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ON LONG-TERM VARIATIIONS OF SOME HYDROGRAPHICAL PARAMETERS IN THE DEEP BASINS OF THE BALTIC PROPER

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ABSTRACT

In the Baltic Sea long-term series of salinity, temperature and dissolved oxygen observations from the main stations exist. The series begin at the end of the last century. Nutrients concentrations have been measured at these stations after W.W.II. Phosphate measurements began in the 1950s and nitrogen compounds and silicate have been measured since the end of the 1960s. By help of these series it has been possible to study long-term trends in the surface water and to follow the large variations in the deep water, caused by inflows of Kattegat water with high density along the bottom of the Baltic proper.

Unfortunately no similar long-term series of biological parameters exist. Therefore it is difficult to draw reliable conclusions regarding biological trends and variations and to couple biological results to the hydrographical changes.

In the present paper series of density and oxygen measurements from the surface to the bottom at the station BY 15, the Gotland Deep are shown. Inflows of water with high density below the halocline are shown to cause stagnation and hydrogen sulphide formation in the bottom water of the deep basins. The stagnation periods are broken by new inflows, improving again the oxygen conditions. Diagrams for phosphate variations from 1967 and nitrate variations from 1968 to present time in the Gotland Deep are also shown. The accumulation of phosphate and disappearance of nitrate in the stagnant water are demonstrated. Trends of some biological parameters are briefly discussed. The observed eutrophication of the Baltic Sea surface water and possible effects on reproduction of fish and also the difficulties encountered in trying to connect fisheries statistics to hydrography are finally discussed.

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In the Baltic Sea we find long-term series of measurements of salinity, temperature and dissolved oxygen beginning at the end of the last century. These series have been taken at the main deep stations rather regularly. The work has been carried out by marine laboratories from different countries surrounding the Baltic Sea. When the ICES was founded in 1902 the work was by agreement divided between the Baltic Sea countries in order to try to cover the main deep stations at least once every year. In the beginning the work could not be carried out very regularly. For some years data are completely missing. Often only one expedition was carried out annually. Unfortunately the work had to be interrupted during the two World Wars (W.W.), due to military operations and lack of research ships. Therefore we find gaps of several years in the series during the war periods.

After W.W. II the amount of observations has increased enormously and all the main stations are now covered at least four times annually. After the war, observations of nutrient concentrations have been introduced in all Baltic Sea countries. The analytical methods have been worked out. Intercalibrations have been carried out in the frame of ICES and we now have quite reliable series of phosphate measurements since 1954. In the middle of the 1960s nitrate and nitrite analyses were introduced. Also silicate and ammonia have been measured on a routine basis since the beginning of the 1970s (Fonselius 1986).

Fig. 1 shows a map of the Baltic Sea with the stations discussed in the paper marked. Fig. 2 shows the variations of density in the deep water of the Gotland Deep (BY 15) from 1883 to 1985. The density is mainly dependent of the salinity in the deep water, where the temperature variations are low and a diagram of the salinity would be very similar to the density diagram. In the figure we can see that an inflow of Kattegat water with high density occurred during W.W.I and that the density then decreased. The high peak in 1928 is caused by a single set of measurements and is obviously wrong. The measurements were carried out by the "Skagerak" and the next day the same station was occupied by the "Aranda", which got quite normal results. The "Skagerak" values have to be reduced with 0.5 salinity units from the surface to the bottom. My reason for this correction is, that the oxygen values of the deep water were extremely low. An inflow of high saline water would have contained oxygen. Fig. 3 shows the oxygen variations in the Gotland Deep in the same manner. We can see periods with hydrogen sulphide formation (the black areas in the fig.). These are always corresponding to periods with decreasing density. The oxygen peaks correspond to inflows of water with high density. If we return to fig. 1 we can see that there was another large water inflow in 1952. This inflow was the largest ever observed in the Baltic Sea. It has been described in detail by Wyrtki (1954). Both the above mentioned inflows caused hydrogen sulphide formation in the bottom water. After the 1952 inflow, increasing periods with stagnation and hydrogen sulphide formation have been observed (fig. 3). The inflow obviously was a catastrophe for the Baltic Sea. It has often been claimed that eutrophication is responsible for the hydrogen sulphide formation in the Baltic Sea (Larssön et al. 1985). The stagnation periods, however, are not caused by eutrophication and the increasing occasions with salt water inflows followed by stagnation, is the primary reason for the bad oxygen conditions and hydrogen sulphide formation. Eutrophication may have increased the oxygen utilization, causing more hydrogen sulphide formation.

