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Negative thermal anomaly of the deep layer in the southern Baltic in 1985

by

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Abstract

Between May 23 and June 3, 1985, hydrological measurements were carried out from the R.V. "Profesor Siedlecki" on 96 stations within the Polish fishery zone. Their aim was to collected data on those environmental conditions which influence the development of biological life as well as the distribution and concentration of Baltic fish species. It was found that although there was no inflow of water into the Baltic between February and May, oxygen level near the bottom increased thanks to a gradual advection of very cold but very well oxygenized water from the west. The mechanism of this advection, which resulted in negative thermal anomaly of the deep water layer, was discussed. A comparison was made with the low temperatures of the deep layer following severe winters in 1956, 1963, 1979.

Introduction

In the autumn of 1984, in the upper water layer of the southern Baltic, positive thermal anomalies were observed. In the deep layer, the most interesting phenomenon was an increase in oxygen level in the Gdańsk Deep in November, 1984 /Wojewódzki, 1986 b/. Thanks to dynamic processes, a large quantity of denser and welloxygenated water could be transported within a short time from the Słupsk Furrow. Water with a lower oxygen level in the Gdańsk Deep was pushed upwards and underwent transformation. This process was still taking place in December, when water with higher salinity /12.21 ^{o}/oo/ and oxygen level /2.71 ml/l/ was transported through the threshold from the Słupsk Furrow /Station B3/ into the Gdańsk Deep. Beginning in January, 1985, this situation was influenced by the extreme conditions of the 1985 winter. Since the beginning of January, air temperatures over the Baltic and adjacent areas were negative, as low as -10 and -20^{o}C. It is enough to compare diurnal temperature drops for station G2: for the November-December period they usually equal -0.06^{o}C, for the December-January period -0.11^{o}C. In the 1985 winter, the temperature drop for November-January was -0.12^{o}C. Heat reserve of the upper water layer from the autumn of 1984 was depleted by the time our investigations began in February 1985. Next measurements were made as late as May from the research vessel "Profesor Siedlecki". The distribution of measurements stations is shown in Fig. 1.

Method

A total of 766 temperature, 763 salinity, and 763 oxygen measurements were made at 96 stations, at standard depths. Water temperature was measured with reversible thermometers with an accuracy of ± 0.01 °C. Water for analysis was taken with Nansen bottles. Salinity was measured with a Plessey 6230N salinometer, while oxygen quantity - by means of the Winkler method. The results of measurements and analyse were processed by means of standard programmes on the vessel Elliot 905 computer.

Results

In February 1985, in the western part of the southern Baltic, negative water temperatures were already noted. In the Bornholm Deep, water temperature was -0.34 °C, and in the Słupsk Furrow -0.32 °C. Negative temperature values in these areas reached down to depths of 50 and 20 m, respectively. At this time, in the Bornholm Deep, in the 40-60 m layer at the boundary with the halocline, a considerable negative temperature anomaly appeared /-5.26 °C at a depth of 60 m/ due to convection and, most likely, advection of waters from the west. Under average conditions of the previous years or after inflows, at this depth there is warmer with higher density /upper halocline layer/, which makes it impossible for the convection to reach that deeply. In the Gdańsk Deep, also, in the 55-80 m layer, negative water

temperature anomalies /about -3°C/ replaced in February positive temperature anomalies from autumn, 1984. Thus, already in February there were initial conditions for gradual cooling of subsequent water areas due to the transport of colder and denser water from the intermediate layers of the Bornholm Deep.

During our measurements in May /23-24/, at a main transect from station "2" to station "16", positive water temperature anomalies were observed only at the bottom of the Bornholm and Gdańsk Deeps /Fig. 2, 3/. The whole of the Słupsk Furrow, its slopes and thresholds down to deep layers were characterized by negative temeprature anomalies. After 6-10 days, measurements were made again at transects perpendicular to the shoreline at station B3 /after 6 days, Table 1/ and station G2 /after 10 days, Table 2/. At the bottom of the Gdańsk Deep, a sharp temperature drop was observed - by 3.19°C /Fig.4, Table 2/. As a result of advection, water with high oxygen level of 4.5 ml/l /previously 1.33 ml/l/ but lower salinity /11.554°/oo, previously 11.774°/oo/ was transported into the Gdańsk Deep. The transport and mixing of this water on the slope was made possible by the thermal factor, which enabled the overcoming of the water density barrier down to the bottom.

