Leibniz Institute for Baltic Sea Research Warnemünde

C r u i s e R e p o r t

r/v "Elisabeth Mann Borgese"

Cruise-No. EMB 102

Monitoring Cruise
5 May – 14 May 2015
Kiel Bight to Northern Baltic Proper

This report is based on preliminary data

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1. **Cruise No.:** EMB 102

2. **Dates of the cruise:** from 05 May to 14 May 2015

3. **Particulars of the research vessel:**
   Name: "Elisabeth Mann Borgese"
   Nationality: Germany
   Operating Authority: Leibniz Institute for Baltic Sea Research (IOW)

4. **Geographical area in which ship has operated:**
   Kiel Bight to Northern Baltic Proper

5. **Dates and names of ports of call**
   No port of call

6. **Purpose of the cruise**
   Baltic monitoring in the frame of the COMBINE Programme of HELCOM

7. **Crew:**
   Name of master: Uwe Scholz
   Number of crew: 10

8. **Research staff:**
   Chief scientist: Dr. Norbert Wasmund

   Scientists: Prof. Dr. Heide Schulz-Vogt
   Dr. Jörg Dutz
   Mercè Berga Quintana
   Anette Christensen

   Engineers: Jan Donath
   Ingo Schuffenhauer

   Technicians: Sven Trinkler
   Michael Pötzsch

   Students: Elisa Rönn
   Diane Enkelmann
   Nicolas Raab

9. **Co-operating institutions:**
All institutions dealing with HELCOM monitoring programmes.

10. **Scientific equipment**
CTD + Rosette water samplers "SBE 911plus", phytoplankton net (Apstein), zooplankton net (WP2), Secchi disk, nutrient analyser Evolution III from Alliance, oxygen analyser Titrino from Metrohm, thermosalinograph, multicorer

11. **General remarks and preliminary results**
This cruise is part of the German contribution to the HELCOM COMBINE program and contributes to IOW's long term data series in the central Baltic Sea. The area under investigation extended from Kiel Bight to the Northern Gotland Sea. Besides the regular

station grid, additional stations were sampled in the southern Baltic Proper and the Gotland Basin to follow the recent mayor salt water inflow (station map see Figs. 1-3). On the way back, selected HELCOM stations in the Bornholm Sea, Arkona Sea and Mecklenburg Bight were sampled a second time for nutrient, phytoplankton and zooplankton data. The hydrographical, chemical and biological investigations were performed according to the Manual of the COMBINE Programme of HELCOM.
Additional research was performed on zooplankton distribution and physiological adaptations (responsible scientist Dr. Jörg Dutz) as well as iron and sulphur oxidizing bacteria in the sediment (responsible scientist Prof. Heide Schulz-Vogt). The results of this additional research are not presented in this report.

11.1 Weather conditions:
Concerning the weather conditions, the cruise can roughly be divided into 6 periods:

1.) 05.05.2015, while cruising through Mecklenburg Bight and Kiel Bight: very deep air pressure (998-1002 hPa), southerly to westerly winds (> 11 m/s), with peak velocity of 27 m/s during a thunderstorm in the afternoon; air temperature during the day 11-15 °C; cloudy and sometimes rainy.
2.) 06.-07.05.2015: From the eastern Mecklenburg Bight to the Bornholm Sea: low air pressure (1008-1015 hPa), southerly to westerly winds of 7- 10 m/s, air temperature 9-13 °C, sunny.
3.) 08.05.-09.05.2015: From the Bornholm Sea to the Eastern Gotland Basin (Station TF0271): high air pressure (1017-1019 hPa), low south-westerly winds up to 8 m/s, low air temperature of about 7-8 °C, but sunny.
4.) 10.05.2015: Eastern Gotland Basin: after a sudden strong drop, the air pressure was increasing from 1012 to1017 hPa. In the morning rain and fog. Wind 6-10 m/s from southwest. Air temperature still about 7-8 °C
5.) 11.05.-12.05.2015: From the Northern Baltic Proper via Landsort Deep to the Western Gotland Basin: Decrease in air pressure from 1024 to 1005 hPa. Increase of wind speed from 2 to 18 m/s from southern directions on the 11.05. air temperature of about 7-10 °C
6.) 13.05.-14.05.2015: Bornholm Sea, Arkona Sea and Mecklenburg Bight: It was mostly cloudy; air pressure ranged from 1009 to 1011 hPa. Westerly winds from 8 to 20 m/s, air temperature from 8 to 10 °C

