Not to be cited without prior reference to the author

ICES STATUTORY MEETING 1993

C.M. 1993/C:14
Sess. V

RECENT CHANGES OF SALINITY AND ITS ANOMALIES IN THE SOUTHEASTERN BALTIC (1992-1993)

by

Zezera A. and E.Zezera

lantNIRO, 5 Dm.Donskoy, Kaliningrad 236000 Russia

ABSTRACT

Basing data collected during four cruises conducted by the "Monokrystal" in 1992 and early 1993 a characteristic for salinity distribution and variations in the Southeastern Baltic between May, 1992 and May, 1993 is given. Deviation of salinity estimates from the longterm means has been calculated for the deep-water areas of the Gotland and Gdansk Basins. Data analysis allowed to reveal the main trends in salinity variations in the Southeastern Baltic. The 1993 data gave a unique possibility to observe the advection development to the Gdansk Basin both in the temporal and spatial scale.

INTRODUCTION

Salinity characteristics at the various sea depths and anomality of the salinity conditions in the Baltic Sea are of great importance for assessment of the hydrological conditions variability.

It is known that in the mid-eighties the next stage of dilution in the Baltic Sea began (Antonov, 1991). From this point of view data on salinity in the Southeastern Baltic collected in 1992 and early 1993 enable to give qualitative and quantitative estimates for the process evolution. To study character of the salinity anomalies the selection of long-term means is a matter of no little importance. Unfortunately, unavailability of the salinity means for the recent years enabled to calculate anomalies only as compared to the long-term means for 1947-1983 (Antonov, 1987). But even these data allow to trace and assess variability of the salinity conditions over the surveyed area and period.

MATERIALS AND METHODS

Analysis of vertical salinity distribution and its temporal evolution was made using data collected during four expeditions of R/V "Monokrystal" (May-June and October-November of 1992 and March and April-May of 1993).

Hydrological observations were performed from the surface to the bottom. Salinity determinations were made in every 5-10 m and in the near-bottom layer. Totally 250 hydrological stations were made using CTD-1000 (Japan). Besides temperature was measured and at some stations hydrochemical determinations were made. Samples were taken by Nansen bottles. The surveyed area was restricted by the EZ-s of Estonia in the north and Sweden in the west. In the autumn of 1992 and spring of 1993 the survey was partially conducted within the EZ of Poland (Fig. 1-4).

DISCUSSION AND RESULTS

In spring of 1992 surface salinity changed from 6.41-7.00°/oo to 7.20-7.33‰. Minimum values were recorded within the coastal zone influenced by the land run-off (to the west of Baltijsk, Liepaya and the Gulf of Riga). Vertical salinity profile over the depths of less than 60-65 m was characterized by insignificant variation of values from the surface to the bottom. Halocline was only found in the surface mayer at the lower border of the diluted water masses. Maximum salinity at the bottom did not exceed 7.3-7.4‰. In the deep-water part of the area vertical salinity gradients began to increase since depth of 75-80 m where salinity increased sharply from 7.2-7.4 ‰ to 9.7-10.2‰ within the layer of 15-20 m. Maximum vertical gradients (0.37‰) were recorded in the Gdansk Hollow between 70 and 80 m. In the Gotland Basin they did not exceed 0.12‰ and 0.15‰ per 1 m in the north and in the extreme south, respectively.

From May to October-November of 1992 absolute salinity estimates did not suffer considerable changes. Surface salinity ranged between 6.63-7.25‰ in the north and 7.21-7.35‰ to the south of 56°N. Minimum values ($<$ 7‰) were found in the central part of the Gotland Basin. The so-called "diluted wave" was observed there extended from the north to the south up to 57°N. Vertical power of the brackish waters attained 35-45 m and corresponded to the thickness of the upper homothermal layer. The depth where the upper limit of the halocline was found increased from the south to the north from 65-75 m to 80-85 m. Maximum vertical salinity gradients changed from 0.12‰/m in the Gotland Hollow to 0.26‰/m in the Gdansk Hollow.

General salinity increase was the main feature of the salinity conditions found for the surface water masses in the Southeastern Baltic in spring 1993. Maximum values at the surface amounted to 7.49-7.52‰ in March and 7.45-7.49‰ in April. In March halocline continued to drop. In the Gdansk Basin and in the extreme south of the Gotland Hollow this process accompanied by increase of the vertical salinity gradients as compared to those of the previous year. In the Central Gotland Hollow maximum vertical salinity gradients were less than 0.1‰/m. The halocline upper limit in the

Gdansk Basin deepened up to 80-85 m i.e. 10 m lower than that of in autumn of 1992 (Fig. 5).

Table 1 contains data on salinity variations registered in the Central Gdansk Basin from May of 1992 to May of 1993. It can be seen from the table that apart from the salinity increase between 0 and 50 m its decrease was found at the lower depths from May of 1992 to March of 1993. The more pronounced salinity decrease was recorded at 75 and 100 m. In April-May of 1993 the salinity conditions in the Gdansk Basin changed sharply (Fig. 5).

Salinity variations over the surveyed period (the Central Gotland Basin) are demontrative as compared to data by Antonov (1991) and Nehring (1989) and our data for 1992 and 1993 (Table 2)

It is clearly seen from Table 2 that absolute salinity values at all depths except surface had showed and pronounced tendency to decrease by May of 1992. Comparatively high surface salinity at the beginning of 1993 may possibly be explained by abnormal droughty summer in 1992, due to which fresh water discharge to the Baltic Sea greatly reduced. "Pumping over" the salt from the near-bottom layer was the factor of no little importance influencing salinity of the surface and subsurface waters. This process had to take place in the Central Gotland Basin where even the maximum vertical salinity gradients within the halocline did not exceed 0.04-0.08‰/m. This fact resulted in an insignificant salinity increase at depths of 75-100 m and between 0 and 200 m on the whole.

