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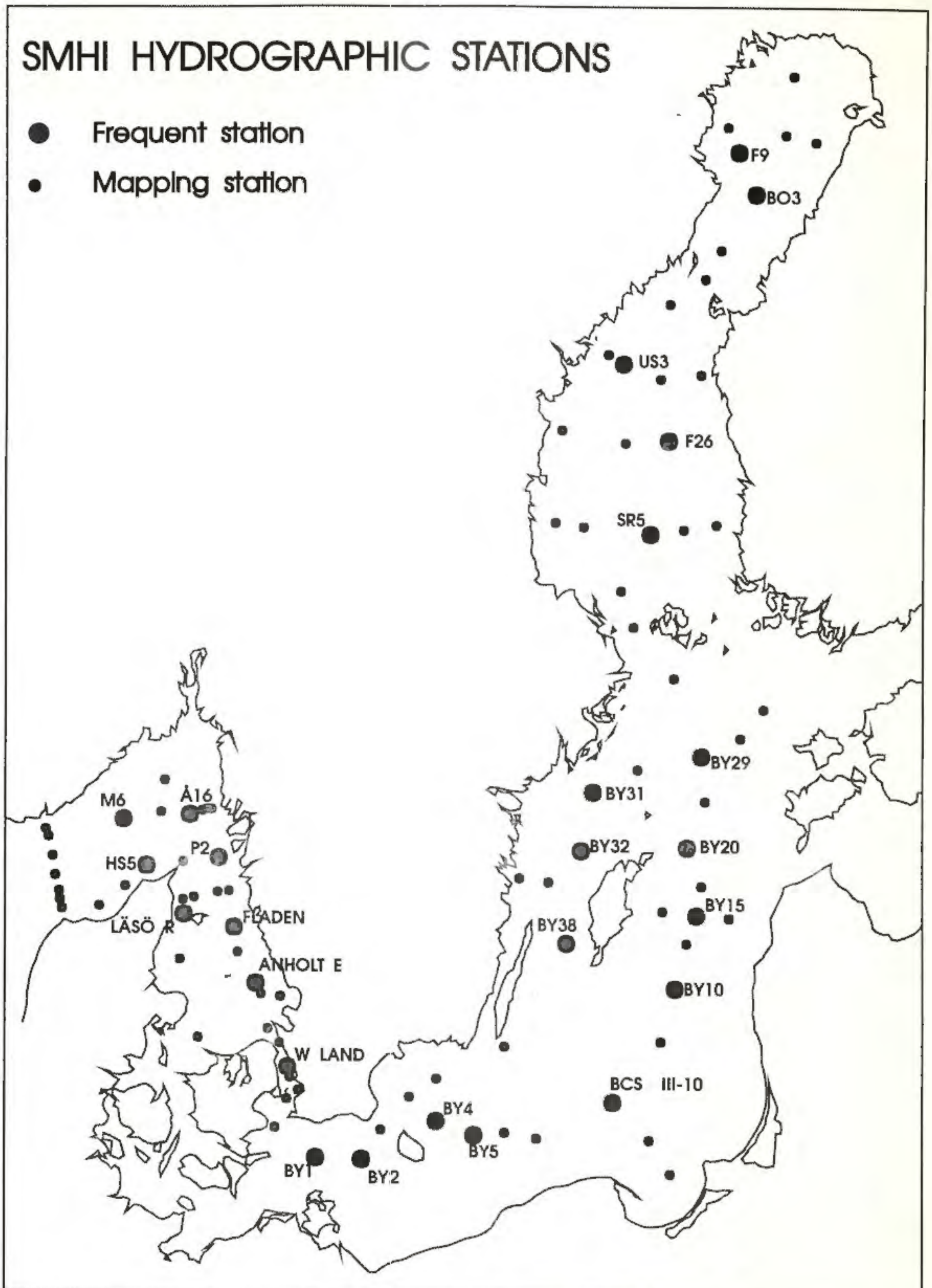
No 20, 1994

THE CONDITIONS OF THE SEAS AROUND SWEDEN

Report of the activities in 1993

Lars Andersson, Björn Sjöberg and Mikael Krysell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SMHI REPORTS OCEANOGRAPHY No 20, 1994

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Report of the activities in 1993

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Abstract

This report describes some basic aspects of the hydrographical conditions in the open sea areas around Sweden, based on SMHIs environmental monitoring program during 1993. A new monitoring program has been implemented, consisting of two types different types of stations. First, frequent stations which are few but have a high sampling frequency making it possible to resolve annual variations. Secondly mapping stations visited only a few times per year as to asses, oxygen conditions in the Kattegat and the Baltic deep waters and the pool of nutrients during the pre bloom season.

The most interesting event during 1993 was the large inflow of salt water to the Baltic that occured in the beginning of the year. As a result the deep water in the East Gotland Basin was renewed and oxygenated for the first time since 1978.

Key words

Baltic Sea, Skagerrak, Kattegat, Baltic monitoring Program, oceanography, temperature, salinity, oxygen conditions, hydrogen sulphide, nutrients

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CONTENTS

1. Introduction

This report describes the hydrographical conditions in the open sea ares around Sweden during 1993. The results are derived from data collected within SMHIs environmental monotoringprogram.

SMHI Oceanographical Laboratory is carrying out a comprehensive investigationg activity in the open seas around Sweden, from the Skagerrak to the northern most part of Bothnian Sea. The objectives are;

> - to persistently and for a long term collect hydropgraphical data of known quality in order to faciliate studies of climatic change, including human influence on the marine invironment
>
> - to annualy account for oceanographical events of importance especialy the water exchange between the Kattegat and the Baltic and the oxygen conditions in the bottom waters of southern kattegat and southwestern Baltic Proper.
>
> - to produce and deliver oceanographical data and reports nationally and internationally especially to the swedish NSEPA, the National Board of Fisheries, HELCOM, IOC and ICES

During 1993 the laboratory has implemented a new sampling strategy and a new monitoring program. The new program consist essentially of two types of stations, frequent and mapping stations. At frequent stations we try to attain a high samping frequency as to resolve annual variations within different subareas. Mapping stations are only visited few times per year as to asses, the oxygen situation in the south of Kattegat and in the Baltic Proper and the pool of nutrients during winter.

The single most important event during 1993 was the large inflow of salt water from Kattegat to the Baltic in the beginning of the year. The first major inflow since 1977! As an effect of the inflow the deep water in the Gotland Bassin was renewed and oxygenated for the first time since 1978.

2. Weather and ice conditions

The beginning of 1993 was characterized by strong winds, mild weather with surface water temperatures well above mean. In April there was a quick change from cold spring to high summer temperatures, one can in fact say that the summer 1993 occurred already in May. During June the weather became more unstable and the warming of the sea ceased. The weather during the rest of the summer continued to be relatively cold and unstable, and the sea surface temperatures dropped below normal values. October was the fifth consecutive month with both air and water temperatures below mean. The cooling of the sea stopped however, and in November the surface temperature was again back to normal.

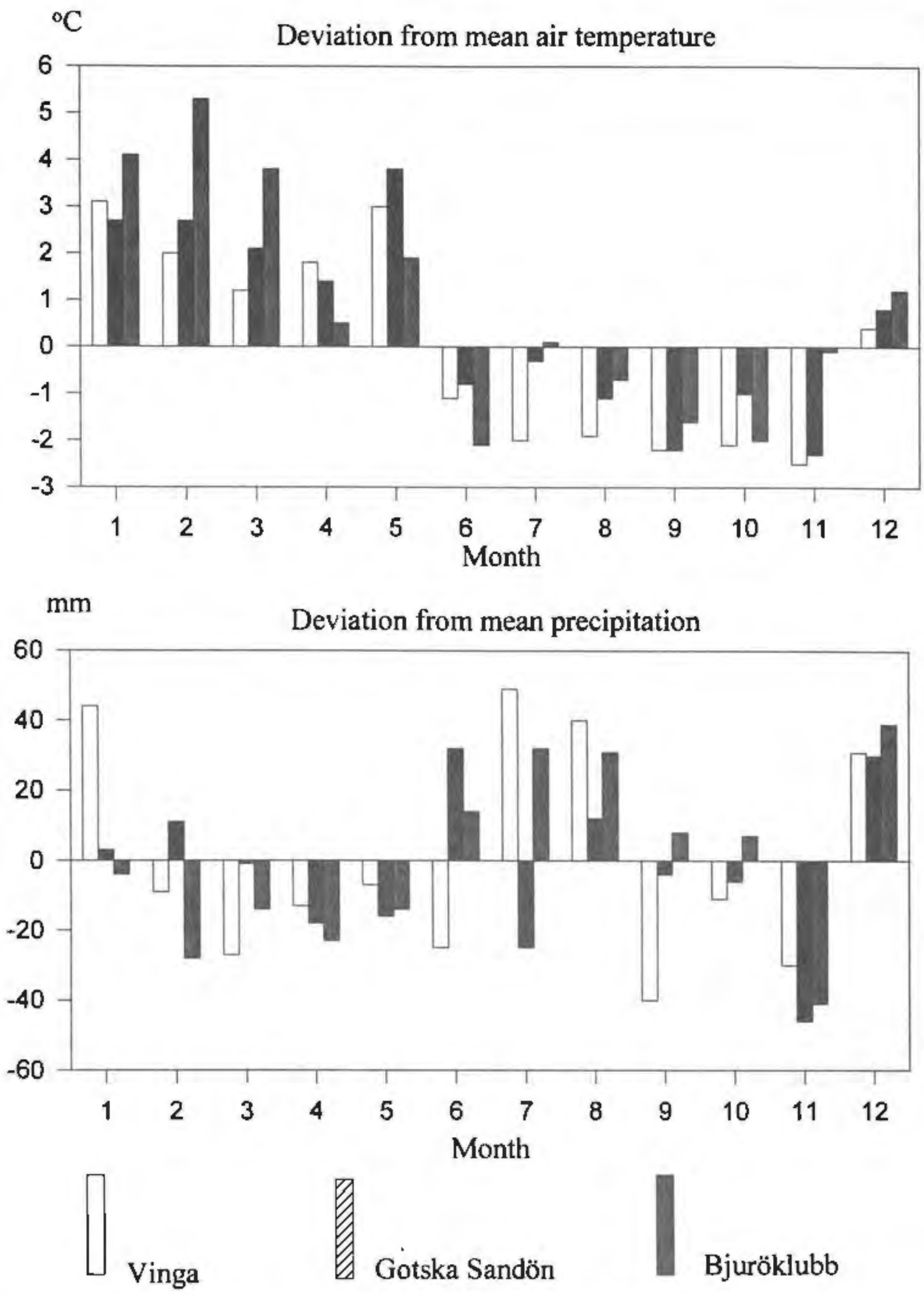


Figure 2.1 Deviation from mean air temperature and deviation from mean precipitation at three different stations, Vinga on the west coast, Gotska Sandön in the Baltic and Bjuröklubb at the coast of the Bothnian Bay.

In the southern part of Sweden there was a peak in the runoff from land already in January. The rest of the winter and the spring was characterized by values close to or below normal. In the end of July there was a marked peak with a runoff, three times the normal. August and December had small peaks while the rest of the autumn was characterized by low runoff. In the north the runoff was normal or above normal the whole year. March and October had small peaks while the runoff during July was twice, and during August four times, the normal.

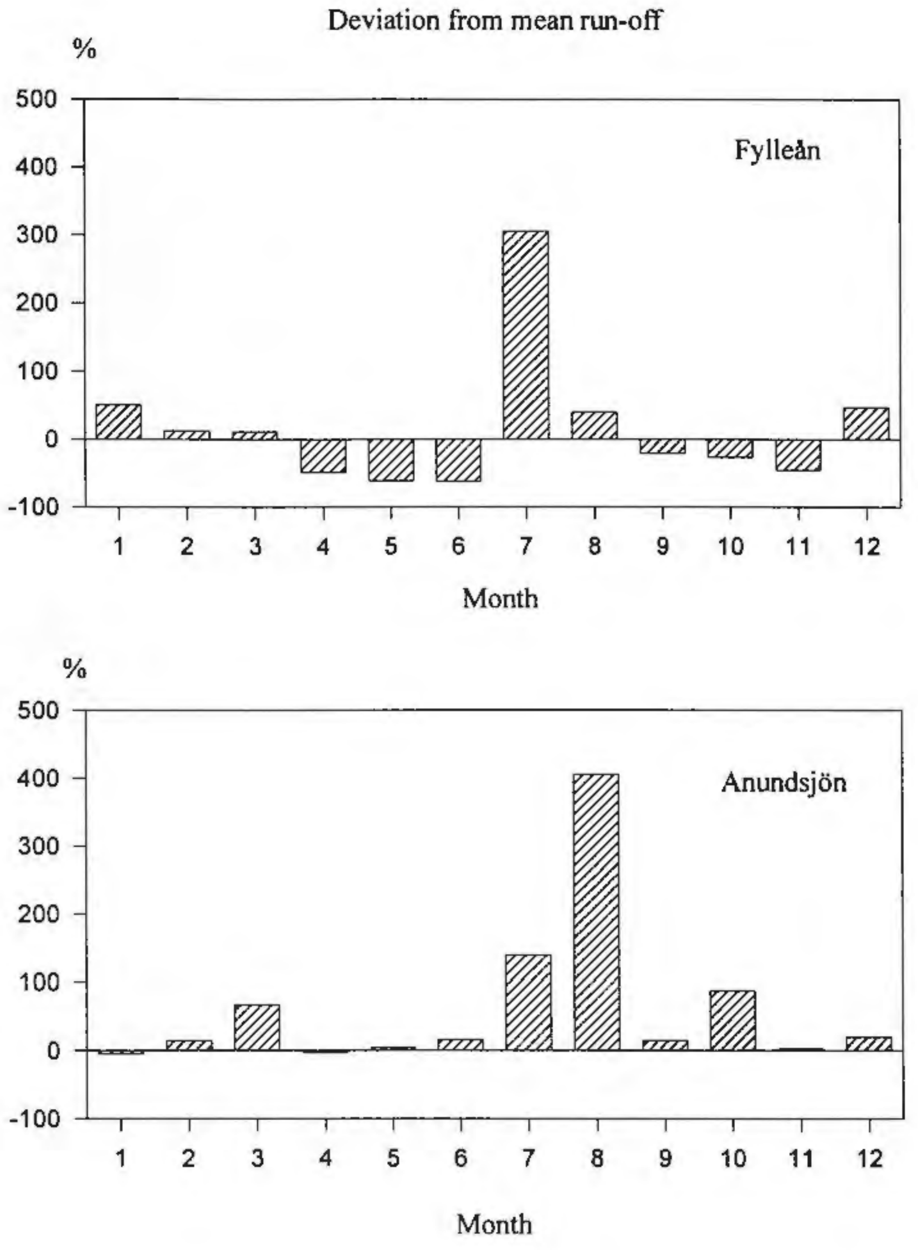


Figure 2.2 Deviation fom mean runoff, Fylleån in the southwestern, and Anundsjön in the northeastern part of Sweden.

For the sixth consecutive winter the ice conditions were very easy. However, the ice started to develop very early but the freezing process stopped. Then the ice extent really started to grow in early February and reached its maximum in the end of the month when the Bothnian Bay and the Quark were coverd with ice. In March the ice drifted over to the Finnish side of the Bothnian Bay and the water was relatively open at the Swedish coast. The ice drifted back to the Swedish coast in early April and there was even a developmet of new ice. The weather became warmer in mid April and the ice started to melt and in late May the waters were completely ice-free.

Figure 2.3 Maximum ice extent during the winter 1992/1993.

3. Oceanographic conditions during 1993

3.1 Skagerrak

In the beginning of April, the conditions were normal for the season in the whole area. During late summer and early autumn the surface water was colder than normal, while the salinity was higher than the mean for the years 1981 to 1990. However, in the southeastern part the surface water was clearly influenced by the outflow from Kattegat and the situation more variable. In the surface layer in the central area nutrient concentrations were slightly below mean during the whole year (April-December). Along the coast of Jylland all nutrients, and especially silicate showed very low values during summer and autumn.