Table 1

Water temperature, salinity, and oxygen level in the B3 station area in May 1985

Level /m/	1985.05.24			1985.05.30		
	T/°C/	S/°/oo/	O_2/ml/l/	T/°C/	S/°/oo/	O_2/ml/l/
40	3.11	7.755	9.37	3.26	7.772	9.49
50	2.04	7.873	9.07	2.08	7.818	8.99
60	0.99	8.658	9.52	1.38	7.999	8.47
70	2.53	8.698	5.76	2.42	8.637	6.48
73	2.70	12.313	5.40	3.15	12.568	4.43

Table 2

Water temperature at station G2 for May after severe winters in the years 1956-1985 and in August 1985

Level /m/	Measurements date					
	1956 maj	1963 20.05	1979 11.05	1985 23.05	1985 01.06	1985 10.08
0	2.10	7.80	4.80	10.65	10.27	16.23
10	2.00	-	-	6.64	10.25	16.37
20	2.00	-	-	4.13	3.48	16.38
30	1.80	-	-	2.91	2.61	16.35
40	2.40	-	-	2.88	2.12	10.88
50	2.60	0,80	1.04	1.82	1.53	6.44
60	1.40	0,80	0.85	1.15	1.60	2.06
70	1.70	2.50	2.02	3.29	1.50	2.15
80	2.60	2.95	4.36	2.25	2.78	3.02
90	4.90	4.15	4.97	6.10	2.39	4.17
100	5.60	-	6.88	6.47	4.52	4.62
106	5.60	5.15	6.93	6.47	3.28	4.64

On both measurement dates /May 23 and June 1/, conventional density of water at the bottom was 9.72 σ_t. At the bottom of the Gdańsk Deep, a rapid change of thermal conditions occurred /compare Figs 2, 4/. Water with low oxygen contents and a temperature above 6°C was transported to the northern part of the Gdańsk Deep /Figs 2, 5/. It appears from Table 2 that the temperature at the bottom of the Gdańsk Deep remained at a stable level of 4.62-4.64°C. For comparison, in the 1958-1984 period, a temperature below 5°C was observed in this area only in 1969 /4.98°C/, 1972 /4.74°C/, and 1984 /4.97°C/. The changes analyzed by us for May 1956, 1963, and 1979 confirm that at those times such low temperatures were not recorded at the bottom of the Gdańsk Deep /Figs 6, 7/. Nehring and Francke /1981/ who discussed hydrological and chemical changes in the Baltic after the previous severe winter in 1979 did not observe such effects either.

Conclusions

The hydrological situation of the southern Baltic discussed on the basis of detailed measurements in May was considered untypical, largely due to the negative thermal anomaly, especially in the deep layer and at the bottom. It appears from comparisons made with the previous periods following severe winters /1956, 1963, and 1979/, that such extreme cooling of a large

volume of water as noted after the winter of 1985 was not observed. At the same time, thanks to the advection process of cold water /despite the absence of inflow/ relatively good oxygen conditions were preserved since the autumn of 1984 and the stagnation of the deep layer was arrested. Thus, the preservation of relatively good oxygen conditions occurred at the expense of thermal conditions. The impact of the thermal situation discussed here on biological processes and stocks and concentrations of fish was preliminarily discussed in papers by Herra /1985/, Orłowski /1985/ and Wojewódzki /1986/. These papers dealt only with certain aspects of biological life and stocks of major Baltic fish stocks.