To study salinity variations oin the near-bottom waters observations carried out over the depth of the 10‰ isohaline location are of appropriate interest. This isohaline represents the border between the Baltic and North Sea waters and allows to assess volume of waters of the North Sea genesis.

In the Central Gotland Basin the 10‰ isohaline location corresponded to depth of 117-123 m from May of 1992 to April of 1993. This location was 5-10 m deeper as compared to that of the late eighties and 32-38 m deeper as compared to the mean long-term location. This was indicative of the sharp reduction of the transformed North Sea waters and conditioned low near-bottom salinity values (Table 2).

From this point of view the situation in the Gdansk Basin was characterized by important peculiarities . From May of 1992 to March of 1993 a steady deeping of the 10‰ isohaline was observed, but according to the observations carried out in May 1993 it varied sharply (Table 3).

If toward the end of March 1993 deviation of the 10‰ isohaline from the long-term mean position exceeded 18-20 m, a month later its location as compared to the norm did not exceed 6 m (Fig. 5).

Hydrological observations of April-May 1993 gave a rare opportunity to record an advection of the transformed North Sea waters to the Southeastern Baltic and assess both temporal and spatial scale of this phenomenon.

In March 1993 salinity increased up to 13.8-14.2‰ in the area of the Slupsky Channed. In October maximum values in this very area did not exceed 12.6‰ (Fig. 6). In early spring of 1993 only in the northern periphery of the Gdansk Basin salinity exceeded 11‰. However, by April all the deep-water part of the basin had been occupied by waters salinity of which exceeded 12.2-12.3‰. By that time they had already"broke off" the area of their origin (Fig. 5).

Fig. 7, 8, 9 differences of the salinity values between autumn 1992, March 1993, April 1993 and spring 1992 for the transect extending across the Gdansk Basin. As it was mentioned above the surface layer was characterized by increase of salinity and this resulted in the development of the positive anomalies from the surface to the halocline. Only some areas in the Gdansk Hollow in May 1993 were an exception. There negative anomalies were observed between 0 and 10 m as a consequence of a high level of dilution. Maximum negative anomalies (> 2‰) were recorded between 75 and 90 m in the area of 54°50'N in March 1993 and that fact may be explained by the deepening of the halocline (Fig. 5 and 8). Variation of the halocline depth resulted in availability of the positive anomalies core in May 1993. And, finally, variation of the sign of the salinity anomaly within the near-bottom layer from negative positive reflected intrusion of high salinity waters into the Gdansk Basin (Fig. 7, 8, 9).

Comparison of data for 1992 and spring 1993 enabled to obtain a comprehensive picture of salinity variation within the near bottom layer in the Gdansk Hollow and extreme southern part of the Gotland Basin (Fig. 10).

In spring 1993 there was no distribution of highly saline waters to the Gotland Hollow. However, in April a "tongue" where salinity ranged from 11.4‰ to 12.3‰ was found in the near-bottom layer to the south of 56°30'N (Fig.11). This fact proved that advection of the saline water masses to the south of the Slupsky Channel took place indeed. Displacement of these waters to the Gotland Basin, possibly, occured to the west of the observation period or limited portion of the North Sea waters had flowed into the Gotland Basin until middle of March 1993.

On the whole salinity variation within the near-bottom layer of the Southeastern Baltic from May 1992 to May 1993 is given in Fig. 12.

Calculation of salinity deviation from the long-term values is of great importance to assess salinity variation in 1992-early 1993. Observation made in the Gotland Basin witnessed the development of considerable negative anomalies. They achieved their maximum values in the near-bottom layer (Table 4). The data analysis showed that in spite of the salinity increase between 0 and 50 m and negative anomaly decrease in the near-bottom layer and within the whole water column absolute salinity values as well as its anomalies at depths lover than 50 m by April had exceeded the minimum values of the given characteristics obtained there during the apogee of the previous stage of freshening (1895-1940) (Antonov, 1987, 1991). Thus , in 1992 and up to spring 1993 a tendency for salinity decrease gone back to the late 1970's -early 1980's showed its further development.

Variation of salinity and its anomaly in the Gdansk Basin are presented in Table 5. Between spring 1992 and March 1993 the negative anomalies were observed in that area as well. Considerable anomalies occured in the near-bottom layer where by late March 1993 mean salinity value was less than 9.3‰. However, by early May due to the advection of the North Sea waters salinity conditions within the Gdansk Hollow had been changed. A considerable increase of salinity both in the near-bottom and intermediate layers was found. Negative anomalies decreased by 2-7 times and did not exceed - 0.2- -0.4‰ within the whole depth range. Thus, influx of the highly saline North Sea waters which moved through the gulfs to the Arkon Hollow in winter 1992-1993 resulted in considerable variation of salinity in the Southeastern Baltic in May 1993.

CONCLUSION

1. Observations carried out in 1992 showed the development of considerable negative salinity anomalies in the Southeastern Baltic, primarily in the near-bottom layers of the deep-water hollows.

2. Absolute salinity values and salinity deviations from the long-term estimates found for spring and autumn 1992 and for April 1993 in the Gotland Basin did not exceed minimum values occured in the area during the apogee of the previous stage of freshening.

3. Analysis of the location depth for the 10‰ isohaline in 1992 and March 1993 showed no influx of the North Sea waters to the deep-water parts of the surveyed area. By early 1993 values of this characteristic exceeded the long-term estimates found for 32-38 m in the Gotland Basin and 14-20 m in the Gdansk Basin.

4. Two cruises conducted in March and March-April 1993 enabled to register considerable variation of salinity in the near-bottom and intermediate layers of the Gdansk Bay which resulted from the April advection of the transformed North Sea waters.