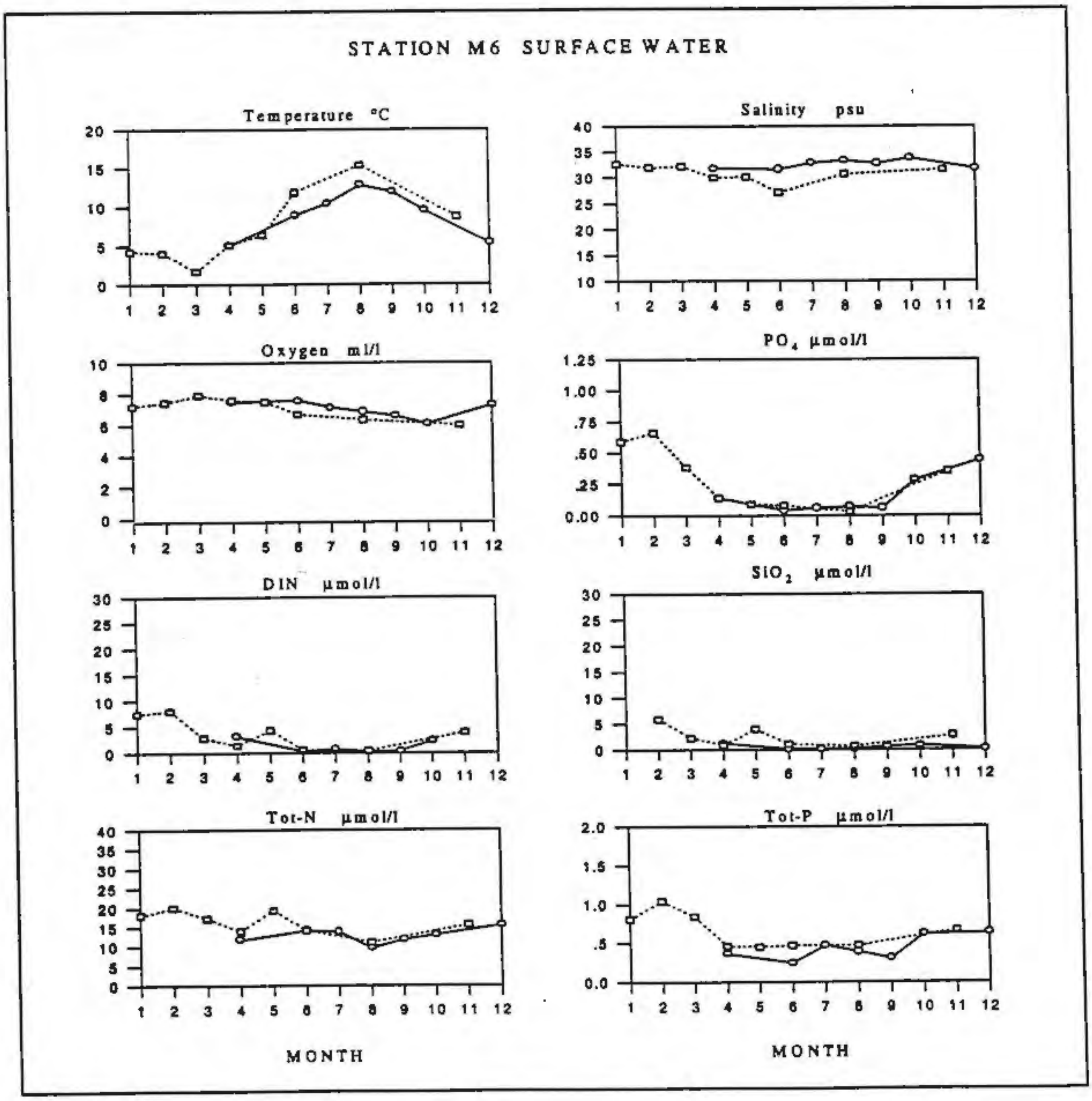


Figure 3.1.1 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station M6 in central Skagerrak.

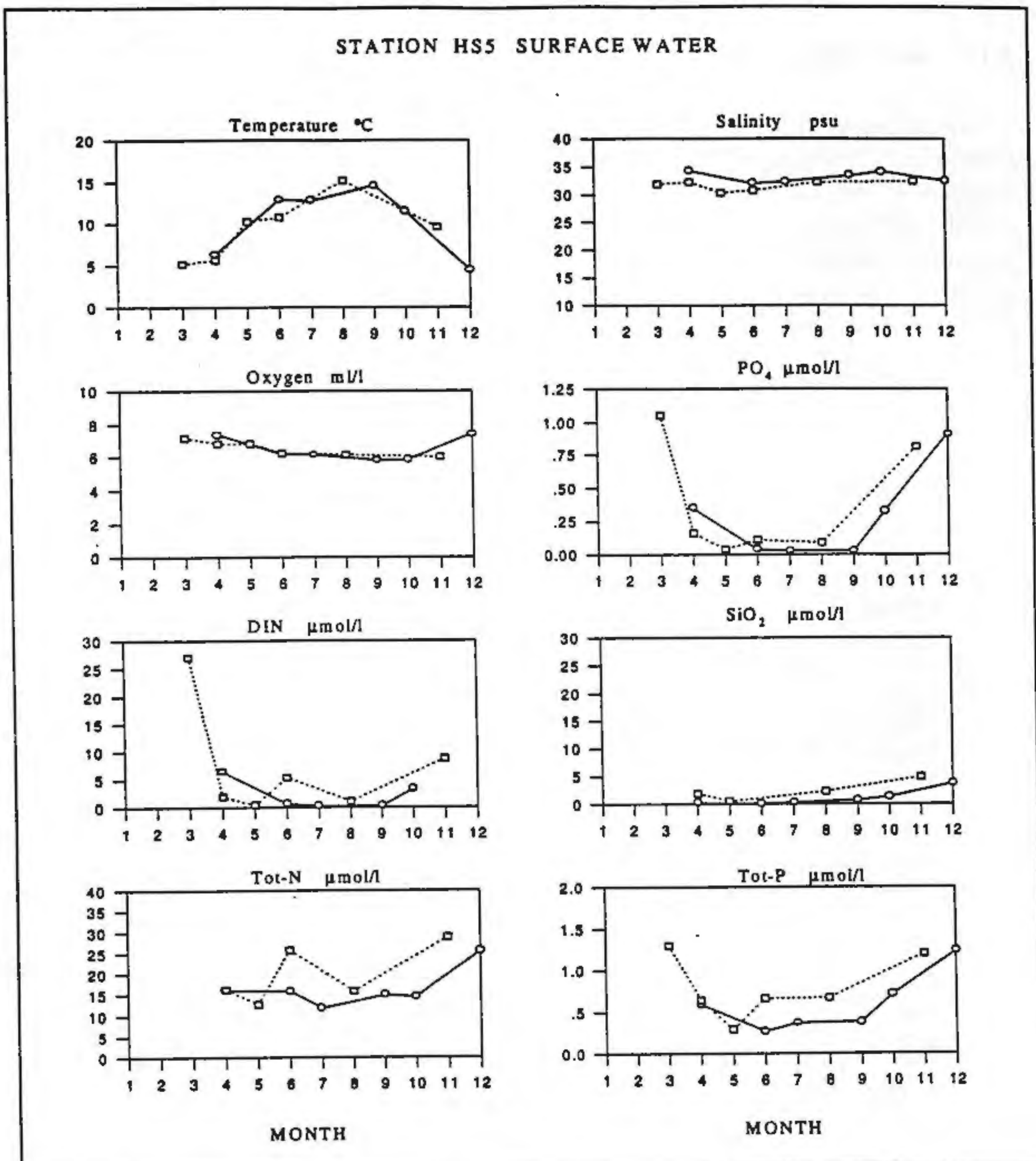


Figure 3.1.2 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station HS5 in southern Skagerrak.

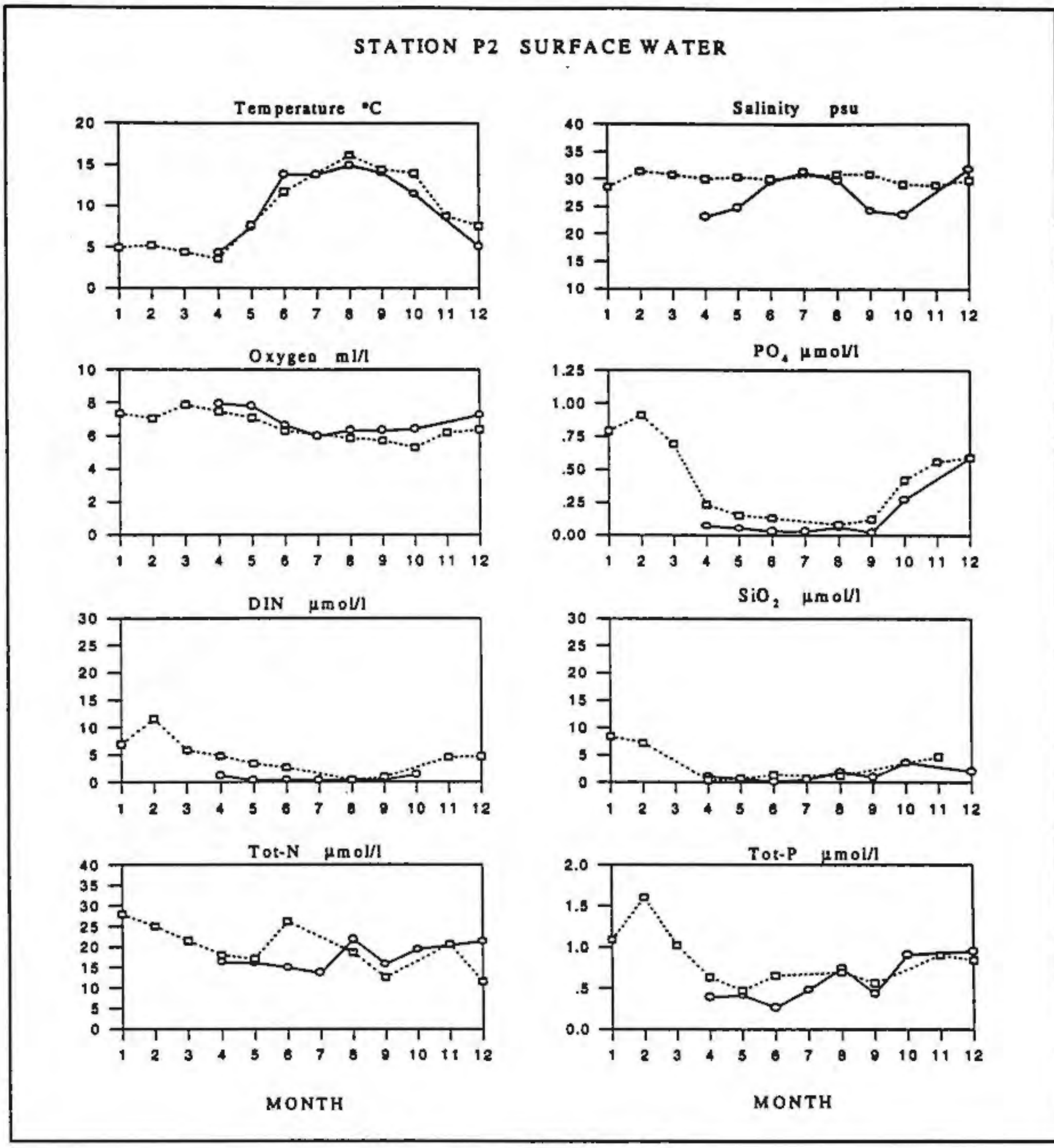
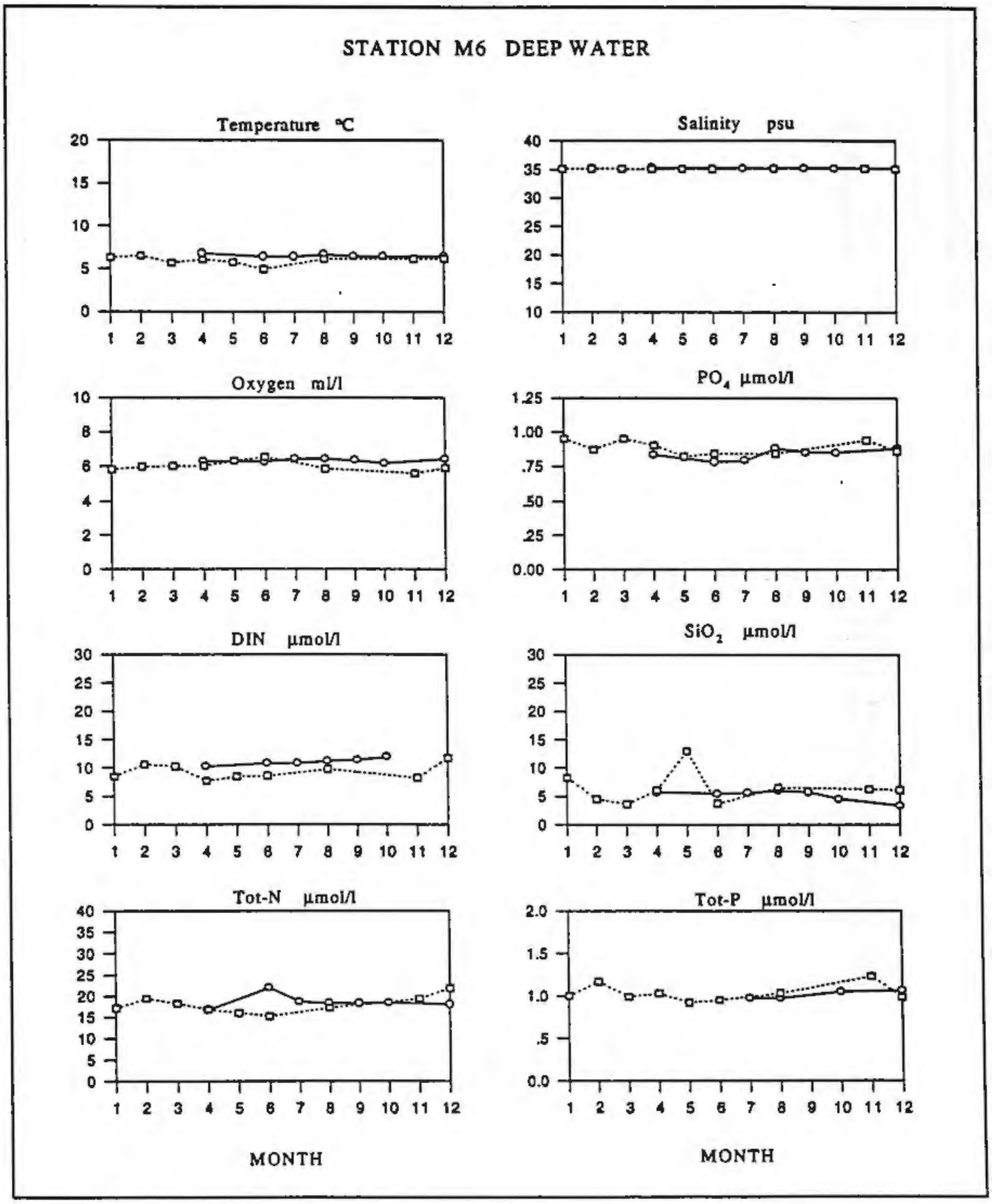


Figure 3.1.3 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station P2 in southeastern Skagerrak.

The temperatures in the Skagerrak deep water, 400 m, was about 0.5 degrees above mean most of the year. The oxygen concentration and the amount of dissolved inorganic nitrogen DIN ($DIN=NO_2+NO_3+NH_4$) were higher than normal while the concentration of phosphate was slightly below mean. In the deep water, 75 m, in the southeastern part the concentrations of silicate and phosphate were below normal during the period May to December, while DIN concentrations were close to mean.



Figures 3.1.4 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station M6 in central Skagerrak.

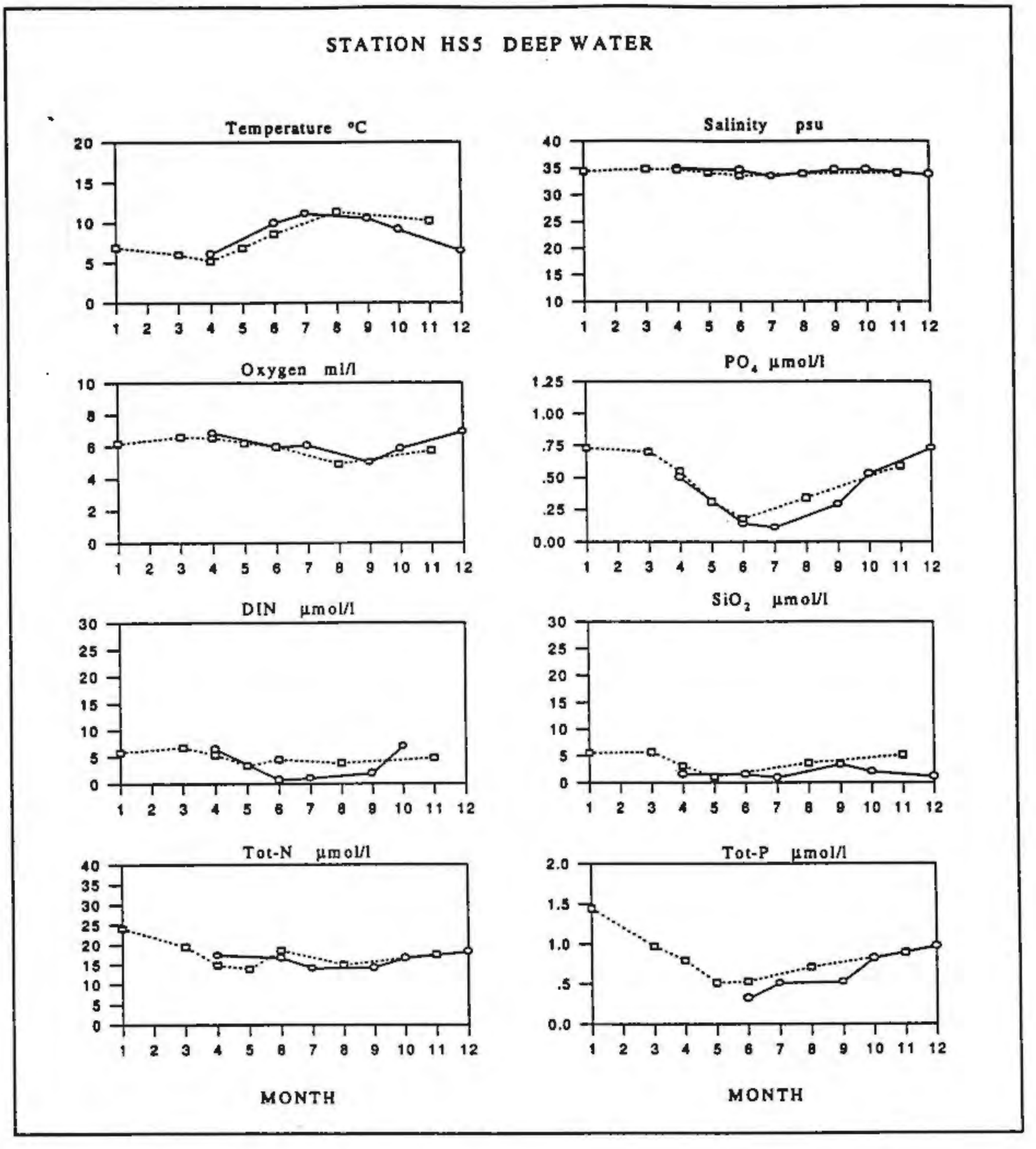


Figure 3.1.5 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station HS5 in southern Skagerrak.

