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Water dynamics, temperature, salinity, and oxygen level in the Baltic

by

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Abstract

On the basis of investigations carried out in the 1981-1985 period, temperature, salinity, and oxygen were analysed. Seasonal temperature and salinity anomalies were calculated.

It was found that the temperature in the upper layer in 1981 and 1982 was close to normal. Distictly warmer periods were observed in 1983 and the first half of 1984. These years were characterized by positive temperature anomalies. 1985 was the coldest year; severe winter had a great impact on the change of hydrological conditions. Lower temperatures were observed throughout the whole of 1985, not only in the upper layer but also in the deep layer.

Water salinity in the upper layer was different in each of the following three periods: 1 - salinity decrease in 1981 and 1982; 2 - salinity increase after the inflows in autumn 1982 and the turn of 1983/1984; 3 - a period of repeated salinity decrease from mid - 1984 to 1985, when minimum values were recorded. The salinity of the deep layer was characterized by an increase during the inflows of 1982 and 1983, a slight decrease in 1984, and a substantial decrease in 1985.

Oxygen level in the upper layer in the 1981-1985 period fluctuated between about 10.5 ml/l and 6.5 ml/l. Oxygen contents in the deep layer varied from year to year. In 1981-1982 until an inflow, oxygen levels were at their minimum, increasing afterwards to 2.0-6.2 ml/l. Oxygen conditions after an inflow improved at the turn of 1983/1984 but this situation did not last long. In 1985, oxygen levels ranged from 2.8 to 4 ml/l.

Introduction

In the 1981-1985 period, the Sea Fisheries Institute carried out 48 oceanographic research cruises in the Polish fishery zone. Regular seasonal investigations were conducted from the vessels "Birkut" and "Dr Lubecki". They enabled up-dated evaluation of environmental changes and served for the preparation of quarterly hydrological and fishery forecasts. Additional reconnaissance investigations made it possible, among others, to observed the inflow of October-November 1982. An extensive range

of environmental data was obtained during complex Baltic studies conducted on the research vessel "Profesor Siedlecki" in July 1981, May 1983, August-September 1983, May 1985. The use of this vessel in the Baltic made it possible to study certain physico-chemical processes and biological phenomena at a time when they were undergoing rapid changes. Investigations were carried out twice during a storm, interestings recordings of currents being obtained /Wojewódzki et al., 1985/. Upwelling and mesoscale eddies were localted /Piechura, 1985; Majewicz and Grelowski, 1985/. Twice, research was carried out during a period of stagnation of the deep layer /July 1981, August-September 1983/. In May 1983, a detailed view of water structure was acquired after the inflow of autumn 1982. Finally, in May 1985, an unusual phenomenon of advection of cold water into the deep layer after one of the most severe winters in the Baltic was observed. A total of 55 thousand information units /observations, measurements, analyses, including nutrients/ was collected. Thanks to all these investigations, the Polish fishery zone was one of the best explored areas of the Baltic in the 1981-1985 period.

Method

Water temperature was measured with Japanese and West German reversible thermometers with an accuracy of 0.01 ^{o}C, salinity - with 6230 N Plessey salinometers with an accuracy of 0.001 ^{o}/oo.

Oxygen level was determined by the Winkler method. The data collected from the "Profesor Siedlecki's" cruises was processed by means of standard programmes on the Elliot 905 computer.

The interpretation of the material collected was based on stations representing the main areas of the Polish fishery zone: station B1-IBY-5 /Bornholm Deep/, station B2 /Słupsk Furrow/, station G2 /Gdańsk Deep/. For these stations, mean water temperature and salinity values were calculated for the main months of each season in the 1958-1984 period. These values served as a basis for comparison with the values measured on specific dates.

Results

Water temperature

In the five-year period from 1981 to 1985, water temperature of the upper layer was quite diversified /Fig. 2/. In 1981-1982, seasonal fluctuations slightly departed from mean values; water temperature was higher in the spring-summer season and lower - in the autumn-winter season. The year 1983 was a distinctly warmer period, as well as the first half of 1984; 1985 was the coldest. A characteristic feature is the shape of anomaly curves in the open sea areas /Bornholm Deep, Słupsk Furrow/. Spring periods may be distinguished in the Gdańsk Deep; the highest temperature anomalies reach up to about 4°C /even in the coldest year 1985/. This is a result of the increase in tempera-

ture of the thin surface water layer in the spring, caused by the advection of water from the Gulf of Gdańsk and the Vistula /warmer at that time/.