5. No pronounced advection of the saline waters to the Gotland Basin occured in April 1993 though availability of the waters with salinity of 11.4-12.3‰ to the south of 56°30'N witnessed their partial penetration to the area, possibly,* to the west of the investigation zone.

REFERENCES

Antonov, A.E. 1987. Large scale variability of the hydrometeorological conditions in the Baltic Sea and its influence on the fishery. L. Gydrometeoizdat:247 p. (In Russian).

Antonov, A.E. 1991. Started dilution of the Baltic Sea and its chemical and biological studies. In the book: Hydrometeorological and ecological studies in the Baltic Sea and its basin. L., Hydrometeoizdat, issue 5(18). (In Russian).

Nehring, D. 1989. Die hydrographisch-chemischen Bedingungen in der westlichen und zentralen Ostsee im Jahre 1989-Fisch.-Forsch., Rostock 28(1990) 3, S. 35-45.

Table 1

Salinity at the major depths in the Central Gdansk Basin
(φ = 54°50'N; λ = 19°20'E)

Depth, m	May 1992	October 1992	March 1993	May 1993
0	6.8	7.3	7.5	7.2
25	7.3	7.3	7.5	7.4
50	7.3	7.3	7.5	7.5
75	9.0	7.9	7.5	8.6
100	10.9	10.4	9.8	12.2
Bottom	11.0	10.4	10.4	12.3

Table 2

Salinity at the major depths of the Central Gotland Basin
in various years

Depth, m	August 1987	August 1989	May 1992	April 1993
0	7.5	7.3	7.3	7.4
25	7.5	7.4	7.3	7.4
50	7.8	7.5	7.3	7.5
75	9.3	7.8	7.4	7.6
100	9.8	9.5	9.3	9.4
150	11.9	11.2	10.7	10.5
175	12.1	11.4	10.9	10.8
190	12.1	11.6	11.0	10.9
0-200	10.0	9.5	9.0	9.1

Table 3

Location (m) of the 10‰ isohaline in the Gdansk Basin in various observation periods

	May 1992	October 1992	March 1993	May 1993
Depth, m	84	86	92	77

Table 4

Salinity and its anomalies in spring, autumn 1992 and in spring 1993 (Central Gotland Basin)

	Central Gotland Basin					
	May 1992	Anomaly	October-November 1992	Anomaly	April 1993	Anomaly
Salinity between 0 and 50m	7.3	-0.3	7.1	-0.3	7.4	-0.2
Salinity in the near-bottom layer	11.1	-2.0	11.0	-2.1	11.1	-2.0
Salinity for the whole layer	9.1	-1.6	9.0	-1.8	9.3	-1.4
Salinity between 100 and 200 m	10.5	-1.3	10.5	-1.3	10.4	-1.4

Table 5

Salinity and its anomalies(‰) in spring and autumn 1992 and in spring 1993
(Gdańsk Basin)

	Gdansk Basin							
	Value for May 1992	Anomaly	Value for Oct. 1992	Anomaly	Value for March 1993	Anomaly	Value for May 1993	Anomaly
Salinity at 0-50 m	7.2	-0.4	7.3	-0.3	7.5	-0.1	7.3	-0.3
Salinity in the near bottom layer	10.2	-1.3	9.8	-1.9	9.1	-2.4	11.3	-0.2
Salinity within the whole layer	8.1	-0.6	8.0	-0.8	7.9	-0.8	8.5	-0.2

Figure legends

Figure 1. Scheme of hydrological stations (16.05-02.06.92).

Figure 2. Scheme of hydrological stations (22.10-04.11.92).

Figure 3. Scheme of hydrological stations (18-28.03.93).

Figure 4. Scheme of hydrological stations (15.04-09.05.93).

Figure 5. Vertical salinity distribution for the transect extending across the Gdansk Basin

A - May, 1992, B - October, 1992, C - March, 1993, D - May, 1993.

Figure 6. Vertical salinity distribution (‰) for the transect from the Slupsky Channel to the southern part of the Gotland Hollow.

A - October, 1992, B - March, 1993

Figure 7. Salinity variations (‰) for the transect extending across the Gdansk Basin (May-October, 1992).

Figure 8. Salinity variations (‰) for the transect extending across the Gdansk Basin (May, 1992-March, 1993).

Figure 9. Salinity variations (‰) for the transect extending across the Gdansk Basin (May, 1992-May, 1993)

Figure 10. Salinity distribution (‰) in the near bottom layer of the Gdansk Hollow during the various observation periods.

Figure 11. Vertical salinity distribution (‰) for the transect extending across the Gotland Hollow (15-22.04.93).

Figure 12. Salinity distribution (‰) in the near bottom layer in May, 1992(1) and in April-May, 1993(2).