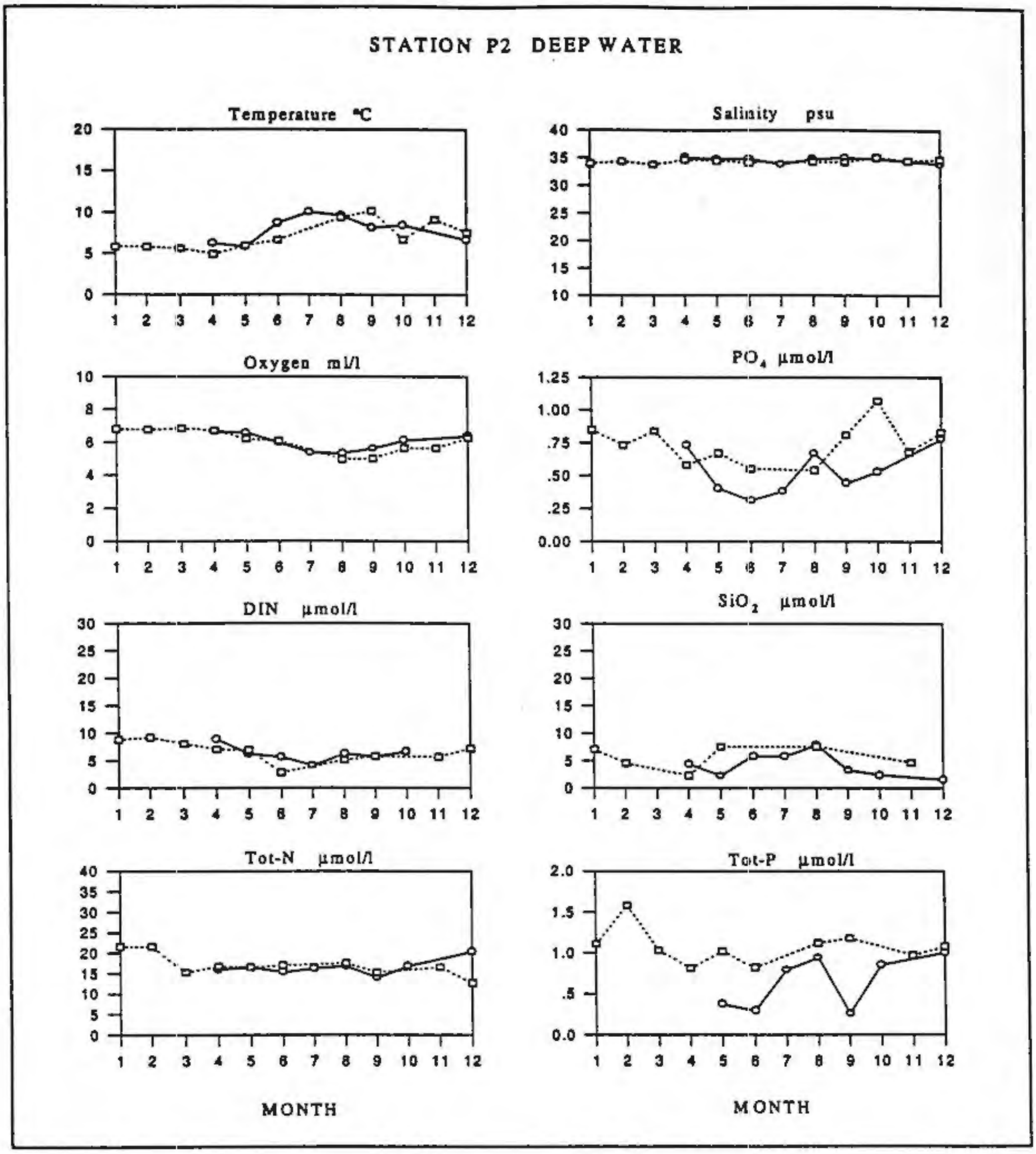


Figure 3.1.6 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station P2 in southeastern Skagerrak.

3.2 Kattegat and the Sound

In the surface layer, the temperature followed the mean annual cycle throughout the year. The salinity however had a peak in the beginning of the year but was lower than mean in the later part. The spring bloom emptied the pool of nutrients in the surface layer in late February and early March. During the rest of the year the nutrient concentrations were clearly below the mean values for the period 1981-1990.

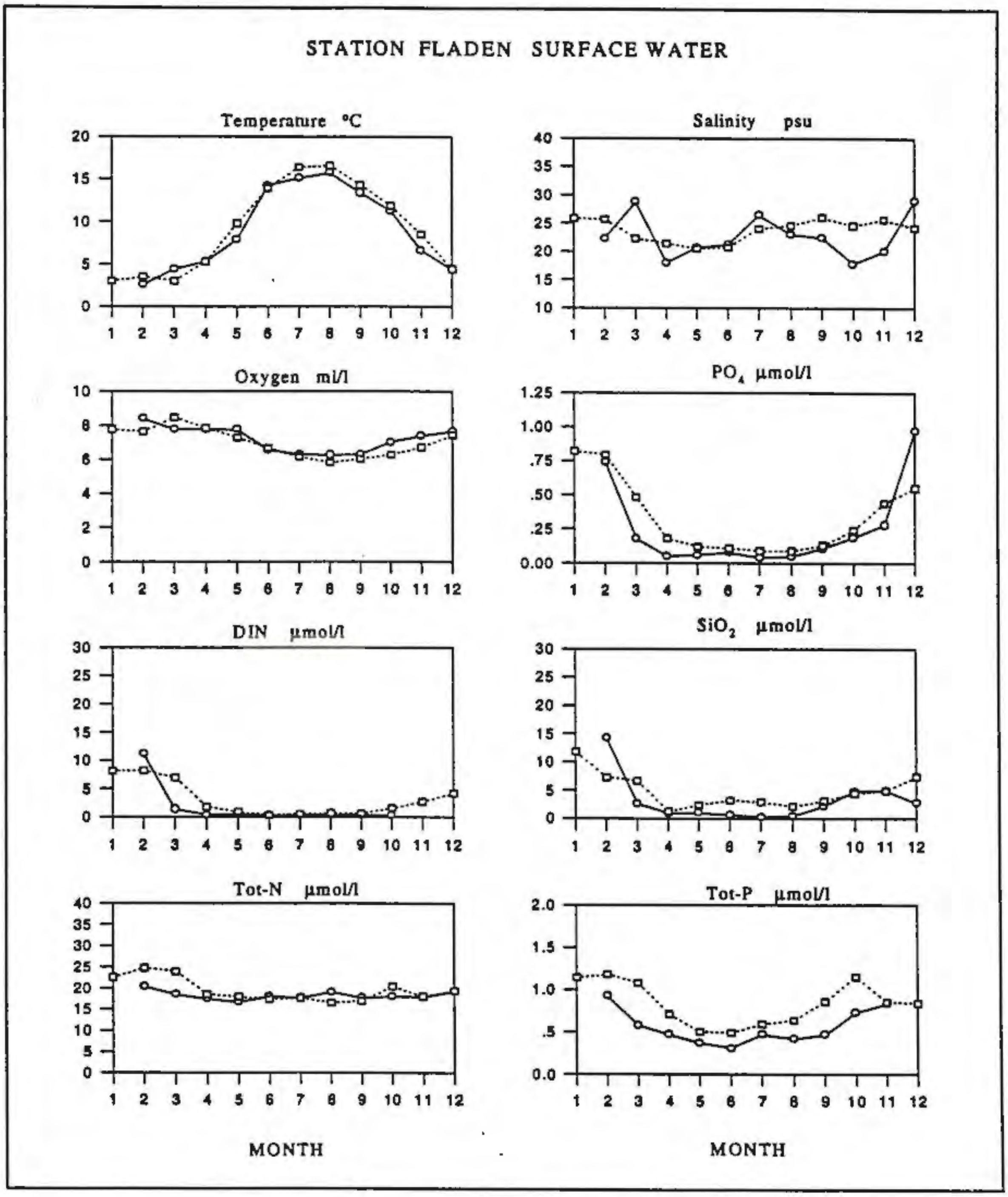


Figure 3.2.1 Monthly mean values 1993, solid line, compared to the mean annuacycle for the years 1981-1990 , dotted line. Station Fladen in northern Kattegat.

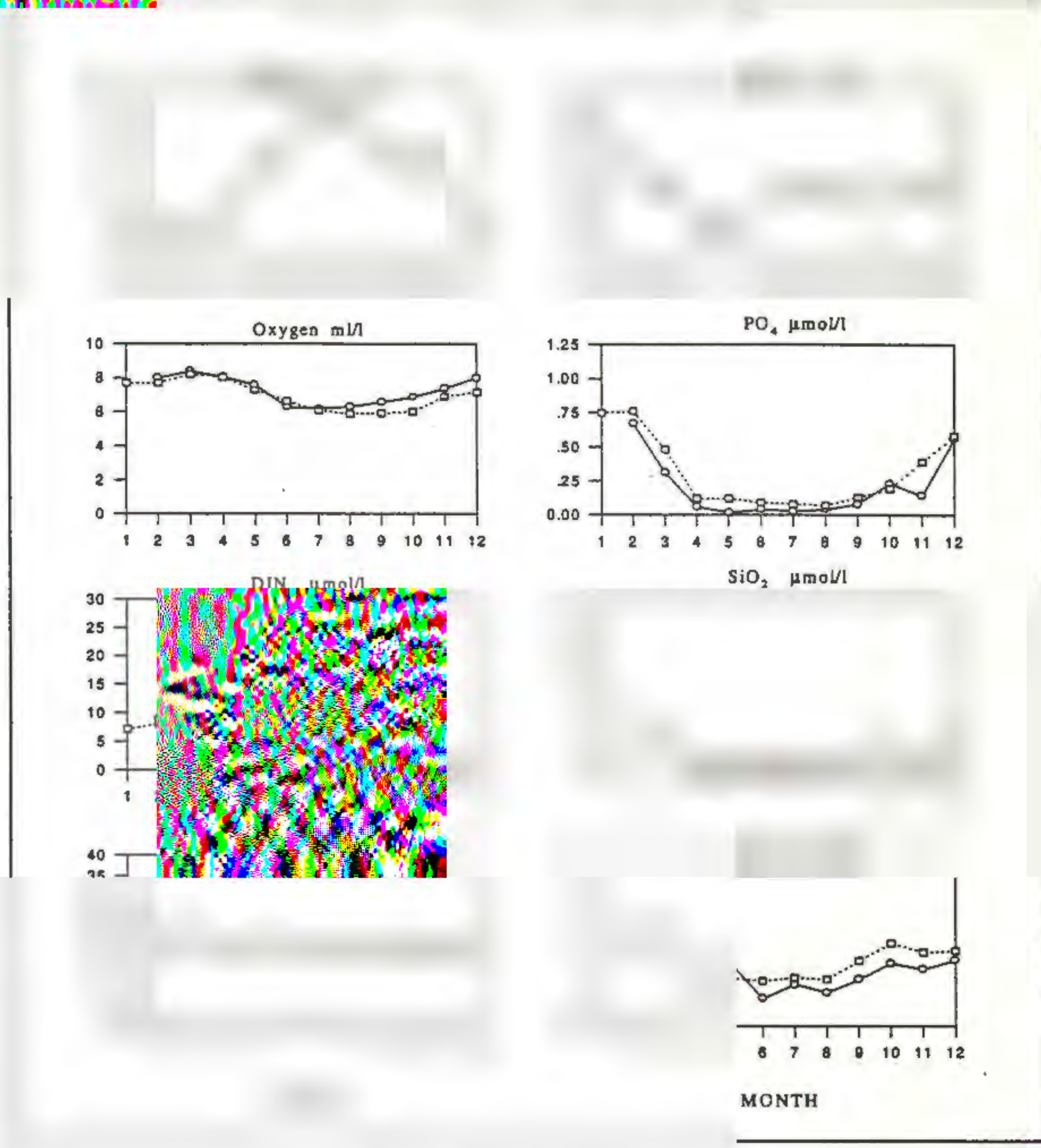


Figure 3.2.2 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station Anholt E in southern Kattegat.

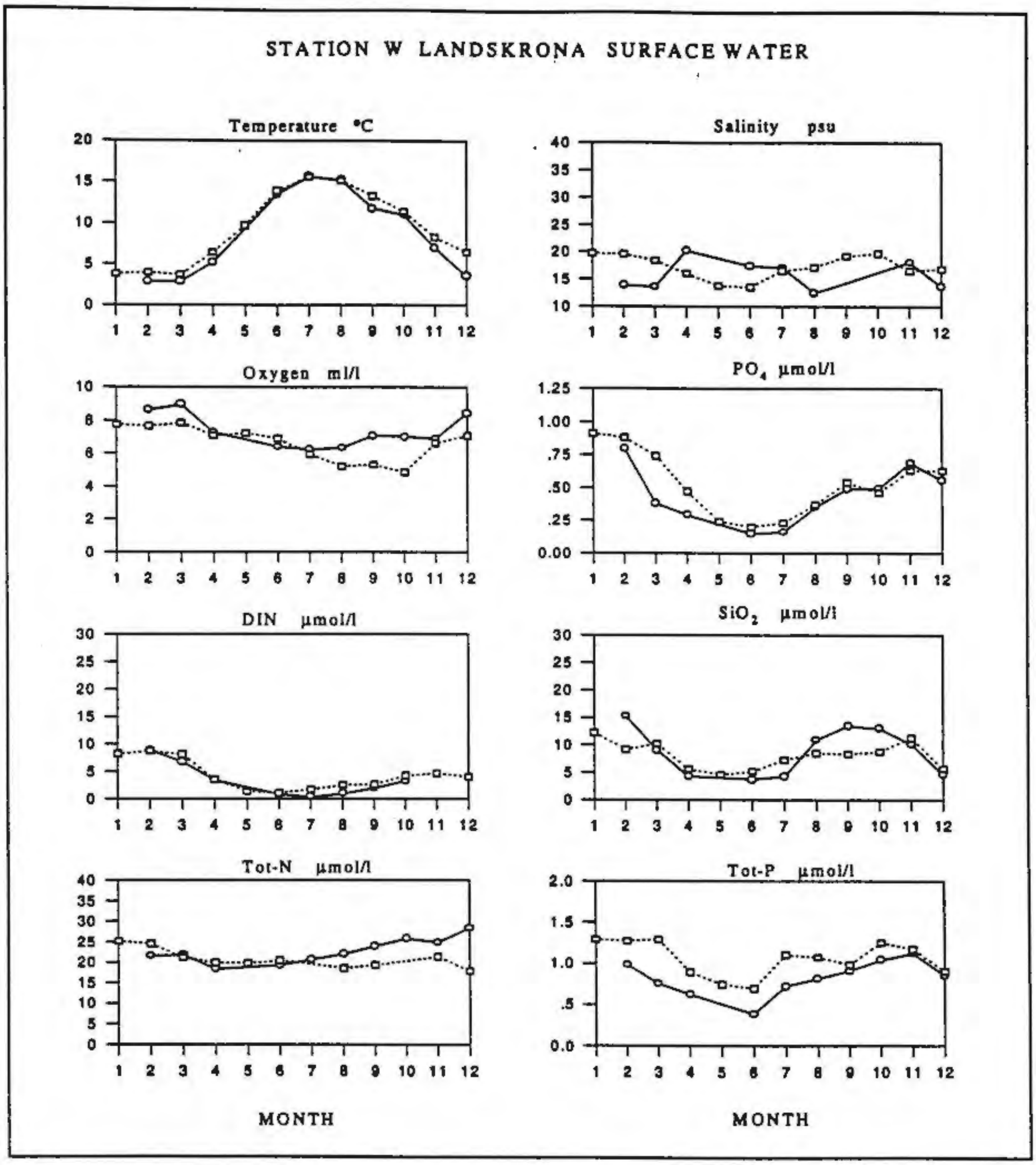
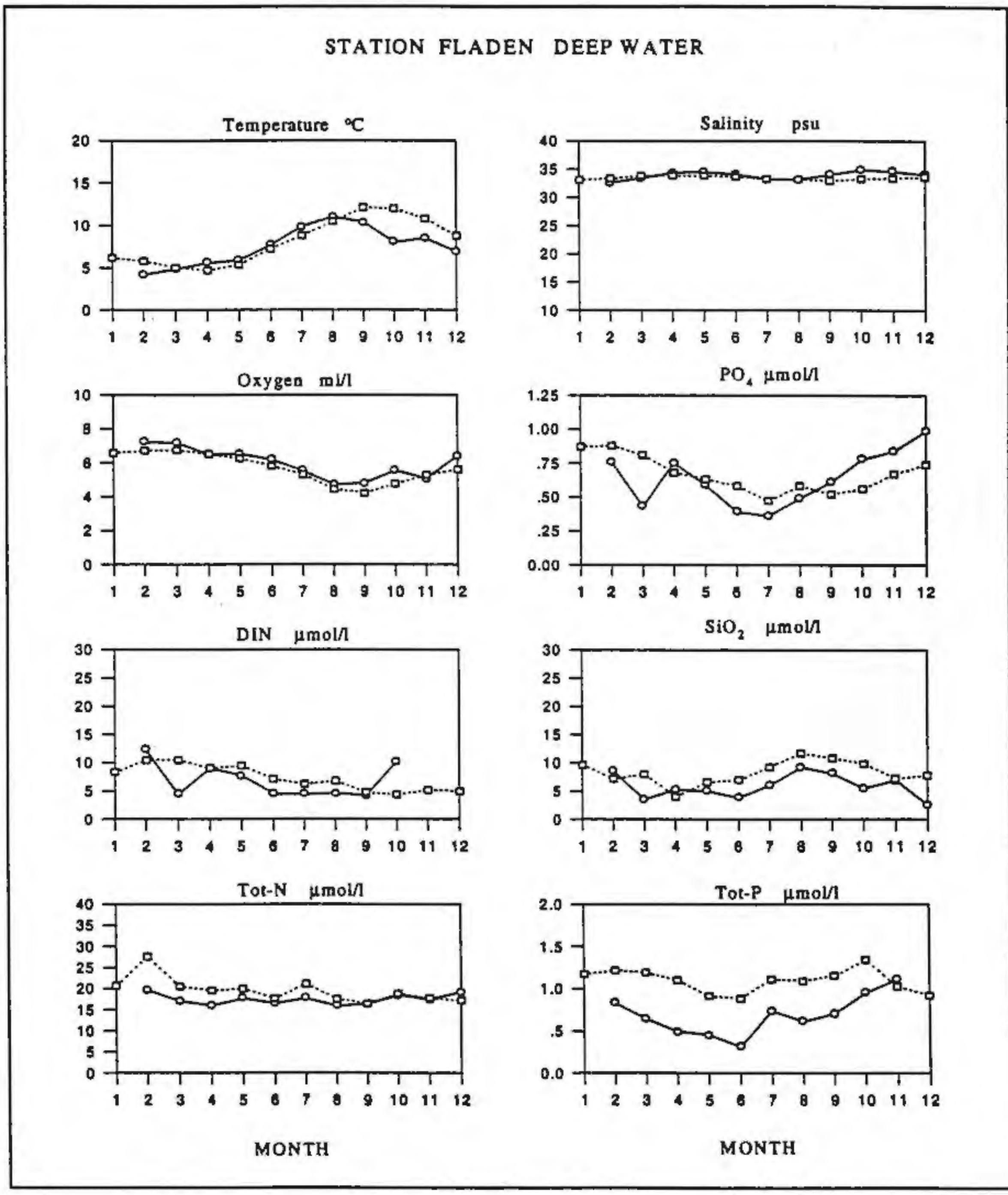


Figure 3.2.3 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station W Landskrona in the Sound.