Fig. 3 presents the water temperature anomaly curve for this part of the upper layer which is positioned directly above the halocline /winter water/. Unlike in the upper near-surface part of the upper layer, negative values of the anomaly predominate here in the five-year study period. The year 1983 is the most typical with positive thermal temperature anomalies, a result of the inflow of 1982 and, at the same time, mild winter. During the period of thermal minimum /February-March/, the temperature of the upper layer ranged in all areas in 1983 between 2 and 3°C. In the summer of that year, the highest surface water temperatures were also observed there for the five-year period: from 18.65°C in the Bornholm Deep to 20.61°C in the Gdańsk Deep.

In the deep layer /Fig. 4/, until the inflow /autumn of 1982/, negative thermal anomalies were maintained the previous inflow of 1980 was an inflow of cold water/. An increase in temperature of the deep layer during the inflow of 1982 was visible in the maximum positive anomaly /over 3°C/ in the Bornholm Deep. As a result of this inflow and the inter-layer inflow in 1983-1984, a two-year period of increased dynamics of deep layer water and maximum storing of heat could be observed in the open-sea areas /stations B1 and B2/. On the other hand, water flowing into the Gdańsk Deep and coming from intermediate layers of the Słupsk Furrow was already cooled. In November 1984, water with

a temperature of 7.03°C flowed into this area, which was visible in the positive thermal anomaly at the turn of 1984/beginning of 1985. An interesting phenomenon was the advection of cold water after the winter of 1985, especially visible in the Słupsk Furrow and the Gdańsk Deep.

Water salinity

In the salinity changes of the upper layer, three characteristic periods may be distinguished: salinity drop in 1981-1982, salinity increase in 1983-1984, as a result of inflows, and a slight drop in salinity in 1985, no doubt a result of the arrested by ice conditions exchange of water with the North Sea /Fig. 5/.

Salinity changes in the deep layer in the five-year period were similar to the changes in the upper layer /Fig. 6/. Minimum salinity was observed in the period of stagnation /1981-1982/. After the autumn inflow of 1982, a maximum value was recorded in the Bornholm Deep /18.36°/oo/ in December, and in the following months in subsequent areas to the east. The next inflow /1983/1984/ was weak and represented an inter-layer inflow; its effects were best visible in the Słupsk Furrow /salinity increase by about 2°/oo/ and the Gdańsk Deep /salinity increase by about 0,5°/oo/. Similarly, in 1985, an increase in salinity was most pronounced in these two areas; it was a result of increased dynamics of intermediate layers and advection of cold water.

Oxygen level in the deep layer

Changes in oxygen level at the bottom corresponded more or less to salinity changes in this layer /Fig. 7/. As far back as 1981, the oxygenation of the main areas was relatively good after the two inflows of 1979 and 1980. However, already in May 1981, a period of stagnation began. In July, the near-bottom layer with a thickness of 25 m in the Bornholm Deep contained less oxygen than 1 ml/l. In the Gdańsk Deep this layer was even thicker /30 m/, and bottom sediments from both areas contained sulphuratted hydrogen /Piechura, 1985/. In the Słupsk Furrow, oxygen level in the spring and summer of 1982 was 0.48 and 0.78 ml/l, respectively. According to our measurements, these were the lowest values in this area in the whole 25-year period. After the autumn inflow of 1982, beginning with the Bornholm Deep, a gradual improvement in oxygen situation was observed. In the Bornholm Deep our measurements /1982.12.18/ showed a level of 6.20 ml/l. Such a high oxygen level remained there for a very short time due to oxygenation processes; besides, the volume of inflow water was lower than expected and it quickly underwent transformation. After the next inflow /an inter-layer one/ of 1983/1984, oxygen conditions improved for a short time in the Bornholm and Gdańsk Deeps /reaching 4 and 2 ml/l, respectively/. In the former area, already in May and until the end of the year, only trace quantities of oxygen were noted. Into the Gdańsk Deep, already in November, water from the Słupsk Furrow was transported thanks to dynamic processes at the bottom and

oxygen level increased to 2.8 ml/l. Further increase to over 4 ml/l was a result of advection of cold water in May 1985.

Conclusions

In the 1981-1985 period, thanks to intensive investigations of the Polish fishery zone, it was possible to observe the most important changes of main hydrological characteristics, and - quite often - the processes responsible for their appearance. The results of these studies formed a background of environmental conditions which enabled a better understanding and explanation of many biological changes as well as development and trends in fish stocks. The most valuable results were collected in July 1984 on the "Profesor Siedlecki". They constituted material for comparisons of results in the following years, including those coming from three cruises of the "Profesor Siedlecki". In each of those cruises, interesting mesoscale phenomena or processes were encountered. This was possible thanks to a dense network of stations investigated within a short time /quasisynopticity of investigations/. In the five-year period under discussion, one of the most important facts was no doubt the almost two-year period /1983-1984/ of optimum thermal, oxygen, and salinity conditions for biological life in the Baltic after the inflows, and the exceptional cooling of the deep layer in 1985. It appears from the analysis of data that the Polish fishery zone is characterized by relatively good environmental conditions

with the exception of the deepest part of the Bornholm Deep. The Słupsk Furrow maintained good oxygen conditions in the whole five-year period, with the exception of spring and summer of 1982. In the Gdańsk Deep, water advection processes from the Słupsk Furrow /the strongest in autumn of 1984 and spring of 1985/, independent of inflows, were observed several times. Thanks to them, salinity and oxygen in this area were relatively good.