11.2 Hydrographical and hydrochemical conditions in the different sea areas:
The hydrographical and hydrochemical characteristics during the cruise are summarized in the appendix (Tables 1 and 2 and Figs. 4 and 5):
The typical stratifications of the water column could be found in each of the Baltic basins. In the central Kiel Bight (stat. TF0360), both salinity and temperature formed a weak pycnocline at 10 m depth and a permanent pycnocline starting at 14 m depth. In Mecklenburg Bight (stat. TF0012), salinity increase and temperature decrease started already below 8 m depth, accompanied by a clear fluorescence maximum (chlorophyll) between 8 and 14 m. The minimum oxygen concentration near the bottom was higher than 5 ml/l and exceeded even 7 ml/l in the eastern Mecklenburg Bight.
In the Arkona Sea, the depth of the halocline was variable, starting between 15 m (stat. TF0113) and 27 m (stat. TF0112). The oxygen concentrations were always higher than 4 ml/l above the bottom in this region. In the Bornholmgat (stat. TF0142, TF0140) and the Bornholm Sea (e.g. stat. 212, 213, 221), the upper border of the halocline shifted to a depth of 40-50 m, but a slight discontinuity of the salinity could also be found as shallow as 20-25 m deep. Within the deep halocline, the water became warmer with depth, reaching 7-8 °C. The oxygen concentration stayed still above 3 ml/l.
On the Slupsk Sill (stat. TF0224) and in the Slupsk Furrow (Stolpe Channel; stat. TF0222), a sharp salinity and temperature gradient occurred at 55-60 m depth, of course followed by a strong oxygen decrease from >8 to <4 ml/l, but even here the oxygen concentrations stayed >3 ml/l above the bottom.

In the southern part of the Eastern Gotland Basin (stat. TF0256, TF0259), the halocline was even situated at 65-70 m depth. Up to these stations, the oxygen minimum was found above the ground, but at the following, more northern stations (TF0255 toTF0253), a water body of almost 10 m thickness was laying above the ground characterized by higher salinity and temperature and a relatively high oxygen concentration of 2-3 ml/l. Above this layer, the oxygen concentration was <1 ml/l.
Further north, the stations became deeper and the oxygenated (~2 ml/l) bottom layer became thicker, reaching up to 100 m depth at stat. TF0250 or 115-118 m at station TF0263 and 260. Several narrow layers of only few metres thickness in the range of 95-120 m (TF0263, TF0260) were oxygen-depleted. The layers of zero oxygen became thicker (in the range of 100-130 m) in the central Gotland Basin around stat. TF0272 with a tendency to less oxygen in the western part in comparison with the eastern part. The western station (GB_B4) in an east-west transect across the Eastern Gotland Basin were obviously not reached by the inflow event as the water was oxygen free from 105 m depth to the bottom (158 m). Generally, the central Gotland Deep (stat. TF0271) was filled with water of oxygen concentrations up to 2 ml/l up to a depth of 130 m with only a narrow layer with zero oxygen at 120-130 m depth. Even this layer is variable within only one day. The inflow of deep water has obviously reached station “Gotland NE” but hardly stations GB_B15, TF0270 and GB_B20, as on the latter stations only an insignificant oxygen signal was noticed near the bottom. Other stations (GB_B16, GB_B19, TF0286, GB_B24) were anoxic below 100m or 110 m depth, station 284 even below 90 m depth..