At Fladen the nutrient concentrations in the deep water were extremely low in March and somewhat lower than normal during the rest of the year. In the southern Kattegat and the Sound the situation was about the same with the exception for the phosphate content that varied strongly during the year. The concentrations of total phosphorus and total nitrogen were low in the surface as well as in the deep water during the whole year.



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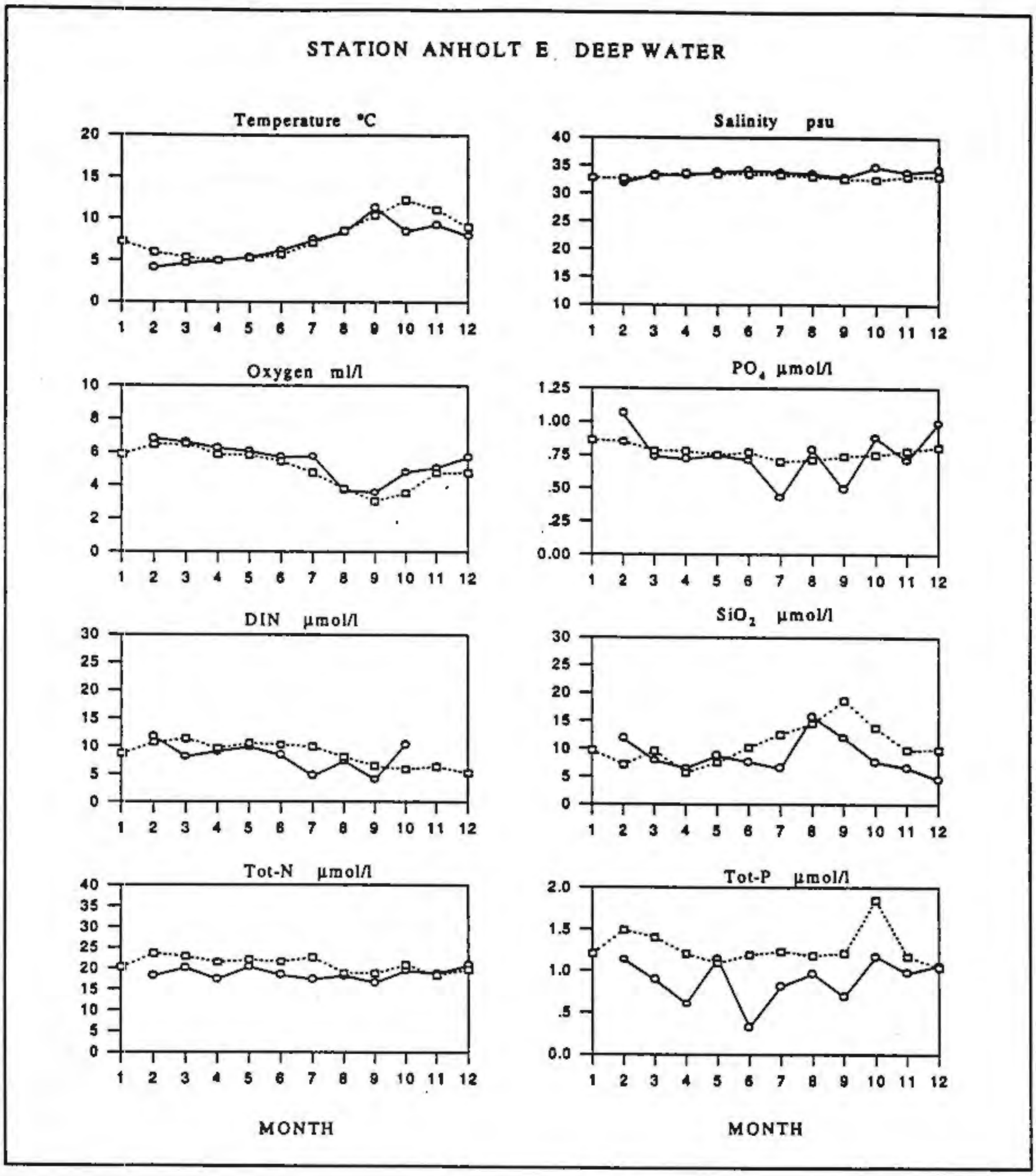


Figure 3.2.5 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station Anholt E in southern Kattegat.

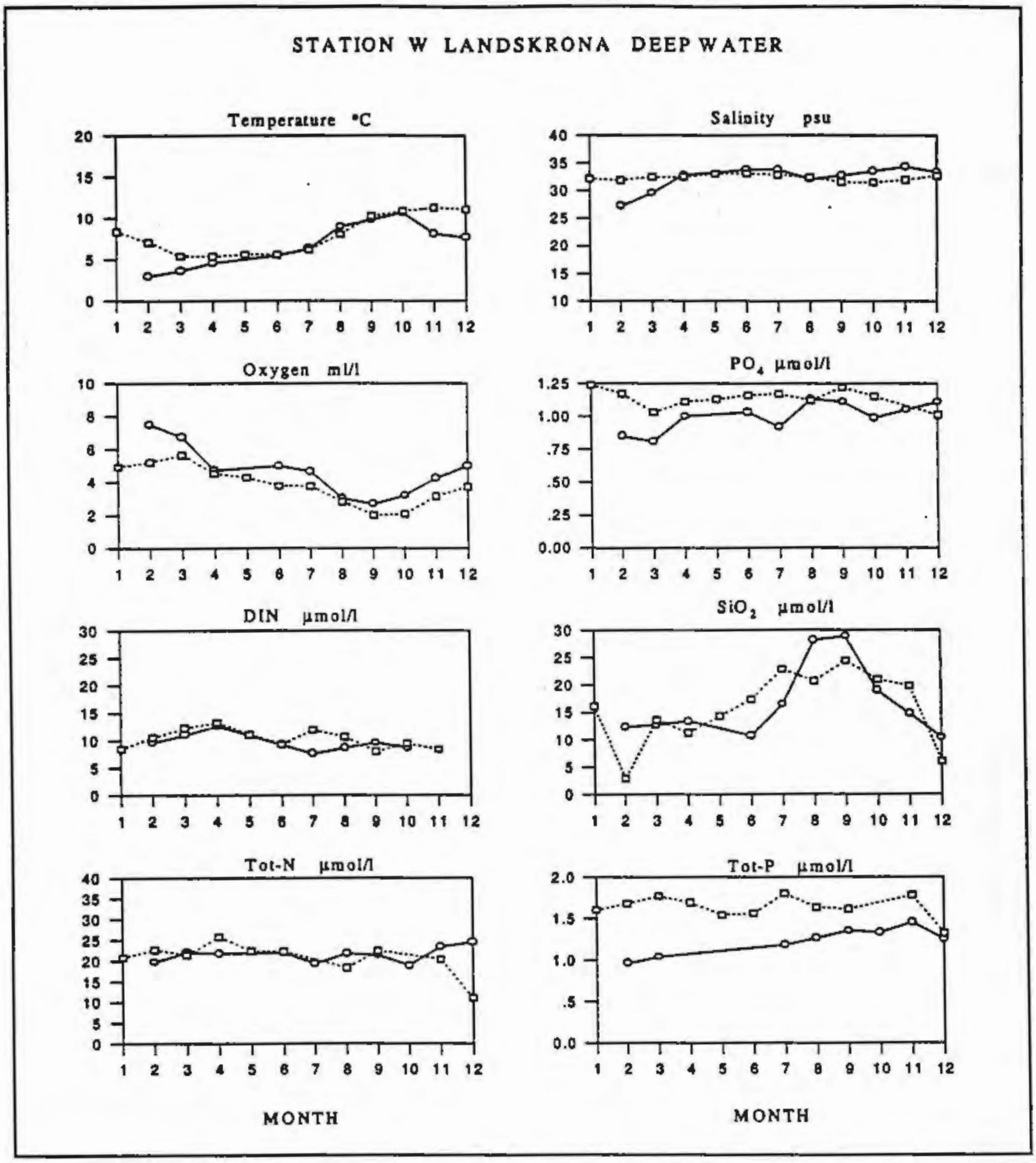


Figure 3.2.6 *Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station W Landskrona in the Sound.*

No severe oxygen deficit was mapped during the autumn in the deep water in the Kattegat area. The lowest concentrations were detected in the southeastern part during the september expedition, while the oxygen content in the northern part was about the same during the whole period.

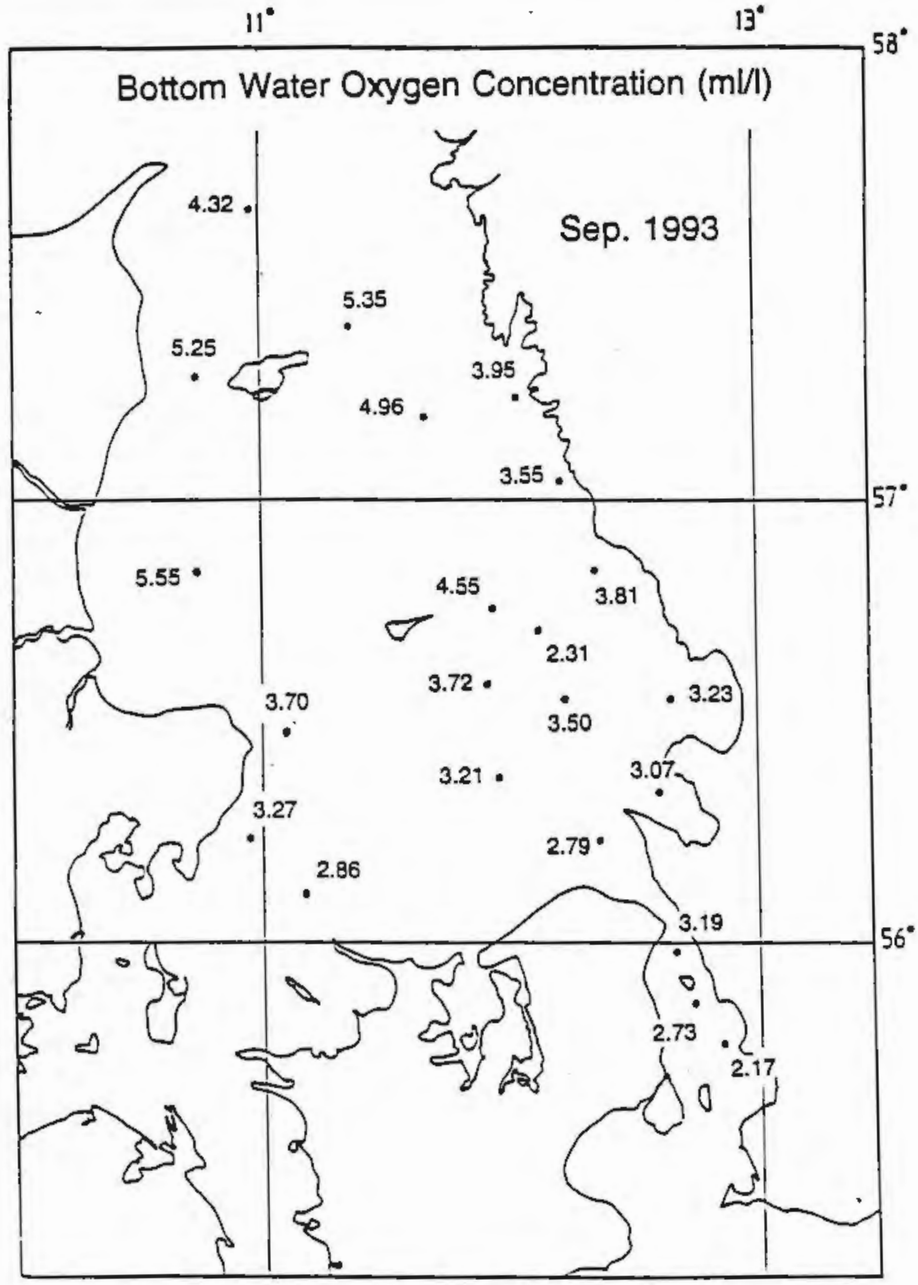


Figure 3.2.7 Oxygen distribution in the bottom water during the September expedition.

3.3 The Baltic Sea

The most dramatic event during 1993 was the large inflow of high saline water to the Baltic that occurred in January. The inflow had effects on the whole water column in the Arkona basin, but further into the Baltic only deeper layers were influenced. During the whole of 1993 the effects of the inflow could be detected further and further into the central parts. The inflow is described in more details below and the ordinary hydrographic description will be restricted to the nutrient conditions in the upper layers.

Southern Baltic (Arkona- and Bornholm basins)

In the beginning of March there was a 35-metre deep homogeneous layer in the Arkona basin. The temperature in this layer was 2.5 °C and the salinity about 8.5 psu. The spring bloom had not really started and the nutrient concentrations were still high.

During April the temperature in the surface layer had increased to between 3.5 and 5 °C that is higher than normal (normal is the monthly mean for the period 1981-1990). The spring bloom was almost over and in the Arkona basin the concentrations of nitrate and phosphorus were below detection limits (0.10 and 0.02 µmol/l respectively), however, there was still some phosphate left in the surface water of the Bornholm basin. It should also be noted that the content of silicate was remarkably lower than normal ca 2.5 µmol/l compared to 8-9.

During the period up to June a strong thermocline at a depth of 15 to 20 m developed, with surface layer temperatures around 10 °C. The concentrations of phosphate had increased in the Arkona basin while they had continued to decrease in the Bornholm basin. The concentrations of nitrogen were close to the detection limit, while the silicate concentrations had increased to levels above the normal.

During the summer months the surface temperatures were 1 to 2 degrees below normal, but since the cooling process during autumn was slower than usual, the temperature was again normal in October. The concentrations of phosphate and nitrogen remained low during summer while silicate concentrations were higher than normal, especially in the Arkona basin. Phosphate and nitrogen concentrations rose again during autumn, silica however, decreased in concentration during the last months of the year instead of rising as usual. It should be noted that an extremely intense bloom of silica algae occurred in October.