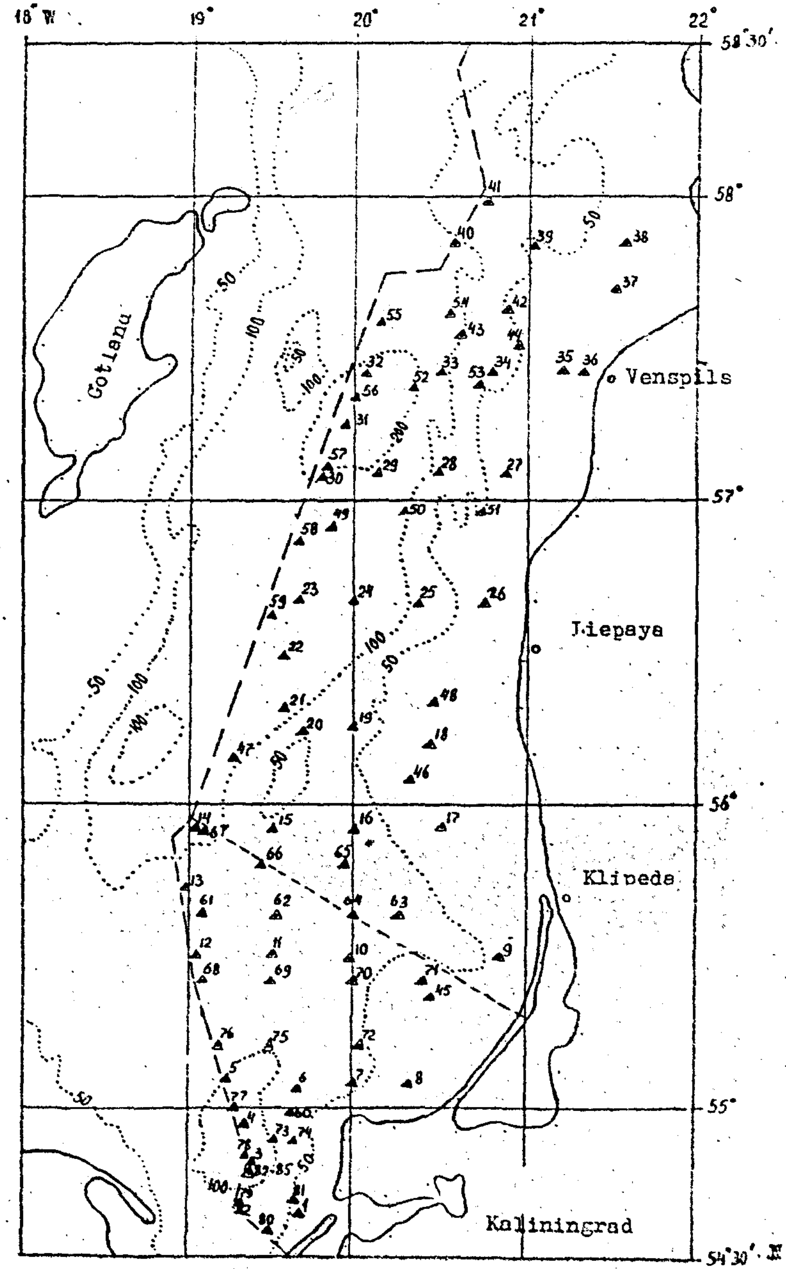

18° W
19°
20°
21°
22°
58°30'
58°
57°
56°
55°
54°30' N
Gotland
Venspils
Liepaya
Klipeda
Kaliningrad
50
100
200

Fig. 1

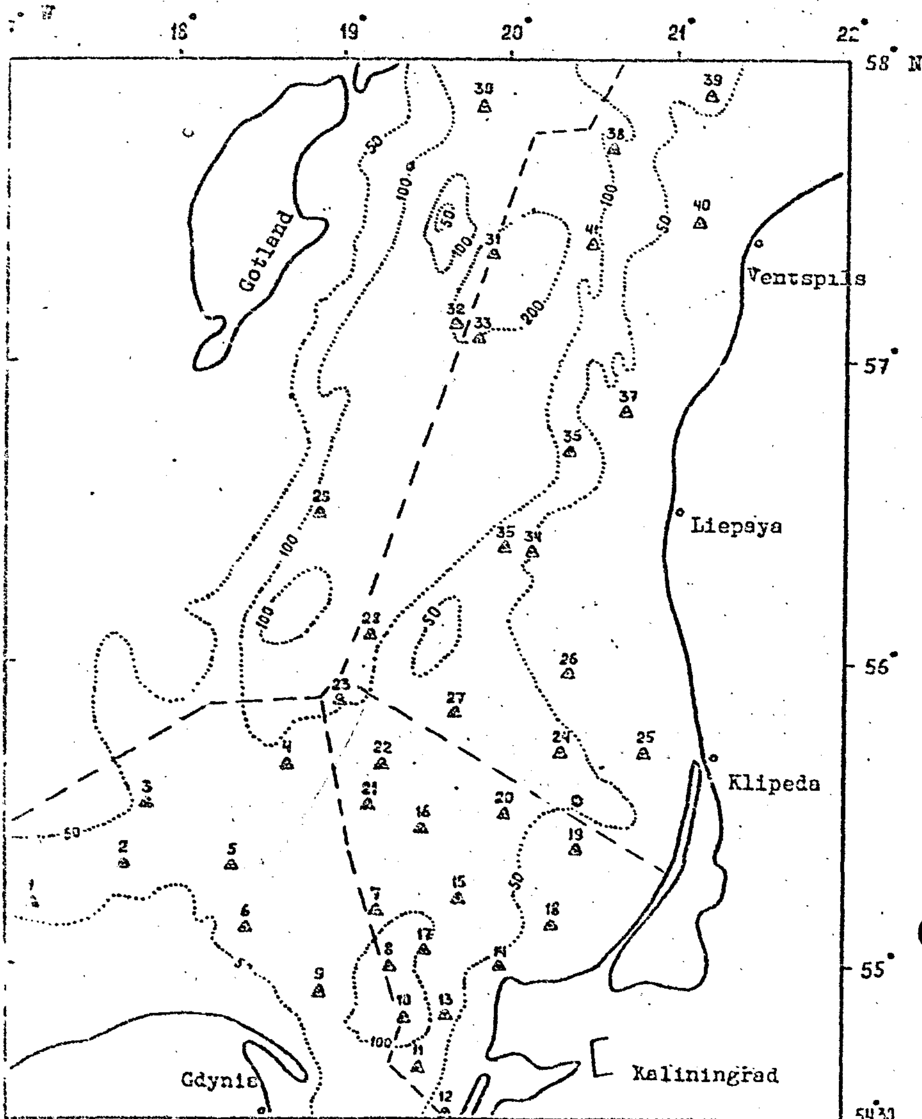

18°
19°
20°
21°
22°
58° N
57°
56°
55°
54°30
Gotland
Ventspils
Liepaya
Klipeda
Kaliningrad
Gdynia
50
100
200