During stagnant conditions phosphate is accumulated in the stagnant deep water and when hydrogen sulphide is formed, phosphate is released from the sediments (Fonselius 1969). Nitrate is also accumulated, as long as oxygen is present in the water. When the dissolved oxygen reach values below 0.5 ml/l nitrate begins to be reduced to nitrogen gas and disappears completely from the stagnant water during reducing conditions, when hydrogen sulphide is formed. Fig. 4 shows the phosphate variations in the Gotland Deep in the whole water mass from 1967 to 1985. We can see in the figure the accumulation of phosphate and the seasonal variations in the surface layer. Fig. 5 shows in the same manner the nitrate variations from 1968. We can see that the nitrate disappears in the deep water completely or almost completely. This is due to the analytical technique, which is not very accurate. Often the zero results are reported as <0.1 and sometimes values are given with two decimals even below 0.10 umol/l, which is meaningless. In the surface layer the nitrate disappears completely during the summer period, indicating that nitrate is one of the production limiting factors.

From these figures it is difficult to see if the nutrient levels in the surface water have increased since the 1960s. Nehring et al (1985) has shown that the nutrient concentrations in the whole surface layer of the Baltic Sea has increased during that period and that the salinity of the water also has increased. Figs. 6, 7 and 8 show examples of this increase in the Gotland Deep, as annual mean values at 40 m depth for salinity, phosphate and nitrate during the period 1960-1985.

Unfortunately we do not have corresponding long-term observations of biological parameters. We do not know if the primary production of the water has increased, we also do not know if the biomass has increased. There are some signs of an increase of the zooplankton biomass, but also contradictory results have been obtained (Wulff et al 1986). Schulz (1985) has shown that the chlorophyll a has increased in the southern Baltic Sea from 1975 to 1983. He could not find satistically significant increases for primary production and zooplankton biomass during the same period.

One of the difficulties in biological long-term investigations is, that gear and methods have been changed several times and that the results therefore are not comparable.

For fisheries long series of catch statistics exist, but the results are hardly useful for conclusions regarding changes in the fish stock. If we look at the conditions in the Baltic Sea, cod was not caught in larger amounts before W.W.II. It was not considered commercially interesting. During W.W.II the German trawling fleet was due to the war conditions excluded from its normal fishing grounds in the North Sea. Therefore it moved into the Baltic Sea. This gives a high response in catch statistics, but of course the result depends on new fishing methods, trawling was not usual in the Baltic Sea at that time, and of course an increased effort (Meyer and Kalle 1950), (Otterlind 1986). Otterlind also points out other factors, which have increased the catches after W.W. II as increased fishing efforts mainly by Poland and USSR using new large trawling fleets, transfer of fishing efforts from the North Sea to the Baltic, changed market conditions etc. (fig. 9).

It is not easy to connect variations in fish catch to hydrographic conditions. We have to remember that there are several links in the food chain between the phytoplankton, which first is influenced by changes in nutrient conditions in the surface water and commercial fish, which is included in fisheries statistics. Hydrographic changes do not only have effects on the nutrient conditions. Stagnation of the deep water may lead to anoxia and hydrogen sulphide formation in the Baltic basins. This may influence the cod reproduction in the Baltic Sea. Important spawning areas are the Bornholm Basin and the Gdańsk Basin, where anoxia may develop. Svansson (1985) has tried to connect good year classes of cod with the hydrographic conditions in the Bornholm Basin (fig. 10). From the fig. we can see that very good classes developed in 1964, 1972, 1976 and possibly 1977. Good classes developed in 1963, 1966, 1979 and 1980. Otterlind (1986) additionally points out 1977 and possibly 1981 as years for good classes. Very bad was the class of 1968. The very good classes coincide with inflows of new water, which improved the oxygen conditions in the whole southern Baltic Sea, thus improving the spawning result. One may of course point out that cod caught in an area does not necessarily originate from that area. Cod is a migratory fish, but the inflow of new water influences the whole Baltic proper and therefore it should not matter if the cod originates from the areas west or east of Bornholm.

