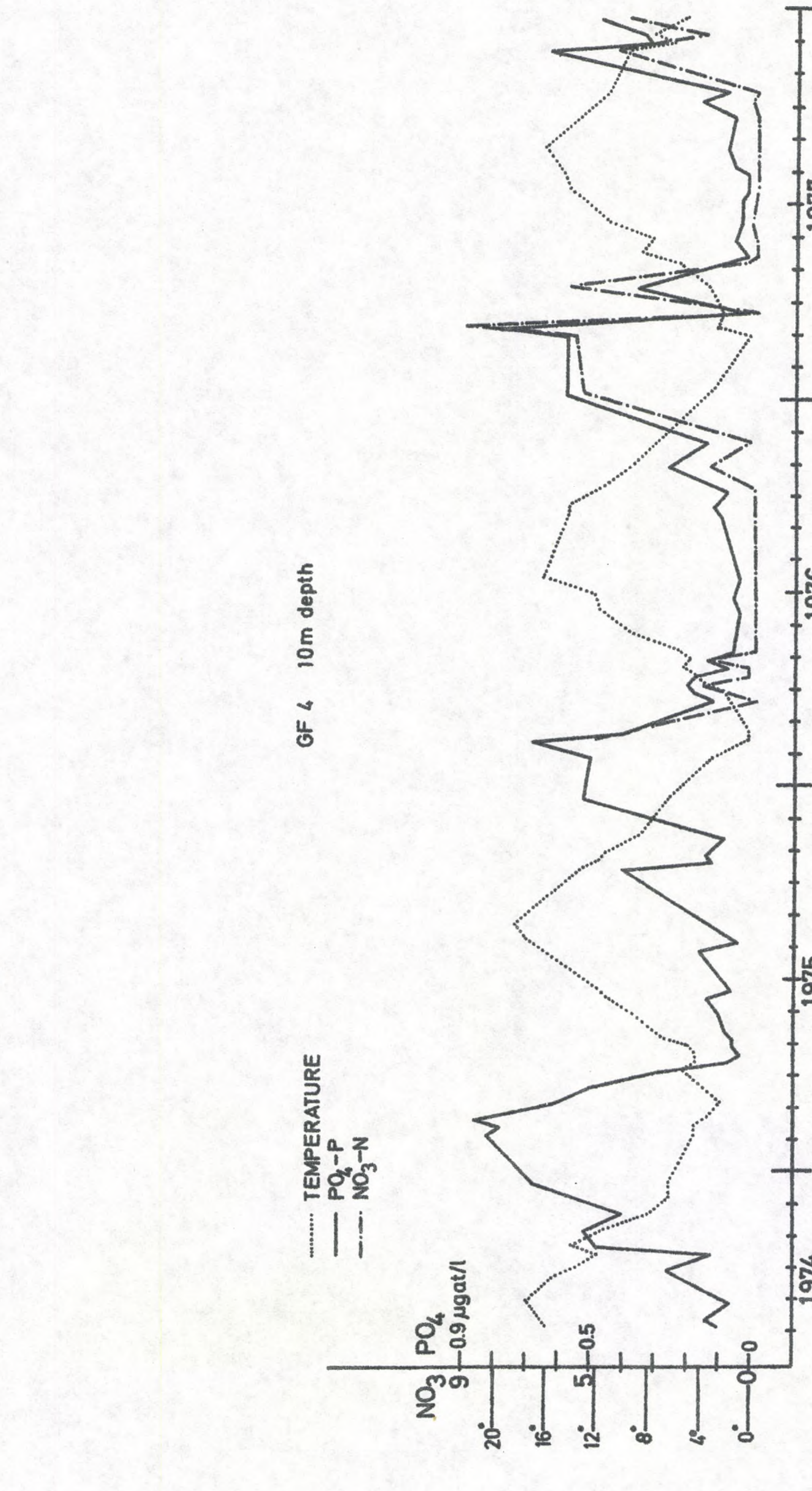
Quarterly mean values 1976 - 77 STATION 4