Fig. 2

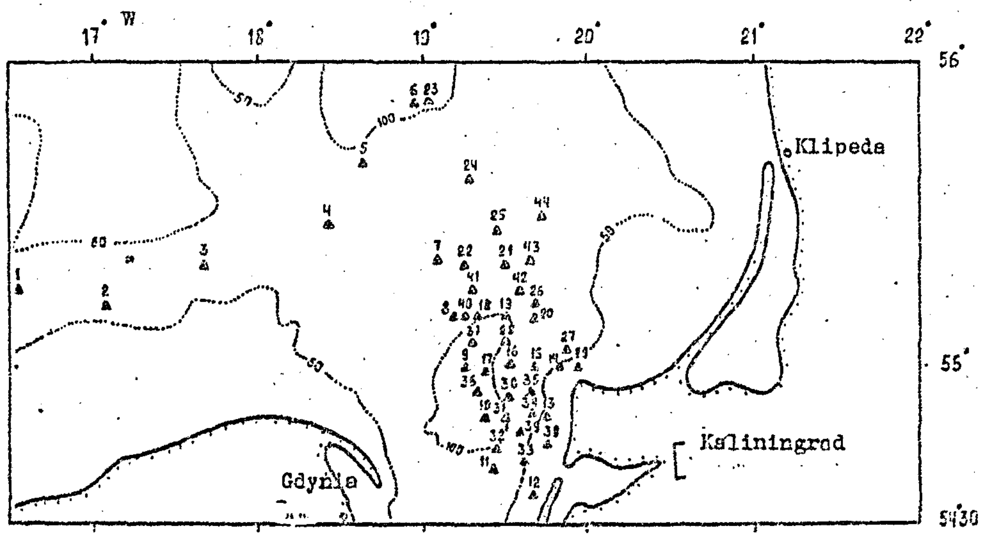


Fig. 3

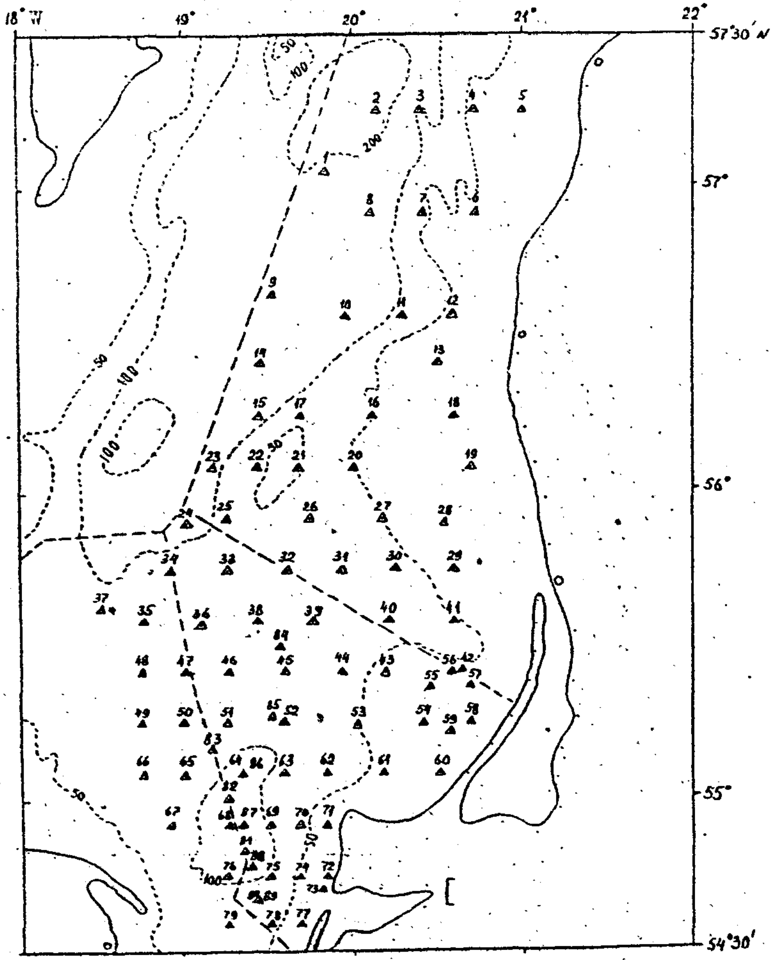


Fig. 4

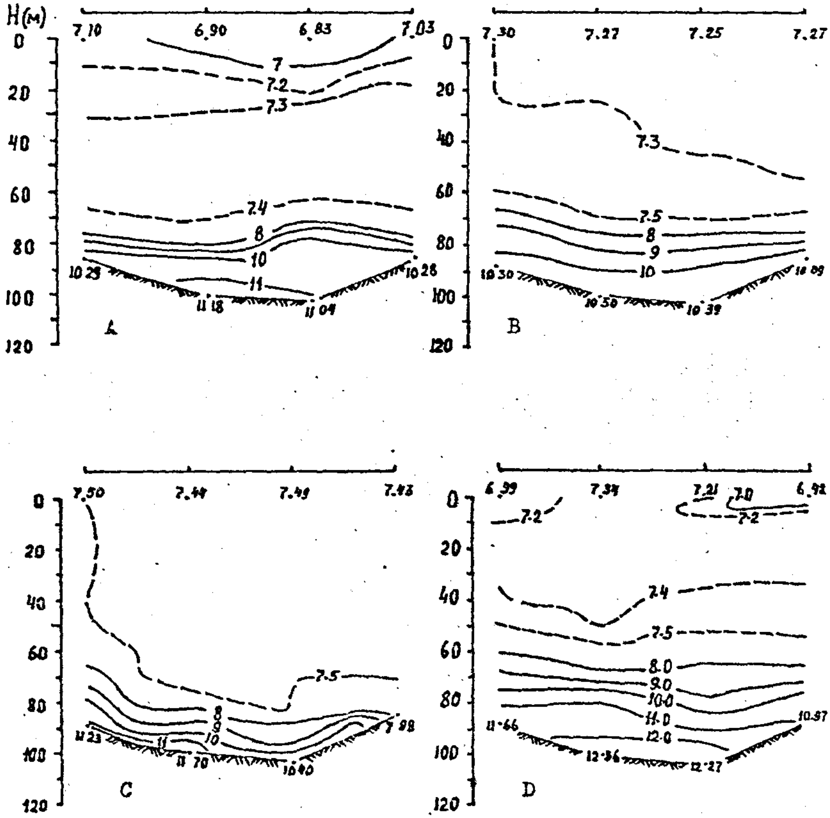

H(м)
7.10
6.90
6.83
7.03
7.30
7.27
7.25
7.27
7.50
7.44
7.49
7.43
6.99
7.34
7.21
6.92
A
B
C
D

Fig. 5

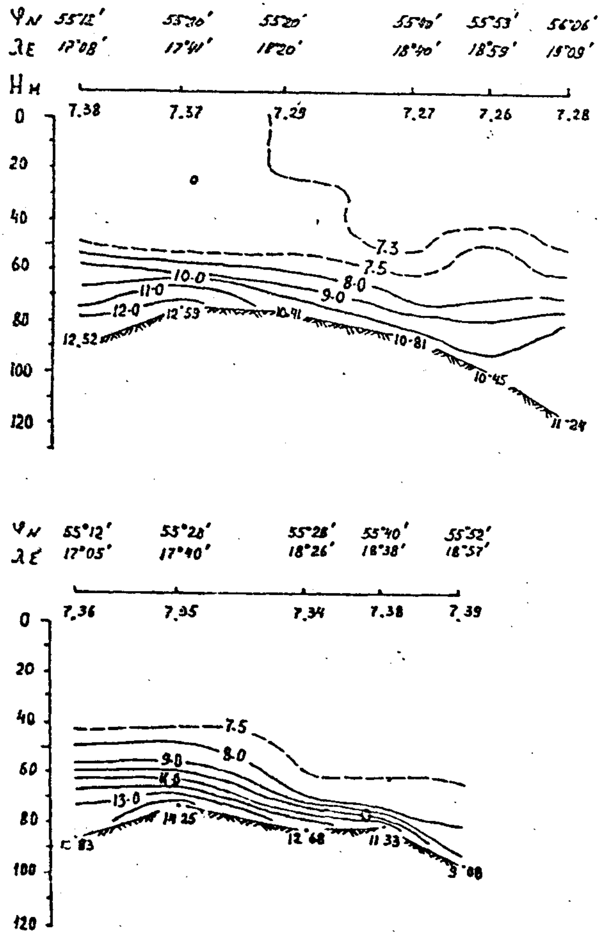

φN
λE
H м
7.38
7.37
7.29
7.27
7.26
7.28
0
20
40
60
80
100
120
7.3
7.5
8.0
9.0
10.0