Literature

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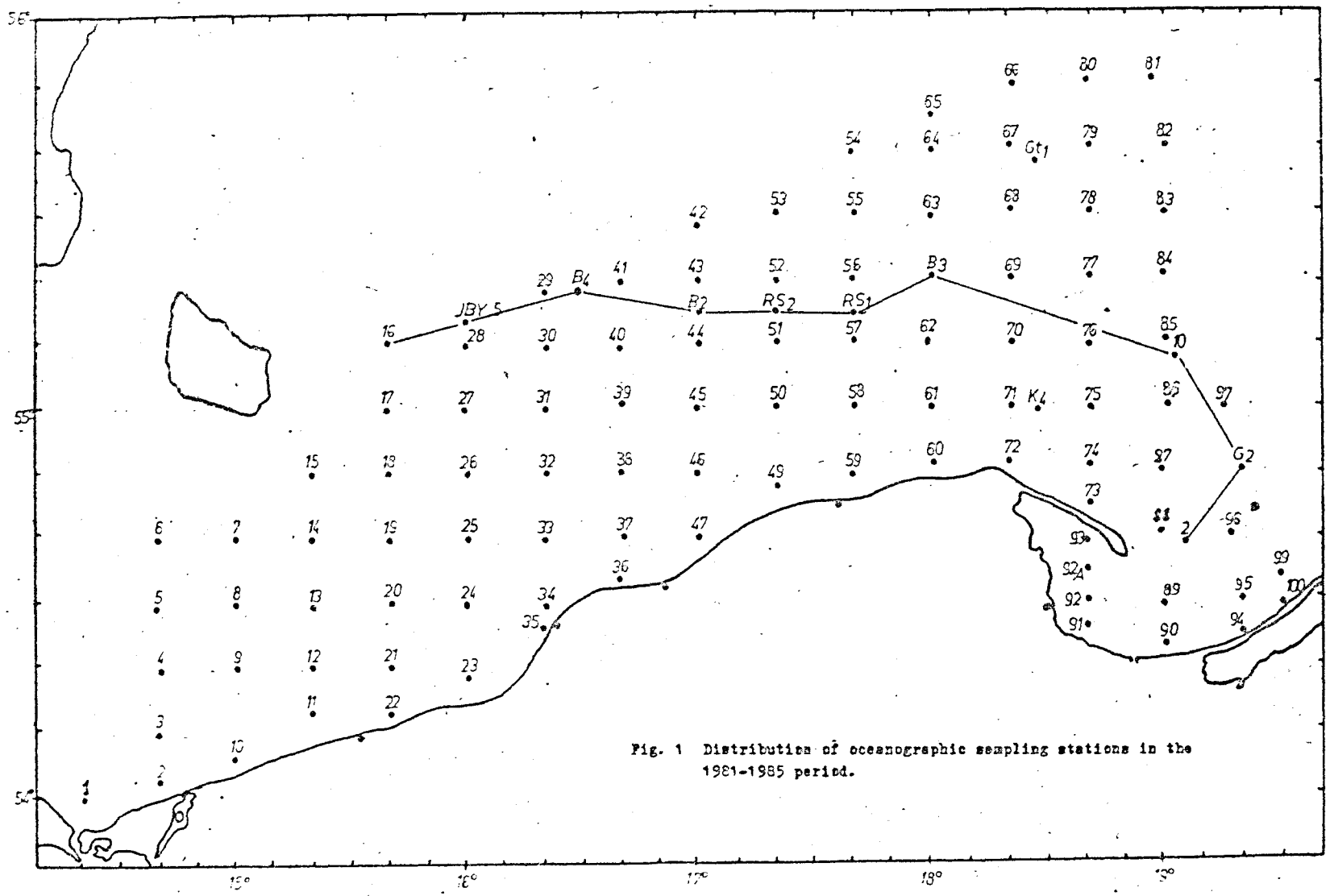

Fig. 1 Distribution of oceanographic sampling stations in the 1981-1985 period.