Quarterly mean values 1975 - 77 STATION 4

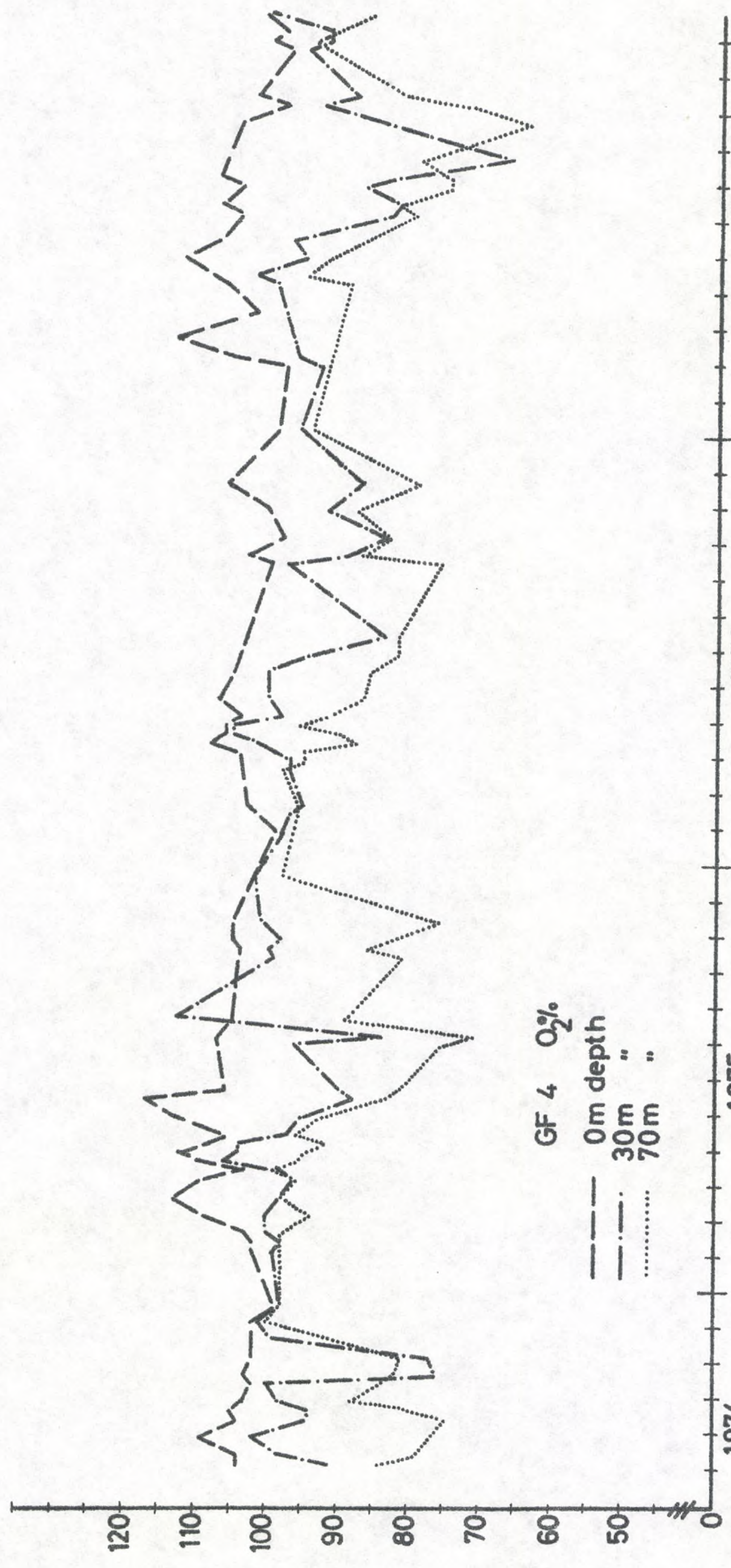
Fig. 2D.

Fig. 21.