11.0
12.0
12.52
12.59
10.91
10.81
10.45
11.24
φN 55°12' 55°26' 55°28' 55°40' 55°52'
λE 17°05' 17°40' 18°26' 18°38' 18°57'
7.36
7.35
7.34
7.38
7.39
7.5
8.0
9.0
13.0
14.25
12.68
11.33

Fig. 6

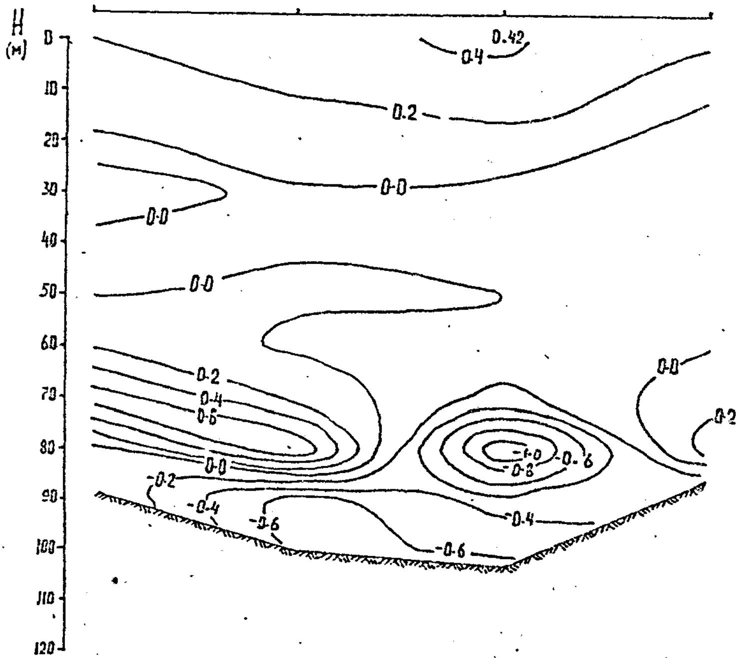

H
(M)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.42
0.4
0.2
0-0
0-0
0-0
0-2
0-4
0-6
0-0
0-0
0-2
-0.2
-0.4
-0.6
-0.6
-0.4
-0.8
-0.6