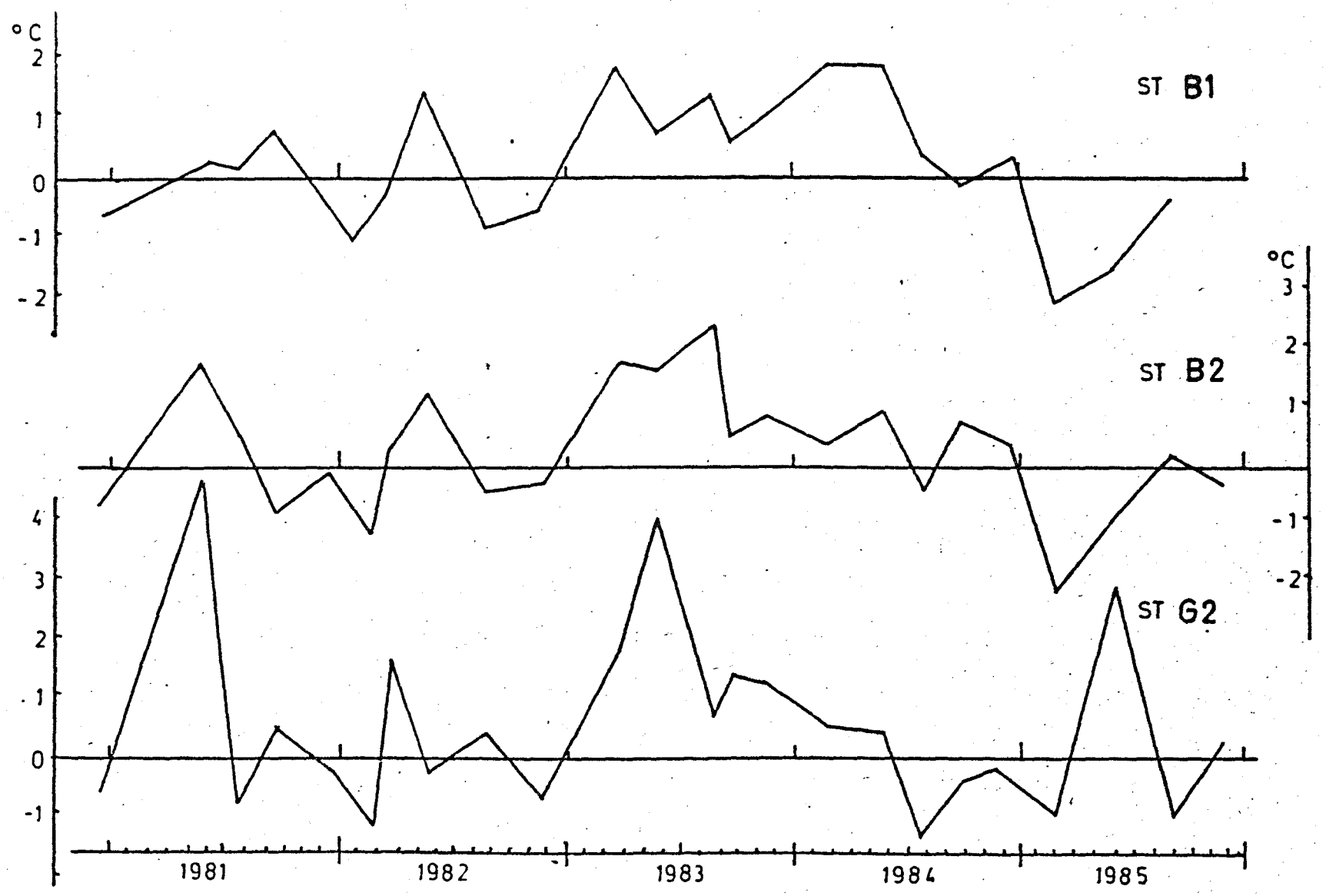

Fig. 2 Surface water temperature anomalies /$\pm\Delta t$, °C/ in the main areas of the Polish fishery zone

