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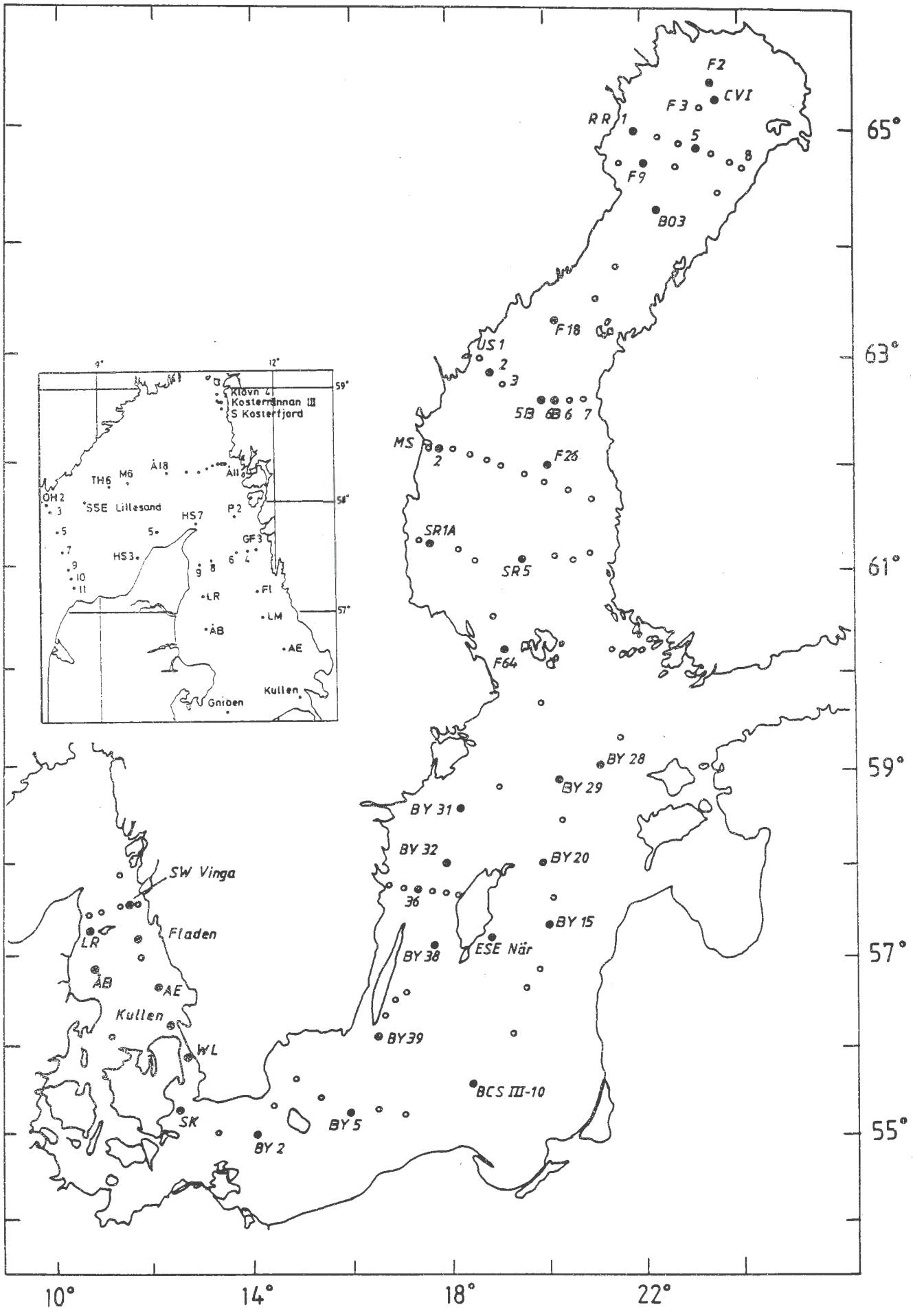
THE CONDITIONS OF THE SEAS AROUND SWEDEN

Reports from the activities in 1992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THE CONDITIONS OF THE SEAS AROUND SWEDEN

Report from the activities in 1992

by

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The Conditions of the Seas around Sweden. Report from activities in 1992.

Abstract

This report describes some aspects of the hydrographical conditions in the open sea areas around Sweden, based on SMHIs environmental monitoring program during 1992. Due to the warm winter the mean sea surface temperature during spring was about 2 °C higher than normal. In Skagerrak events with very high nutrient concentrations accurred close to the Danish coast. No severe oxygen deficits were present in the Kattegat, the lowest value recorded was 0.8 ml/l in the Laholm Bight during September. During autumn silicate in Kattegat surface water was below the detection limit which is very unusual. No major inflow of high saline water to the Baltic has occurred since 1977 and the salinity in the Gotland Deep at the end of 1992 was lowest ever recorded.

Key words

Baltic Sea, Skagerrak, Kattegat, Baltic Monitoring Programme, oceanography, temperature, salinity, oxygen condition, hydrogen sulphide, nutrients, trends phytoplankton, primary production, chlorophyll.

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1. PREFACE

SMHI Oceanographical Laboratory is carrying out a comprehensive investigating activity in the open seas around Sweden, from the Skagerrak to the northern part of the Bothnian Sea. The objective is to persistently and for a long term collect hydrographical data of high quality in order to facilitate the studies of climatological variations and changes, including human influence on the marine environment.

Physical, chemical and biological parameters are studied in water samples, zoobenthos is studied in sediment grab samples and samples of fish and mussels are collected for determination of harmful substances in the Kattegat, the Sound (Öresund), the Baltic Proper and the Gulf of Bothnia. The work is partly funded by the National Swedish Environmental Protection Agency (NSEPA) on contract basis together with the National Board of Fisheries which permits sufficient working hours onboard R/V Argos.

During 1992 the laboratory has actively participated in the assessment work initiated by the NSEPA for the national monitoring programme (PMK). The laboratory has been represented in four different working groups which have presented their reports before the national and international evaluation of the marine part of PMK. Besides, the staff of the laboratory was given the responsibility for coordinating the assesment of the Kattegat and Skagerrak.

Due to the revision of the monitoring programme the measurements during 1992 are a mixture of the old programme and the proposed one.

This report describes the hydrographical conditions in the open sea areas around Sweden, based on a part of SMHIs environmental monitoring. A part of the results from the project are also reported as a national Swedish contribution to the Baltic Monitoring Programme (BMP) of the Helsinki Commission (HELCOM).

Acknowledgements

We would like to thank the NSEPA for the continuous cooperation and renewed contract within PMK. We also thank the National Board of Fisheries for one more year of good cooperation. Our special thanks to the Argos crew who, as always, took care to see to that we were on "station". For the help rendered to us during winter sampling in the Bay of Bothnia we thank the National Swedish Administration for Shipping and Navigation.

2. WEATHER AND ICE CONDITIONS

For the fifth consecutive year the annual mean air temperature was above normal. 1992 was somewhat warmer than 1991 but not as warm as 1989 or 1990. The wintermonths were characterised by strong winds, even if the storm frequency during the winter months were unusually low. However, the frequency of westerly and southwesterly winds were 40-60 %, which is about twice the normal during winter season. The most extraordenary events during 1992 was the drought in the beginning of the summer, most extreme in southeastern Sweden, but also the early entry of winter in October.

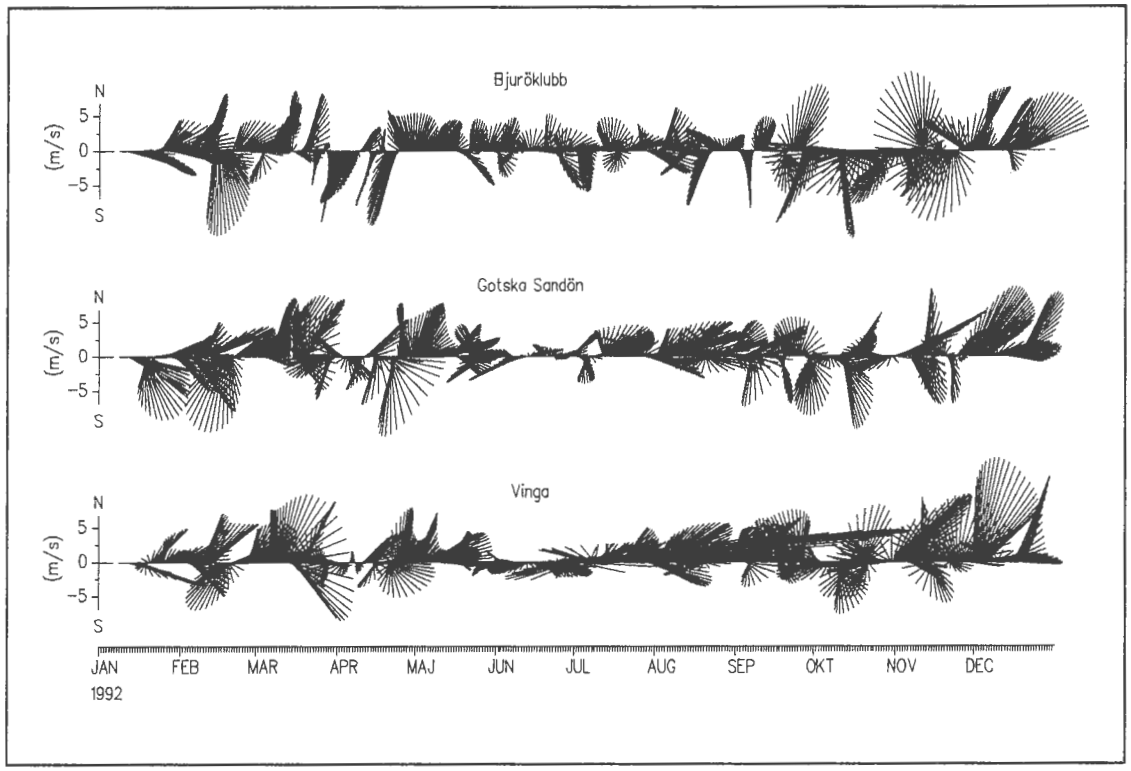


Fig 2.1 Windvectors from three coastal stations showing wind direction and speed. Data have been averaged and filtered to strengthen timescales of a week and longer.

The ice-conditions were very easy during the winter 91-92. The mean monthly temperatures in the northern waters were 5 to 7 degrees higher than normal. On February 20 the ice-extent reached its maximum, the Bay of Bothnia and the Quark was ice covered. However only after a few days the ice broke up and was compressed against the Finnish coast. During March the ice extension was probably the smallest ever during the 20th century. The offshore areas were ice-free on April 14, about a week earlier than normal.

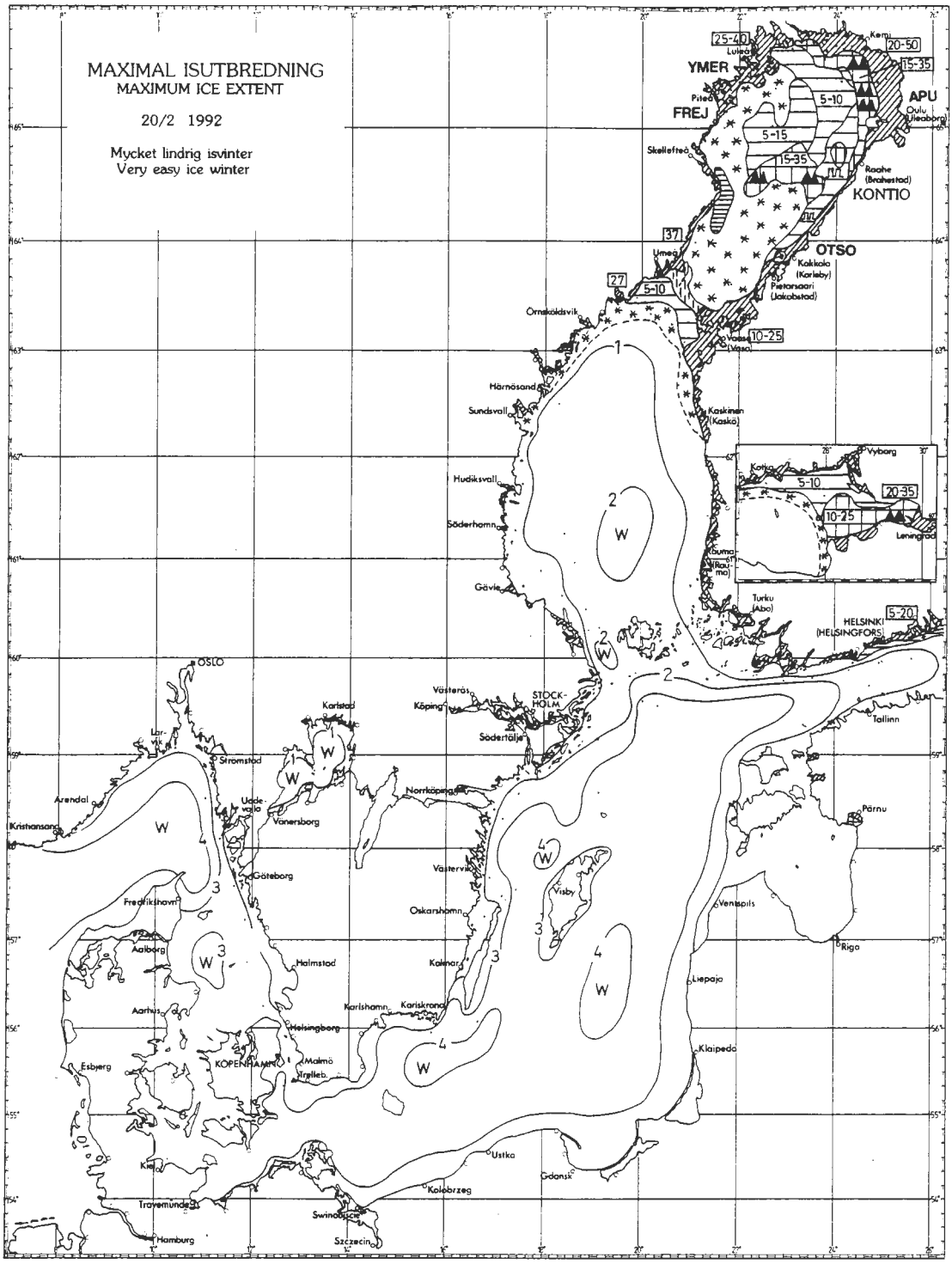


Fig 2.2 Maximum ice extent 1992.