But occasional improvements of the oxygen conditions should not cause the observed large increasing of the cod stock. That should probably be connected to the increasing eutrophication of the surface water, regardless if this is caused by natural or anthropogenic processes.

References:

Fonselius, S. 1969: Hydrography of the Baltic Deep Basins III. Fishery Board of Sweden, Series Hydrography, No 23.

Fonselius, S. 1986: On long-term variations of dissolved oxygen in the deep water of the Baltic Sea. Baltic Sea Monitoring Symposium, Tallinn, USSR. 10-15 March 1986. Proceedings. (in print). Manuscript.

Larsson, U., R. Elmgren and F. Wulff. 1985: Eutrophication and the Baltic Sea: Causes and Consequences, Ambio, Vol. 14:1.

Meyer, P.F. and K. Kalle. 1980: Die biologische Umstimmung der Ostsee in den letzten Jahrzehnten - eine Folge hydrographischer Wasserumschichtungen. Archiv fur Fischereiwissenschaften. 2:1-9.

Nehring, D., G. Aertebjerg, A. Trozosinska, S. Fonselius, P. Tulkki, P. Alenius, V. Tervo, M. Hannus, V. Astok and A. K. Yurkovaskis . 1986: First Periodic Assessment of the State of the Baltic Sea, Chapt. 2. Nutrients. Baltic Marine Environment Proceedings. (in print). Manuscript.

Otterlind, G. 1986: On Fluctuations of the Baltic cod stock. J. Cons. Int. Explor. mer. (in print). Manuscript.

Schluz, S. 1985: Ergebnisse ökologischer Untersuchungen im pelagischen Ökosystem der Ostsee, Akad. der Wissensch, der DDR Inst. fur Meeresk. Rostock-Warnemunde. Printed manuscript. 185 pp.

Svansson, A. 1985: Fiskerihydrografi. Medd. Havsfiskelab. Lysekil, Nr 307. Inst. Hydrogr. Res. Göteborg Series, No 31, 121 pp.

Wulff, F., G. Aertebjerg, G. Nicolaus and Å. Niemi. 1986: First periodic Assessment of the State of the Baltic Sea. Chapt. 4. Pelagic Biology. Baltic Marine Environment Proceedings. (in print). Manuscript.

Wyrtki, K. 1954: Der grosse Salzeinbruch in die Ostsee im November und Dezember 1951. Kieler Meeresforschungen, 10:1.