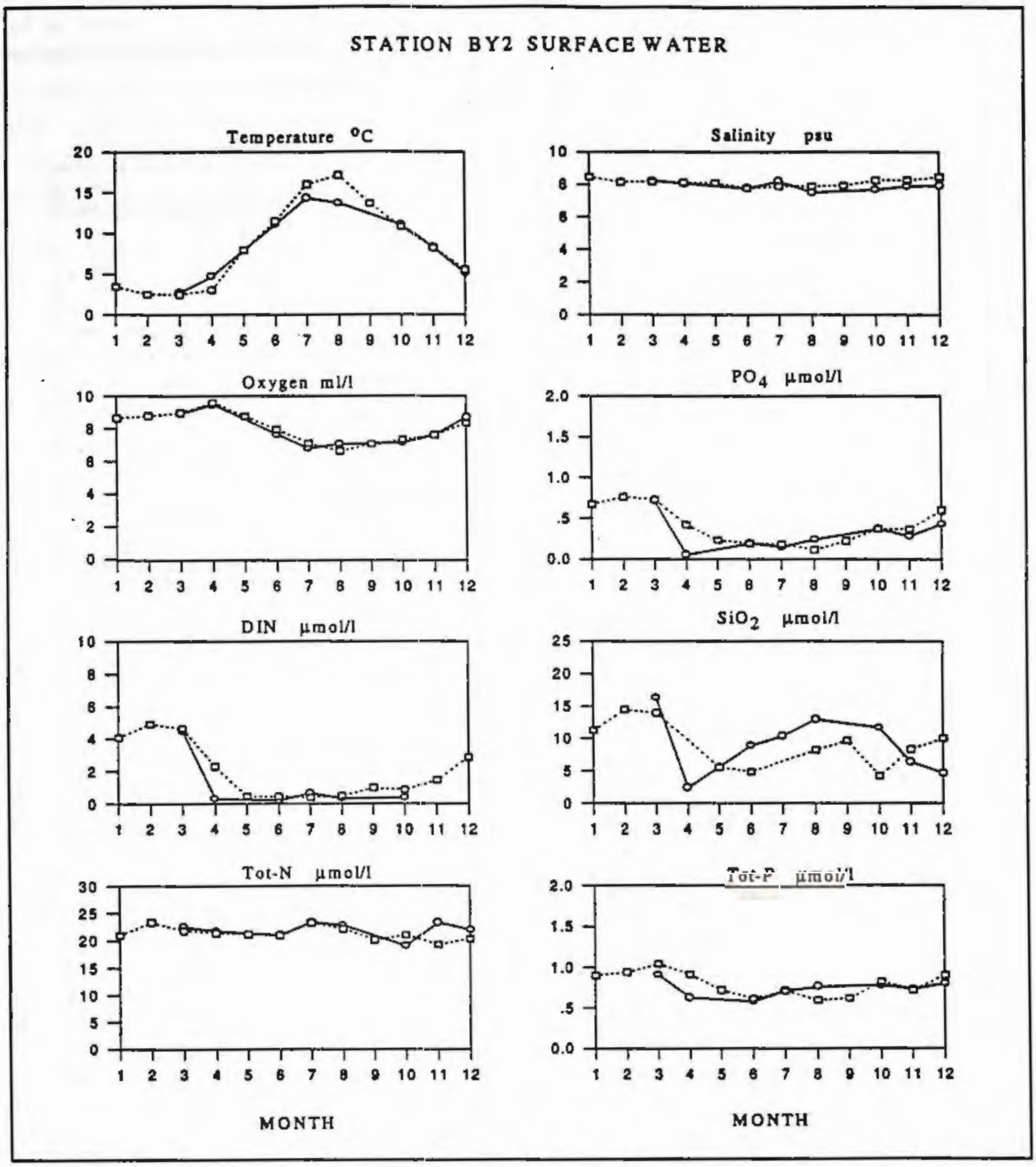


Figure 3.3.1 *Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station BY2 in the Arkona Basin.*

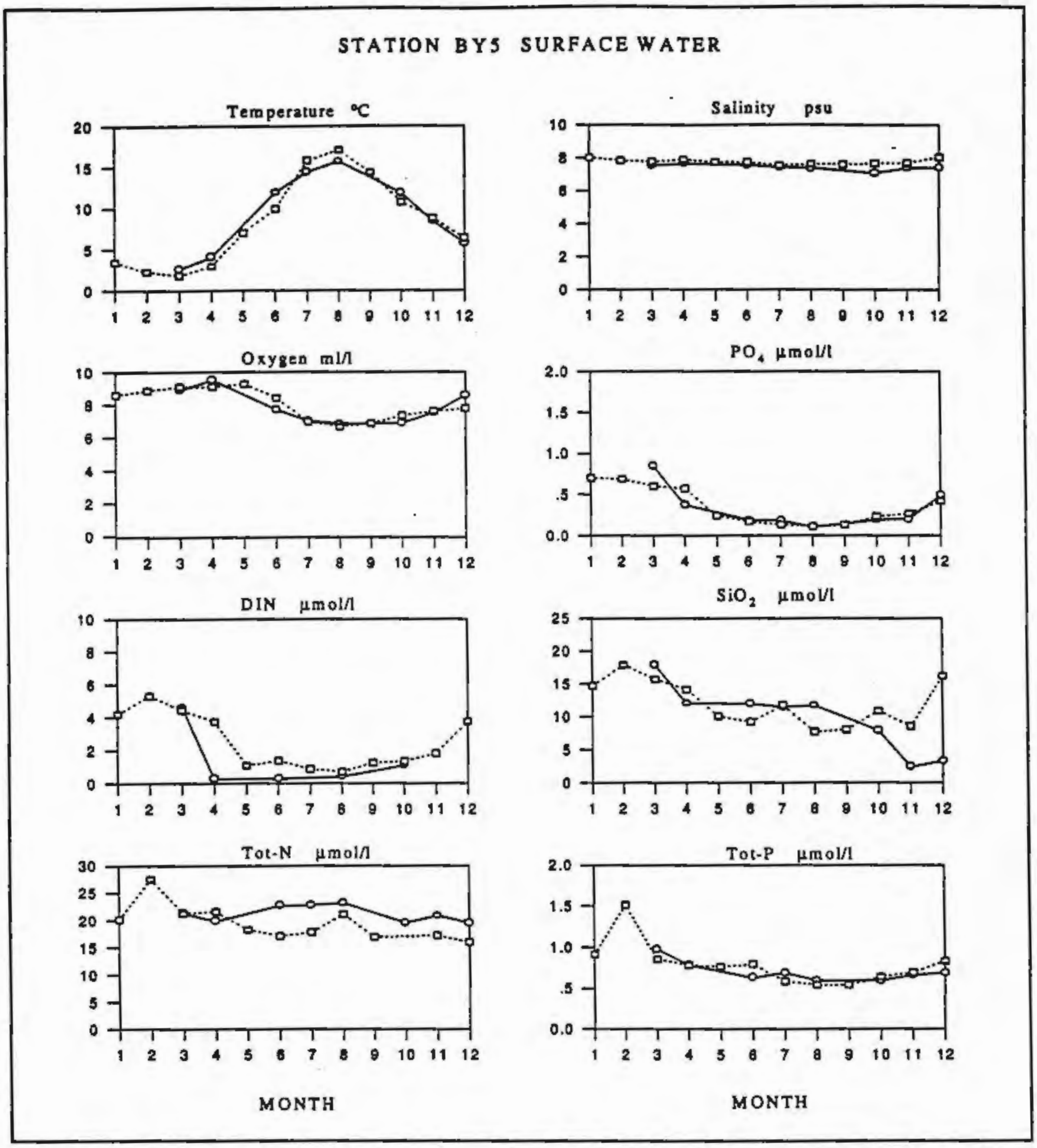


Figure 3.3.2 *Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station BY5 in the Bornholm Basin.*

Considering the deep water, the first expedition was conducted too late to detect the effects of the inflow in the Arkona basin. In the Bornholm basin, however, a marked increase in salinity was clear the whole year. The inflow is most clearly reflected in the oxygen measurements, which gave concentrations well above mean in March. The oxygen content then decreased during the year and reached normal values in late December. The concentrations of phosphate and silica were also lower than normal while the nitrogen concentrations did not seem to be influenced.

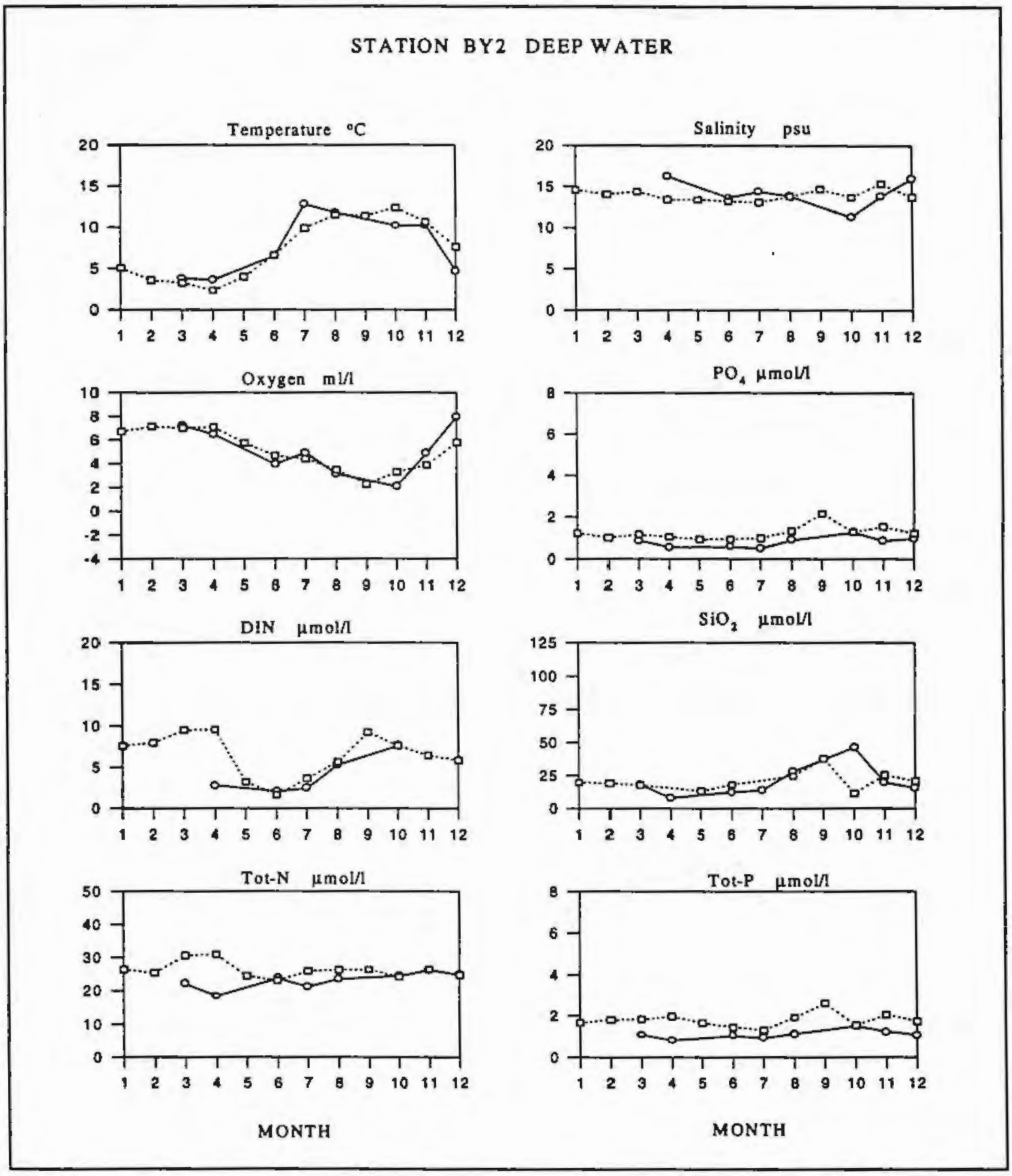


Figure 3.3.3 Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990, dotted line. Station BY2 in the Arkona Basin.

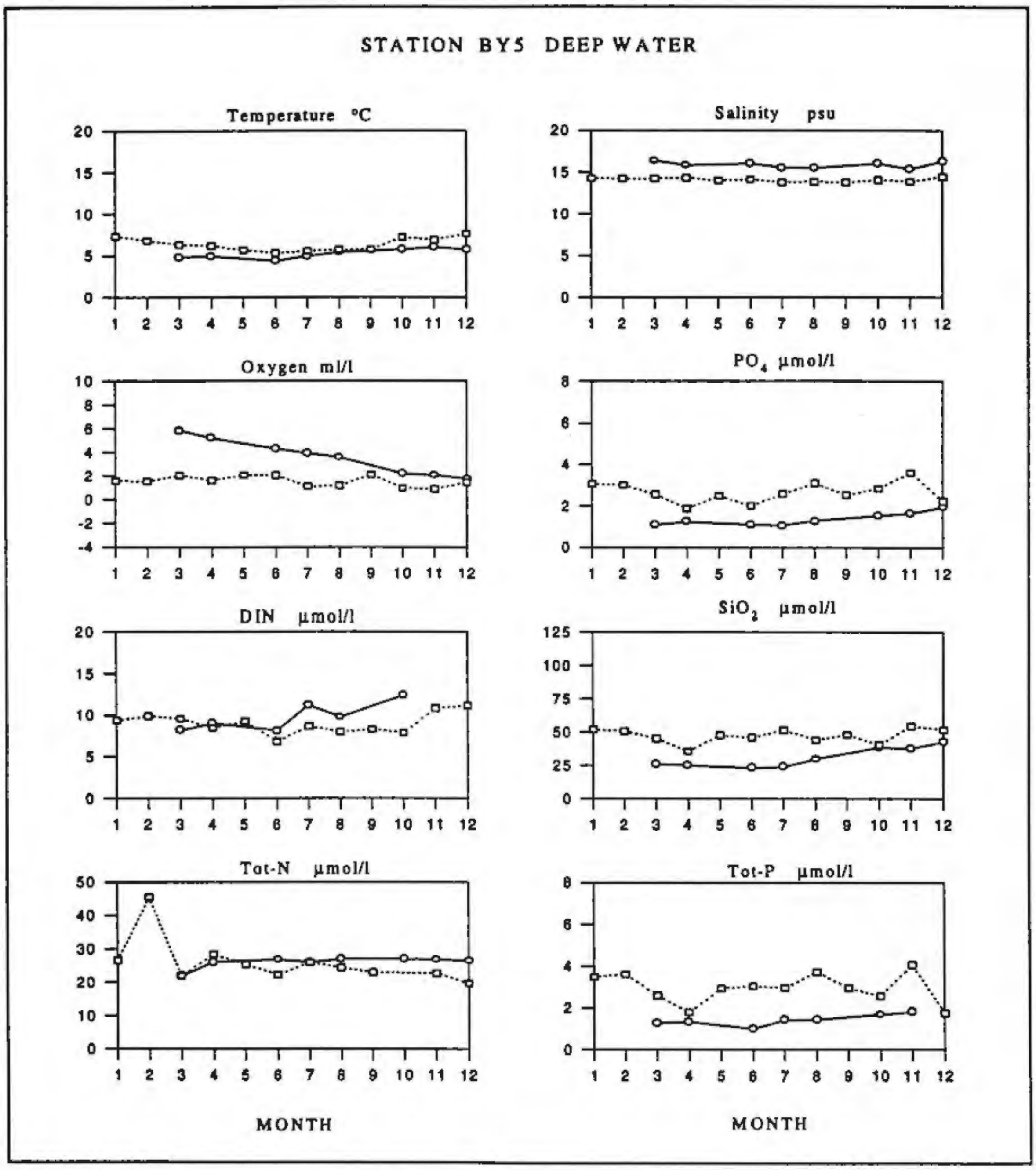


Figure 3.3.4 *Monthly mean values 1993, solid line, compared to the mean annual cycle for the years 1981-1990 , dotted line. Station BY5 in the Bornholm Basin.*

Central Baltic Proper

The situation in the central Baltic Proper, during March, was very much alike the situation in the southern part, with the exception that the surface water was homogeneous down to 100 metres. The temperature in the upper layer was significantly higher than mean the whole year except for the last two months, which were colder than normal. A thermocline developed during spring and was during summer located at a depth of 15 to 20 m. The spring bloom started as usual in late March but continued longer than normal. The concentrations of phosphate and nitrogen did not reach the common low levels until June-July instead as normal in late May. As in the southern part, the concentration of silicate was remarkably high during summer, and decreased to levels clearly below mean during autumn.

In the bottom water at the station BY15 in the Gotland deep, no clear increase in salinity was detected during the year, however, a rise in the oxygen content was clear during spring but the effect did decrease during summer. The concentrations of phosphate and silicate decreased while nitrogen is more difficult to analyse since the redistribution between the different forms, depending on the amount of dissolved oxygen in the water.