Fig. 7

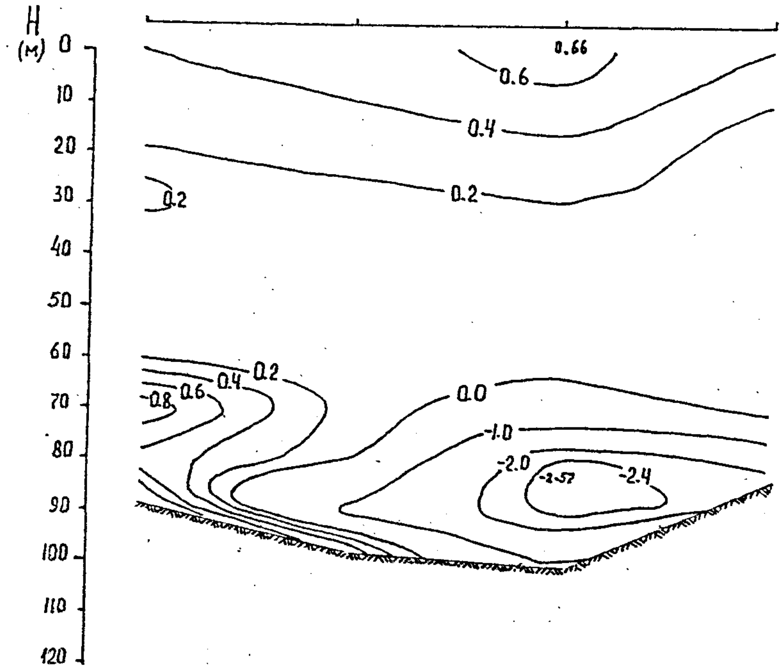

H
(м)
0
10
20
30
40
50
60
70
80
90
100
110
120
0.66
0.6
0.4
0.2
0.2
0.2
0.4
0.6
-0.8
0.0
-1.0
-2.0
-2.57
-2.4

Fig. 8

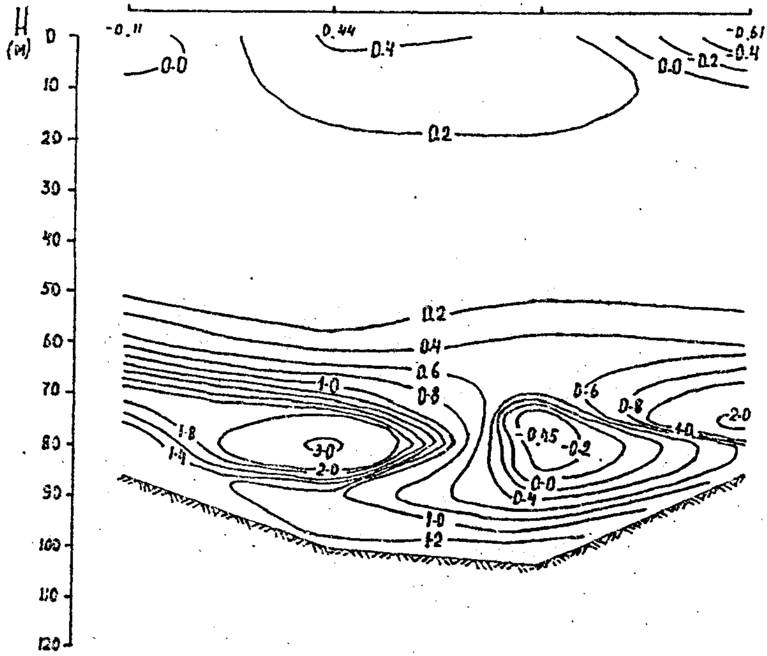

H
(m)
0
10
20
30
40
50
60
70
80
90
100
110
120
-0.11
0.44
-0.61
0.0
0.4
0.2
0.0
0.2
0.4
0.2
0.4
0.6
0.8
1.0
1.8
1.4
3.0
2.0
0.6
0.8
2.0
1.0
-0.15
-0.2
0.0
0.4
1.0
1.2