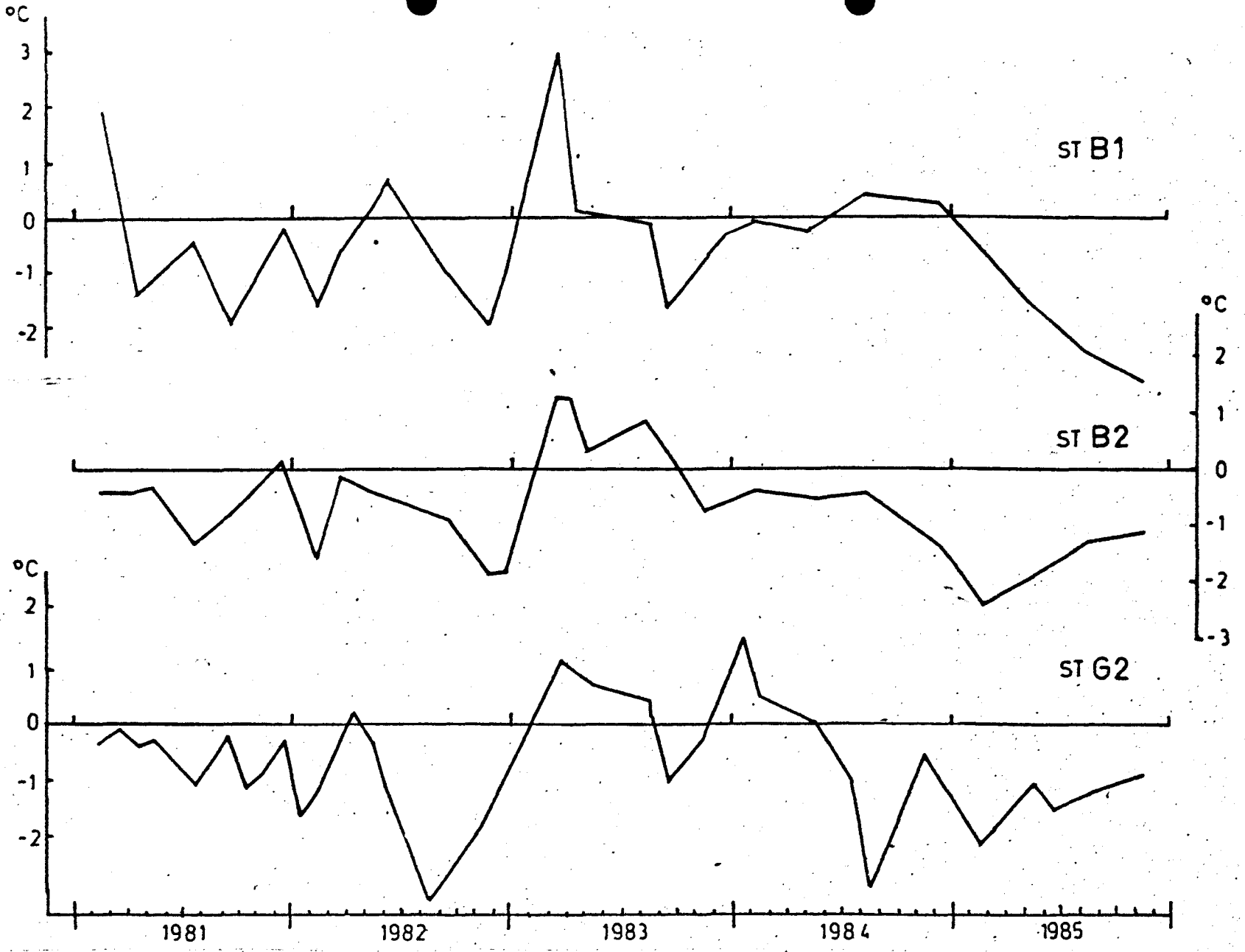

Fig. 3 Water temperature anomalies /$\pm\Delta$ t, ^{o}C/ of the upper layer /above the halocline/ in the main areas of the Polish fishery zone.