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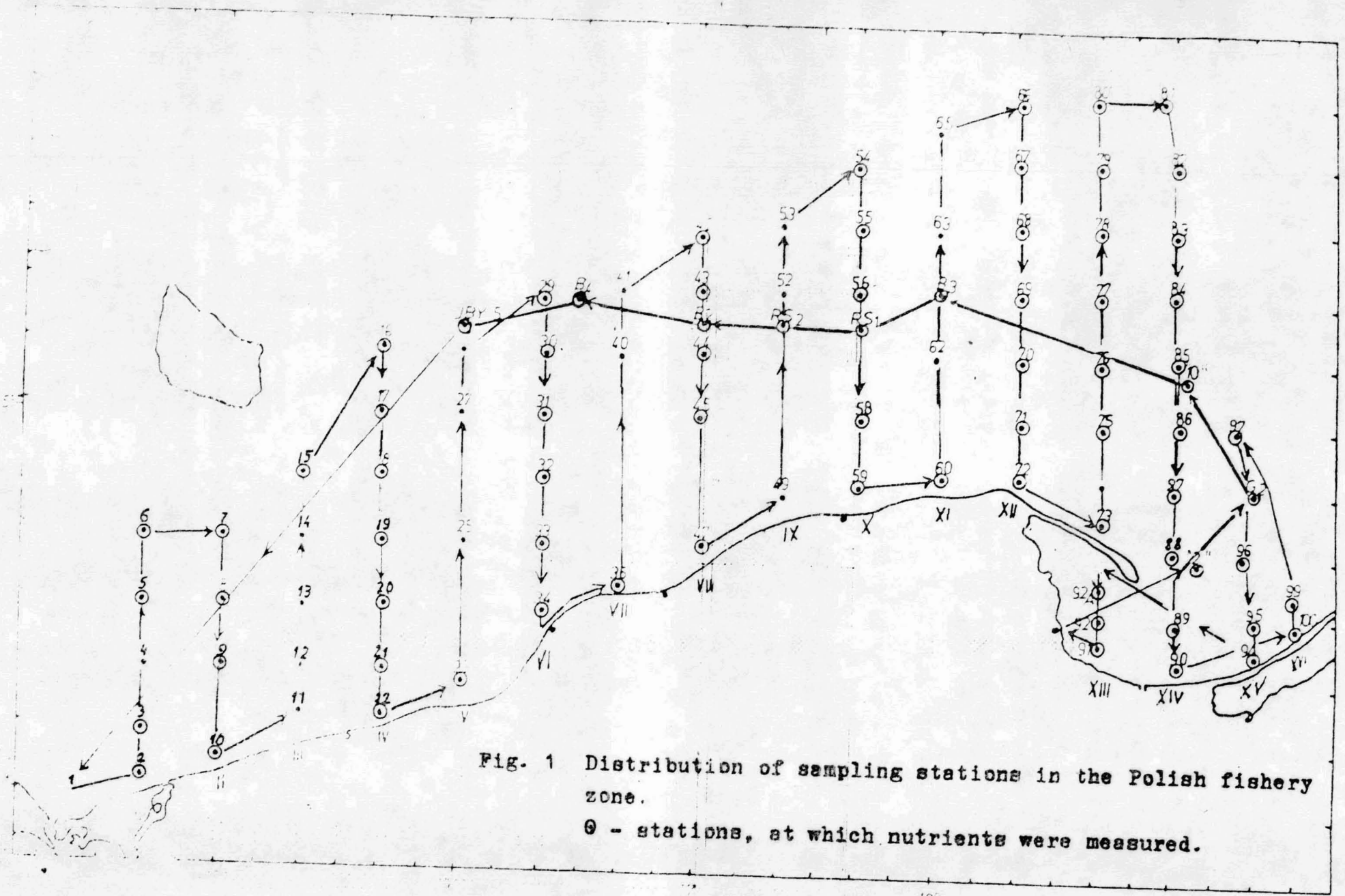

Fig. 1 Distribution of sampling stations in the Polish fishery zone.

● - stations, at which nutrients were measured.