3. OCEANOGRAPHIC CONDITIONS

3.1 Skagerrak

The spring bloom started very early this year, already in February the nutrient concentrations began to decrease.

Surface	M6			P2		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Feb 92	0.43	5.94	5.6	0.42	6.29	5.1
Feb 80-89	0.64	8.61	3.6	0.74	10.42	8.7

Table 3.1.1 Surface water concentrations of PO_4, NO_3, and SiO_2 together with February-means for the period 1980-1989, at the stations M6 in central-and P2 in the southeastern Skagerrak.

The lowest surface temperatures were observed in the turn of the months March/April, in the low saline water along the Swedish coast. In the central parts the halocline extended from the surface down to 30 m depth, under which the salinity was almost constant. Along the Danish coast, the salinity was high and the water homogeneous regarding all parameters.

There were large horizontal variations in nutrient concentrations in the surface layer. The lowest values were found close to the Swedish coast, the highest along the Jutland coast. Phosphate values varied between 0.05 and 0.4 µmol/l, while the nitrate concentrations ranged from values under the detection limit (0.10 µmol/l) up to 7.9 µmol/l.

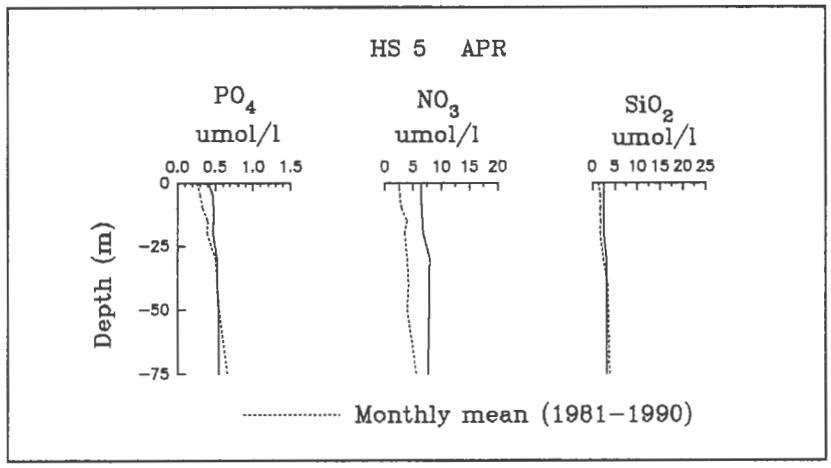


Figure 3.1.1 Nutrient profiles from the station HS5 in southern Skagerrak, together with mean profiles for April, for the period 1981-1990.

In late spring, May-June, the surface water started to warm up and the temperature was nearly constant in the entire water mass. The surface salinity was highest in the southern region along the Jutland coast (>34 psu). At depths exceeding 70 m in the central parts of the Skagerrak, the salinity was higher than 35 psu. The lowest oxygen concentrations measured during spring was 5.9 ml/l, equivalent to 86% saturation, in the

bottom waters of the central region.

Along the Norwegian and Danish coasts the phosphate concentrations were below detection limit (0.02 µmol/l) in the surface layer , in the other parts the concentrations varied from 0.02 to 0.07 µmol/l. Also the nitrate concentrations were below the detection limit (0.10 µmol/l) in the surface layer, except along the Jutland coast where concentrations were high, >15 µmol/l at Jammer Bight and around 4 µmol/l at Skagen.

Surface	M6			P2		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
May 92	0.03	<0.10	1.1	0.21	<0.10	2.0
May 80-89	0.06	1.00	2.1	0.08	0.44	0.6

Table 3.1.2 Surface water concentrations of PO_4, NO_3, and SiO_2 together with May-means for the period 1980-1989, at the stations M6 in central- and P2 in southeastern Skagerrak.

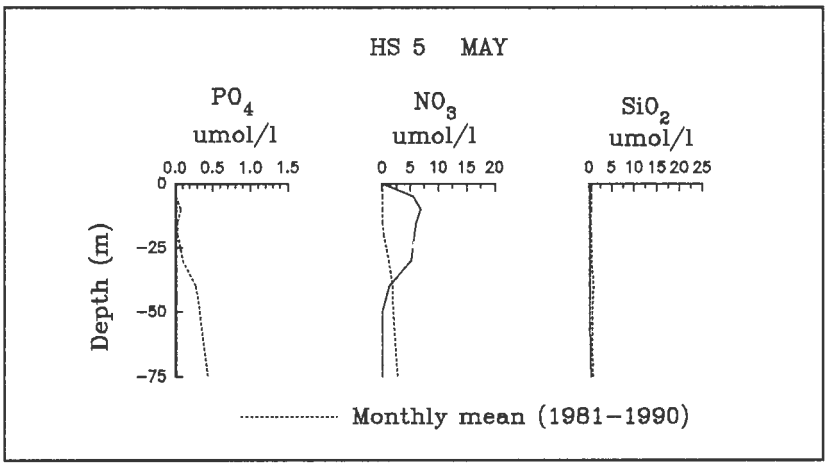


Figure 3.1.2 Nutrient profiles from the station HS5 in southern Skagerrak, together with mean profiles for May, for the period 1981-1990.

In the autumn (October) surface temperatures varied from 7.7°C in the southeast part along the Swedish coast to 11.8°C in the southwest. The warmest water was found in an intermediate layer at 15-30 m depth. Oxygen values varied very little, between 5.1 and 6.8 ml/l in the whole water mass. The phosphate concentrations were lowest, 0.02 µmol/l in the Baltic water near the Swedish coast, and highest 0.37 µmol/l in the North Sea water outside Hanstholm. Nitrate concentrations varied from values below detection limit (0.10 µmol/l) up to 1.7 µmol/l without any specific pattern. The concentrations of silicate were generally low, exept along the Jutland coast where values of above 3 µmol/l, which was observed.

3.2 Kattegat and the Sound

The hydrographical conditions in the Kattegat were at the beginning of the year characterized by a continuous stratification and the absense of a homogeneous surface layer. The phosphate conditions were normal for the season, while the nitrate and silicate

values were below mean. In the Sound the situation was typical for the winter season.

Surface	Fladen			Anholt E		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Jan 92	0.80	4.86	5.2	0.92	4.21	5.1
Jan 80-89	0.75	8.85	11.6	0.75	6.25	10.0

Table 3.2.1 Surface water concentrations of PO_4, NO_3 and SiO_2 together with January-means for the period 1980-1989, at stations Fladen in northern- and Anholt E in central Kattegat.

Surface	W Landskrona		
month	PO4	NO3	SiO2
Jan 92	0.85	3.58	16.5
Jan 80-89	0.73	5.80	11.9

Table 3.2.2 Surface water concentrations of PO_4, NO_3 and SiO_2 together with January-means for the period 1980-1989, at the station W Landskrona in the central part of the Sound.

In late winter (February-March) the temperatures in the surface layer of the Kattegat varied from 2.4°C in the southern part to 4.1°C in the north, which was about 1.5 °C higher than the mean value for the years 1980-1989. The halocline were located at a depth of aproximately 30 m. The phosphate concentrations were clearly below normal in the entire water column, while other nutrients were found in normal amounts.

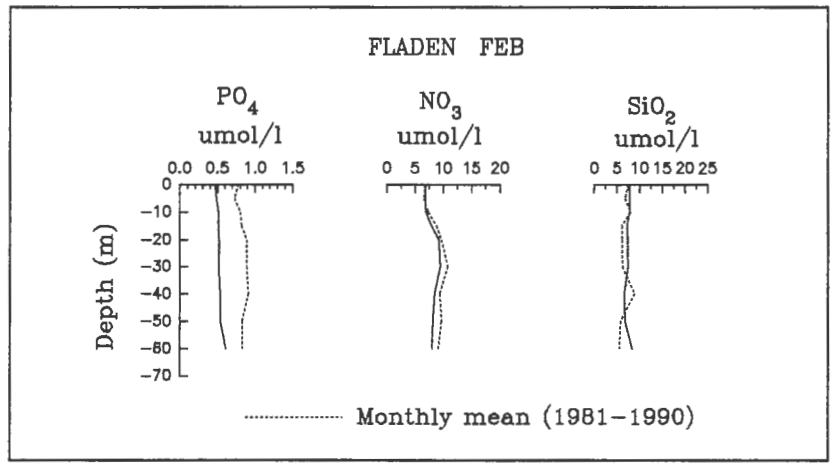


Figure 3.2.1 Nutrient profiles from the station Fladen in northern Kattegat, together with mean profiles for February, for the period 1981-1990.

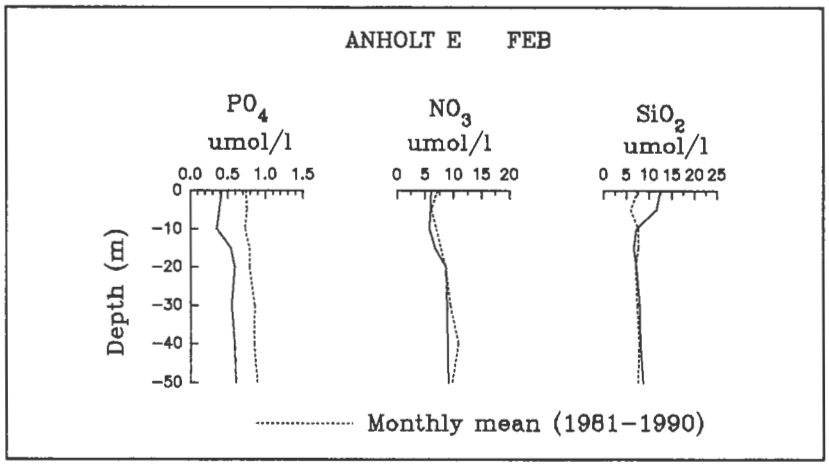


Figure 3.2.2 Nutrient profiles from the station Anholt E in central Kattegat, together with mean profiles for February, for the period 1981-1990.

In early spring, April-May, the water mass was again nearly continuously stratified from surface to bottom both with regards to temperature and salinity. Lowest oxygen value, 5.5 ml/l, was in the southern parts. Nitrate concentrations were below the detection limit in the entire surface layer except outside Göteborg, where the water was affected by the outflow from Göta älv. The phosphate values were also low, 0.05-0.1 µmol/l with the highest values in the south. Low chlorophyll concentrations were found in the eastern part of Kattegat (0.5-2.5 µg/l), whereas concentrations of 2-6 µg/l were measured in the western part.

In the Sound the surface water temperature was normal for the season, nearly 3.5°C. In the southern part the water was to a large extent homogeneous regarding salinity, around 8-9 psu, while in other parts there existed great vertical differences. The highest salinity 32.7 psu and the lowest oxygen value, 5.10 ml/l (amounting to 72% saturation) were measured in the deep region just west of Landskrona.

Surface	W Landskrona		
month	PO4	NO3	SiO2
Mar 92	0.13	2.02	11.9
Mar 80-89	0.51	5.15	13.1

Table 3.2.3 Surface water concentrations of PO_4, NO_3 and SiO_2 together with March-means for the period 1980-1989, at the station W Landskrona in the central part of the Sound.

The last week of May the surface temperatures in the Kattegat varied around 10-12°C, one and a half week later they had risen to between 15-18°C. The nutrient concentrations were generally low in the surface water, as usual after the spring bloom, but also in the deep water, which is unusual for the season. Late May a subsurface chlorophyll maxima started to develop, concentrations of above 9 µg/l were observed. Two weeks later these subsurface maxima had disappeared.

The surface water temperature in the Sound varied between 10.3 and 11.3°C. At 10-20 m depth in the northern part of the Sound down to Landskrona there was a distinct halocline, where the the salinity increased with depth from 13 to 31 psu. The conditions were more homogeneous in the southern part. The lowest oxygen value, 4.49 ml/l, corresponding to 64% saturation was measured in the deep west of Landskrona.