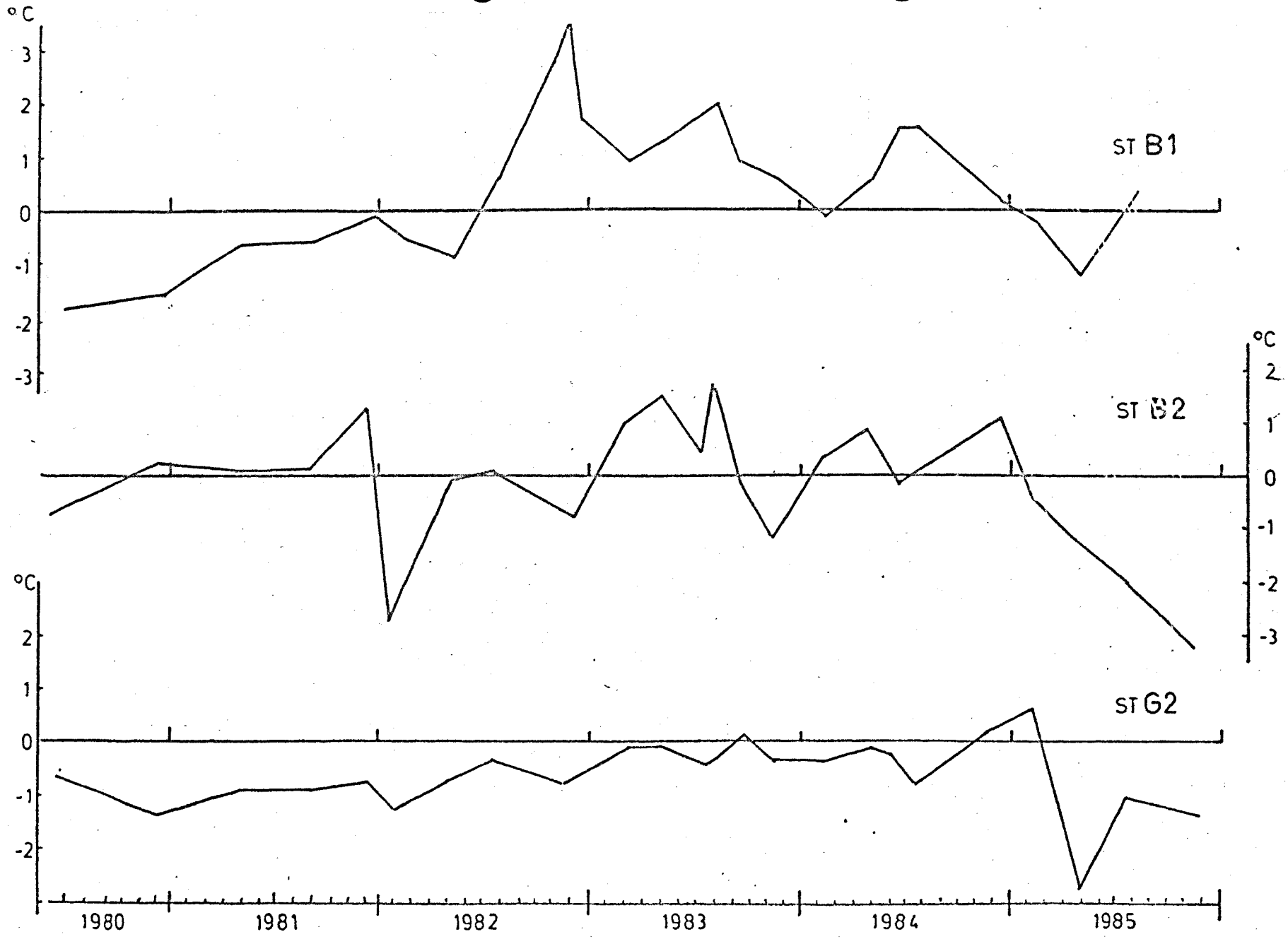

Fig. 4 Temperature anomalies /$\pm\Delta t$, °C/ of the deep layer in the main areas of the Polish fishery zone.