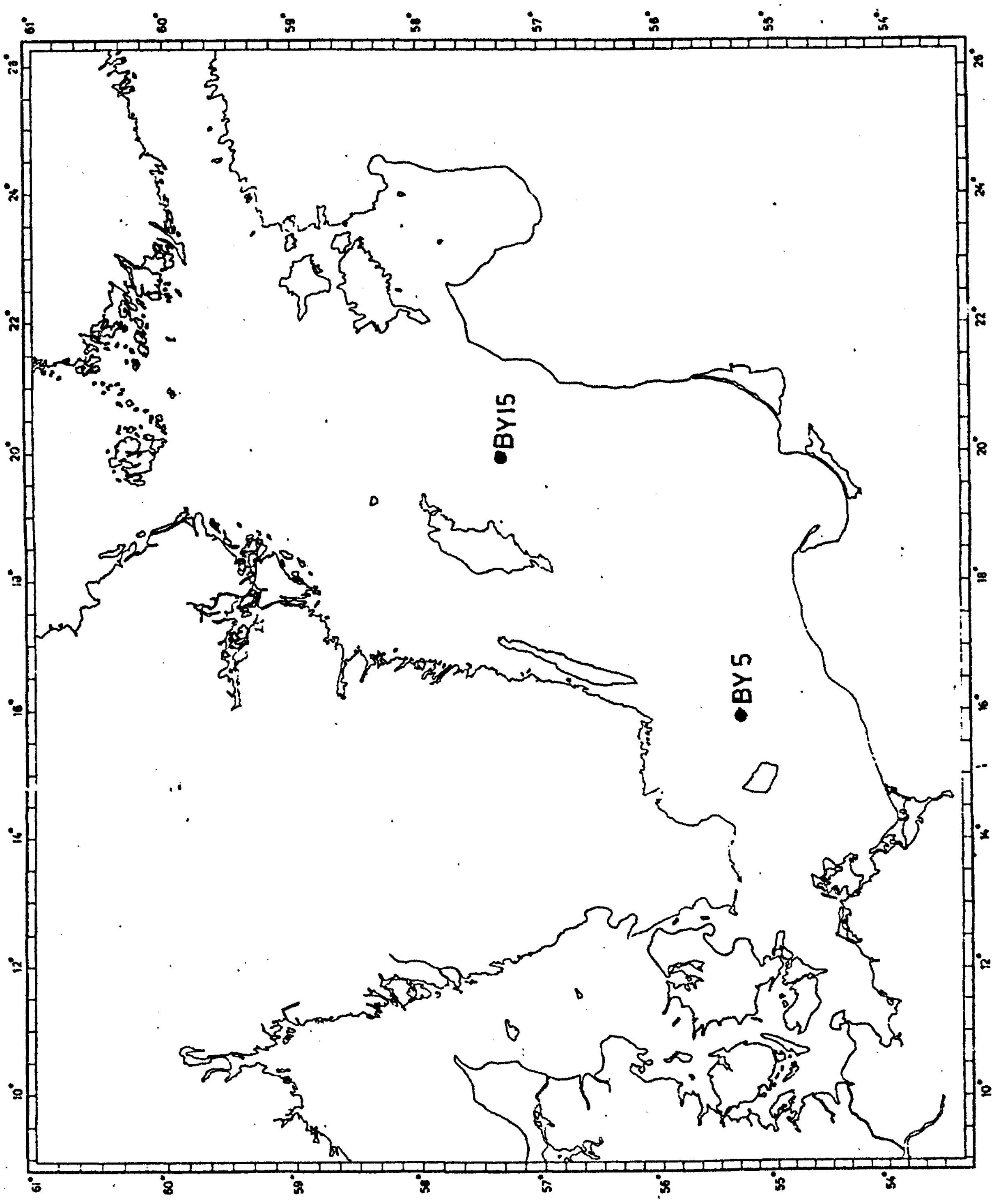


Fig. 1

Density distribution in the Gotland Deep from 1893 - 1985

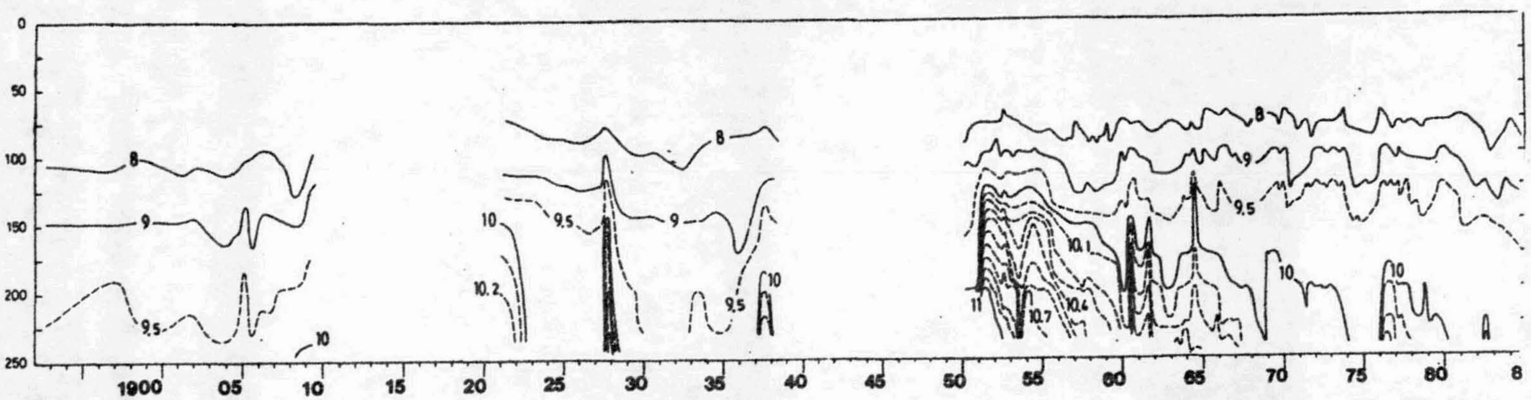


Fig. 2