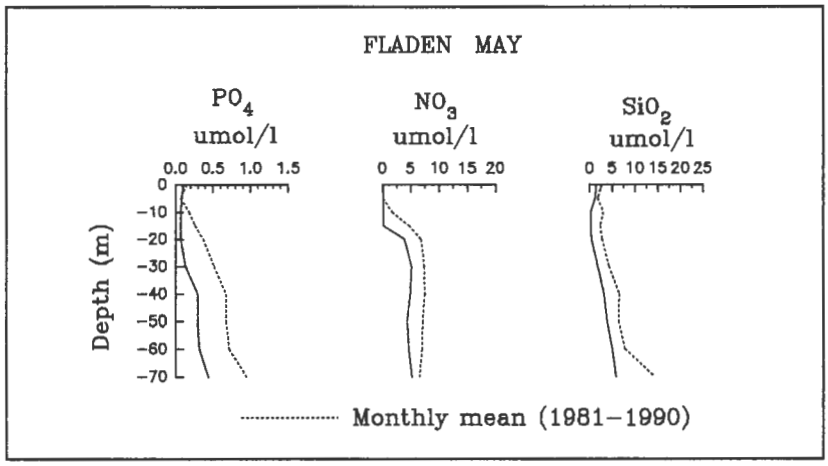


Figure 3.2.3 Nutrient profiles from the station Fladen in northern Kattegat, together with mean profiles for May, for the period 1981-1990.

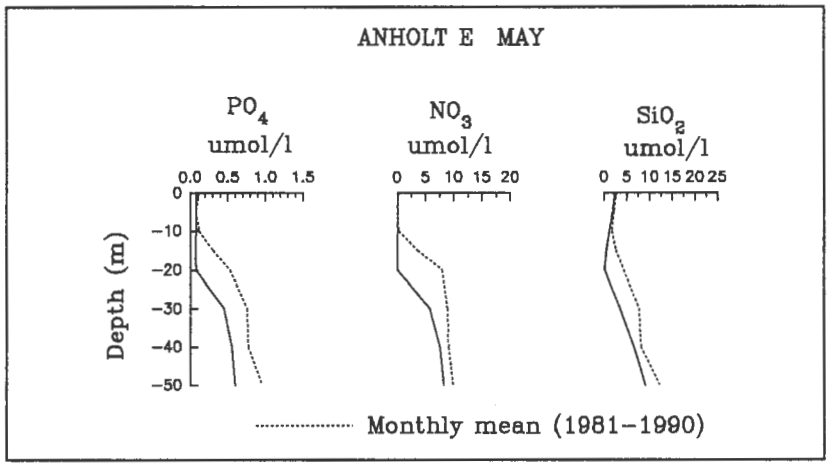


Figure 3.2.4 Nutrient profiles from the station Anholt E in central Kattegat, together with mean profiles for the period 1981-1990.

	GF9		GF8	GF7	GF6		GF5		GF4		GF3
0	4.96	2.80	1.64	2.10	1.44	1.80	2.15	2.19	2.35	2.64	2.41
5		2.16			1.48	1.71					
	4.78										
10	9.26		1.82	3.57			1.51	1.73	1.44	1.96	2.28
		5.34				3.12					
15	2.40				0.87					1.76	
			3.40	3.90			1.03	9.25	4.08		1.25
20		1.25									

Figure 3.2.5 Distribution of chlorophyll along the GF-section in the northern Kattegatt in the beginning of May.

Surface	W Landskrona		
month	PO4	NO3	SiO2
May 92	0.22	<0.10	9.6
May 80-89	0.13	0.24	3.7

Table 3.2.4 Surface water concentrations of PO_4, NO_3 and SiO_2 together with May-means for the period 1980-1989, at the station W Landskrona in the central part of the Sound.

In late summer (August) the Kattegat surface temperature varied from 15.5°C in the northwest to 16.8°C in the south. The salinity in the surface layer varied from 15 psu in the south to 22 psu in the north. Under the halocline the water was homogeneous, with a salinity above 35 psu in the northernmost parts. Beneath the halocline the oxygen saturation decreased abruptly. Concentrations in the bottom waters varied from 4.4 ml/l in the north to 1.3 ml/l (21 % saturation) in the south. The lowest values, < 2 ml/l, was measured in the Laholm Bight. All the nutrient concentrations were below the detection limits, except for silicate which varied around 4 µmol/l in the sothern parts. It is unusual that silicate concentrations are that low.

Surface	Fladen			Anholt E		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Aug 92	<0.02	<0.10	<0.1	<0.02	<0.10	0.1
Aug 80-89	0.12	1.83	2.3	0.08	0.15	1.8

Table 3.2.5 Surface water concentrations of PO_4, NO_3 and SiO_2 together with August-means for the period 1980-1989, at the stations Fladen in northern- and Anholt E in central Kattegat.

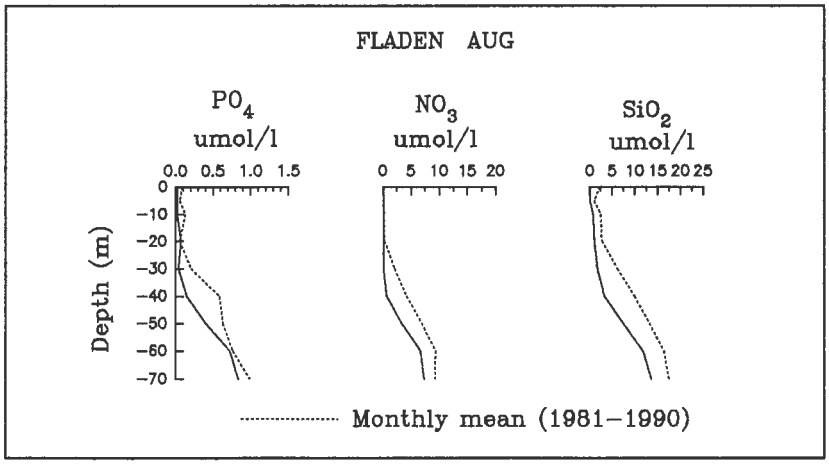


Figure 3.2.6 Nutrient profiles from the station Fladen in northern Kattegat, together with mean profiles for August, for the period 1981-1990.

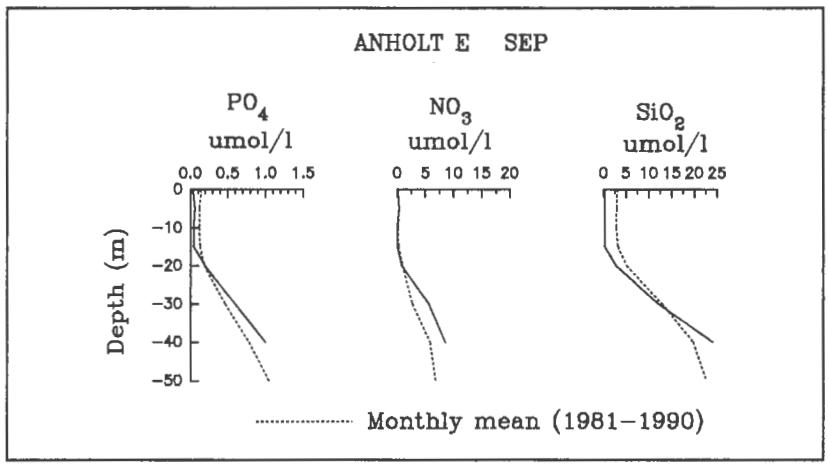


Figure 3.2.7 Nutrient profiles from the station Anholt E in central Kattegat, together with mean profiles for August, for the period 1981-1990.

In the Sound the thermocline was located at 5 m depth. The surface layer temperature was 17°C. The surface salinity increased from 9.8 psu in the south to 15.0 psu in the north. North of the sill at Saltholm the salinity in the deep waters exceeded 31 psu. Oxygen concentrations were in general low in the bottom waters, lower than 3 ml/l between Kullen and Saltholm. The lowest value 2.2 ml/l, amounting to 35 % saturation was measured outside Barsebäck. North of Ven the phosphate concentrations were below the detection limit in the surface layer. Further south the concentrations were higher and the difference between surface and bottom water values was small. The nitrate concentrations in the surface water showed a maximum value of 0.36 µmol/l in the central part of the Sound, while the concentrations were low south and north thereof. The surface silicate values varied from 4.9 µmol/l in the north to about 13 µmol/l in the south.

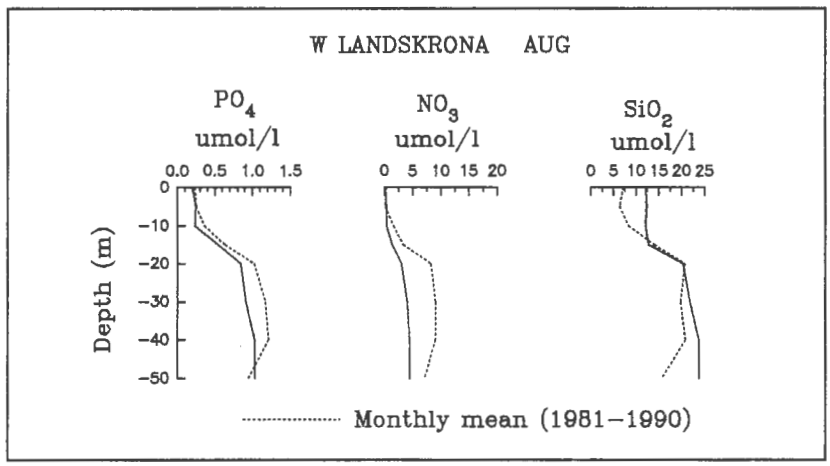


Figure 3.2.8 Nutrient profiles from the station W Landskrona in the central part of the Sound, together with mean profiles for August, for the period 1981-1990.

In the beginning of September the entire Kattegat was characterized by a thoroughly mixed surface layer with a thickness of 10 to 20 m, and a salinity of 25 psu in the north decreasing to 22 psu in the south. The bottom water salinity was 33 psu in the entire area. The bottom waters in the Laholm Bight and Skälderviken had oxygen

concentrations below 2 ml/l, which nowdays can be considered as normal for the autumn season. In the warm surface water the nutrient concentrations were low compared to the mean value, while they were higher in the colder Baltic waters in the south.

Surface	Fladen			Anholt E		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Sep 92	0.03	0.35	0.5	0.03	0.02	0.2
Sep 80-89	0.16	3.48	3.1	0.13	0.22	3.2

Table 3.2.6 Surface water concentrations of PO_4, NO_3 and SiO_2 together with September-means for the period 1980-1989, at the stations Fladen in northern- and Anholt E in the central Kattegat.

The Sound was strongly stratified with a halocline at 20 m depth. The surface temperature was 15°C, ca. 2°C higher than the mean temperature. Below the halocline the water temperature was normal, around 10°C. In the bottom waters the oxygen concentratios were very low, < 2ml/l, yet slightly higher than in 1991.

The surface layer had very low concentrations of phosphate, nitrite and nitrate comparable to the concentrations in the Kattegat. Silicate concentrations on the other hand were conciderably higher than normal.

Surface	W Landskrona		
month	PO4	NO3	SiO2
Sep 92	0.19	<0.10	14.1
Sep 80-89	0.31	0.47	5.8

Table 3.2.7 Surface water concentrations of PO_4, NO_3 and SiO_2 together with September-means for the period 1980-1989, at the station W Landskrona in the central part of the Sound.

In the latter half of September the situation was very similar to that in the beginning of the month. The nutrient concentrations were still very low in the Kattegat surface water. In the Sound the silicate concentrations were considerably higher than normal while other nutrient concentrations were below mean values.

Surface	W Landskrona		
month	PO4	NO3	SiO2
Sep 92	0.19	<0.10	14.1
Sep 80-89	0.31	0.47	5.8

Table 3.2.8 Surface water concentrations of PO_4, NO_3 and SiO_3 together with September-means for the period 1980-1989, at the station W Landskrona in the central part of the Sound.

In October the nutrient concentrations in the surface water were still lower than usual, although the difference from the mean value had decreased since September. The Oxygen conditions in the bottom waters had improved slightly.

Surface	Fladen			Anholt E		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Oct 92	0.06	<0.10	0.5	0.09	<0.10	0.6
Oct 80-89	0.25	3.16	5.2	0.22	0.72	3.0

Table 3.2.9 Surface water concentrations of PO_4, NO_3 and SiO_2 together with October-means for the period 1980-1989, at the stations Fladen in northern- and Anholt E in central Kattegat.

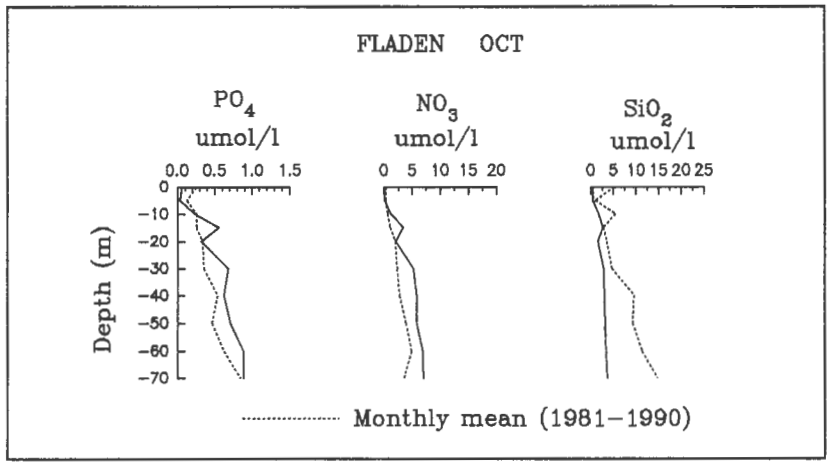


Figure 3.2.9 Nutrient profiles from the station Fladen in northern Kattegat, together with mean profiles for October, for the period 1981-1990.