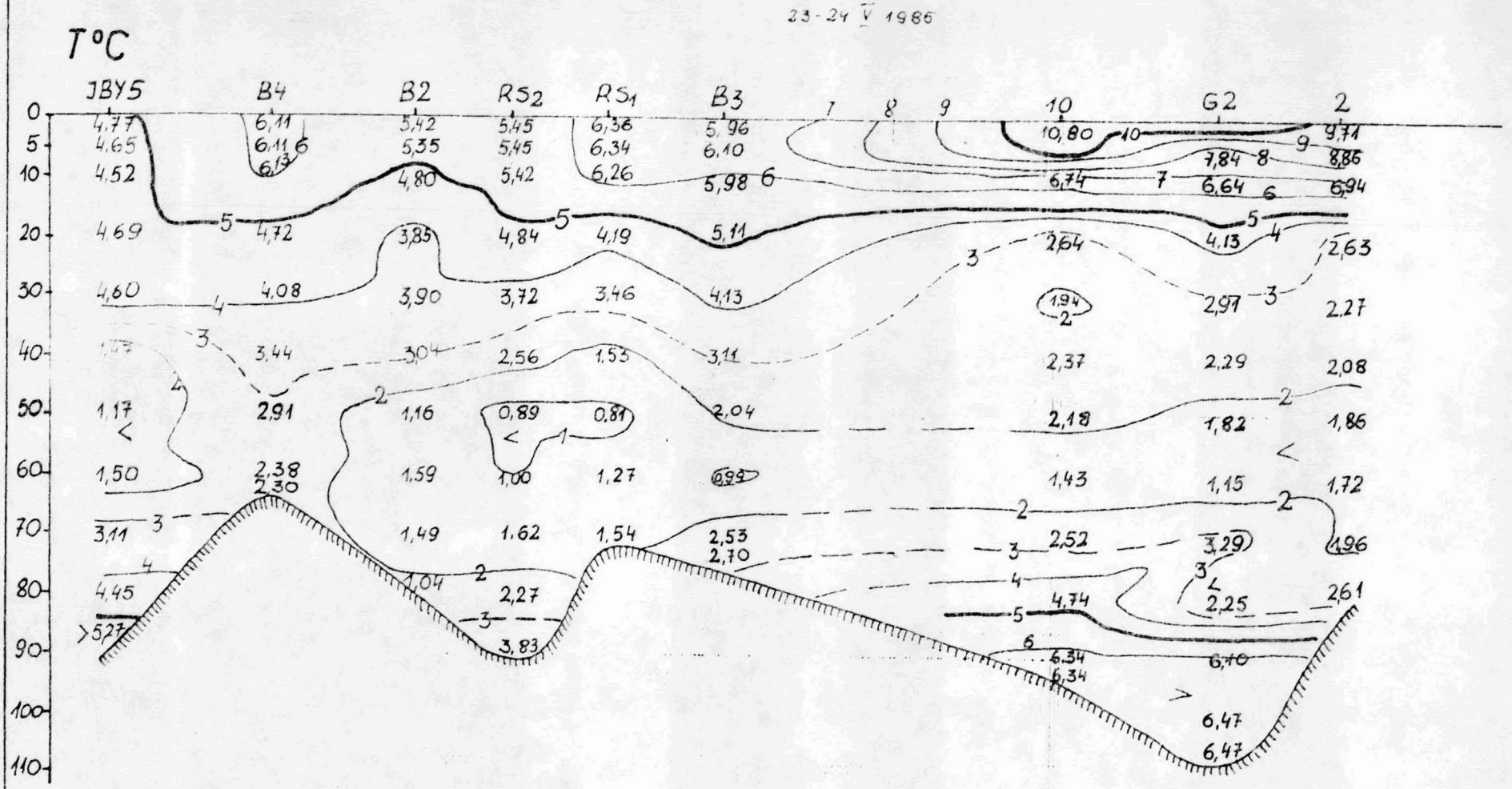

Fig. 2 Vertical water temperature distribution in May 1985 /Gulf of Gdańsk-Bornholm Deep/.