OXYGEN CONDITIONS IN THE DEEP WATER IN THE GOTLAND DEEP FROM 1893 - 1985

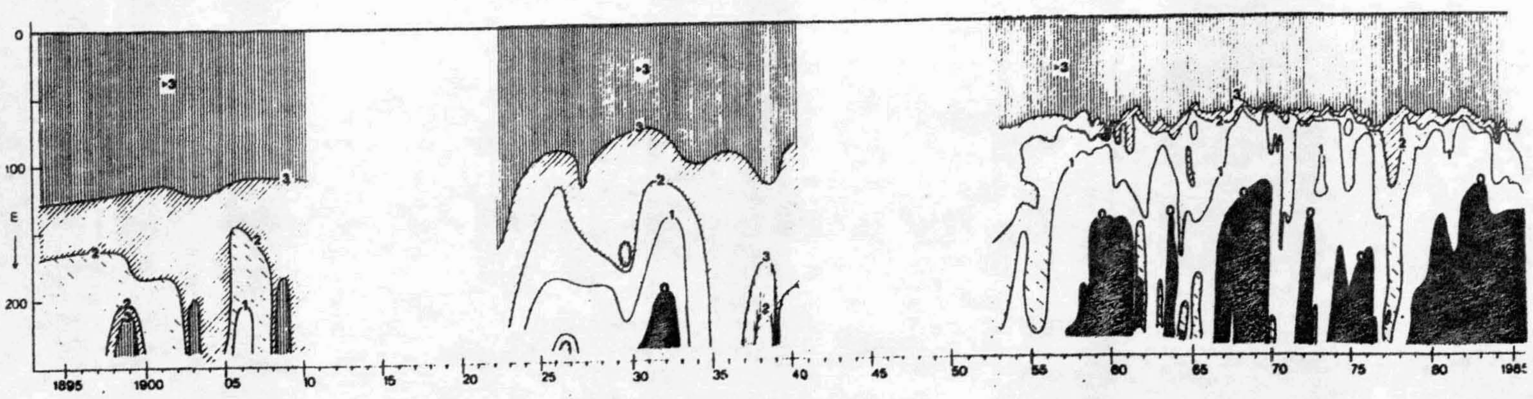


Fig. 3

O_2

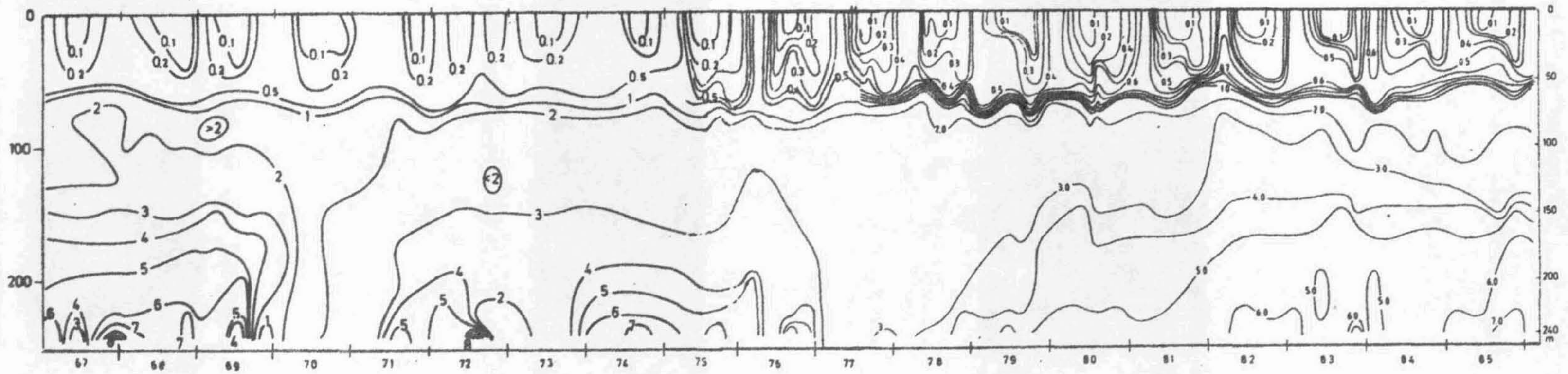
3 ml/l

3-2 "