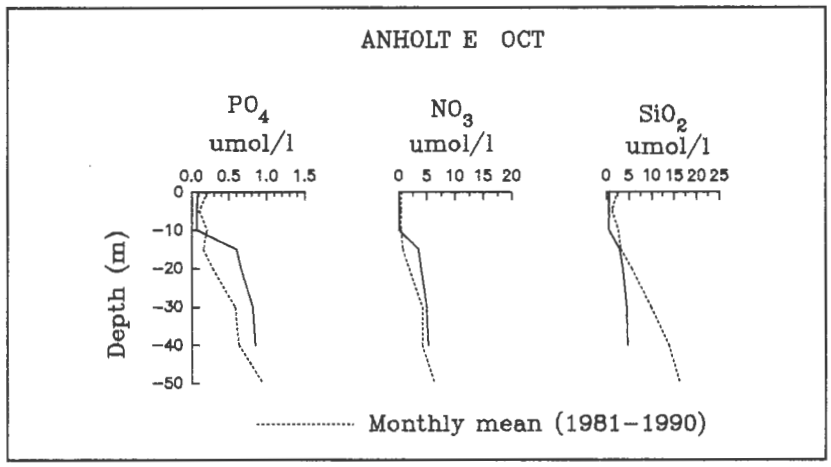


Figure 3.2.10 Nutrient profiles from the station Anholt E in central Kattegat, together with mean profiles for October, for the period 1981-1990.

In November the oxygen concentrations in Kattegat bottom waters varied from 5.2 ml/l in the north to 3.7 ml/l outside Kullen in the south. Silicate were approaching typical concentrations for the season. Phosphate and nitrate concentrations were lower than normal in the northern Kattegat, while the values in the south were close to the mean. There were relatively high concentrations of chlorophyll, considering the time of the year. The Sound revealed the same hydrographical character as the southern Kattegat. The lowest oxygen concentrations were measured on the shallow stations in the southernmost

parts, 1.5 ml/l at 15 m depth. The chlorophyll concentrations was everywhere less than 2 µg/l.

Surface	Fladen			Anholt E		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Nov 92	0.22	1.62	4.3	0.23	1.10	3.6
Nov 80-89	0.41	6.40	5.3	0.38	0.97	5.7

Table 3.2.10 Surface water concentrations of PO_4, NO_3 and SiO_2 together with November-means for the period 1980-1989, at the stations Fladen in northern- and Anholt E in central Kattegat.

	GF4	Fladen	Kullen	W Landsk
0	2.76	2.63	3.15	1.80
	2.47	2.35	3.23	1.80
5	2.43	2.51	3.04	1.77
10	2.47	2.70	0.87	1.64
15	2.33	0.47	0.42	0.59
20	1.01	0.29	0.47	0.50

Figure 3.2.11 Distribution of chlorophyll along a north-south transect in the eastern Kattegat in the beginning of November 1992.

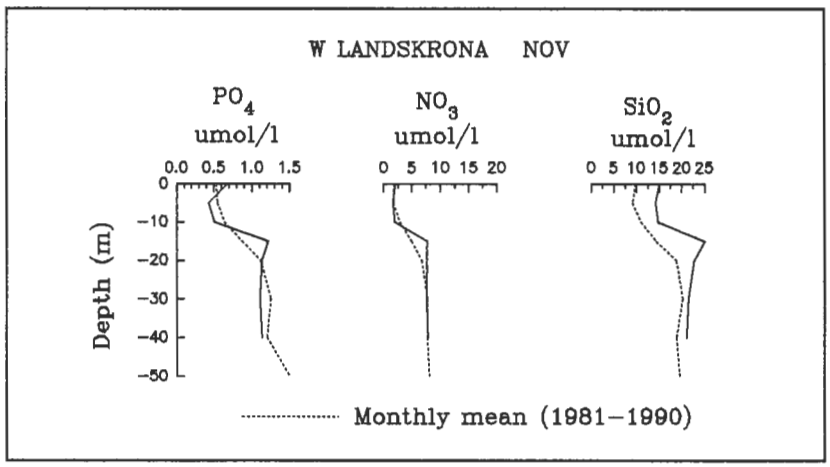


Figure 3.2.12 Nutrient profiles from the station W Landskrona in the central part of the Sound, together with mean profiles for November, for the period 1981-1990.

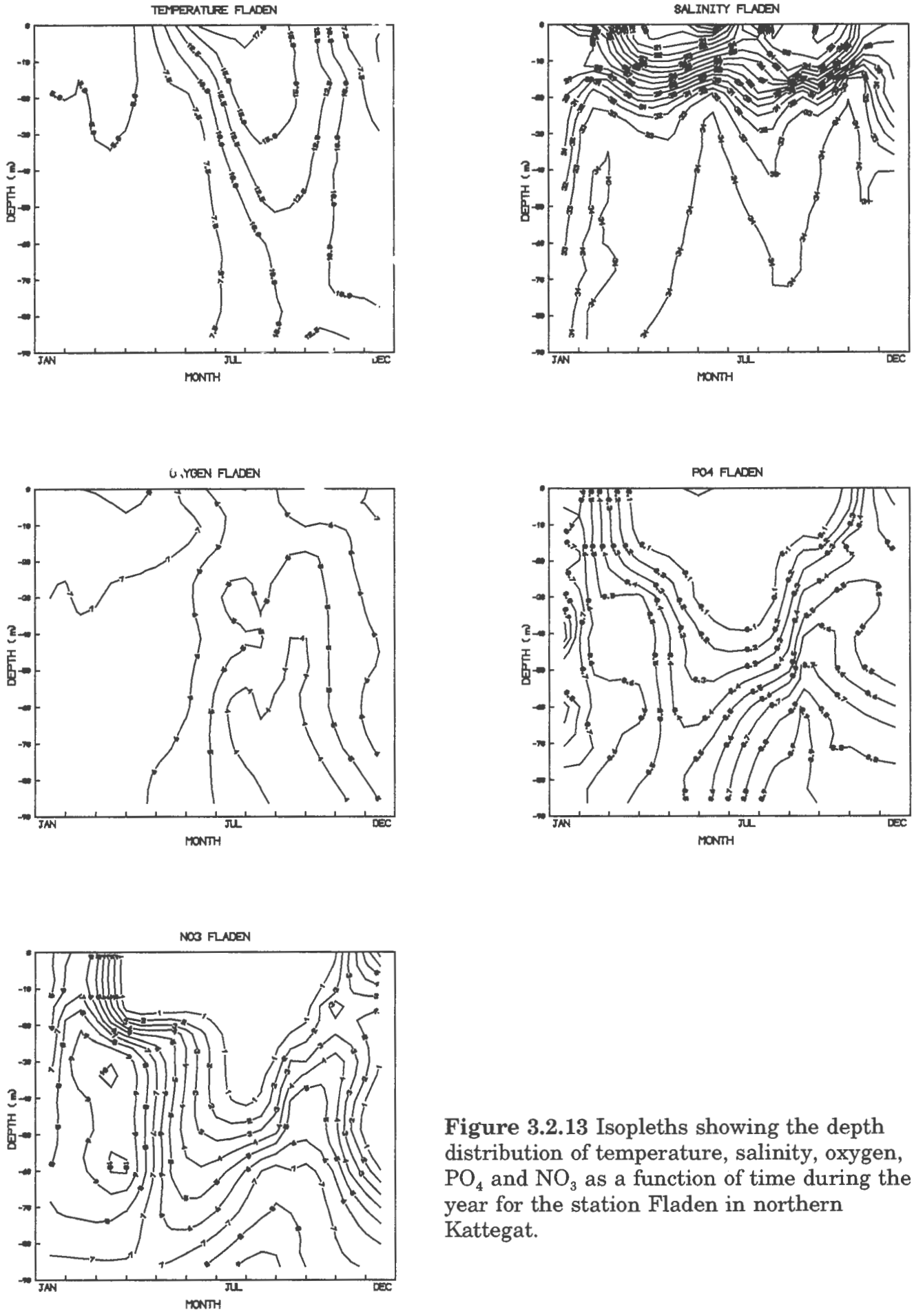


Figure 3.2.13 Isopleths showing the depth distribution of temperature, salinity, oxygen, PO_4 and NO_3 as a function of time during the year for the station Fladen in northern Kattegat.

Oxygen conditions in the Kattegat

Oxygen concentrations continued to decrease during the autumn and, as usual, the lowest values were found in the southeastern parts. During September the concentrations fell rapidly, but a change in weather with strong winds mixed the water and the situation never became severe.

Station	31/8-1/9	14-16/9	22-23/9	27-28/9
Fladen	3.6	3.4	3.3	3.2
Anholt E	2.9	2.3	2.0	1.8
Laholm-2	1.3	1.2	--	0.8

Table 3.2.11 Changes in oxygen concentrations, in the deep water during September, at three stations in the Kattegat.

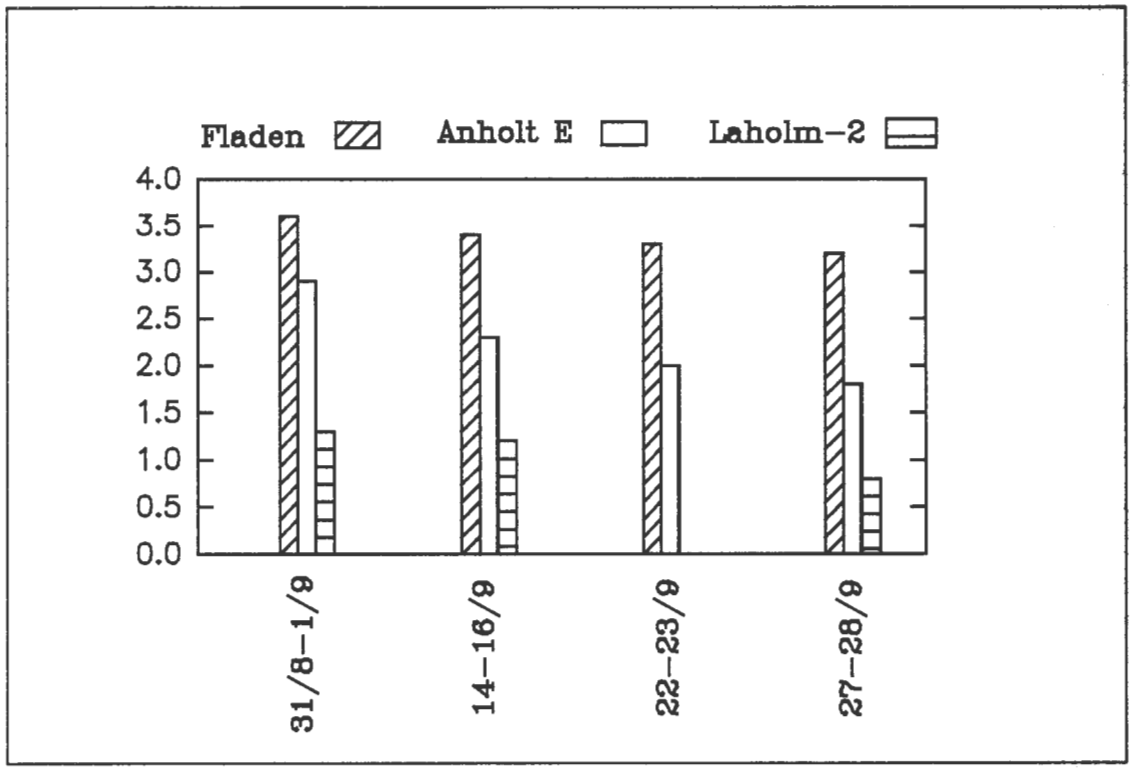


Figure 3.2.14 Changes in oxygen concentrations, in the deep water during September, at three stations in the Kattegat.

3.3 The Baltic Sea

At the beginning of the year the surface temperature was 1-2°C higher than the mean for 1980-1989. The density stratification had weakened and the salinity values in the deeper parts had decreased by approximately 0.1-0.2 psu as compared to the conditions last January. At 240 m depth in the eastern Gotland Deep the salinity was 11.18 psu, the lowest ever measured. In the Bornholm Deep the surface layer extended down to a depth of 40-60 m and in the other parts of the Baltic Proper down to 80 m. This was about 10-20 m deeper than last year, which could be an effect of erosion, strengthened by the weakened stratification, caused by vertical convection due to the winter cooling.

The entire surface layer was to a large extent saturated with oxygen, with concentrations around 8 ml/l. In and below the pycnocline the concentrations decreased abruptly. Low oxygen concentrations (< 2 ml/l) were encountered in the eastern parts of the Bornholm Deep, in the deeper parts of the Gdansk Bight, and in the eastern Gotland Deep including the northern parts of the western Gotland Deep. Hydrogen sulphide was present east of Gotland, and the redoxcline were located at 130-140 m depth. Nutrient concentrations in the entire area were normal for the season.