11.3 Development in comparison with earlier cruises

Salinity
The mayor Baltic inflow from December 2014 had a volume of 198 km^3 and transported 4 Gt salt and 2.04 * 10^6 t oxygen into the Baltic Sea (Mohrholz et al. 2015). Correspondingly, the salinity in the bottom layer has strongly increased in comparison to the cruise from Mai 2014 (see table below).

Salinity in the bottom layer

Area:	May 2015	May 2014
Gotland Deep	13.54	12.21
Farö Deep	12.11	11.42
Landsort Deep	10.54	10.32
Karlsö Deep	9.60	9.48

Temperature
The surface water temperatures (0-10 m; °C) of selected stations of this cruise are compared with our cruises from May 2013 and early long-term mean values (1971-1990) collected during our May cruises in the 1970s and 1980s in the table below. Surface water temperatures in the first half of May of 2015 were much higher than long-term data from the beginning of the systematic monitoring programme.

Temperature in the surface layer (°C)

Area:	2015	2013	1971-1990
Mecklenburg Bight (stat. TF0012)	9.66	8.2	2.64
Arkona Sea (stat. TF0113)	8.16	6.2	2.14
Bornholm Sea (stat. TF0213)	7.96	4.5	2.41
Eastern Gotland Sea (stat. TF0271)	6.97	4.8	2.60
Farö Deep (stat. TF0286)	4.26	5.3	2.30
Karlsö Deep (stat. TF0245)	6.55	4.6	2.16

The long-term trend of increasing water temperature [°C] is representatively reflected in the deep water layers of the central deeps of the Baltic Proper.

Temperature in the bottom layer (°C)

Area:	May 2015	May 2014	May 2013	Mean 1971-1990
Bornholm Deep	7.00	5.60	5.12	6.12
Gotland Deep	6.88	6.62	6.41	5.62
Farö Deep	6.50	5.71	5.94	5.20
Landsort Deep	5.42	5.32	5.39	4.76
Karlsö Deep	5.01	4.99	5.33	4.18

Oxygen

After the mayor inflow of deep water, the development of the oxygen concentrations in the deeper layers of the water column is most interesting.

During the Cruise EMB099 from 17 to 30 March 2015 (see cruise report by Mohrholz 2015: http://www.io-warnemuende.de/tl_files/forschung/pdf/cruise-reports/cremb099.pdf), the oxygen concentration was already above 4 ml/l in the deep layers of the Bornholm Basin and the Slupsk Furrow. The Eastern Gotland Basin was anoxic at intermediate depths between 120 and 170 m but was already oxic in deeper layers. Below 170m depth, oxygen concentrations ranged from 0.4 to 0.9 ml/l in March 2015. In comparison with the situation in March 2015, the oxygen concentrations in the bottom layer increased further (see table below) and the anoxic zone was reduced to a thin layer between 120 and 135 m depth, measured at the first CTD cast. On the next day, this oxygen-depleted layer could not be found; instead oxygen concentrations of 0.16 ml/l could be measured in the oxygen minimum zone. Such high variability within one day was already mentioned from station TF0271by Mohrholz in his report from cruise EMB099. The “negative oxygen” was already reduced in the Farö Deep in March 2015, but the situation has not improved further until May 2015 (see table below).

Oxygen concentrations in the bottom layer (ml/l)
Hydrogen sulphide was converted into negative oxygen equivalents.