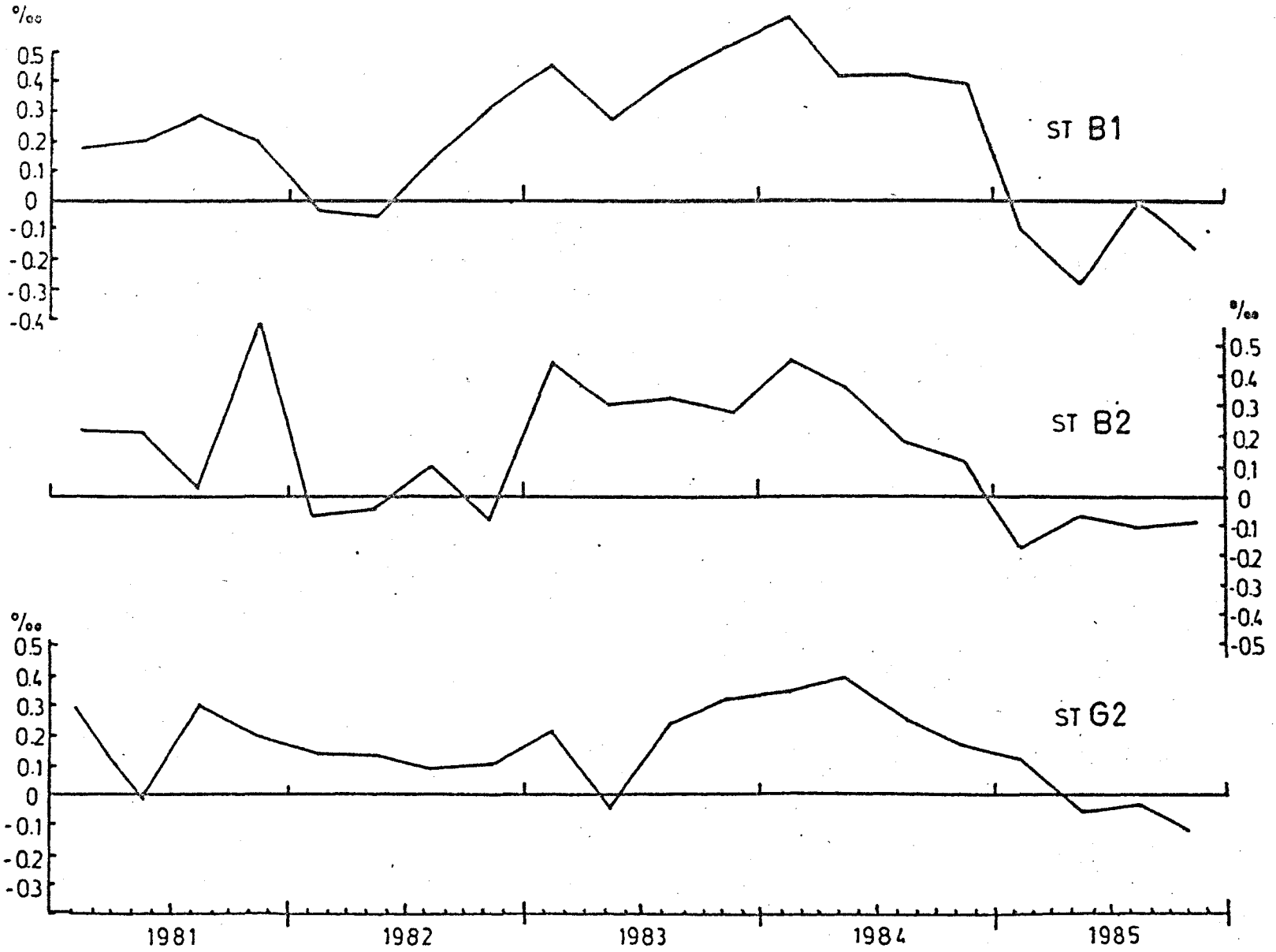

Fig. 5 Salinity anomalies /±Δs, °/oo/ of the water surface in the main areas of the Polish fishery zone.