Surface	BY2			BY15		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Jan 92	0.77	3.87	12.9	0.49	3.96	10.6
Jan 80-89	0.66	4.07	12.5	0.52	3.27	11.4

Table 3.3.1 Surface water concentrations of PO_4, NO_3 and SiO_2 together with January-means for the period 1980-1989, at the stations BY2 in southwestern- and BY15 in central Baltic.

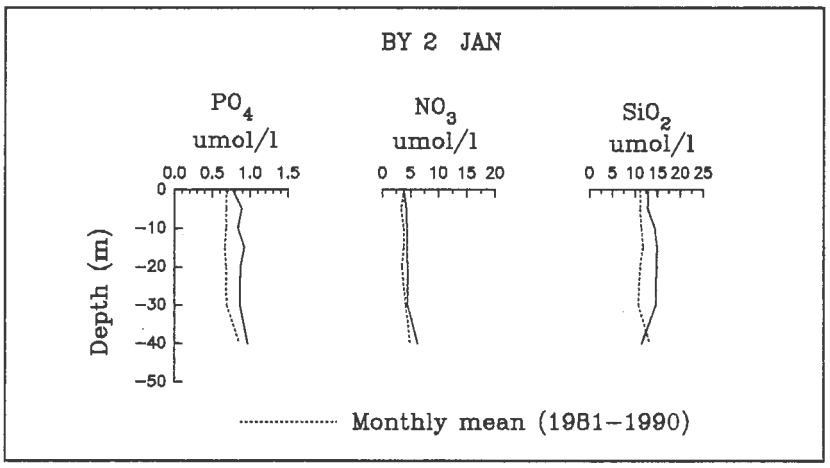


Figure 3.3.1 Nutrient profiles from the station BY2 in the southwestern part of the Baltic, together with mean profiles for January, for the period 1981-1990.

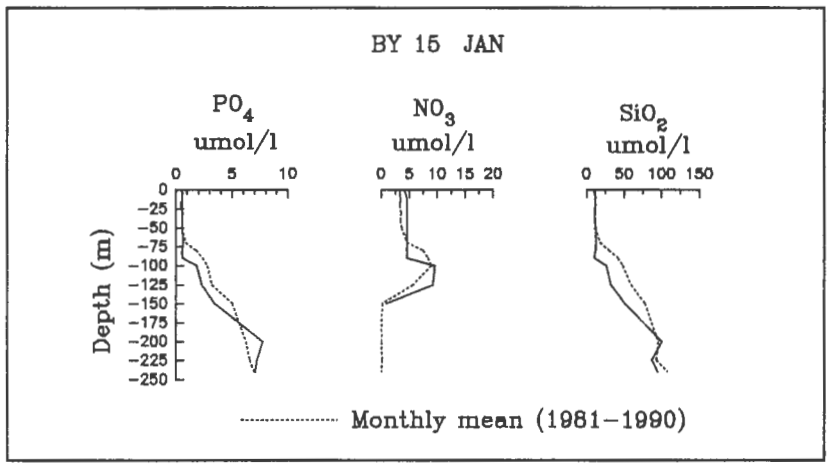


Figure 3.3.2 Nutrient profiles from the station BY15 in the central part of the Baltic, together with mean profiles for January, for the period 1981-1990.

In spring (March) the surface water was isothermal down to about 50 m depth and the temperature varied between 3.1 and 4.0°C. Since January some new deep water had entered into the Gotland Deep and the salinity at 240 m depth had increased to 11.23 psu.

Oxygen concentrations decreased quickly in and below the halocline. Values below 2 ml/l were measured in the eastern Gotland Deep and in the northernmost parts of the western Gotland Deep. Hydrogen sulphide was measured in the eastern Gotland Deep at depths exceeding 140-150 m, and also outside the entrance to the Gulf of Finland at depths exceeding 175 m.

Surface	BY2			BY15		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Mar 92	0.54	3.41	14.8	0.25	4.38	13.8
Mar 80-89	0.72	4.60	17.3	0.62	4.54	14.4

Table 3.3.2 Surface water concentrations of PO_4, NO_3 and SiO_2 together with March-means for the period 1980-1989, at the stations BY2 in southwestern- and BY15 in central Baltic.

Late May the temperatures were lower than normal in the entire Baltic Sea. In the beginning of June the surface temperatures increased rapidly, approaching normal conditions. The halocline was located at 60 m depth in the central parts, north and south thereof the halocline depth varied betwwen 20 to 30 m. The isoline for 2 ml/l oxygen was found at a depth of 100 m in the Eastern Gotland Basin. In other parts no values below 2 ml/l were noted. The phosphate varied in the surface layer from <0.02 µmol/l to 0.33 µmol/l. Nitrate concentrations were under detection limit in the entire surface layer. The lowest silicate concentrations, 3.1 µmol/l, were found outside the Gulf of Finland, and increased towards south and southwest. At the station BY2 in southern Baltic the silicate concentrations were double compared to normal. The chlorophyll concentrations were low in the southern and western parts of the Baltic. In the eastern part, however, high concentrations (up to 10 µg/l) were measured. As in Kattegat subsurface chlorophyll

maxima were found at several stations.

Surface	BY2			BY15		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
May 92	0.17	<0.10	11.6	0.04	<0.10	12.1
May 80-89	0.25	0.24	4.8	0.20	0.22	5.5

Table 3.3.3 Surface water concentrations of PO_4, NO_3 and SiO_2 together with May-means for the period 1980-1989, at the stations BY2 in southwestern- and BY15 in central Baltic.

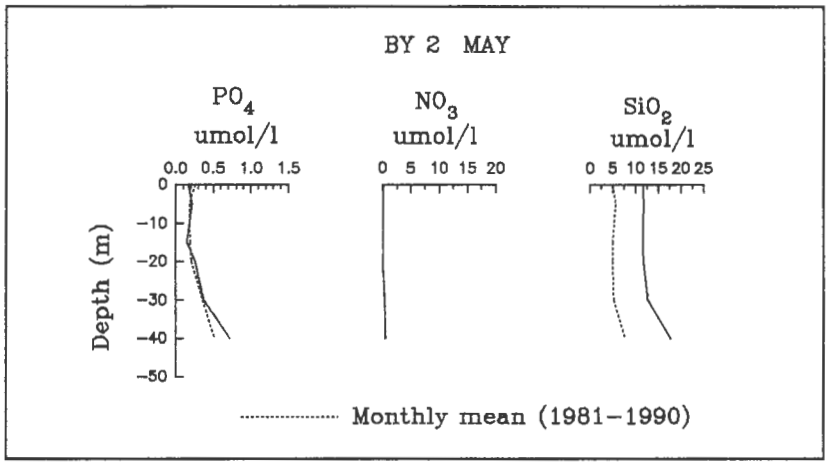


Figure 3.3.3 Nutrient profiles from the station BY2 in the southwestern part of the Baltic, together with mean profiles for May, for the period 1981-1990.

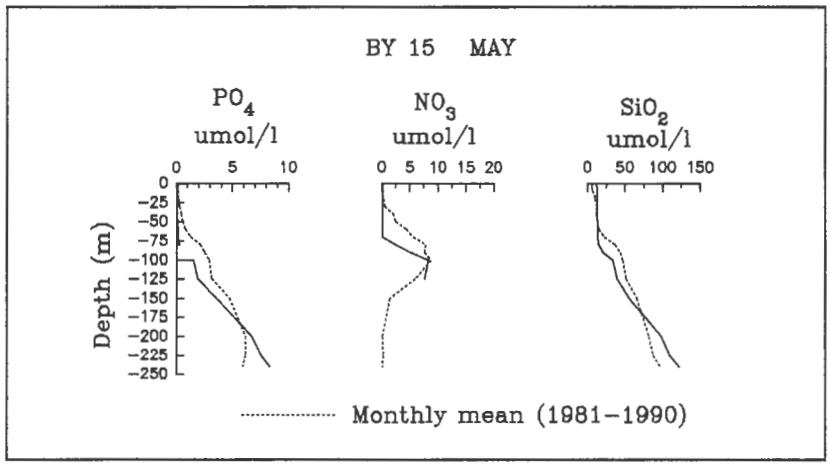


Figure 3.3.4 Nutrient profiles from the station BY15 in the central part of the Baltic, together with mean profiles for May, for the period 1981-1990.

In late summer the temperature stratification was distinct except in the southernmost part of the Baltic Sea. The temperature of the surface water was 15-17°C. Nutrient concentrations were typical for the season, except for the silicate concentrations in the southern Baltic, which still were higher than normal.

Surface	BY2			BY15		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Aug 92	0.13	<0.10	11.9	0.06	<0.10	6.6
Aug 80-89	0.12	0.18	7.6	0.09	0.15	5.2

Table 3.3.4 Surface water concentrations of PO_4, NO_3 and SiO_2 together with August-means for the period 1980-1989, at the stations BY2 in southwestern- and BY15 in central Baltic.

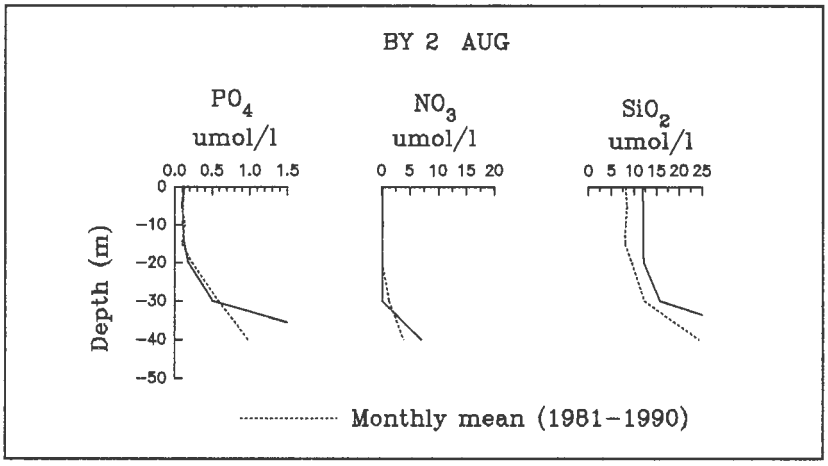


Figure 3.3.5 Nutrient profiles from the station BY2 in the southwestern part of the Baltic, together with mean profiles for August, for the period 1981-1990.

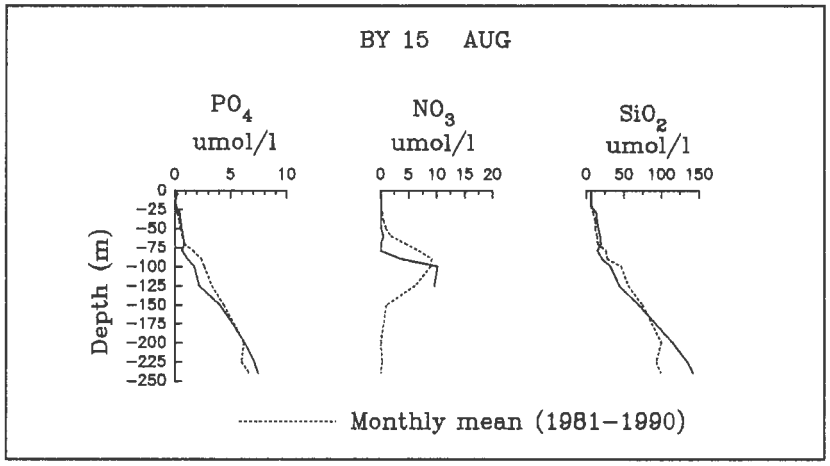


Figure 3.3.6 Nutrient profiles from the station BY15 in the central part of the Baltic, together with mean profiles for August for the period 1981-1990.

In the autumn, October-November, the temperature in the surface layer varied from 9.9°C in the southern Baltic to 6.1°C in the northwest. In the southern and northern Baltic the thermocline was located at 20-30 m while in the central parts at 40-50 m depth. The salinity in the bottom waters of the Gotland Deep was in this month the lowest ever registered (11.15 psu).

The isoline for 2 ml/l oxygen was located at 70 m depth in the Bornholm Deep and at 110-125 m depth in Gotland Deep. Hydrogen sulphide was measured only in the Eastern Basin.

In the early autumn (September) the nutrient concentrations in the surface water were very low, the nitrite and nitrate concentrations were below the detection limit in the southern Baltic. Later on, in October-November, the nutrient concentrations had increased and were normal for the season in the entire area. High chlorophyll concentrations (2-4.5 µg/l) were in November still present in the southern Baltic. This was also thrue for the East Gotland Bassin, wher the concentrations were high, >3 µg/l. In other areas the concentrations varied around 1.5 µg/l.

Surface	BY2			BY15		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Nov 92	0.35	0.49	9.0	0.21	0.65	7.8
Nov 80-89	0.36	0.90	8.1	0.22	0.83	8.0

Table 3.3.5 Surface water concentrations of PO_4, NO_3 and SiO_2 together with November-means for the period 1980-1989, at the stations BY2 in the southwestern- and BY15 in central Baltic.