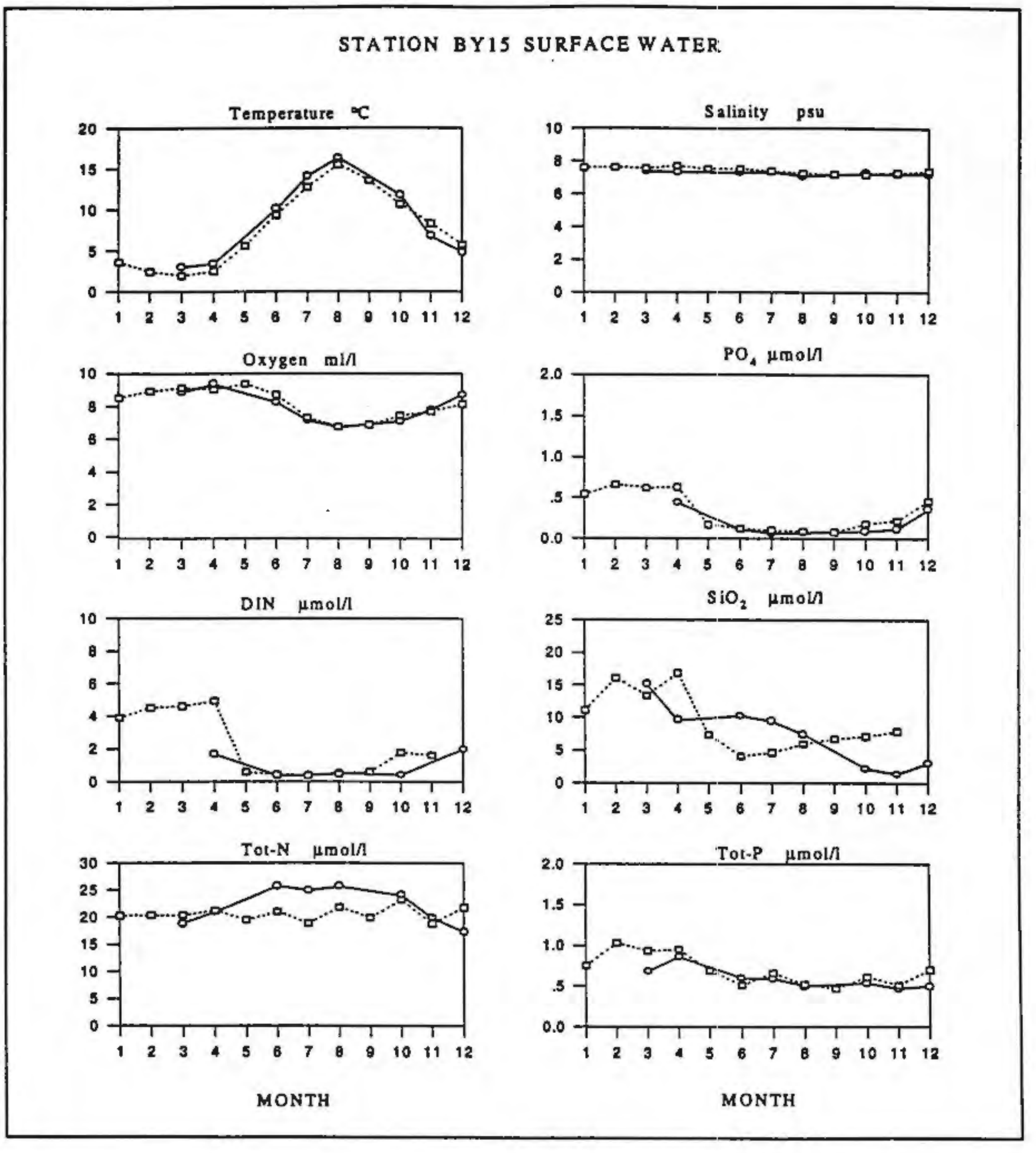


Figure 3.3.5 *Monthly mean values 1993, solide line, compared to the mean anual cycle for the years 1981-1990, dotted line. Station BY15 in the Eastern Gotland basin.*

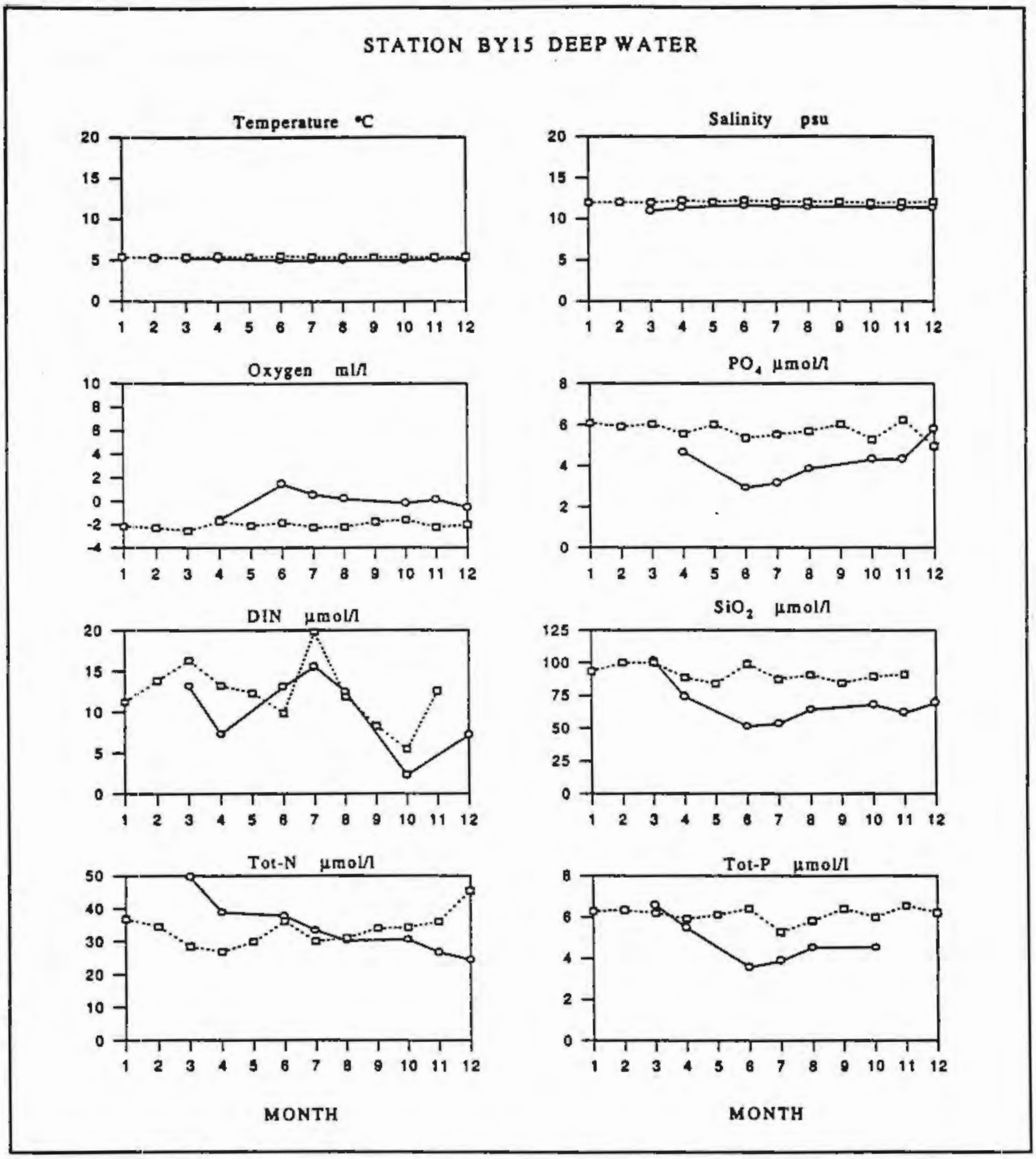


Figure 3.3.6 *Monthly mean values 1993, solide line, compared to the mean anual cycle for the years 1981-1990, dotted line. Station BY15 in the Eastern Gotland basin.*

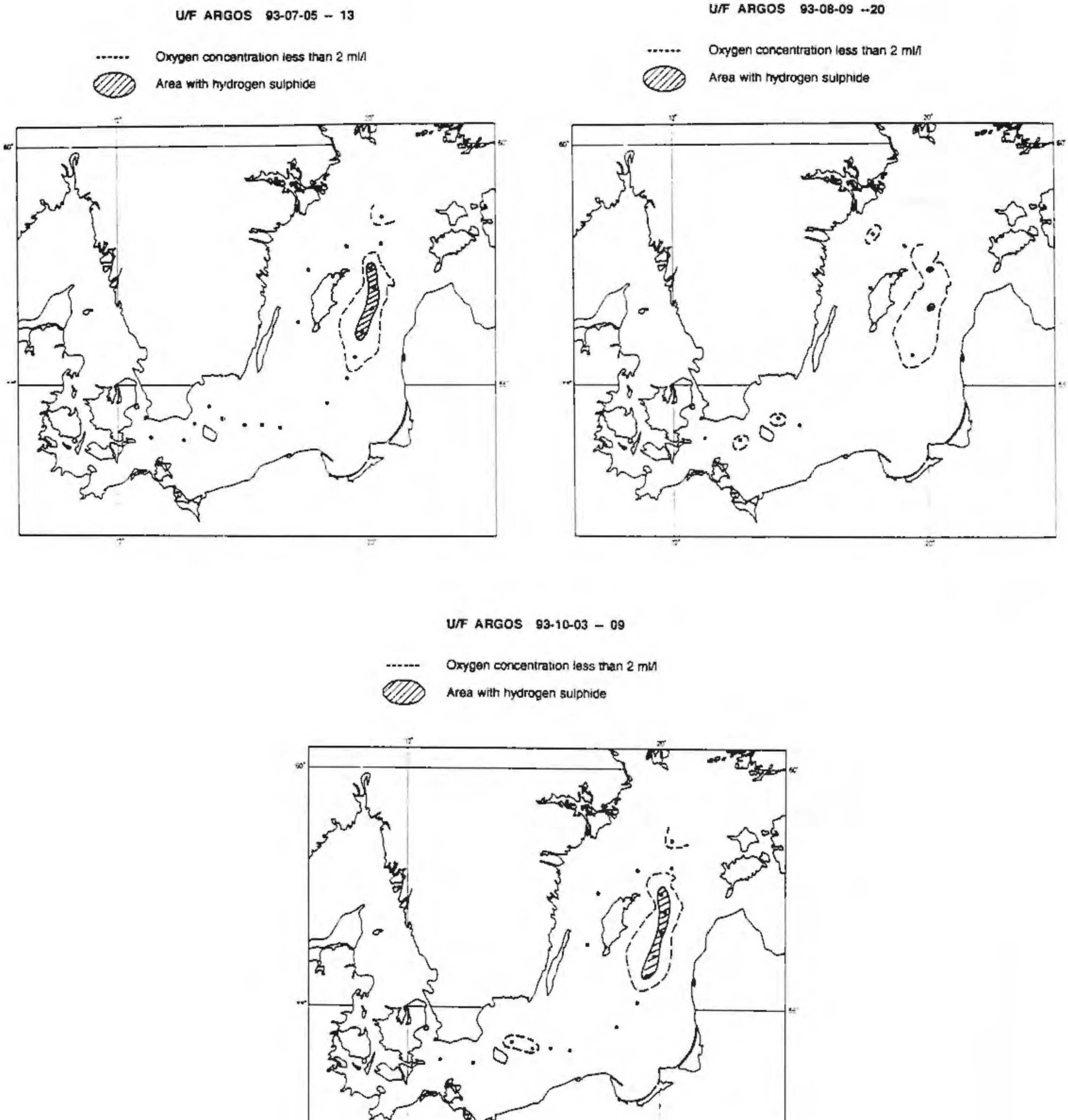


Figure 3.3.7 Oxygen distribution in the deepwater during three expeditions, July, August and October.

3.4 The Gulf of Bothnia

Two visits were made to the area during the year, one in June and one in December. The situation in the Bothnian Sea surface water (station F26) was normal for the season in June with the exception for the silicate concentrations that were only half of what is considered as normal. In the deep water phosphate, silicate and total-phosphorus all had concentrations well below mean. In the Bothnian Bay the summer situation was normal in both surface and deep water. In December all parameters except total-phosphorus showed concentrations close to normal in both subareas. Total-phosphorus showed values below normal in both deep and surface water.

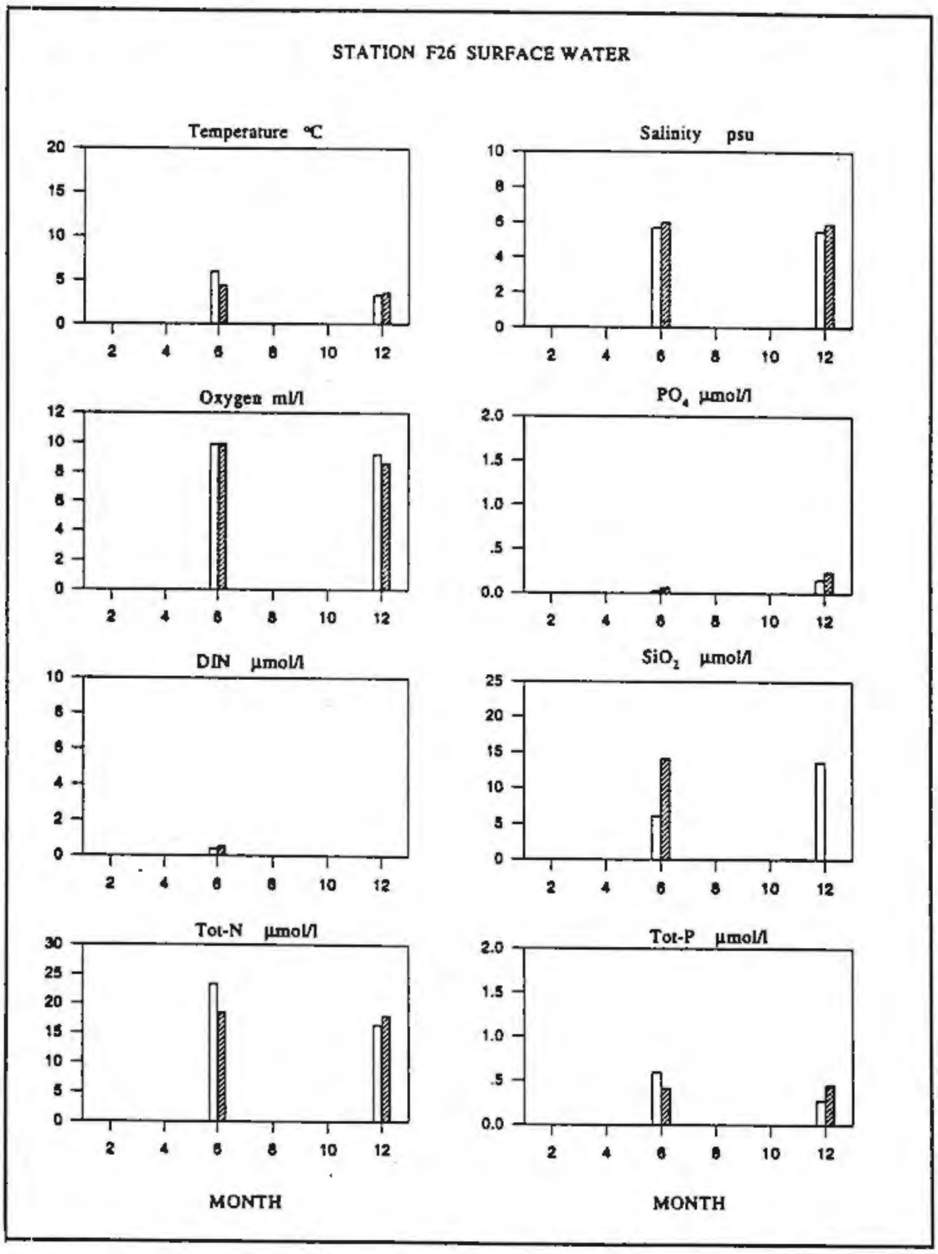


Figure 3.4.1 Monthly mean values 1993, white bars, compared to the mean for the years 1981-1990, dashed. Station F26 in the Bothnian Sea.

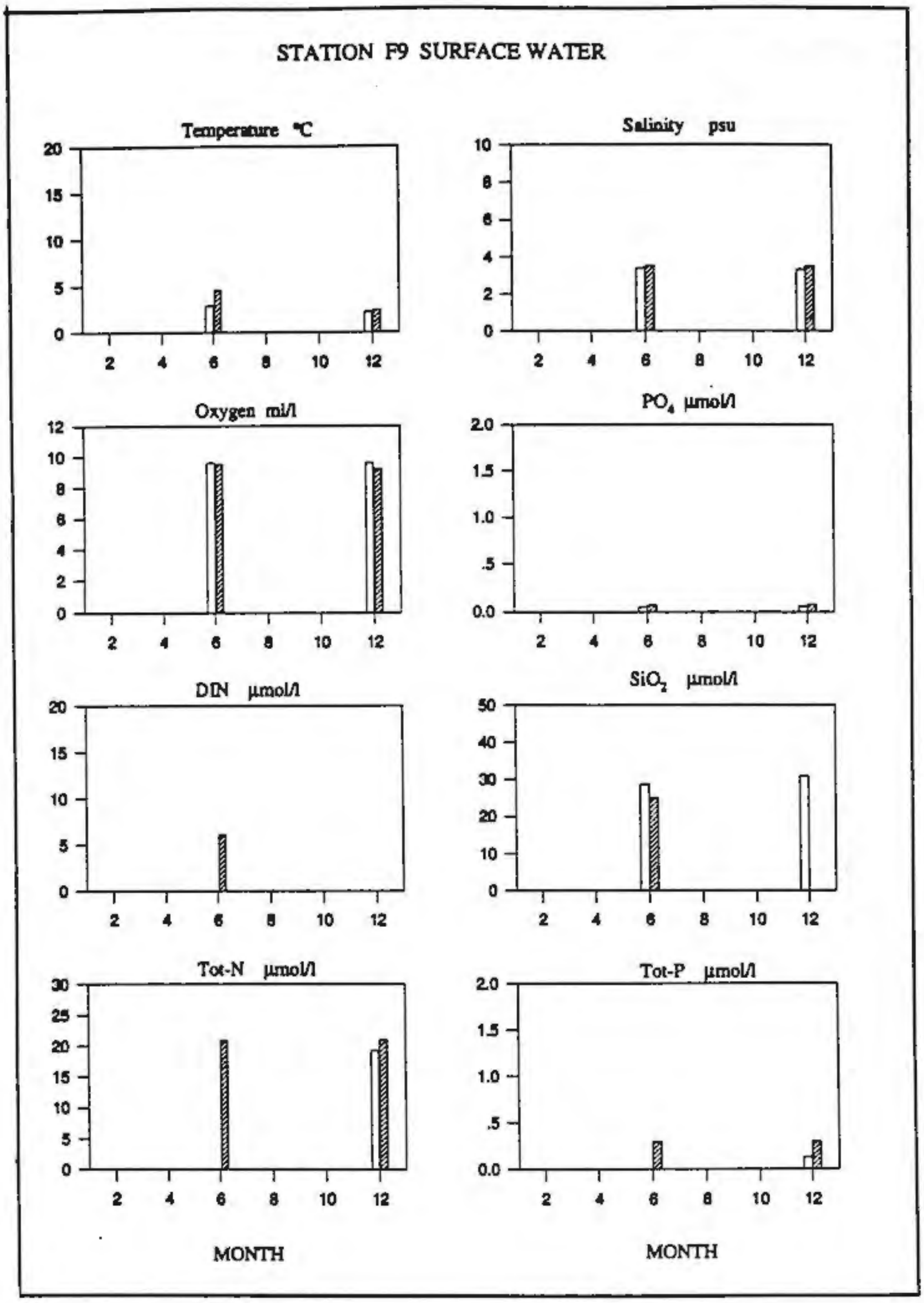


Figure 3.4.2 Monthly mean values 1993, white bars, compared to the mean for the years 1981-1990 , dashed. Station F9 in the Bothnian Bay.