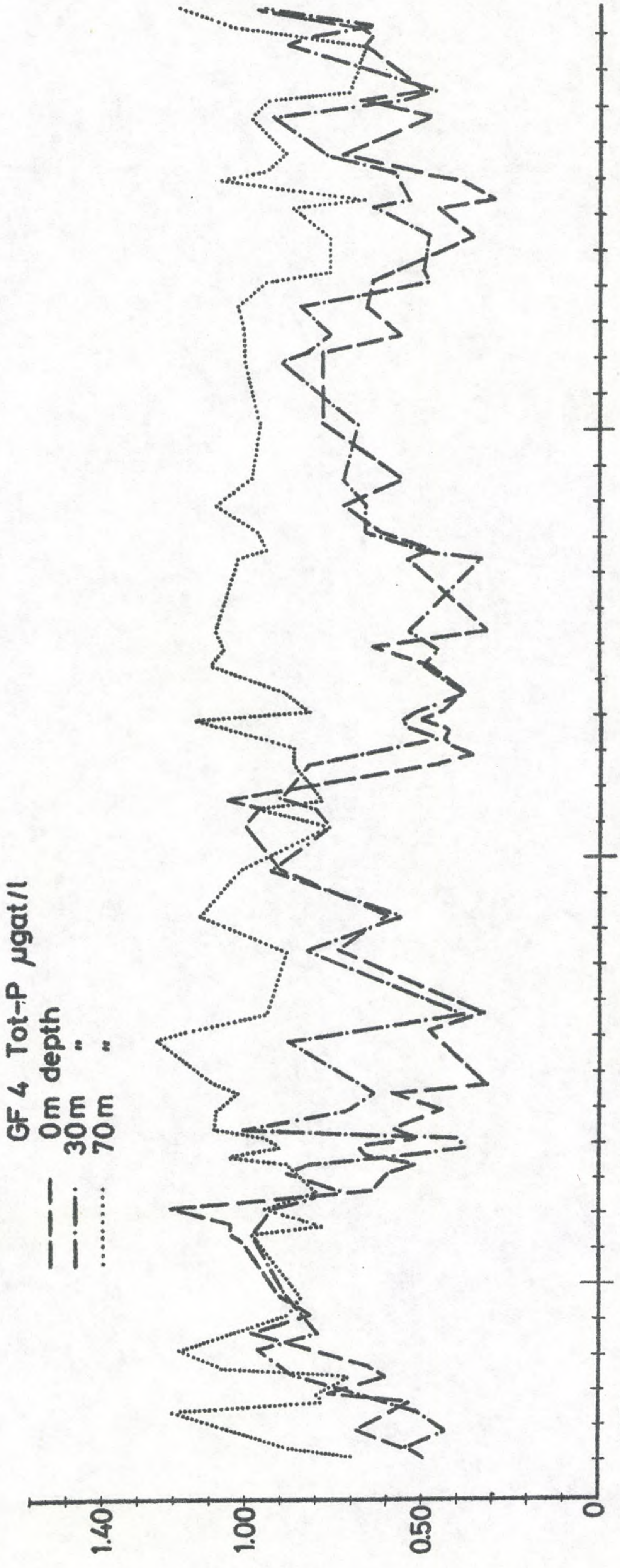
GF 4 10m depth
TEMPERATURE
PO_4-P
NO_3-N
NO_3
PO_4
0.9 µgat/l
9
5
0
0.5
0
20°
16°
12°
8°
4°
0°
1974
1975
1976
1977

Fig. 22.



GF 4 O_2%
0m depth
30m "
70m "
120
110
100
90
80
70
60
50
0
1974
1975
1976
1977

Fig. 23.



GF 4 Tot-P µgat/l
0m depth
30m "
70m "
1.40
1.00
0.50
0
1974
1975
1976
1977

Fig. 24.