Area:	May 2015	March 2015	May 2014	May 2013
Gotland Deep	2.09	0.89	-6.03	-7.59
Farö Deep	-1.18	-1.14	-3.58	-3.57
Landsort Deep	-0.73	no sample	-3.13	-0.78
Karlsö Deep	-0.84	-0.70	-0.74	-0.70

Nutrients

Due to the relative shortage of nitrogen in comparison with phosphorus in relation to the Redfield ratio, the combined nitrogen is almost exhausted in the surface water after the spring bloom, whereas phosphorus is still available in the Baltic Proper (Table 1 in Appendix). In the bottom-near layer, the situation changed strongly due to the inflow of oxygenated water: phosphate concentrations decreased and nitrate+nitrite concentrations increased in comparison with the situation before the Mayor Baltic Inflow (see Table below).

Area:	Phosphate May 2015	Phosphate May 2013	Nitrate+Nitrite May 2015	Nitrate+Nitrite May 2013
Gotland Deep	1.95	9.45	10.53	0.14
Farö Deep	3.30	7.45	0.25	0.52
Landsort Deep	3.70	4.95	0.35	0.18
Karlsö Deep	3.95	3.50	0 34	0.11

This effect is strongest in the Gotland Deep, after the end of the long stagnation period. The phosphate concentration is also affected in the Farö Deep which is an indication that the MBI has touched also this station. Even the Landsort Deep may have been influenced, as already suggested by the oxygen concentration near the bottom (comparison with May 2014, see table above).

Biological Data
The biological data will be analysed and are not available yet.

Reference:
Mohrholz, V., M. Naumann, G. Nausch, S. Krüger and U. Gräwe (2015). Fresh oxygen for the Baltic Sea — An exceptional saline inflow after a decade of stagnation" J. Mar. Sys. 148: 152-166.

Appendix

Tables 1& 2: Preliminary results for selected parameters in the surface layer and the near-bottom layer (unvalidated results)

Figs. 1-3: Station grid (total grid and two sub-maps)

Fig. 4: Oxygen /hydrogen sulphide concentrations in the near-bottom layer for selected stations

Fig. 5: Transsect from the Kiel Bight to the Farö Deep for temperature, salinity and oxygen (unvalidated data)

Dr. Norbert Wasmund

Scientist in charge

Table 1: Surface layer (0 - 10m)