2-1 "

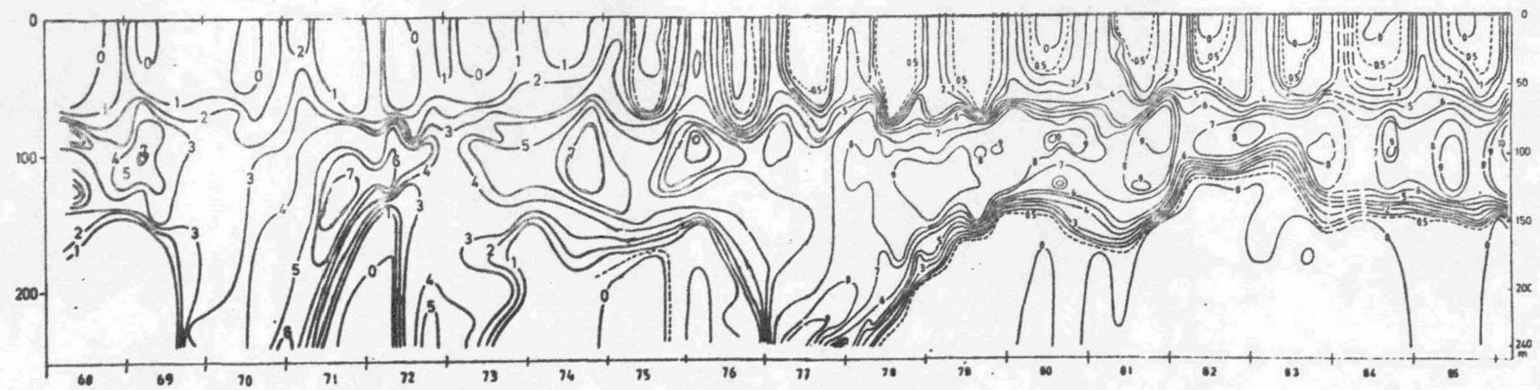
1-0 "