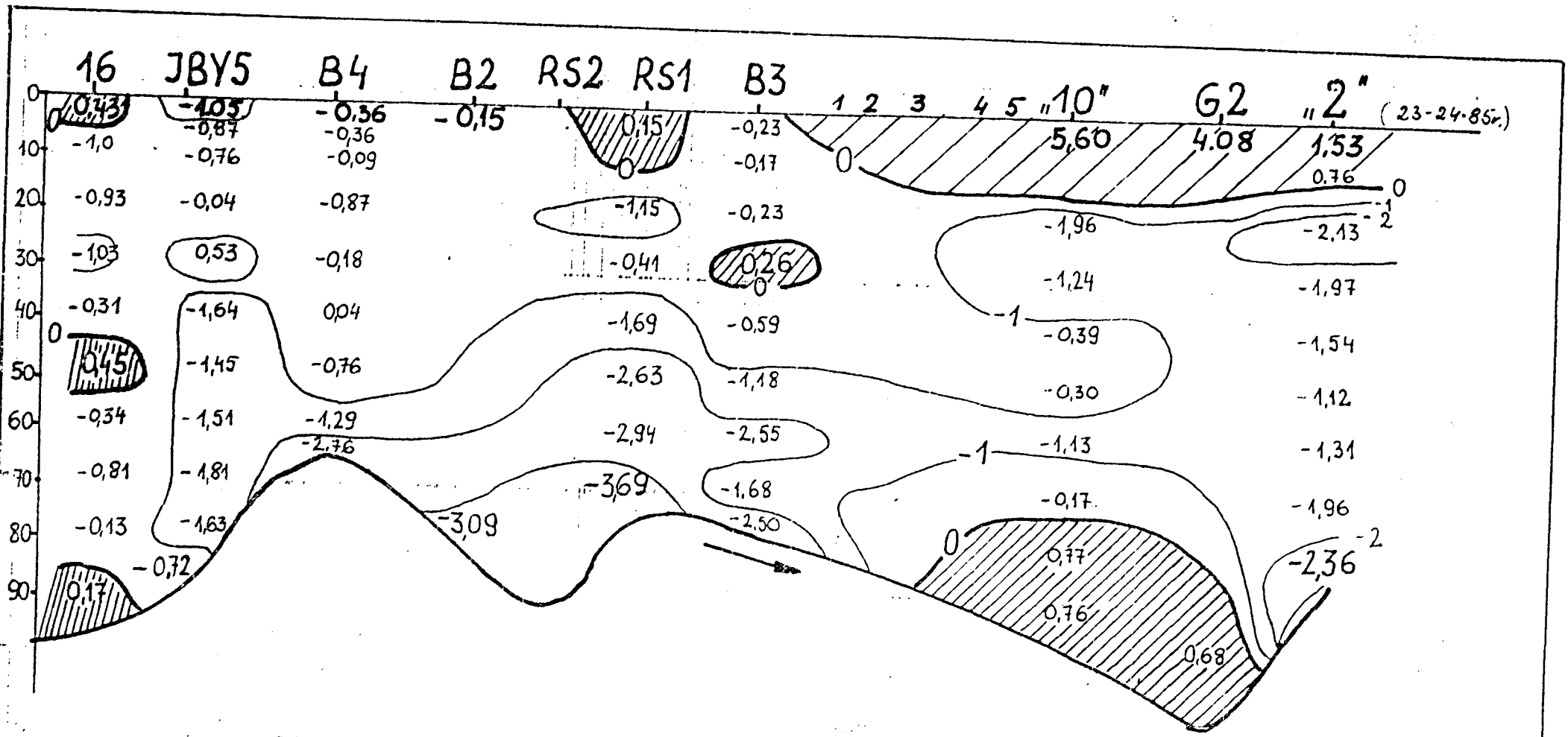

Fig. 3 Anomalies /± Δt, °C/ in the vertical temperature distribution in May 1985 /Gulf of Gdańsk-Bornholm Deep/.