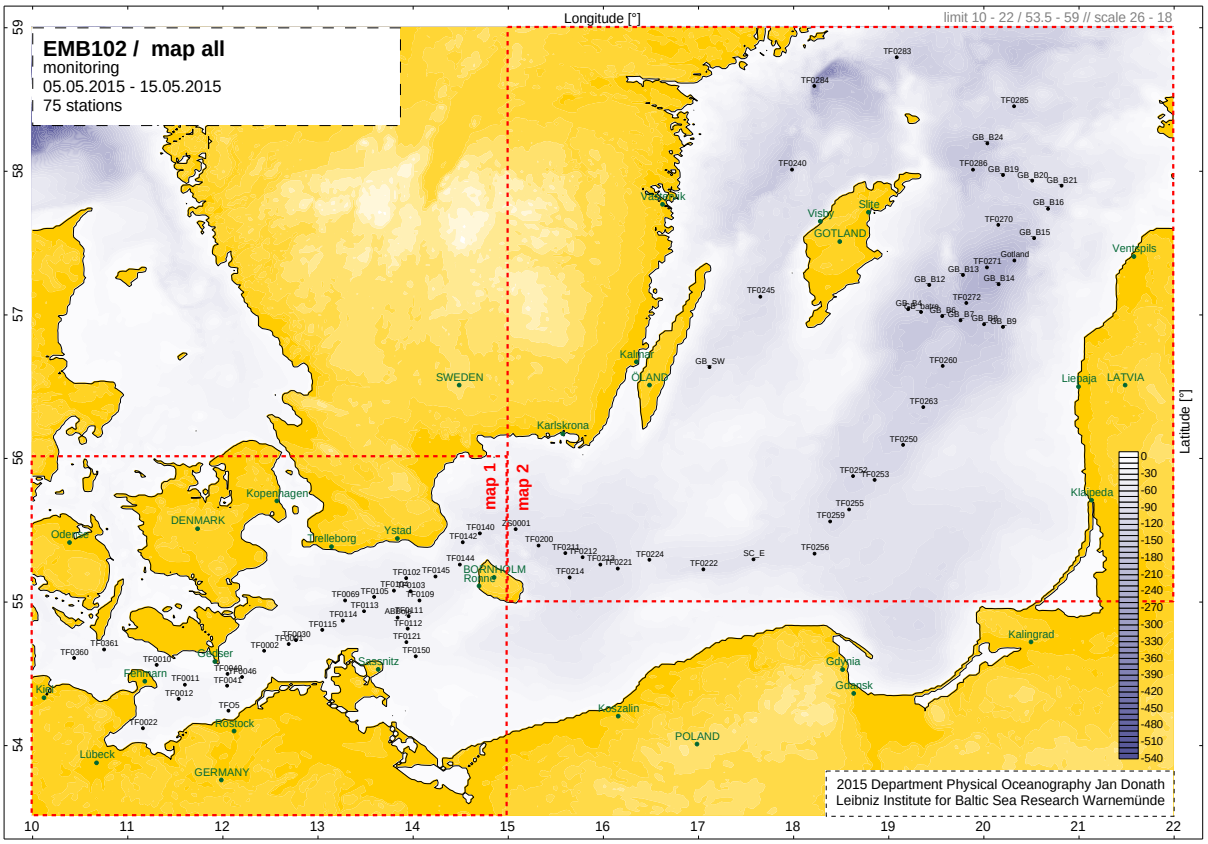
Area	Station	Temperature	Salinity	PO_4^{3-}	NO_{23}^{-} *
Date	Name/ No. **	°C	PSU	µmol/dm³	µmol/dm³
Kiel Bight 5.5.2015	TF0360/ 005	10.27	15.67	0.09	0.22
Meckl. Bight 6.5.2015	TF0012/ 007	9.66	9.78	0.05	0.11
Lübeck Bight 5.5.2015	TF0022/ 006	10.32	13.73	0.04	0.03
Arkona Basin 6.5.2015	TF0113/ 017	8.16	8.04	0.36	0.12
Bornholm Deep 7.5.2015	TF0213/ 037	7.96	7.75	0.35	0.07
Stolpe Channel 8.5.2015	TF0222/ 040	7.08	7.60	0.36	0.19
SE Gotland Basin 8.5.2015	TF0259/ 043	6.12	7.24	0.51	0.15
Gotland Deep 9.5.2015	TF0271/ 060)[a]	6.79	7.09	0.33	0.20
Fårö Deep 11.5.2015	TF0286/ 068	4.26	7.21	0.24	0.10
Landsort Deep 11.5.2015	TF0284/ 072	7.51	6.31	0.26	0.27
Karlsö Deep 12.5.2015	TF0245/ 074	6.55	7.10	0.60	0.26

* Σ NO_2^- + NO_3; NO_2 was present only in traces in most areas under investigation
** Station name see maps (Fig. 1 - 3)

Table 2: Bottom-near water layer

Area	Station	Sampl. Depth	Temp.	Salinity	O_2	PO_4^{3-}	NO_{23}^- *
Date	Name/ No. **	m	°C	PSU	cm^3/dm^3	$\mu mol/dm^3$	$\mu mol/dm^3$
Kiel Bight 5.5.2015	TF0360/ 005	17	5.59	20.39	5.30	0.48	3.15
Meckl. Bight 6.5.2015	TF0012/ 007	24	6.21	18.10	5.64	0.43	2.43
Lübeck Bight 5.5.2015	TF0022/ 006	22	4.62	20.04	3.27	0.64	9.55
Arkona Basin 6.5.2015	TF0113/ 017	46	5.17	17.46	4.39	0.82	0.50
Bornholm Deep 7.5.2015	TF0213/ 037	88	7.00	19.49	2.47	1.53	11.25
Stolpe Channel 8.5.2015	TF0222/ 040	89	6.97	15.66	3.78	1.47	8.93
SE Gotland Basin 8.5.2015	TF0259/ 043	88	5.80	11.39	1.27	2.50	5.95
Gotland Deep 9.5.2015	TF0271/ 060)[a]	234	6.88	13.54	2.09	1.95	10.53
Fårö Deep 11.5.2015	TF0286/ 068	190	6.50	12.11	-1.18	3.30	0.25
Landsort Deep 11.5.2015	TF0284/ 072	437	5.42	10.54	-0.73	3.70	0.35
Karlsö Deep 12.5.2015	TF0245/ 074	108	5.01	9.60	-0.84	3.95	0.34