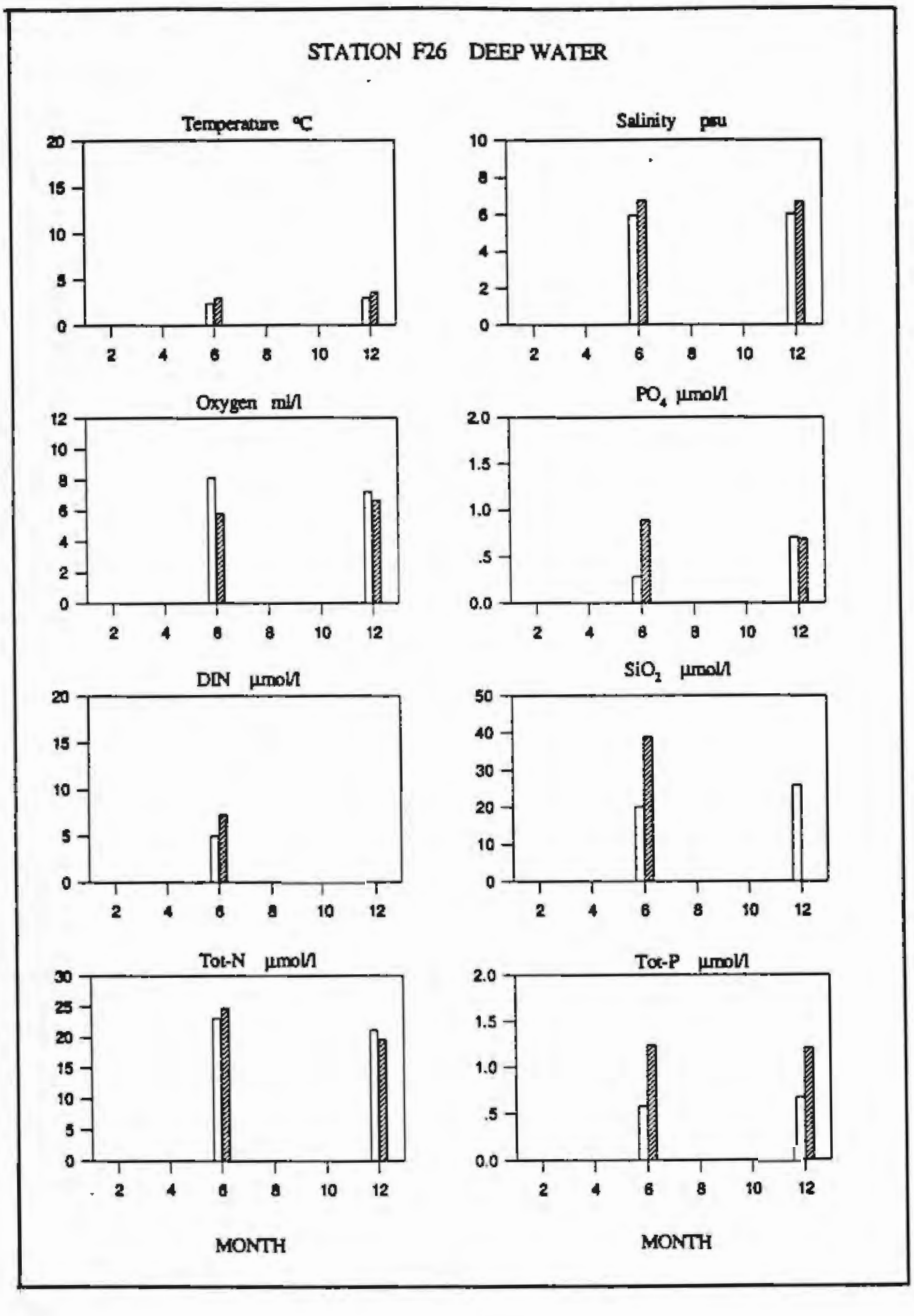


Figure 3.4.3 Monthly mean values 1993, white bars, compared to the mean for the years 1981-1990, dashed. Station F26 in the Bothnian Sea.

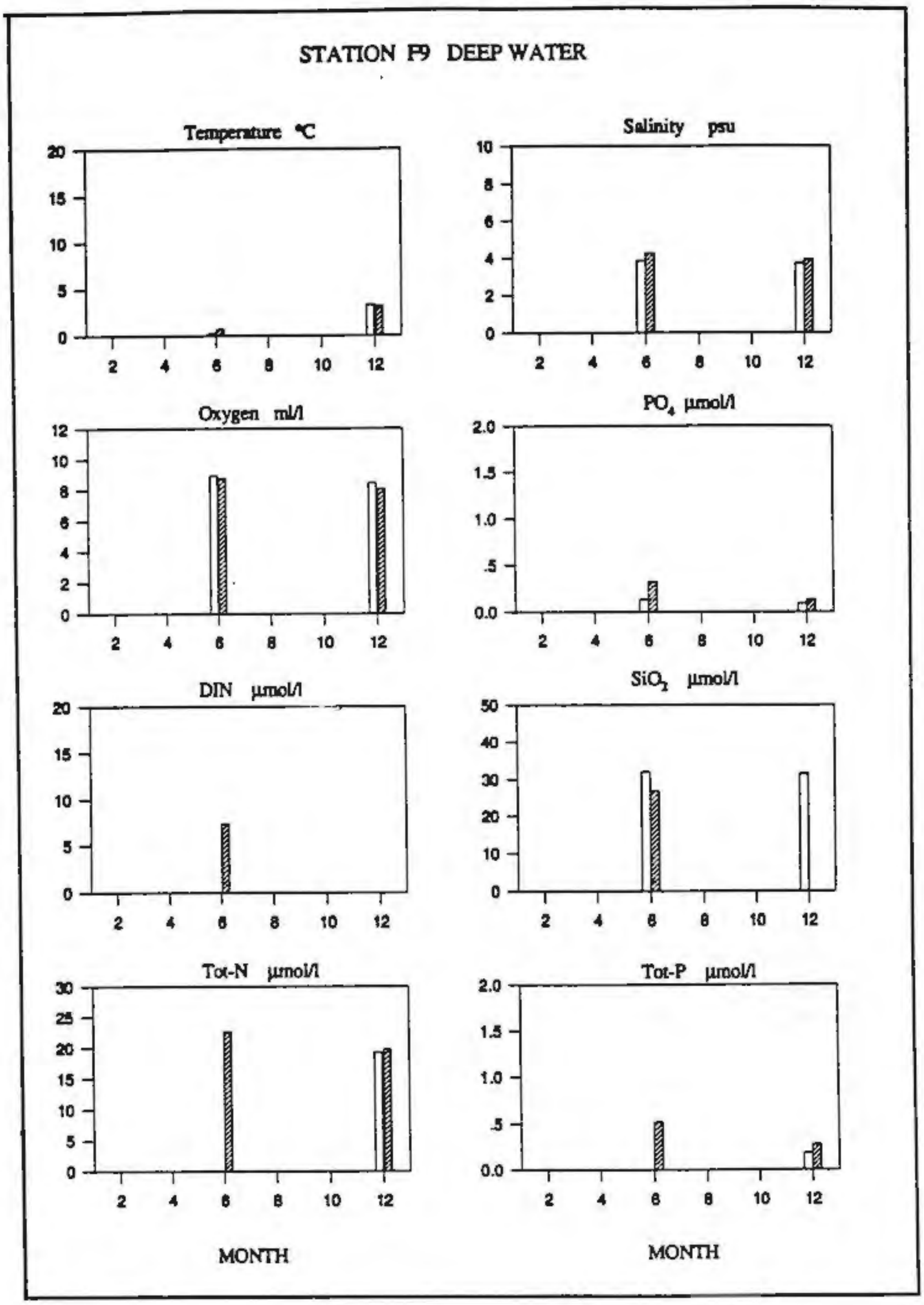


Figure 3.4.4 Monthly mean values 1993, white bars, compared to the mean for the years 1981-1990, dashed. Station F9 in the Bothnian Bay.

4. The major inflow to the Baltic

In January 1993 there was, for the first time since 1977, a major inflow of saline water to the Baltic. At the turn of the year, a strong high pressure was located east of Sweden, causing the water level in the Baltic to descend below mean. When the high pressure weakened, low pressure areas began to move into Sweden from west causing strong westerly winds. This meant that the water level rose quickly on the west coast and water with high salinity from the North Sea and Skagerrak filled the Kattegat area.

The normal stratification in Kattegat is characterized by a typical two layer structure, where water with low salinity from the Baltic flows on top of the more saline deep water originating in the Skagerrak. When a major inflow occurs the first thing that happens is that the conditions in Kattegat changes so that the stratification weakens while surface salinity in the southern parts increases. During the period January 6 to 26 about 80 km^3 of water with high salinity entered the Baltic through the Sound. During the same time about 220 km^3 entered through the Danish Belts, the salinity of this water was however not that high. As a total the volume in the Baltic increased with 300 km^3 during this period.

4.1 General hydrographic conditions of the Baltic

The Baltic Sea can be considered as a large fiord with more or less permanent salinity stratification. A halocline located at a depth of 40 to 100 metres, varying between the different basins, separates the surface water from the bottom water. The conditions in the surface water are influenced by fresh water supply and cooling/heating and vary through the year. The same annual variations do not occur in the deep waters, where the conditions can be relatively constant for long times, stagnation periods that can last for several years. These stagnation periods can be suddenly broken when new water enters through the Sound or through the Belts or due to waterexchange from one basin to another.

The oceanographic conditions of the Baltic are mainly dictated by the topography, the water exchange with the Kattegat/Skagerrak and by the fresh water supply. The shallow sills in the Belts and the Sound hamper the water exchange. At Darss Sill in the southern Belt Sea the sill depth is 18 metres and at Drogden in the southern part of the Sound only 8 metres. As a comparison, the mean depth of the Baltic is 62 metres.

The water exchange is driven by the difference in water levels between the Baltic and Kattegat, caused by the weather conditions. The situation changes with the weather and the current direction is often reversed several times during a period of a few days. Normally the total exchange during a year is large enough to maintain the stratification in the Baltic but not enough to influence the deep water. Inflows of greater magnitude, which have influence on the deep water takes place irregularly, sometimes with intervals of several years and only under very special weather conditions. Such conditions mainly occur during the winter months, December to February. Even if the sill depth in the Sound is more shallow than the sill at Darss, the Sound is considered as an important passage during an inflow. This is mainly because the distance through the Sound is much shorter than the way through the Belts. The mixing processes can only work on a shorter time scale and the salinity of the water passing through the Sound is therefore often higher.

4.2 The stagnation period preceding the inflow

The stagnation period before the inflow 1993 is the longest ever recorded and lasted for 16 years. From 1977 the stratification in the inner deep basins weakened successively and the salinity in the deep waters decreased. In 1992 the lowest salinity ever, was measured in the eastern Gotland Basin, 11.1 psu. The oxygen conditions were rapidly becoming bad after the 1977 inflow, and 1982 a redoxcline had developed at a depth of ca. 125 metres. The redoxcline was located at the same depth during the whole period even if there was a tendency of deepening the last years because of weekend stratification. The stratification in the Gdansk Basin weekend so much during the stagnation period that it completely broke down due to vertical mixing during the winter 91/92. The deep waters were again oxic and would have continued to be so if no new deep water had entered.

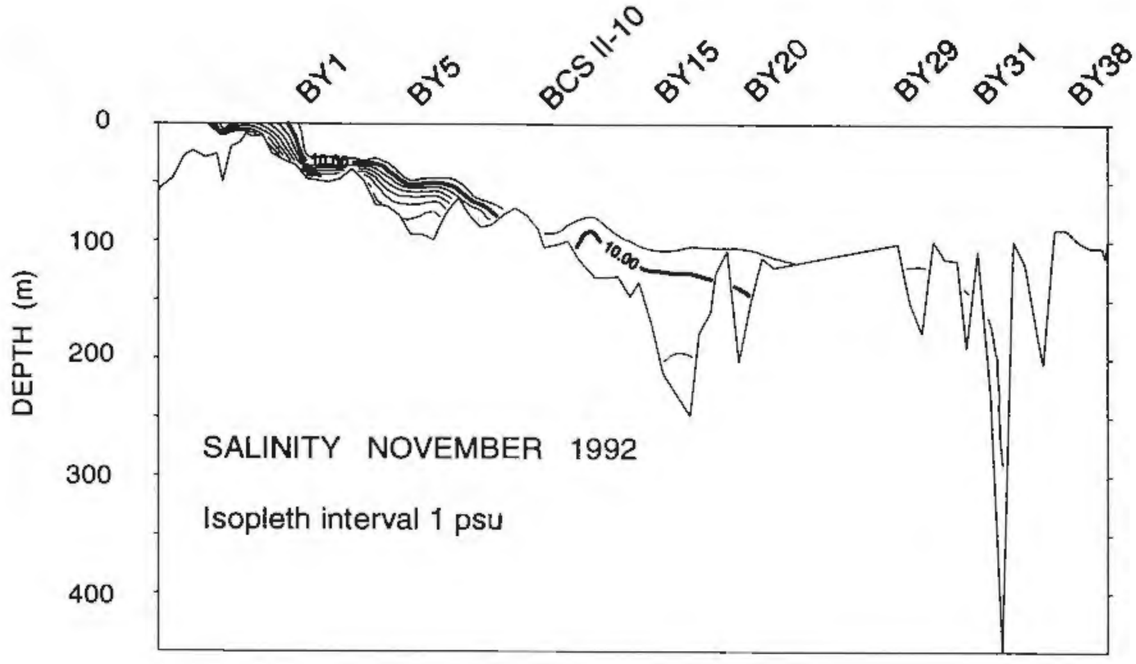
4.3 The inflow

Starting the first week in January and ending the 27th the same month, strong winds were blowing over the Kattegat and the southern Baltic. The direction of the wind varied but there was always a westerly component. The water level in southern Kattegat increased 0.5 metres while the water level in the southern Baltic decreased with 0.3 metres. The difference in water levels caused a flow of water through the Belts and the Sound into the Baltic. The 6th of January there was an abrupt increase in salinity in the southern part of the Sound and water with high salinity (>20 psu) flowed across the sill and into the Arcona Basin. At the Darss sill the salinity did not increase until 16-18 January due to the longer way through the Belts.

The inflow caused the water level in the Baltic to rise, and on the 27th of January when the westerly wind ceased the water level had increased 80 cm. The change in weather, reversed the currents and the main inflow ended.

During the three weeks the inflow lasted about 300 km^3 entered the Baltic. Out of this 125 to 150 km^3 was high saline water, i.e. having a salinity of more than 20 psu. Approximately 65 % of this water came through the Sound. The total volume of the inflow was comparable to the volume below the sill depth in the Bornholm Basin or half the volume of anoxic water in the eastern Goland Basin. The total amount of salt that entered with the inflow was ca $2*10^{12}$ kg that is 27% of what enters the Baltic during a normal year.

Within a week from the beginning of the inflow the Arkona Basin was filled with new water. The bottom water salinity increased from 14 -15 psu up to 20-22 psu, and the oxygen concentrations from 2-4 ml/l up to 6-7 ml/l. A week after the end of the inflow the amount of new high saline water in the Arkona was estimated to be 25 - 35 km^3. Of the original 120-150 km^3 about 50 km^3 was mixed up into the surface layer and partly transported out of the Baltic the remaining 50-80 km^3 had flown further into the Bornholm Basin via the sill between Bornholm and Sweden. In the beginning of March the new water had reached the Bornholm Basin and a layer with a thickness of 10 to 20 metres covered the bottom of the basin. The old bottom water was lifted up to the level of the sill at 60 metres depth, and transported further east through the Stolpe Furrow. The salinity increased from 15-16 psu up to 18-19 psu and the oxygen concentrations from 0.5-1 ml/l up to 6-7 ml/l. During the first half of April the bottom water in the Gdansk Bay was



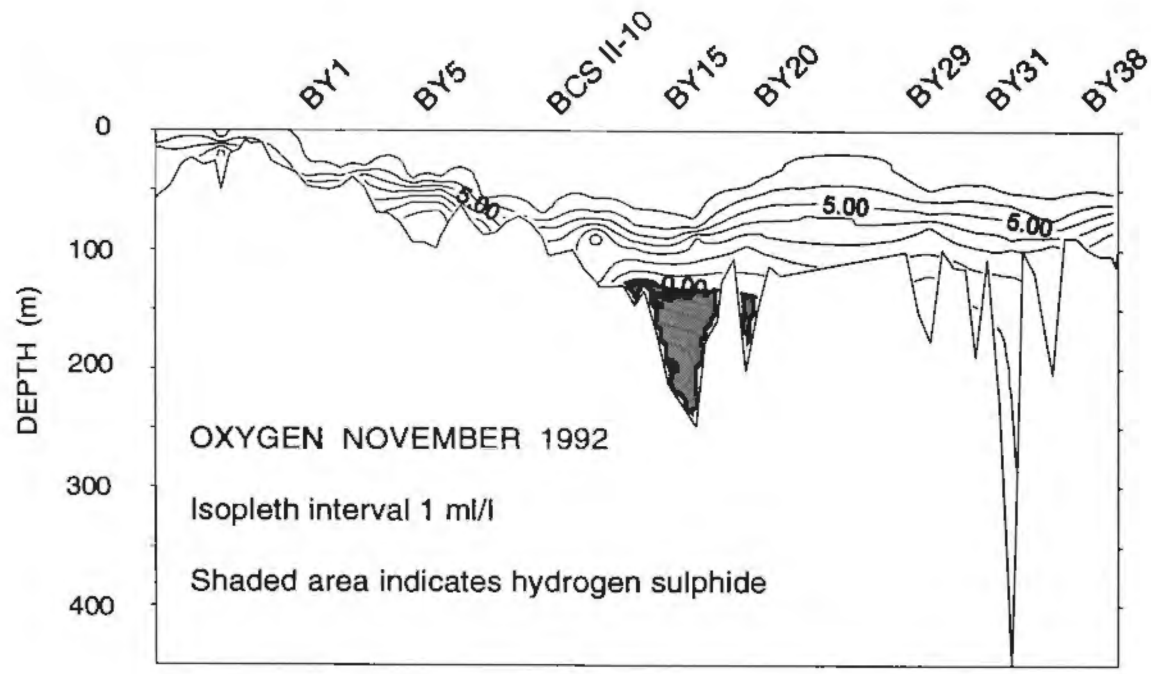


Figure 4.3.1-4.3.2 Cross-sections of salinity, and oxygen in November 1992, before the inflow.