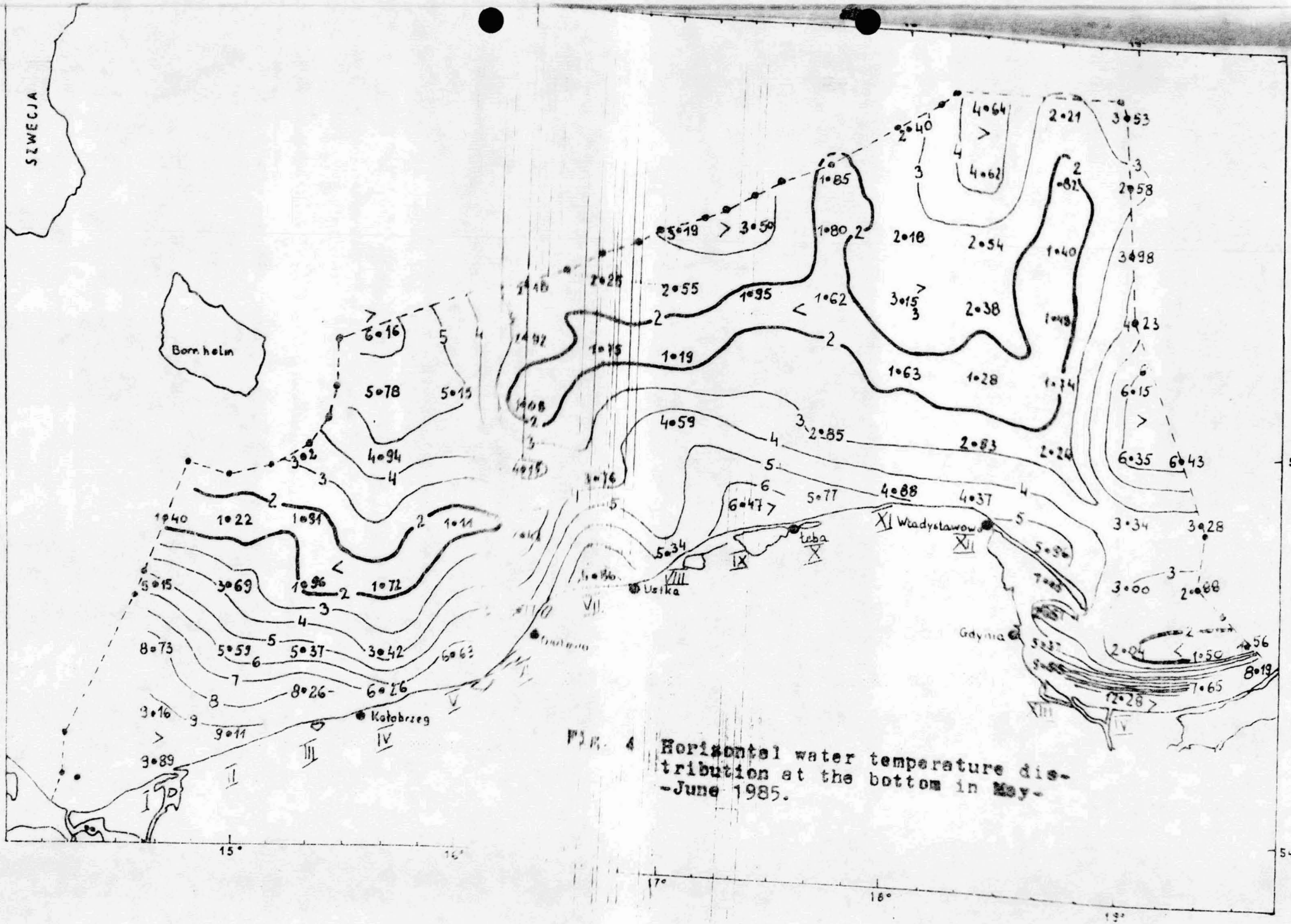

FIG. 4 Horizontal water temperature distribution at the bottom in May-June 1985.