* Σ NO_2^- + NO_3; NO_2 was present only in traces in most areas under investigation
** Station name see maps (Fig. 1 - 3)



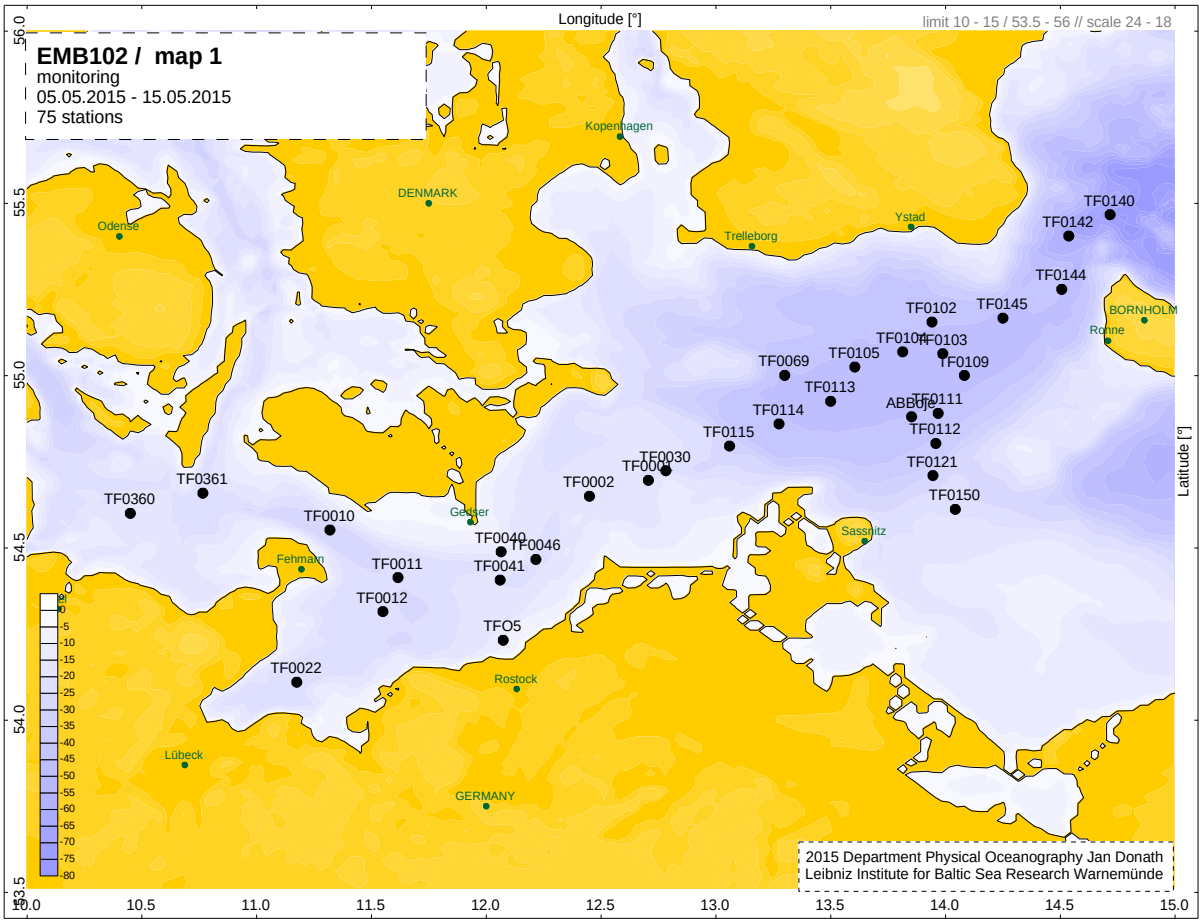