H_2S



St. BY 15 A The phosphate variations in µgat P/l

Fig. 4



St. BY 15 A The nitrate values in µgat N/l

Fig. 5

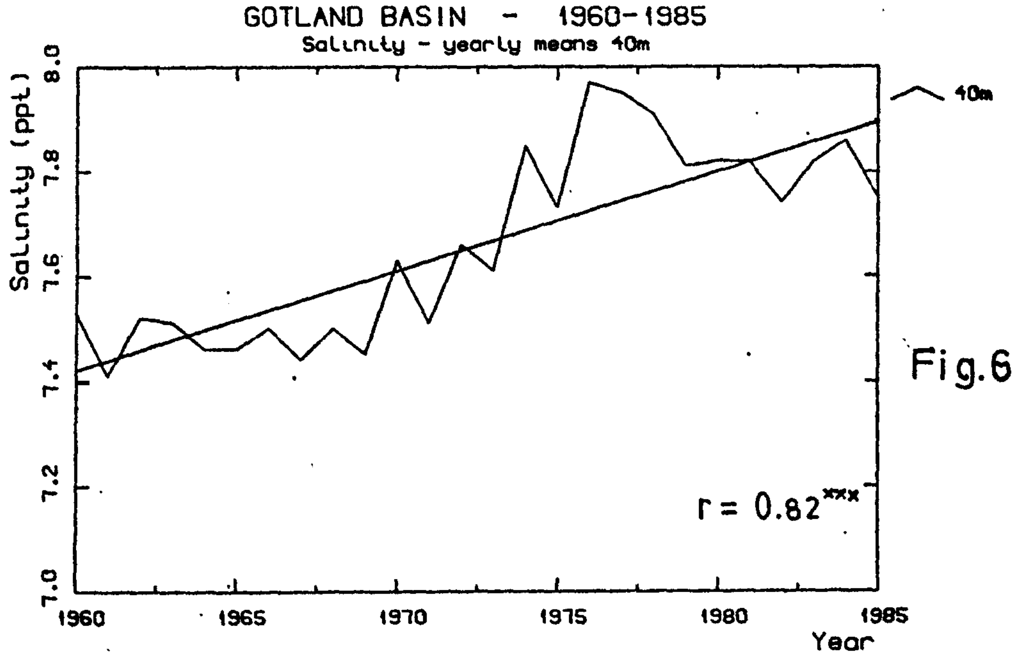


Fig.6

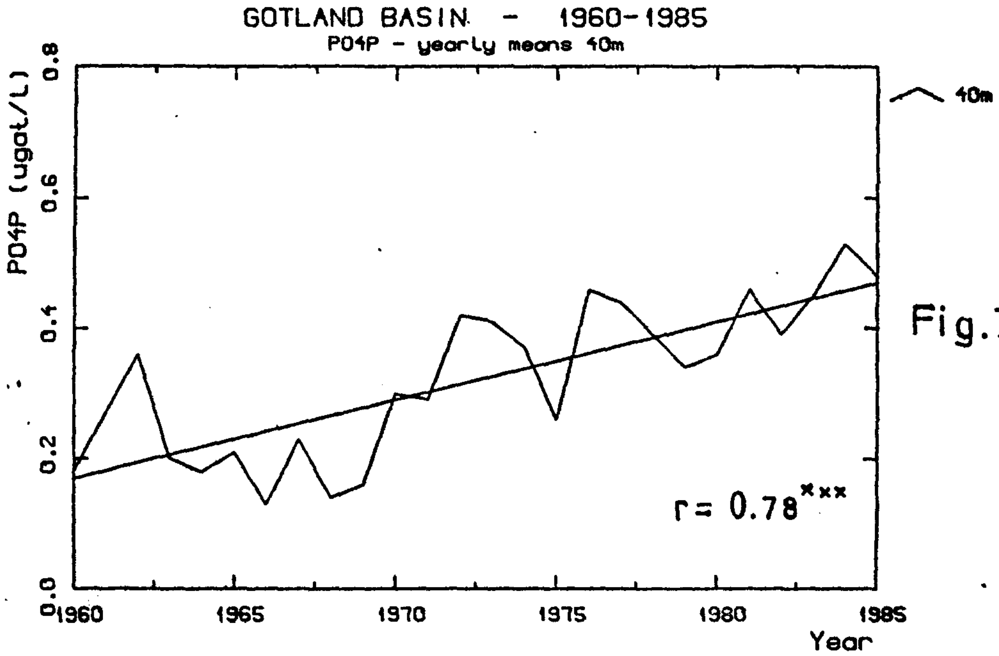


Fig.7

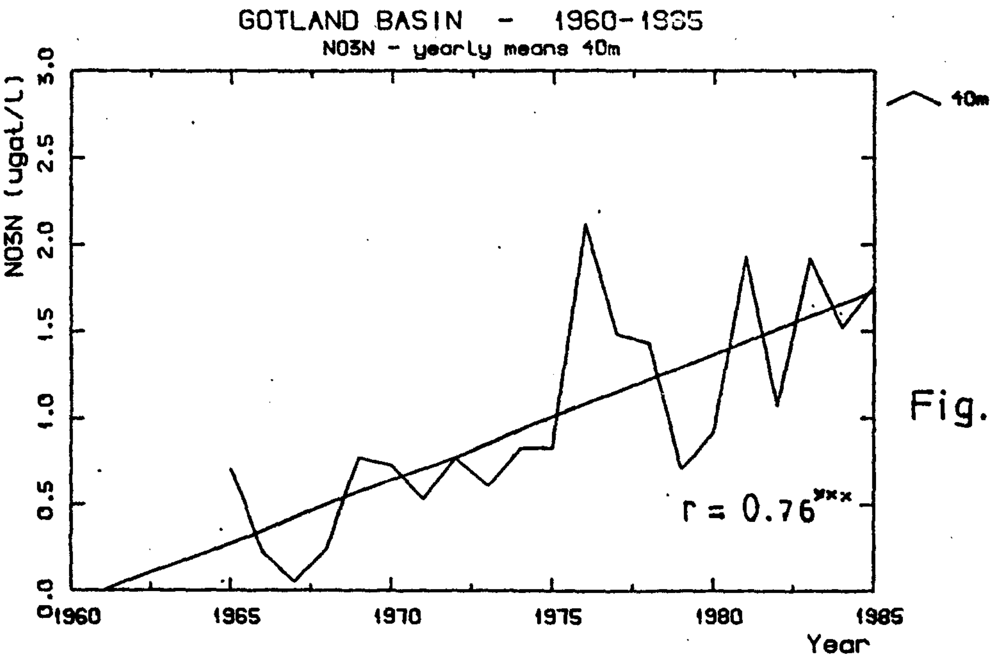


Fig.8