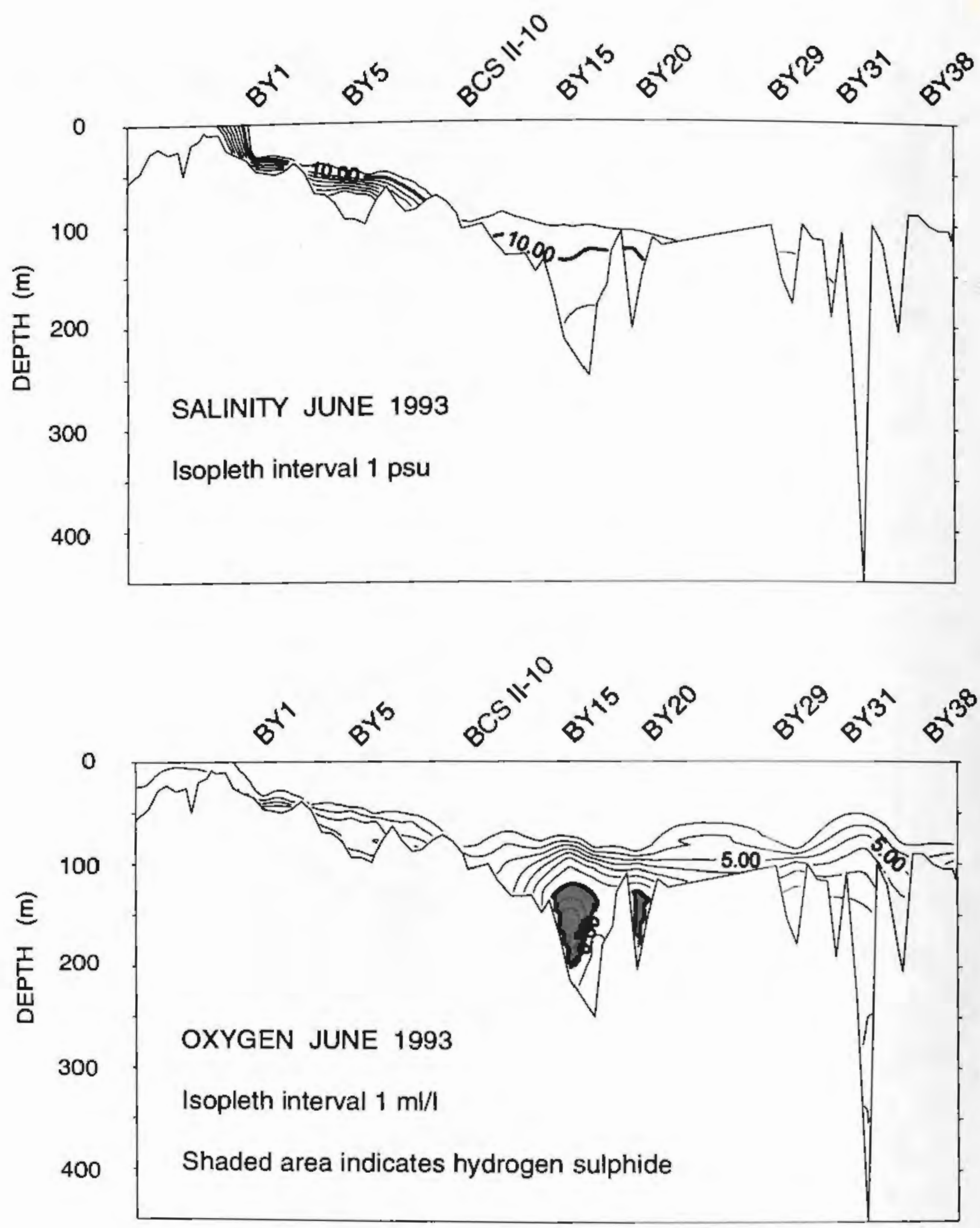
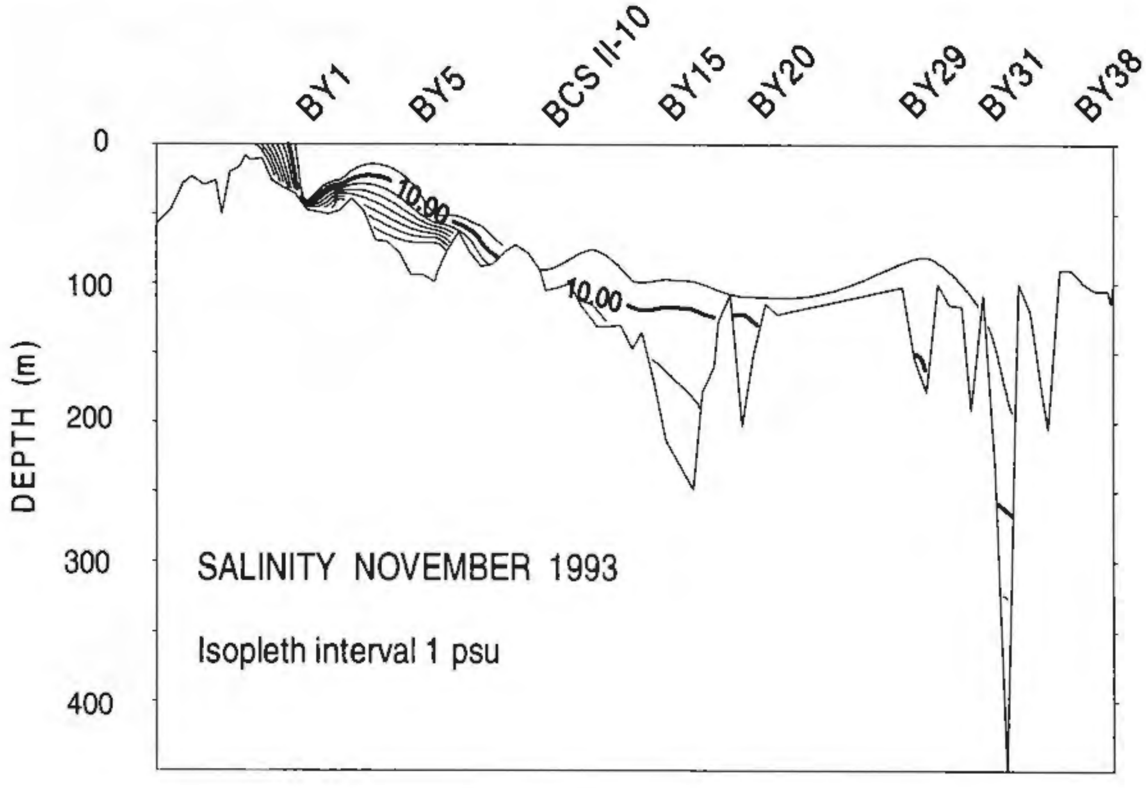


Figure 4.3.3-4.3.4 *Cross-sections of salinity, and oxygen in June 1993, during the inflow.*



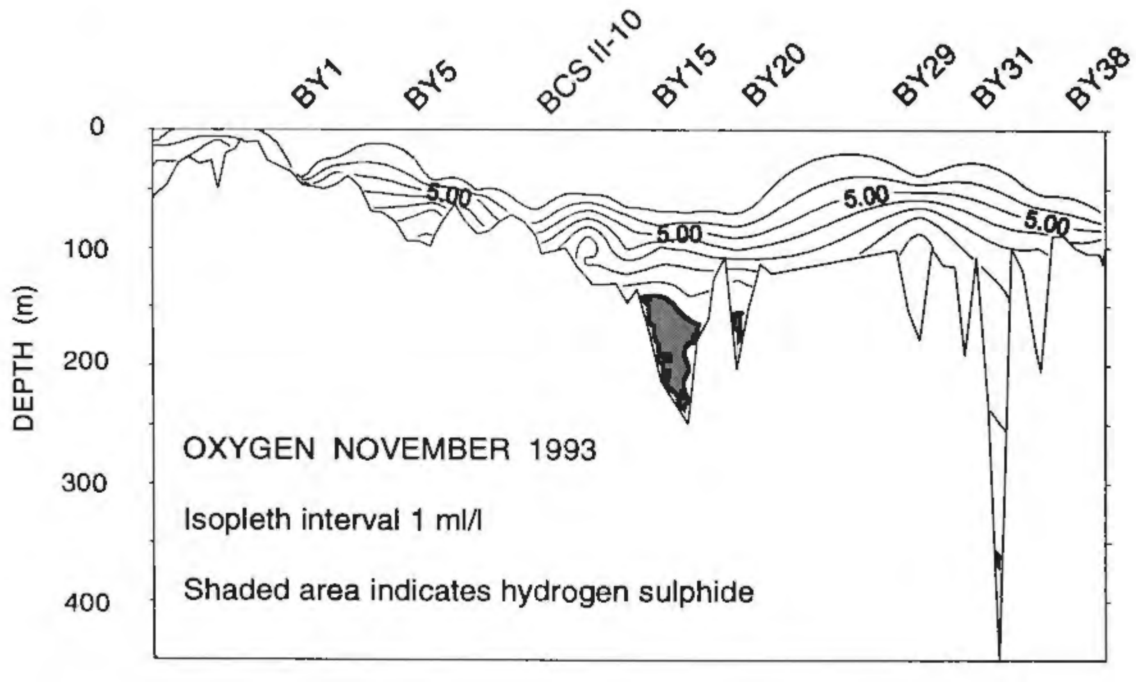


Figure 4.3.5-4.3.6 *Cross-sections of salinity, and oxygen from November 1993, after the inflow.*

renewed and a vertical stratification was again developed. At the same time the first signs of an ongoing renewal of deep water in the eastern Gotland Basin were detected. At the turn of the months May/June the result of the waterexchange was that part of the deep water in the eastern Gotland Basin were free of hydrogen sulphide for the first time for 15 years. In the deeper parts of the basin, in the earlier anoxic water, the oxygen concentrations rose to 1 ml/l while the salinity increased with 0.8 psu.

The detectable effects of the inflow decreased strongly further north. In August, the first effects were noted as elevated salinity in the Fårö deep. The increase was not more than 0.3 psu and the waterexchange was not strong enough to oxygenize the bottom water, even if there was a clear reduction of hydrogen sulphide.

4.4 Long term effects

In comparison with other known and documented inflows during the twentieth century, the inflow 1993 is characterized as a medium sized one, considering both volume and salinity. Since the inflow was preceded by the longest stagnation period known, the effects will be limited in the long run. For example, in the eastern Gotland basin the inflow has resulted in that the salinity conditions are similar to the ones that were present 1989, i.e. if there are no new inflows the effects will disappear in a few years. The effects on oxygen will disappear even faster, and already in November/December a redoxcline at a depth of 130 metres was developed in the eastern Gotland basin.

It is however known by experience that inflows often occur in groups, and since the salinity still is rather low in the central Baltic there are good chances that new inflows will oxygenize the deep water. During the beginning of 1994 increasing salinity and oxygen concentrations were detected in the eastern Gotland basin. The oxygen concentrations were as high as 2-3 ml/l in the deep water, the highest for 30 years.

5. Acknowledgement

We would like to thank the NSEPA for continuous cooperation and the renewal of the contract within the national environmental monitoring program. We would also like to thank the National Board of Fisheries for a year characterized by improved and deeper relations. Our special thanks goes to the crew on board the r/v Argos who, as always, showed good spirit and supplied us with professional support around the clock when at sea. For the help renderd us during winter sampling in the Bothnian Sea we thank the Swedish Administartion for Shipping and Navigation.

Appendix: Quality assurance

The concept of quality assurance

Historically, the quality assurance of chemical, physical and biological measurements carried out at the SMHI Oceanographical Laboratory has mainly included elements such as participation in intercomparison exercises, use of well established analytical methods as well as experienced and skilled personnel. During 1993 we have formalised the concept of quality assurance rather strictly, building up a quality system for overall control of our testing activities. A quality system is defined as "organisational structure, routines and resources aiming to lead and steer the operations concerning their quality". In other words, a quality system at a monitoring and testing laboratory like the Oceanographical Laboratory includes all steps taken to make sure that the collected data is of the correct quality and reliable.

The key components of any quality system are a) to decide what the data will be used for, and what kind of quality and how much data this requires b) activities aimed at making the laboratory capable of producing the required data quality, and c) interlaboratory comparisons, follow-up activities and traceability to prove that the data is reliable and correct.

The most visible changes caused by the establishment of the quality system at the Oceanographical Laboratory have been the appointment of a *quality manager*, the creation of a *quality handbook*, understandable and updated *method descriptions*, a very formal keeping of *laboratory books* and the use of *control charts* for internal quality control. We have furthermore initiated a scheme for continuous internal education of all members of the staff. The latter was considered as extremely important in order to keep the staff motivated and interested in quality assurance.

A *quality manager* is a person responsible for implementing the quality system and to make sure that it is functioning in the intended way. The *quality handbook* contains among other things, detailed information on how the laboratory is organised, personal responsibilities and standard procedures for handling information, planning sampling activities, checking data etc. The *method descriptions* describe the analytical methods in detail regarding preparation, sampling, measurement, calibration and evaluation. Copies of all descriptions are kept in one dedicated binder that is always kept updated by the quality manager. This ensures that every person carrying out any testing or measurement will have access to the latest version of the method description. The staff are encouraged to always have the method descriptions at hand, no matter how experienced they are within the field. A formal keeping of *laboratory books* considerably strengthens the traceability of all activities and, together with the method descriptions, aims at minimizing the number of mistakes made in the daily work. *Control charts* make it possible to subjectively decide whether a method is under control or not. They are created by analysing a control solution containing a known amount of the analyte in every batch of samples, and subsequently plotting the result in a diagram together with the mean value and the control limits (mean plus and minus two and three standard deviations). An example of a control chart is given in Figure xx.If the results from the control solution fall outside the acceptable limits according to given rules, the measurements are abandoned until the procedure is under control again. Control charts are, together with motivated and experienced staff, the most important element of internal quality control.

Changes in analytical methodologies

In conjunction with the formalising of the method descriptions most physical, chemical and biological methods used at the laboratory have been investigated in detail and scrutinized for weaknesses. As a result of this many of them have undergone minor technical changes, mainly to increase the confidence in the results obtained through more reliable calibration procedures, the use of control charts and other quality assurance measures.

The manual method for measuring the alkalinity in sea water samples was abandoned overall in late 1993. Instead a more modern, automated, titration with hydrochloric acid has been implemented. Extensive intercomparisons between the two methods showed that the results coming out were identical in accuracy for a range of alkalinity's and salinity's, and that the repeatability (precision) was better with the new method. An automated titration of oxygen (Winkler method) has been tested during 1993 but not yet established as the standard method. Small discrepancies between the old and the new method were found in the intercomparisons carried out; this has to be looked into in more detail before implementing the automated method.

Interlaborative testing comparisons

During 1993 the laboratory has taken part in a number of traditional intercomparison exercises (intercalibrations), both national and international. As a measure of our own performance in these exercises we have started to use the z-score, which is calculated as the difference between our result and the mean result of the group, divided by the standard deviation of the group. For a start we have defined a z-score of more than one as a failure. In other words, as long as our result is less than one standard deviation away from the mean result of the group the intercomparison will be considered a success. The z-score cannot be used in exercises with just two or three participants, an unfortunate limitation, but has been a very valuable tool to assess our performance in larger intercomparisons. So far we have been able to keep the z-score below one in all intercomaparisons and for all parameters with only the odd exception. If this trend continues we will discuss lowering the z-score limit slightly to put more pressure on ourselves in the future.

Apart from the traditional intercomparisons we have taken part in the interlaboratory exercise "QUASIMEME", a project funded by the European Union aimed at assuring the quality of data in European marine monitoring programmes. In contrast to other intercomparisons, this project has included an ambitious programme for exchange of information between laboratories, a training scheme for laboratories who do not perform well and workshops for discussion and support. All results are open to all participants, i.e. the laboratory's name is disclosed together with the results in the internal reports. This has created a very open and friendly atmosphere within the project, where participants do not hesitate to admit present or former weaknesses in their methods and to reveal how they have been tackled.

The QUASIMEME intercomparisons have this far included nutrients, heavy metals and chloroorganics (chlorinated biphenyls, CBs). Since we do not measure heavy metals we have taken part in nutrients and CBs only. The results have been encouraging for us, particularly for the CBs where we have very little experience but nevertheless performed well in the first round. the samples sent out were standard solutions and fish oil. The results for the nutrients, in spiked sea water samples at three different concentration levels, confirmed our status as a skilled and reliable laboratory within that field.

Accreditation

Formal accreditation means that a laboratory has a quality system as required by the Swedish and European standard SS-EN 45001, and that the laboratory thus has the competence and the resources required to carry out certain measurements. The laboratory still has to prove, for example by participating in intercomparison exercises or by the use of certified reference materials, that the data produced actually is correct. Preparations for seeking accreditation for the majority of the chemical, physical and biological measurements carried out at the laboratory are well underway. Most of what was described under the "quality assurance" section above is also valid for a laboratory seeking accreditation. A formal application to SWEDAC, the official body for accreditation in Sweden, was filed in early 1994.

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