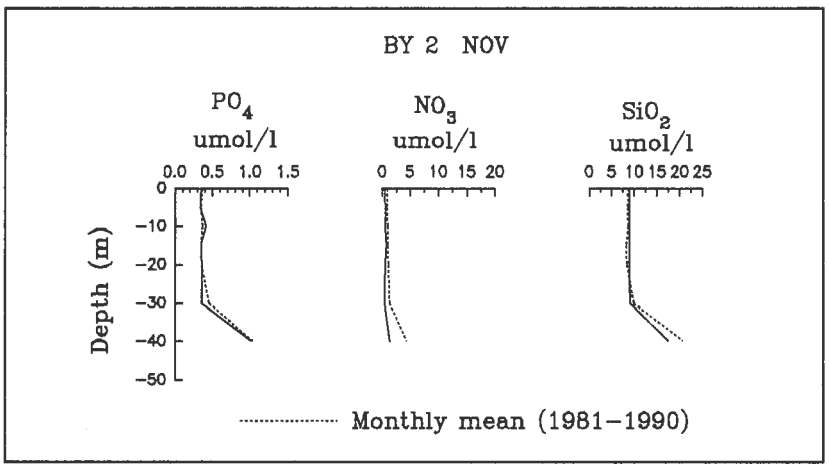


Figure 3.3.7 Nutrient profiles from the station BY2 in the south western part of the Baltic, together with mean profiles for November, for the period 1981-1990.

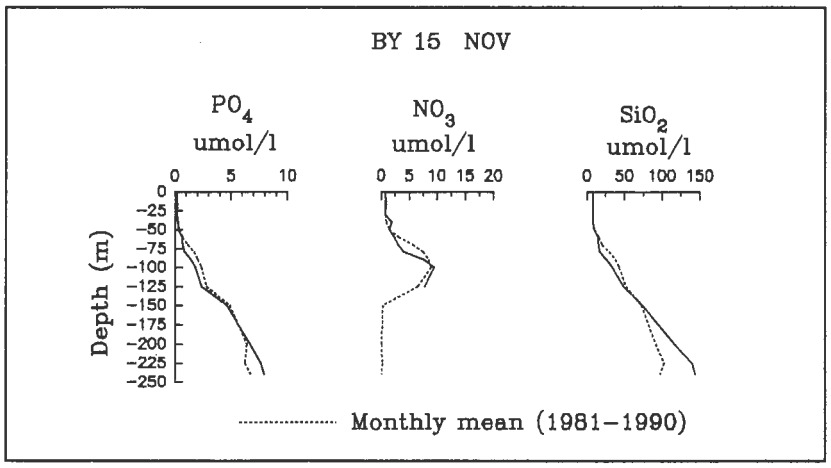


Figure 3.3.8 Nutrient profiles from the station BY15 in the central part of the Baltic, together with mean profiles for November for the period 1981-1990.

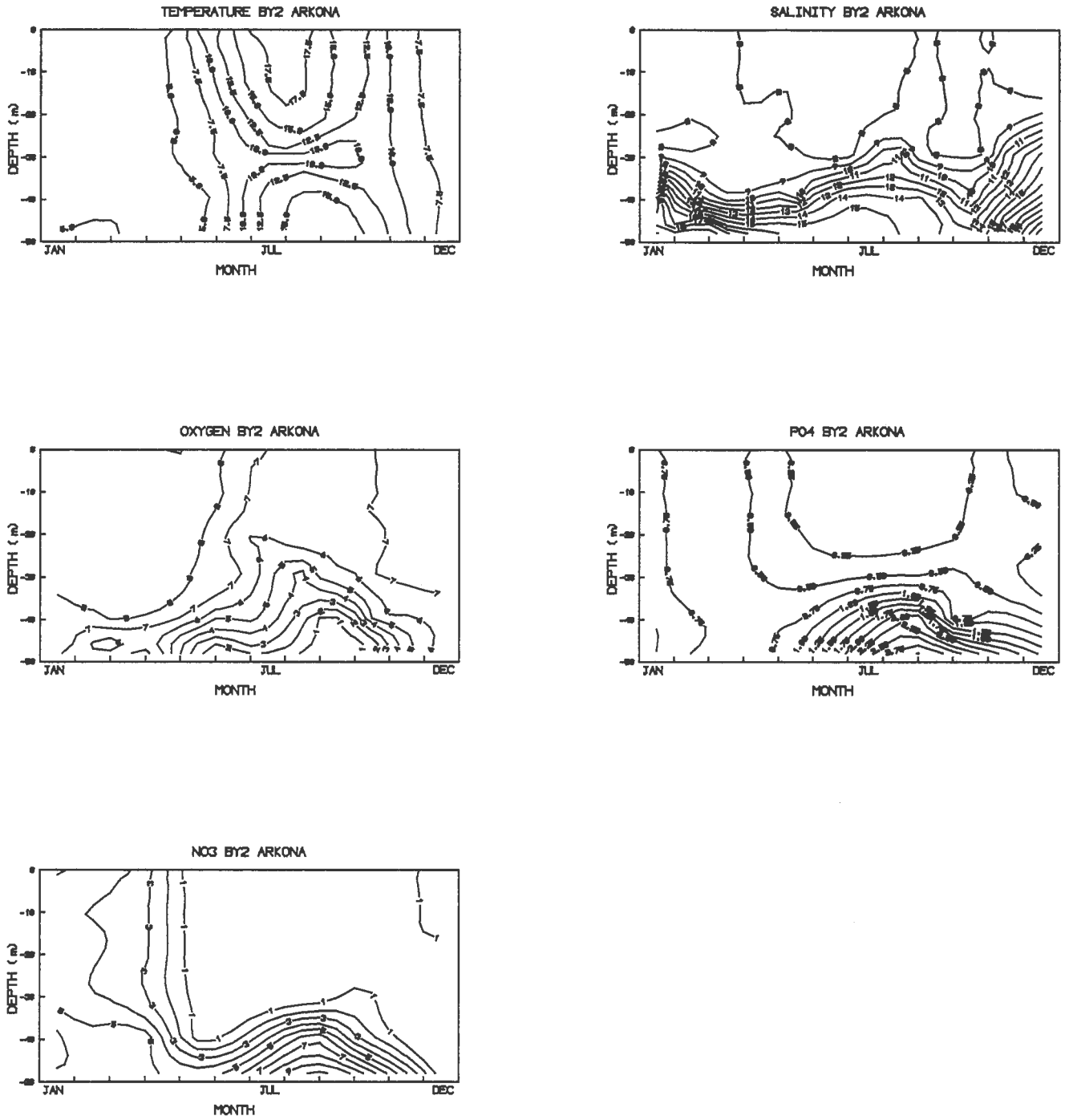


Figure 3.3.9 Isopleths showing the depth distribution of temperature, salinity, oxygen, PO_4 and NO_3 as a function of time during the year for the station BY2 in the southern Baltic.

Oxygen situation in the Baltic Sea

No major salt water intrusion to the Baltic Sea has occurred since 1977. During 1992 the salinity continued to decrease in the Gotland Deep and reached in November the lowest value ever registered. In January 1993 a major inflow of high saline water occurred, and the results of this phenomenon in the Baltic Sea will be revealed during the coming year.

Depth	Januar	March	May	August	November
150 m	10.27	10.54	10.45	10.60	10.56
200 m	11.02	11.06	11.03	11.03	11.03
225 m	11.18	11.19	11.16	11.17	11.13
240 m	11.18	11.23	11.22	11.20	11.15

Table 3.3.6 Salinity concentrations (in psu) during the year at four different depths at the station BY15 in the central Gotland Basin.

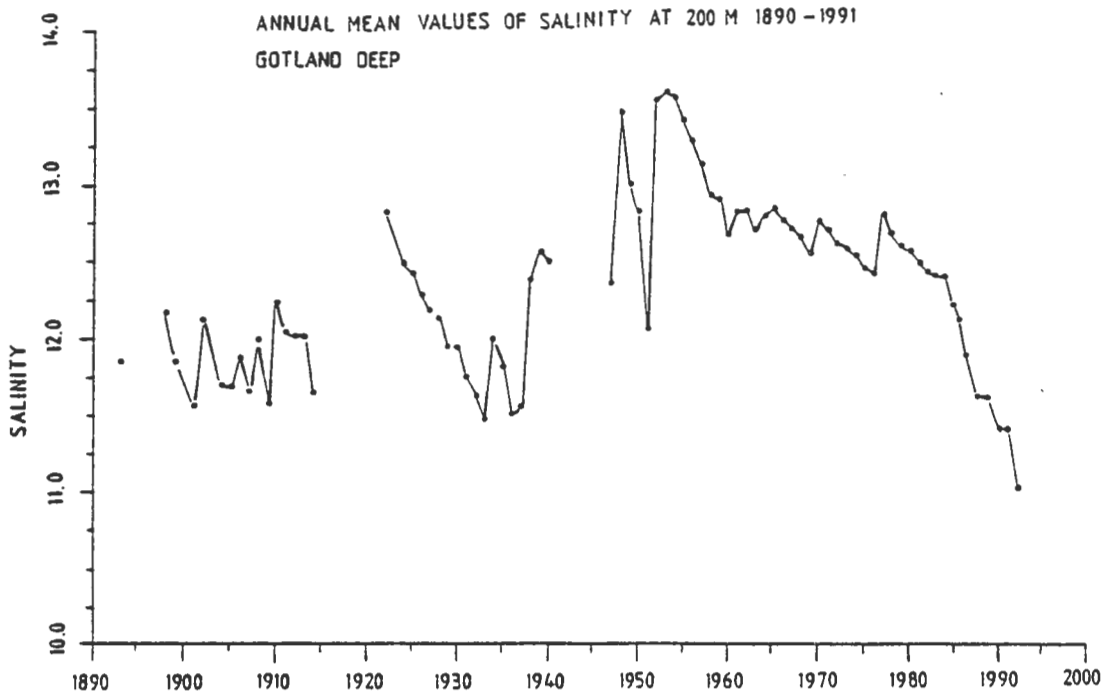


Figure 3.3.10 Time-series showing the salinity at 200 m depth in the Gotland Deep.

Figures 3.3. 11-16 Maps showing the approximate extension of hydrogen sulphide and low (< 2ml/l) oxygen concentrations in the Baltic for different periods during 1992.

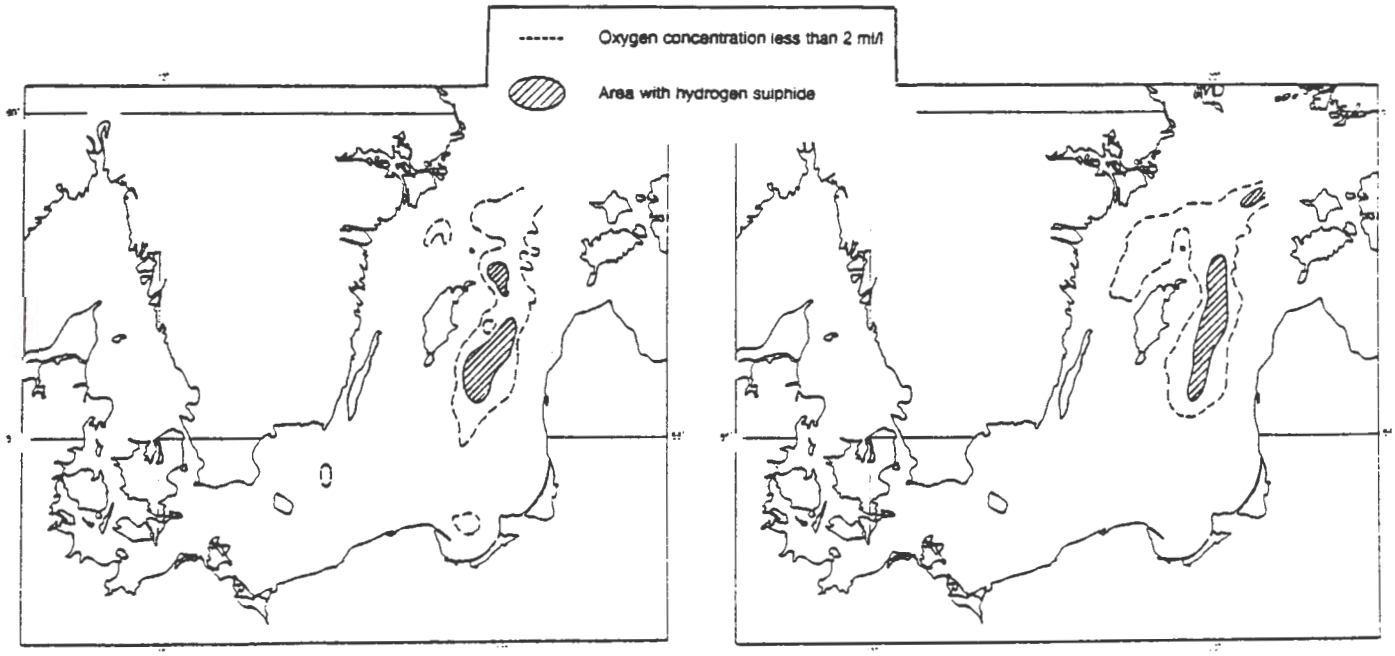


Figure 3.3.11 January 1992.

Figure 3.3.12 March 1992.