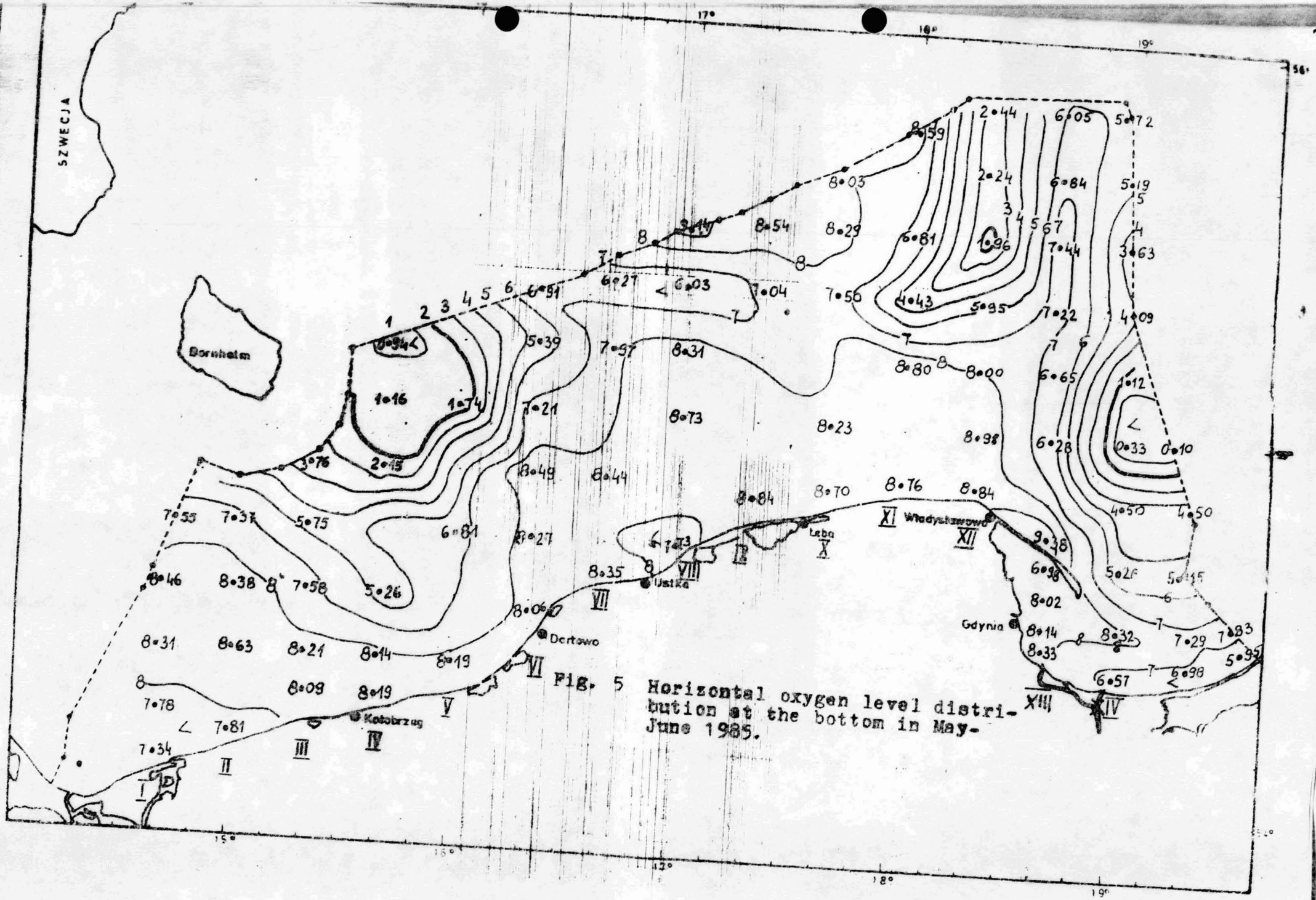

Fig. 5 Horizontal oxygen level distribution at the bottom in May-June 1985.

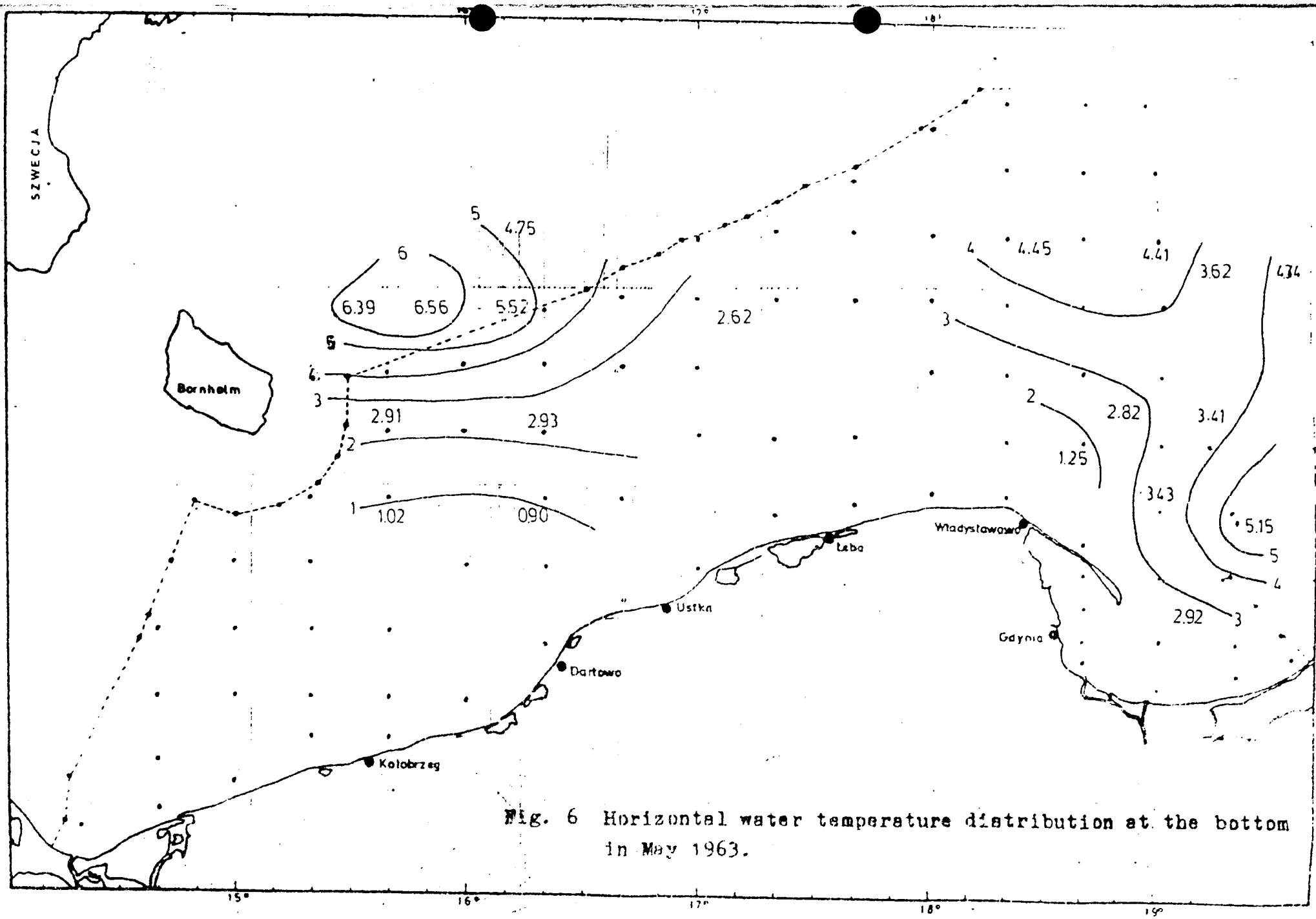

Fig. 6 Horizontal water temperature distribution at the bottom in May 1963.