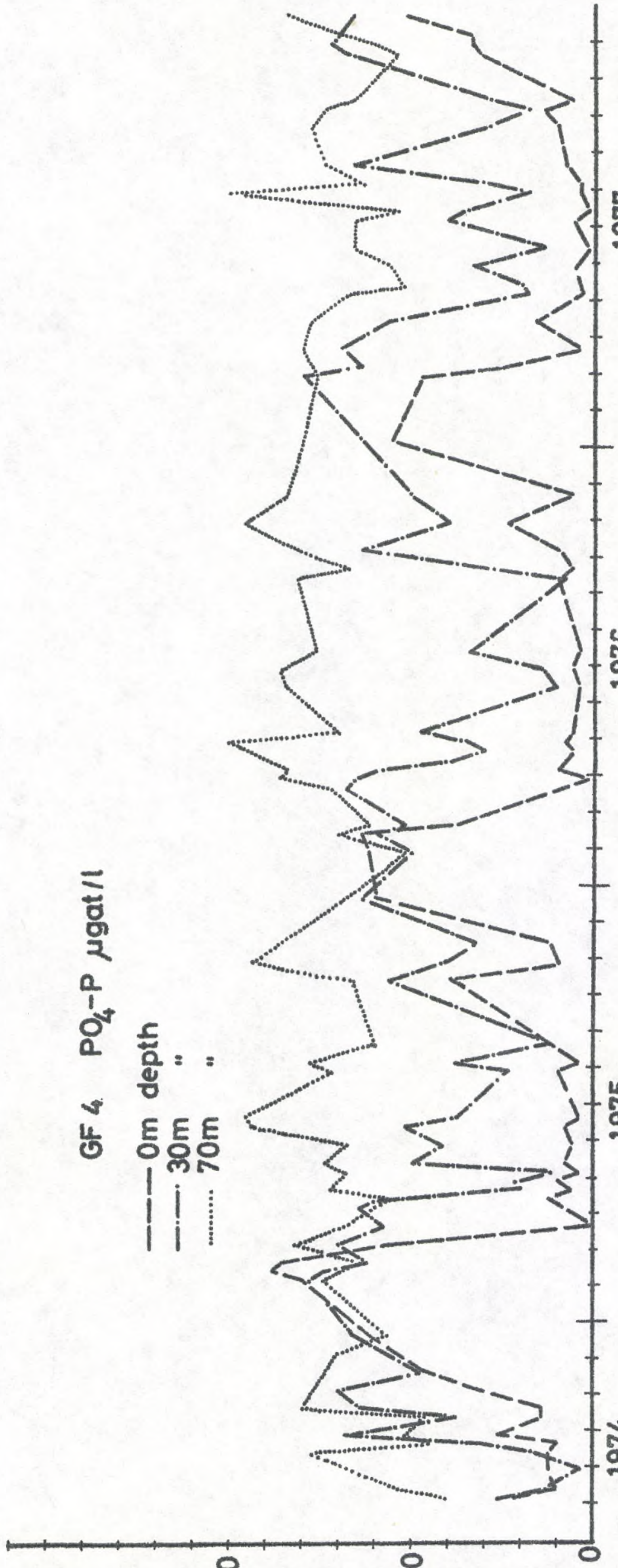
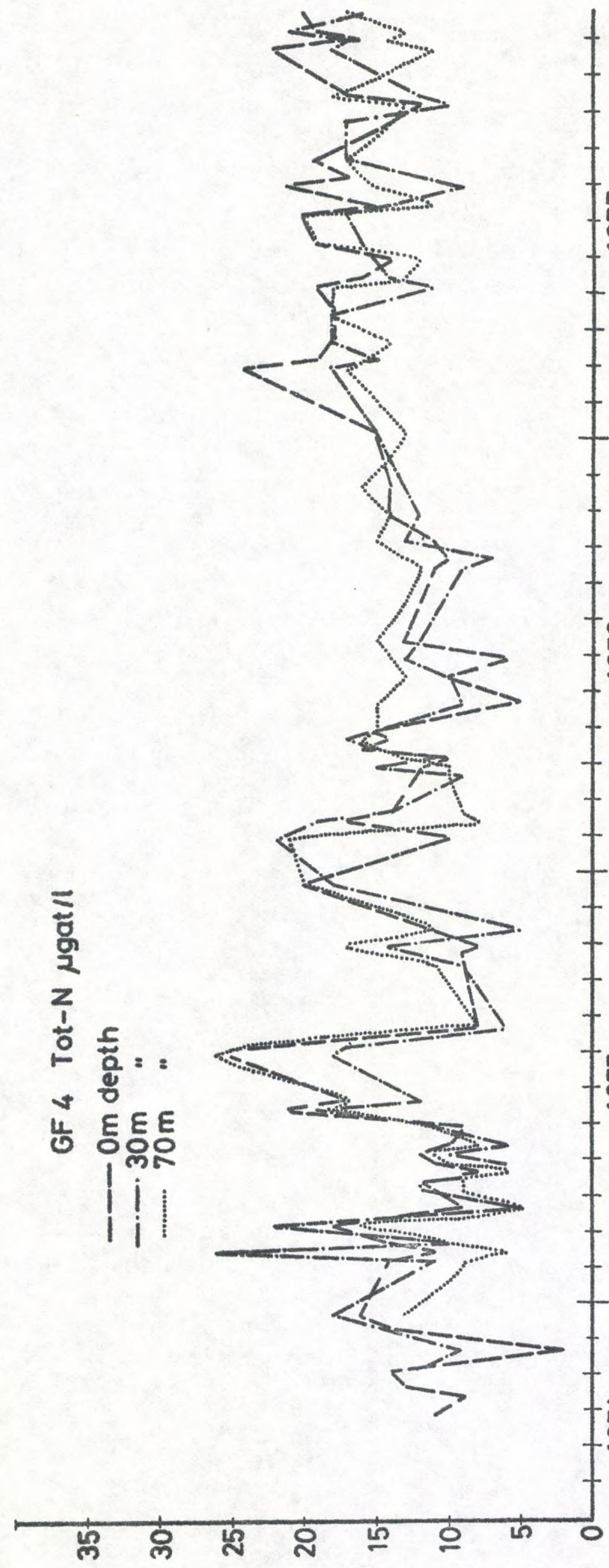


Fig. 25.


GF 4 Tot-N µgat/l
0m depth
30m "
70m "
35
30
25
20
15
10
5
0
1974
1975
1976
1977