Fig. 9

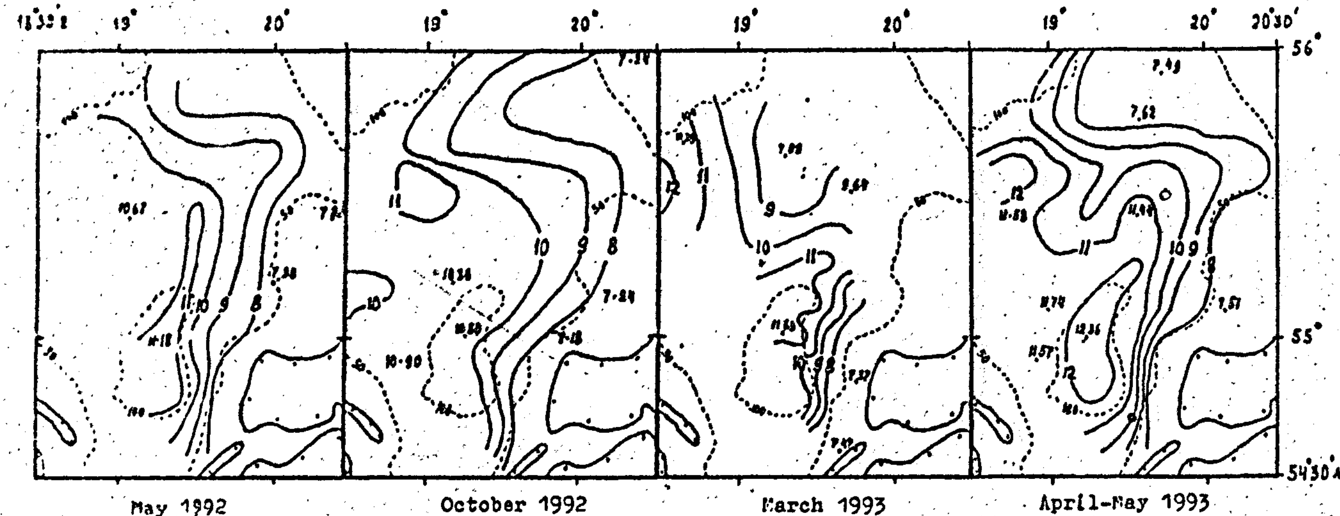
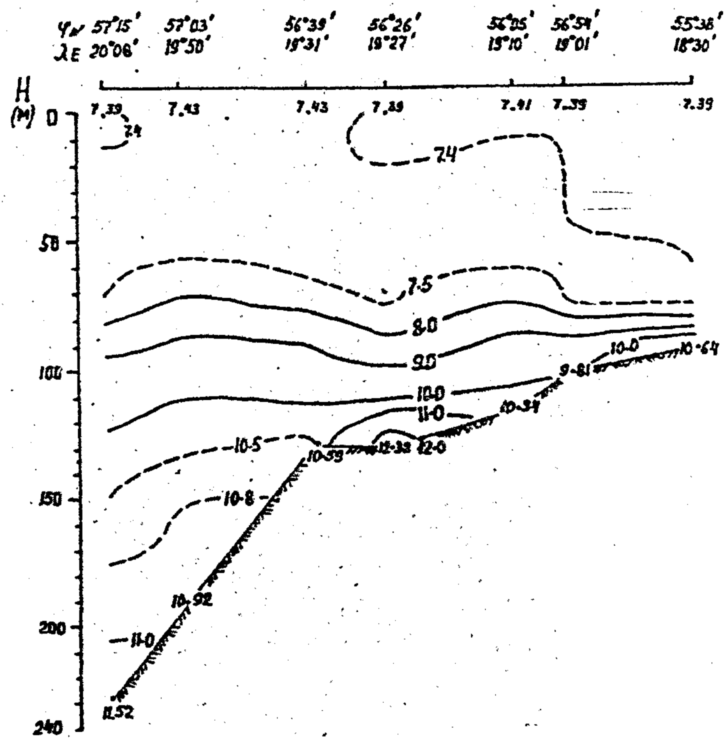

18°33' E
19°
20°
20°30'
56°
55°
54°30' N
May 1992
October 1992
March 1993
April-May 1993

Fig. 10



φN 57°15' 57°03' 56°39' 56°26' 56°05' 56°54' 55°36'
λE 20°08' 19°50' 19°31' 19°27' 19°10' 19°01' 18°30'
H
(M)
0
50
100
150
200
240
7.39
7.43
7.43
7.39
7.41
7.39
7.39
7.4
7.4
7.5
8.0
9.0
10.0
11.0
10.5
10.8
11.0
10.0
10.64
9.81
10.34
10.39
12.33
12.0
10.92
11.52

Fig. 11

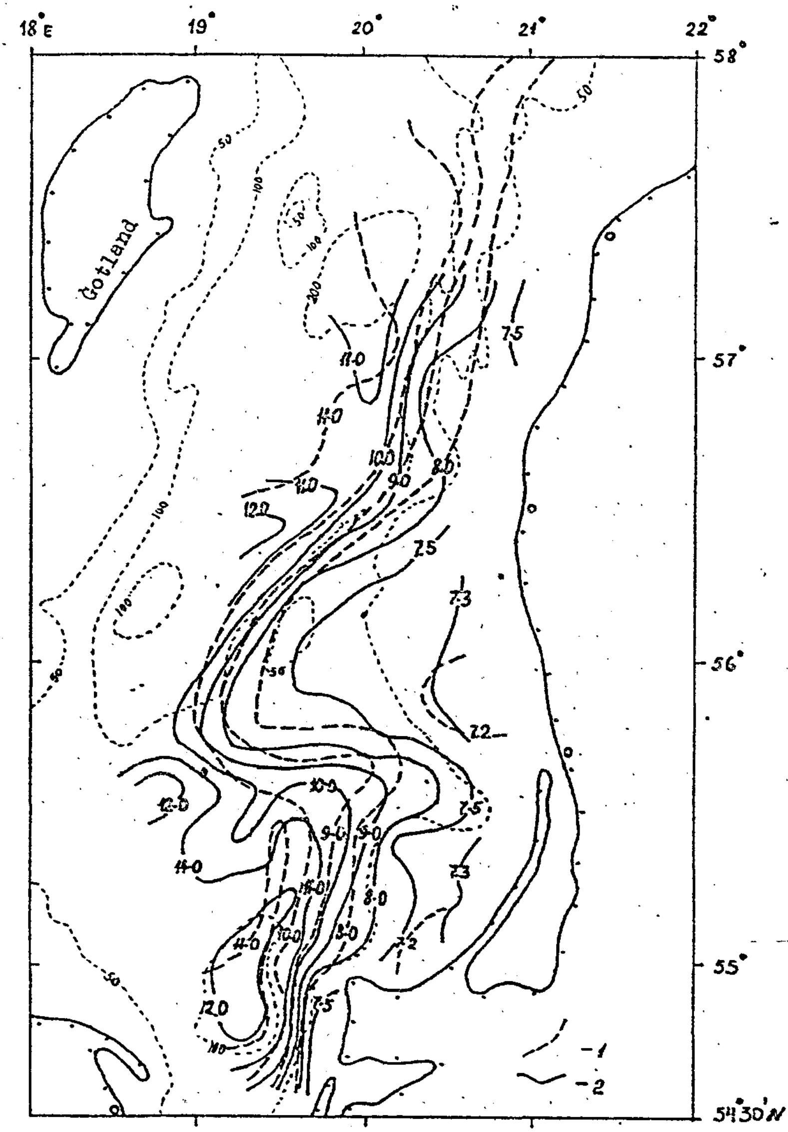


Fig. 12