Fig1 and 2: Total station map and detailed map of the western Baltic Sea .

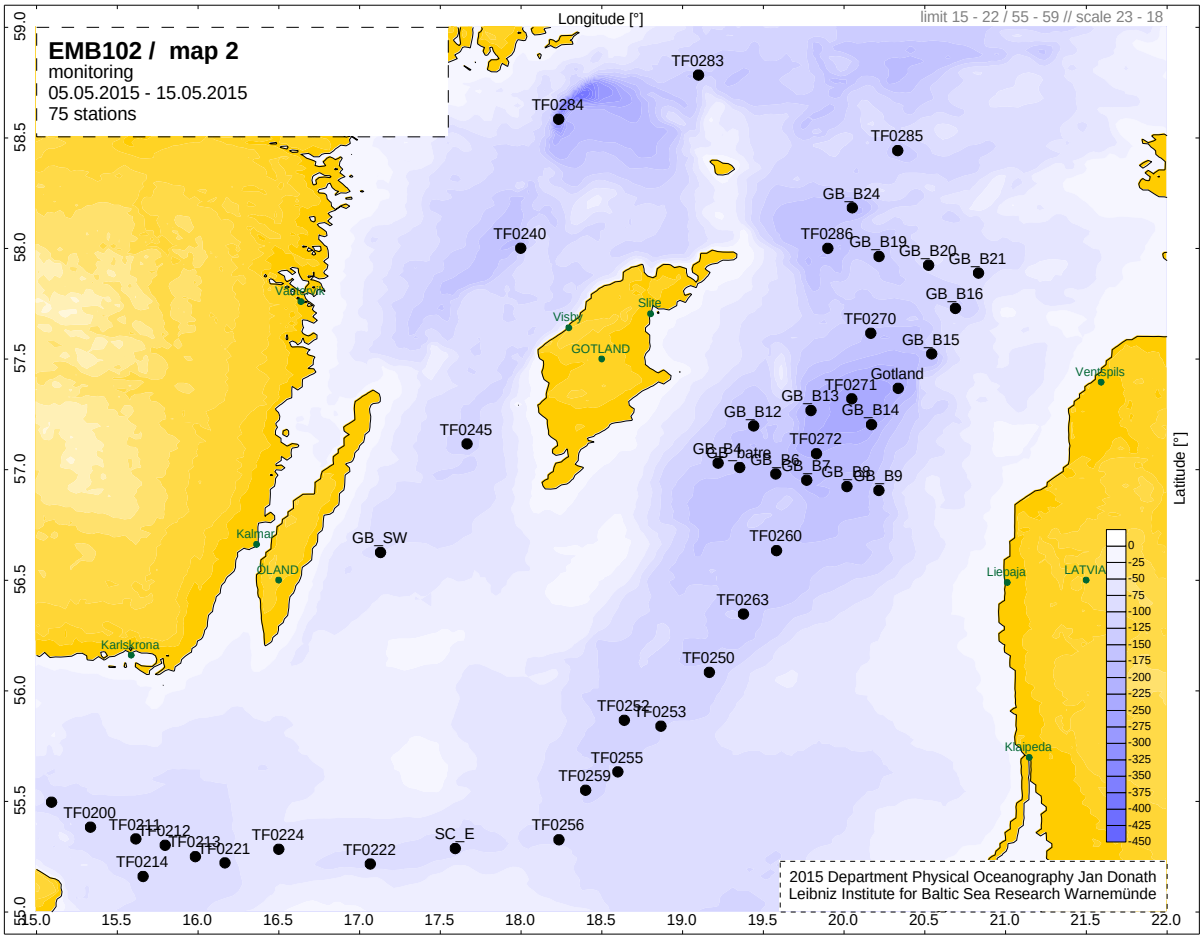


Fig. 3: Map of monitoring stations in the Baltic Proper.