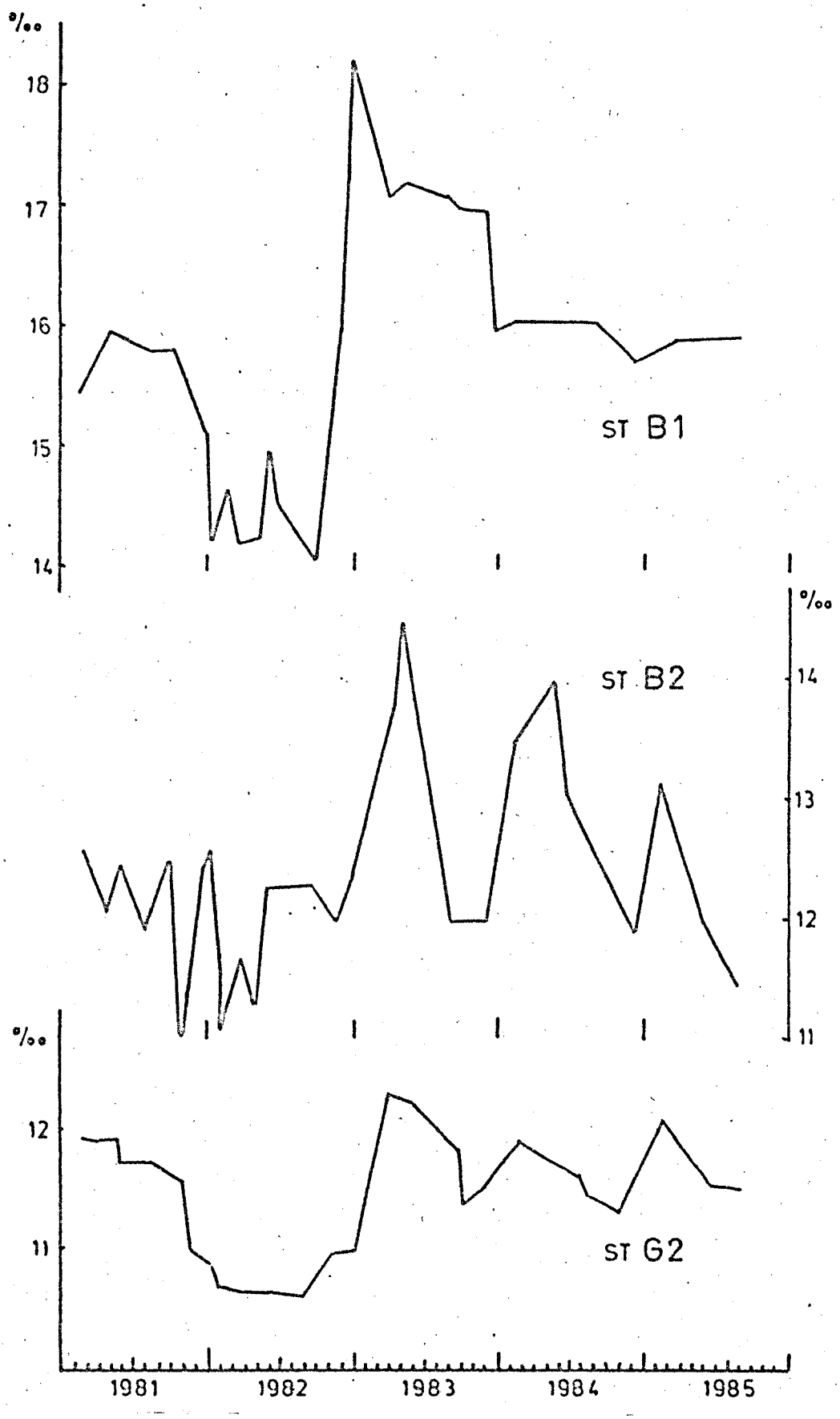

Fig. 6 Salinity at the bottom in the main areas of the Polish fishery zone.

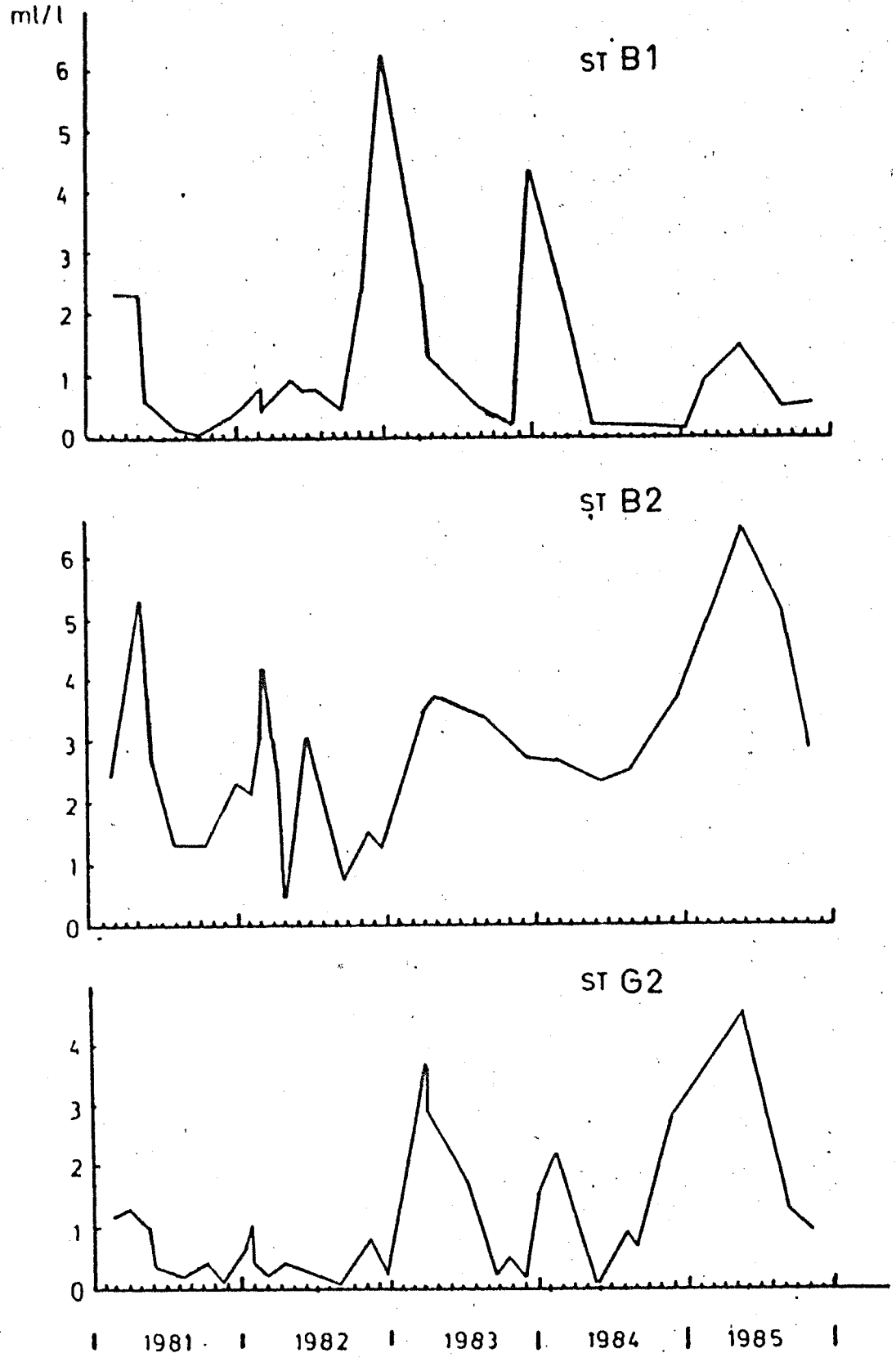

Fig. 7 Oxygen level at the bottom in the main areas of the Polish fishery zone.