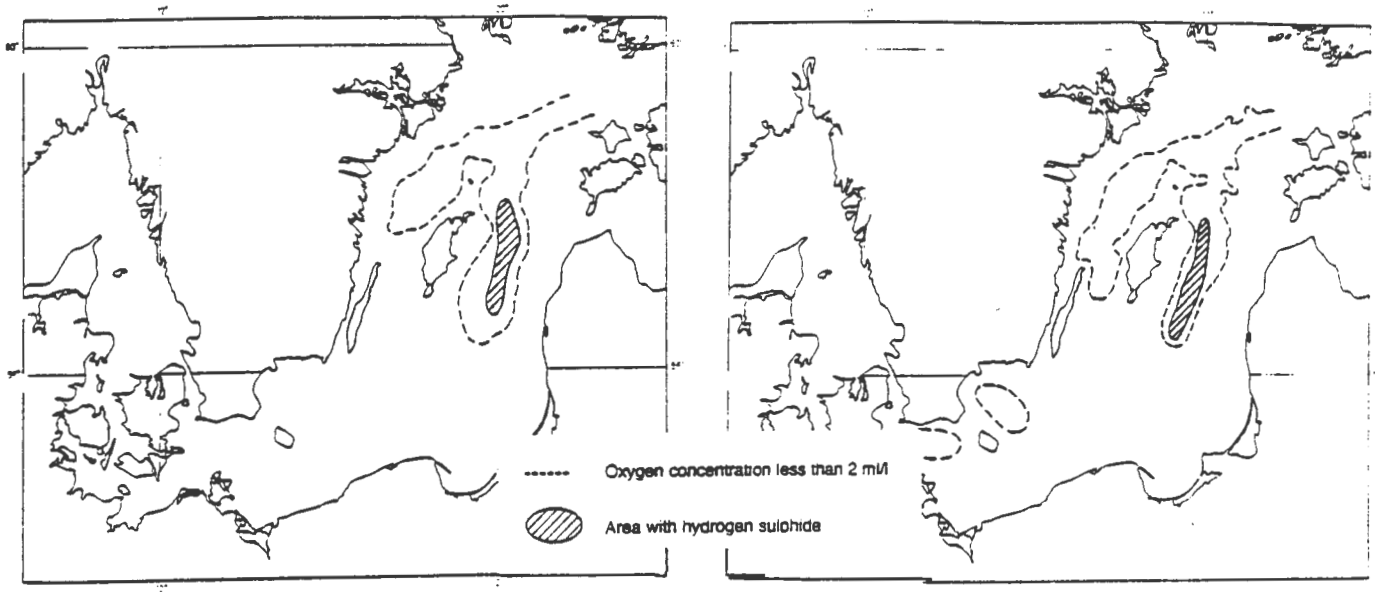


Figure 3.3.13 May 1992.

Figure 3.3.14 August 1992.

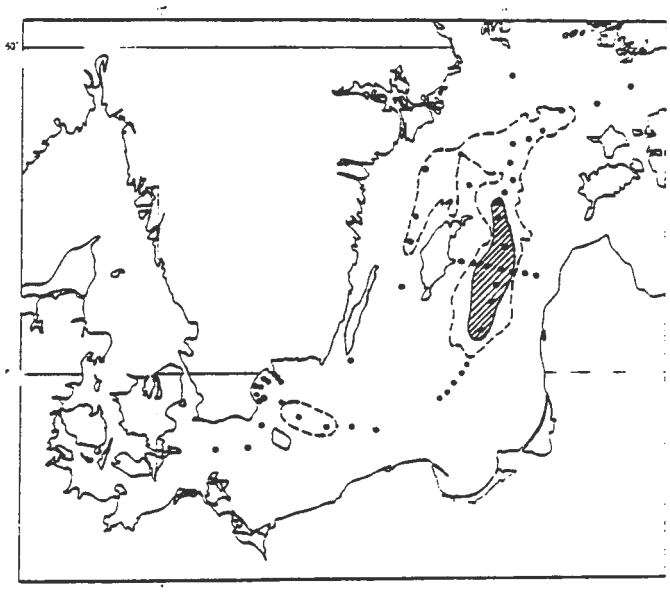


Figure 3.3.15 November 1992.

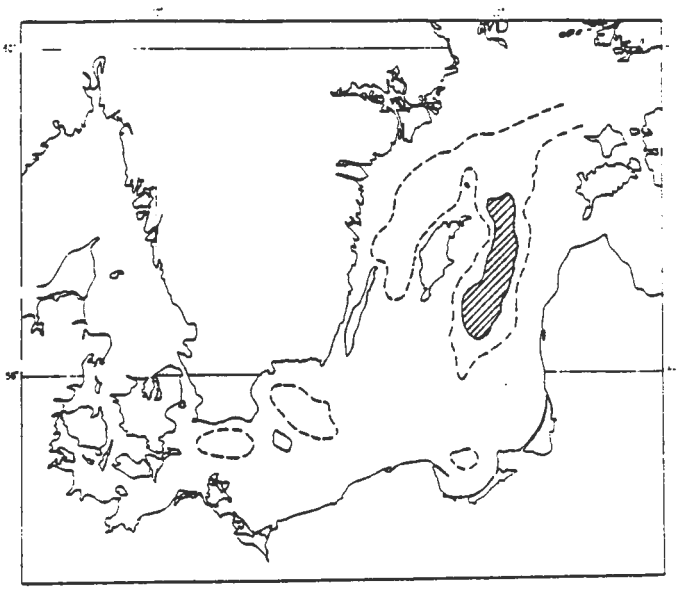


Figure 3.3.16 Maximum extension.

3.4 Bothnian Bay

In May the surface water temperature varied from 2 to 11°C. The highest values were noted in the southeastern Bothnian Sea, and the lowest in the central parts of the Bothnian Bay. The thermocline was strongly developed in the southwest parts of the Bothnian Sea but only weakly formed in the Bothnian Bay. Salinities varied from 2.8 psu in the surface water in the north to 6.7 psu in the deep waters in the south. The strongest horizontal gradients were encountered in the Quark while the vertical stratification was strongest along the Swedish coast.

The oxygen content varied between 10 to 7 ml/l. The surface water was oversaturnated, especially in the Bothnian Sea wit values around 130 %. In the Bothnian Sea the surface water down to ca. 25 m was depleted of nitrate. In the Quark the concentrations in the surface water increased gradually and reached a value of 6-7 µmol/l in the Gulf of Bothnia. To a large extent phosphate too was exhausted in the surface water of Bothnian Sea. Under the thermocline the concentrations increased and the highest, 0.7 µmol/l was measured in the Bothnian Sea. In the Bothnian Bay the concentrations in general were low, below 0,06 µmol/l.

The silicate values varied between 5 and 40 µmol/l, the lowest in the surface water of the Bothnian Sea and the highest in the deep waters of the Bothnian Bay. In the Bothnian Sea the concentrations increased with the depth, whereas in the Bothnian Bay high concentrations were noted in the entire water column.

In the southern part the spring bloom was still going on. Chlorophyll concentrations of 3-7 µg/l, including subsurface chlorophyll maxima, were found. In the northern part the concentrations were less than 2 µg/l, indicating that the spring bloom was just starting to develop.

Surface	SR5			F9		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
May 92	0.05	<0.10	3.6	0.03	5.46	27.9
May 80-89	0.08	0.41	11.2	0.07	6.64	27.1

Table 3.4.1 Surface water concentrations of PO_4, NO_3 and SiO_2 together with May-means for the period 1980-1989, at the stations SR5 in the Bothnian Sea and F9 in the Bothnian Bay.

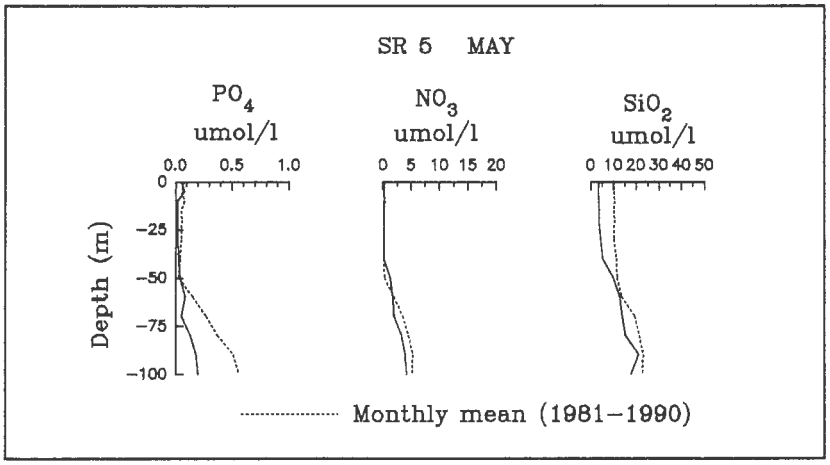


Figure 3.4.1 Nutrient profiles from the station SR5 in the Bothnian Sea together with mean profiles for May for the period 1981-1990.

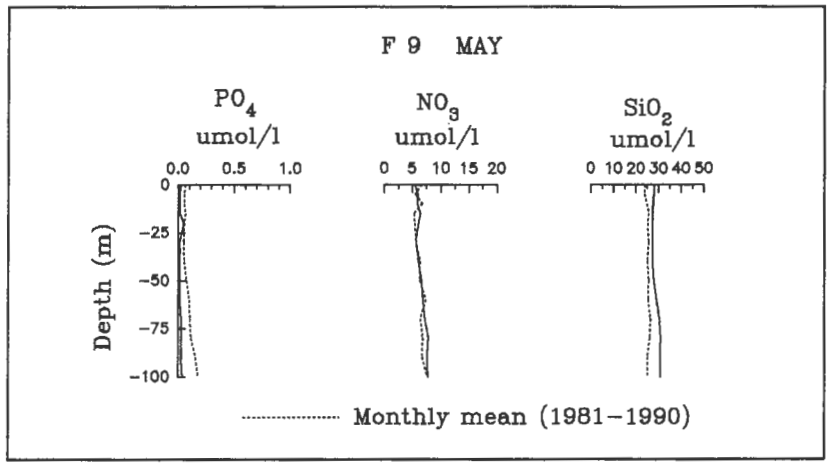


Figure 3.4.2 Nutrient profiles from the station F9 in the Bothnian Bay together with mean profiles for May for the period 1981-1990.

In late autumn the temperature in the surface water of the Bothnian Sea varied between 6.2°C in the southern and eastern parts to 2,3°C in the northwest. Vertically the temperature variations were small, and the same temperature pattern was observed in the deep water. In the Bothnian Bay the lowest temperature 2.4°C was measured in the surface layer and the highest 4.2°C in the deep waters. In the Bothnian Sea the variations in the salinities were as usual small, lowest values (< 5.2 psu) was measured in the surface layer farthest northwest, while the highest, above 6.5 psu, was measured in the deep waters of southernmost region. No typical pattern of salinity distribution was observed in the Bothnian Bay. The values varied between 3.1 and 3.4 psu in the entire area and there was no vertical stratification.

In the Bothnian Sea the oxygen saturation ranged from 98 % in the surface to 75 % in the deep parts. The oxygen concentrations in the Bothnian Bay were around 8.5 ml/l both in surface as well as in deep waters (95 % saturation).

Concerning nutrients the situation was normal i.e. the phosphate was depleted to a great extent, while nitrogen was present and silicate in plenty. There was still some chlorophyll (1-1.5 µg/l) left in the water.

Surface	SR5			F9		
month	PO4	NO3	SiO2	PO4	NO3	SiO2
Nov 92	0.06	2.36	9.5	0.06	6.39	34.2
Nov 80-89	0.10	1.57	11.8	0.07	5.59	26.6

Table 3.4.2 Surface water concentrations of PO_4, NO_3 and SiO_2 together with November-means for the period 1980-1989, at the stations SR5 in the Bothnian Sea and F9 in the Bothnian Bay.

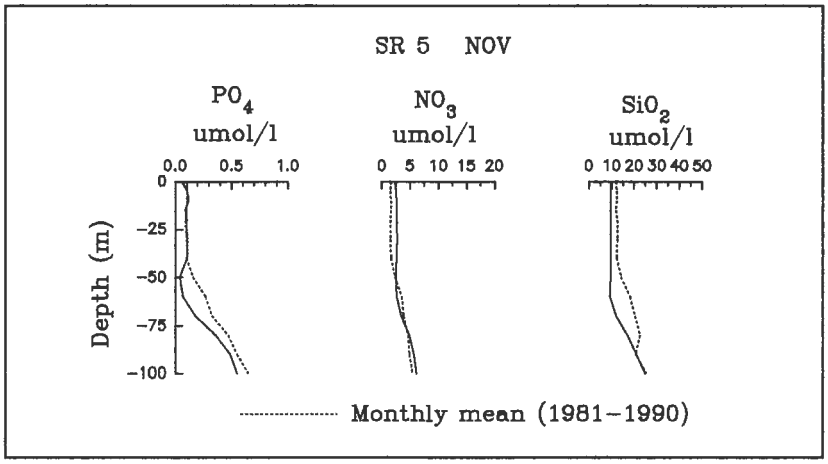


Figure 3.4.3 Nutrient profiles from the station SR5 in the Bothnian Sea together with mean profiles for November for the period 1981-1990.