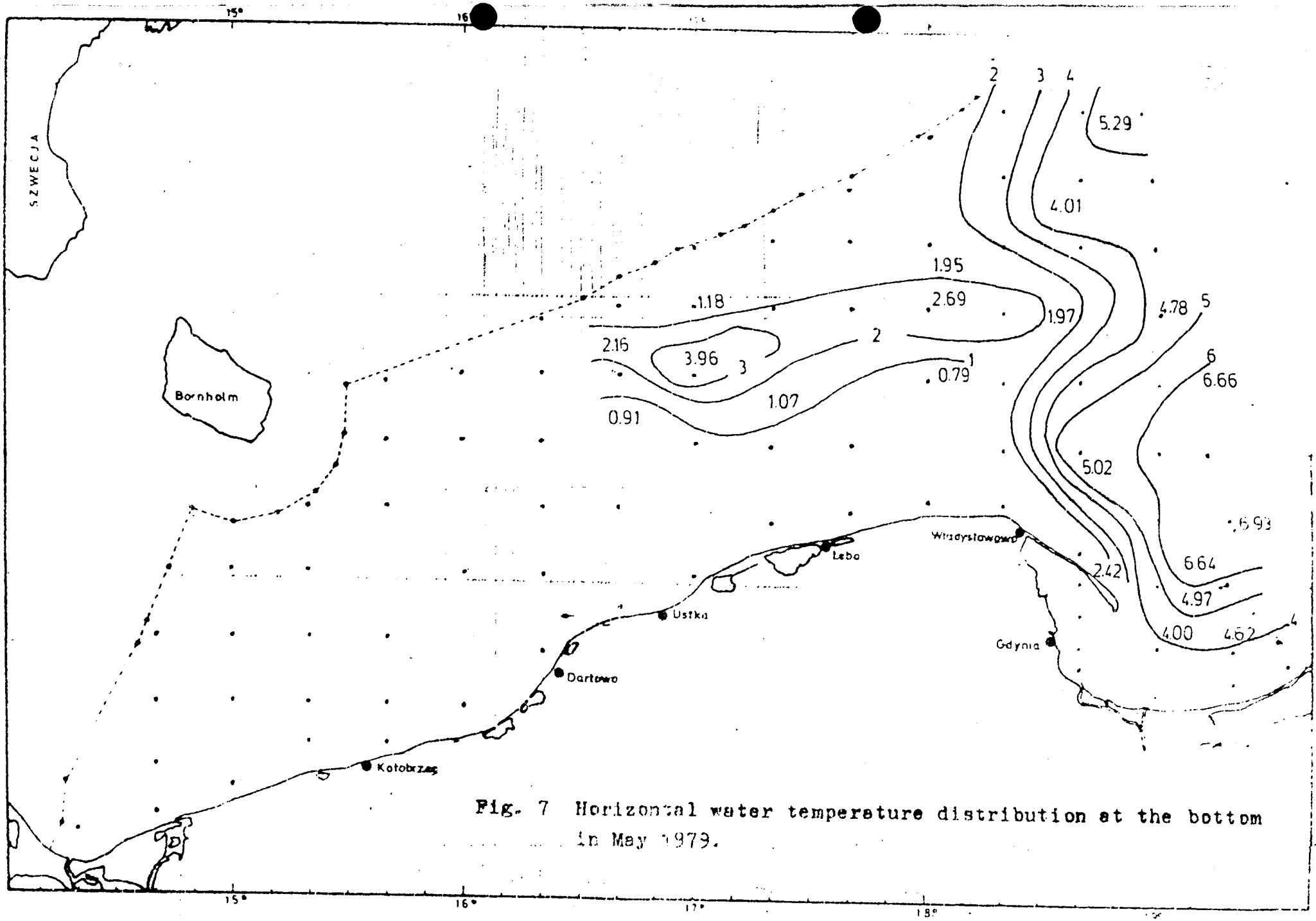

Fig. 7 Horizontal water temperature distribution at the bottom in May 1979.