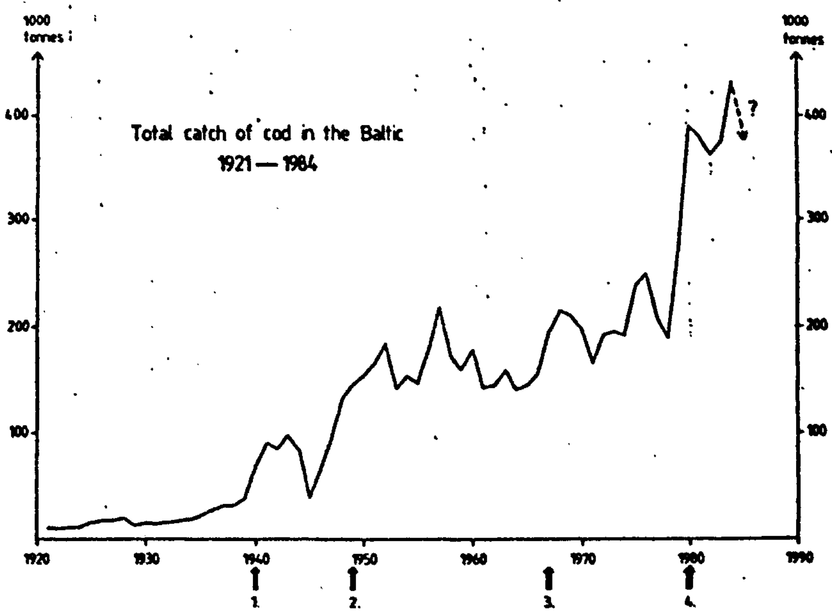
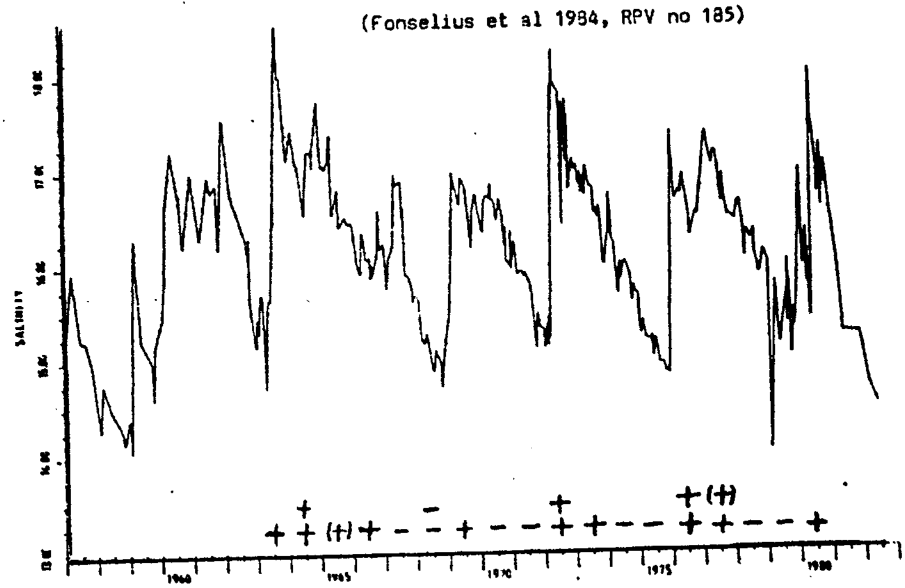


Fig.9 (Otterlind 1986)

BORNHOLM DEEP BOTTOM SALINITY 1957-1982
(Fonselius et al 1984, RPV no 185)



(Svansson 1985)

Cod year class

Good +

Very good ‡

Bad —

Very bad =

Fig.10