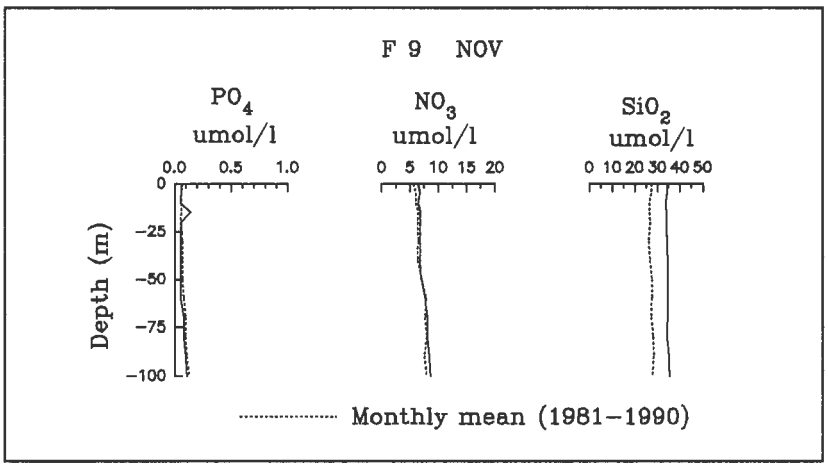
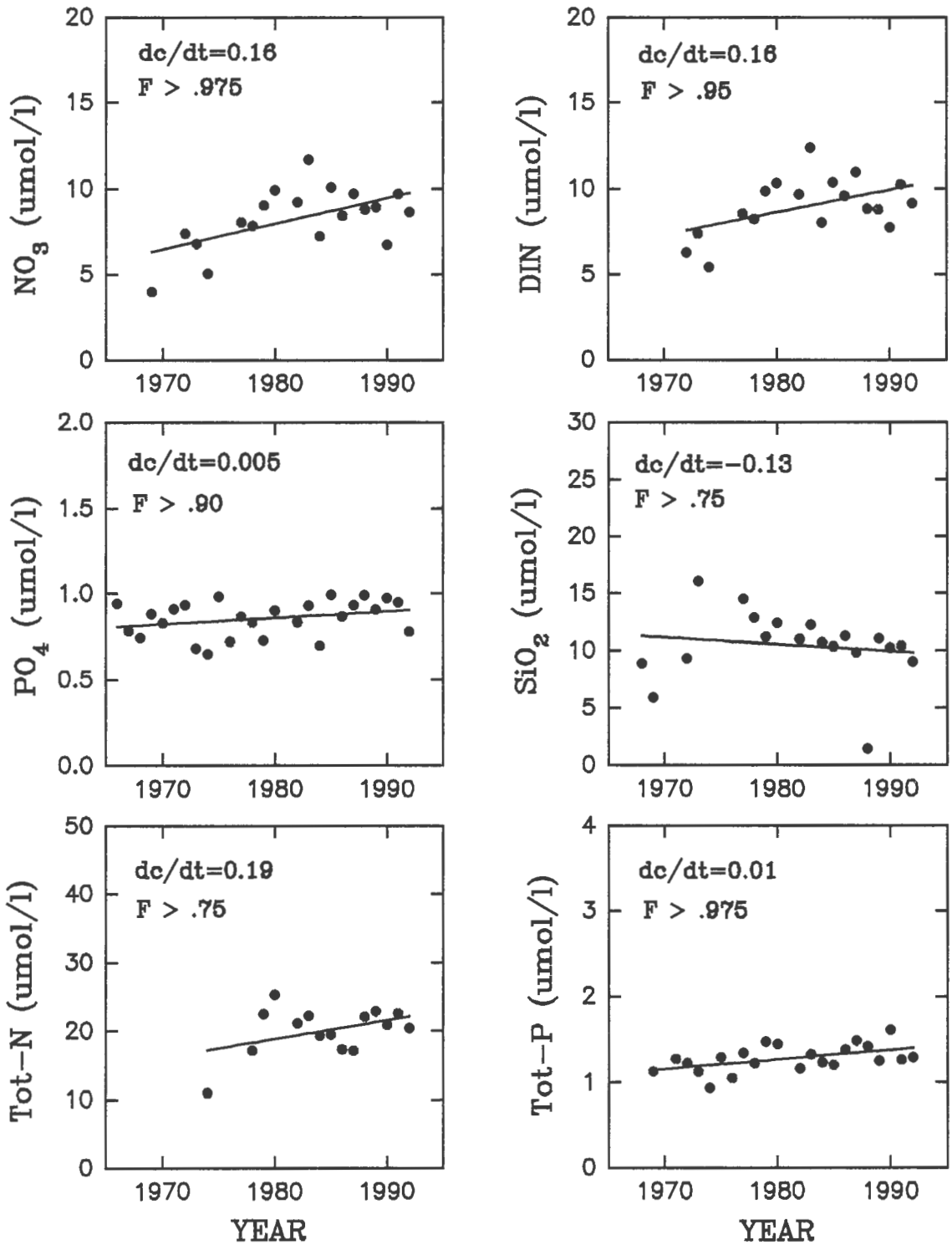


Figure 3.4.4 Nutrient profiles from the station F9 in the Bothnian Bay together with mean profiles for November for the period 1981-1990.

4. Project for Research and Progress

4.1 Nutrients and Oxygen trends in the Kattegat

A project to analyse the nutrients and oxygen trends in Kattegat and Skagerrak is going on in SMHIs Oceanographical Laboratory. The project has been in progress for the past two years financed by the National Swedish Environmental Protection Agency (NSEPA). Data from 1965-1992 are processed for the purpose, and the results will be published in a special report. Some examples of information hitherto brought forward are shown below. Trends calculated by linear regression for NO_3, DIN (DIN = NO_2+NO_3+NH_4), PO_4, SiO_2, Tot-N and Tot-P are shown for surface water in southern Kattegat during winter together with trends for oxygen and oxygen saturation for deep water in the autumn. In the figures are given inclination dc/dt and also the significance level F. In the final report results based on non-parametric methods will be presented.



Figur 4.1.1 Trends in nutrient concentrations in the Kattegat surface water during winter season.

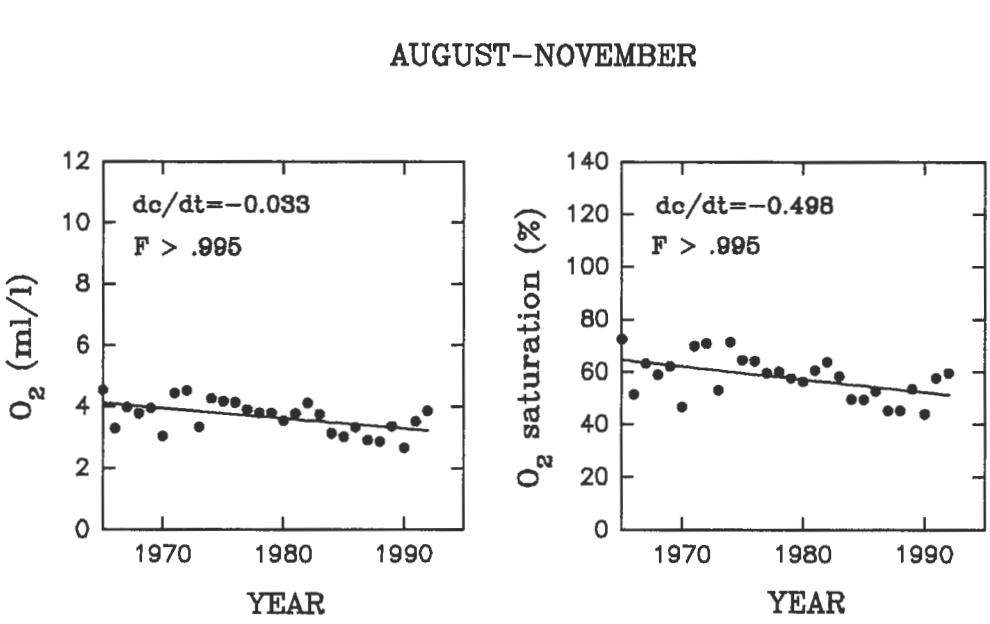


Figure 4.1.2 Trends in oxygen in the kattegat deep water during autumn.

Increase of NO_3 together with DIN and Tot-P is clear, while the increase of PO_4 and Tot-N and also decrease of SiO_2 are below significance level. Oxygen concentrations during autumn months in the deep waters have decreased in average 0.03 ml/l/yr during the period and the decrease is very clearly significant both concerning oxygen concentrations and saturation.

4.2 Continous measurements of salinity, temperature and chlorophyll fluoroscens

In the autumn 1992 a system for continous measurements of salinity, temperature and chlorophyll fluoroscens started to operate. Water is pumped from 3 m depth. At the same time as the three parameters are measured and stored, the position of the vessel is stored in the computer. The system will be in full operation in 1993.

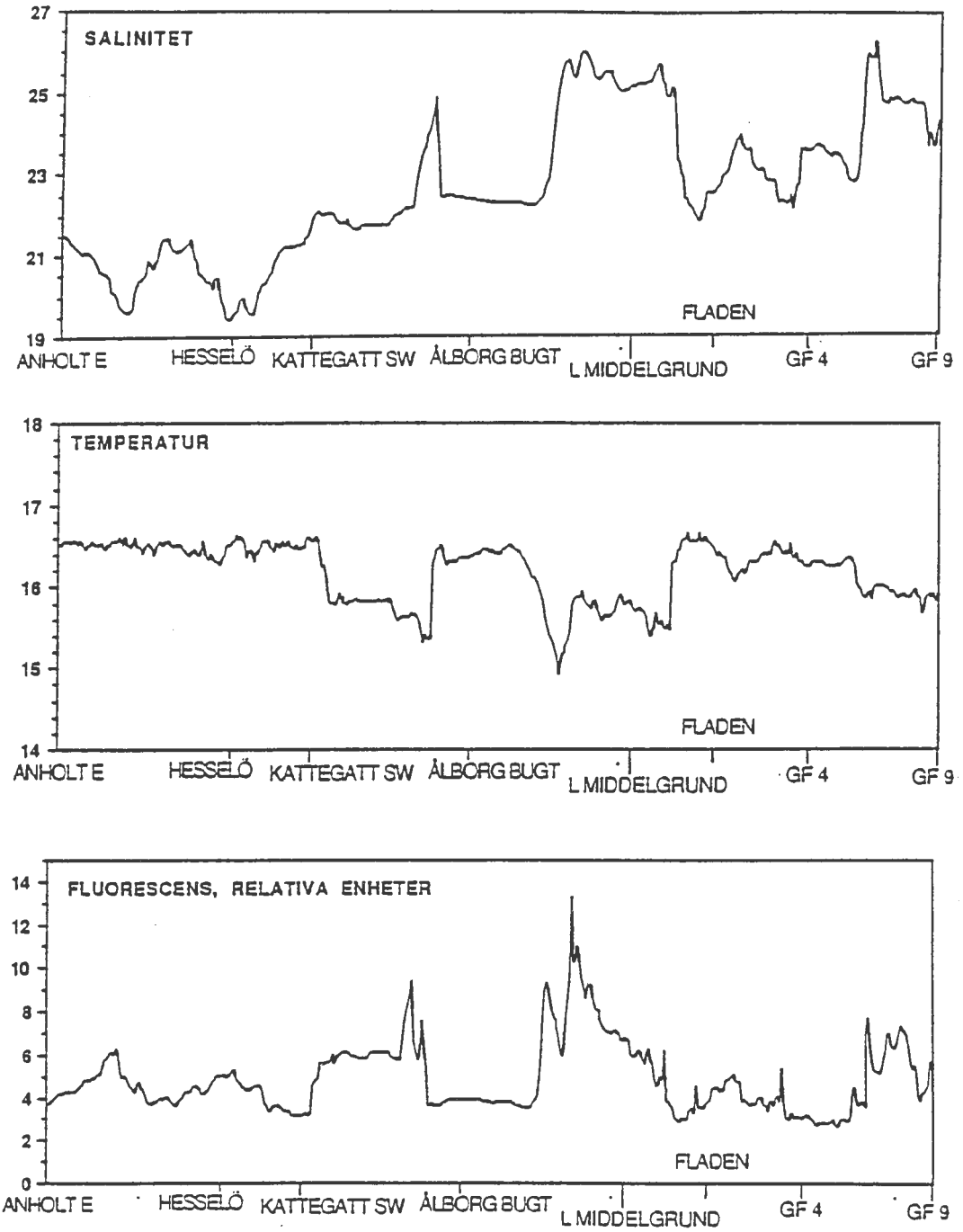


Figure 4.2.1 Transects of salinity, temperature and chlorophyll fluoroscens measured continously in the Kattegat in September.

In the figure is shown an example of the output from this system. The measurements were made in Kattegat in September 1992.
In the transect from Anholt E to Kattegat SW the temperature showed little variation, whereas the salinity showed two marked minima. In these fronts a considerable change in chlorophyll fluoroscens was also observed.

In the two transects along the latitudes in the northern part of Kattegat several fronts with drastic changes in all parameters indicated several different watermasses in the Kattegat.

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SMHI rapporter OCEANOGRAFI (RO)

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Ymer-80, satellites, arctic sea ice and weather.
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5 Stig Carlberg, Sven Engström, Stig Fonselius, Håkan Palmén, Eva-Gun Thelén, Lotta Fyrberg och Bengt Yhlen.
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