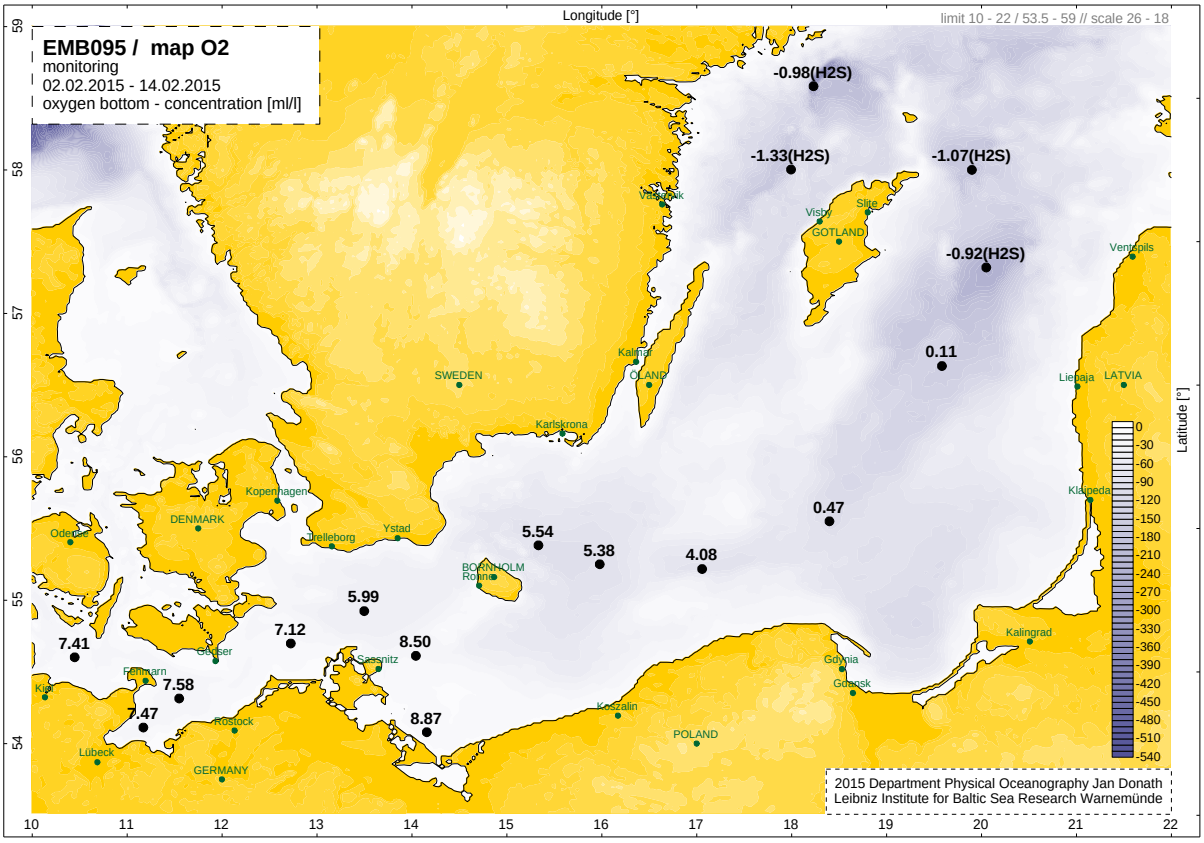
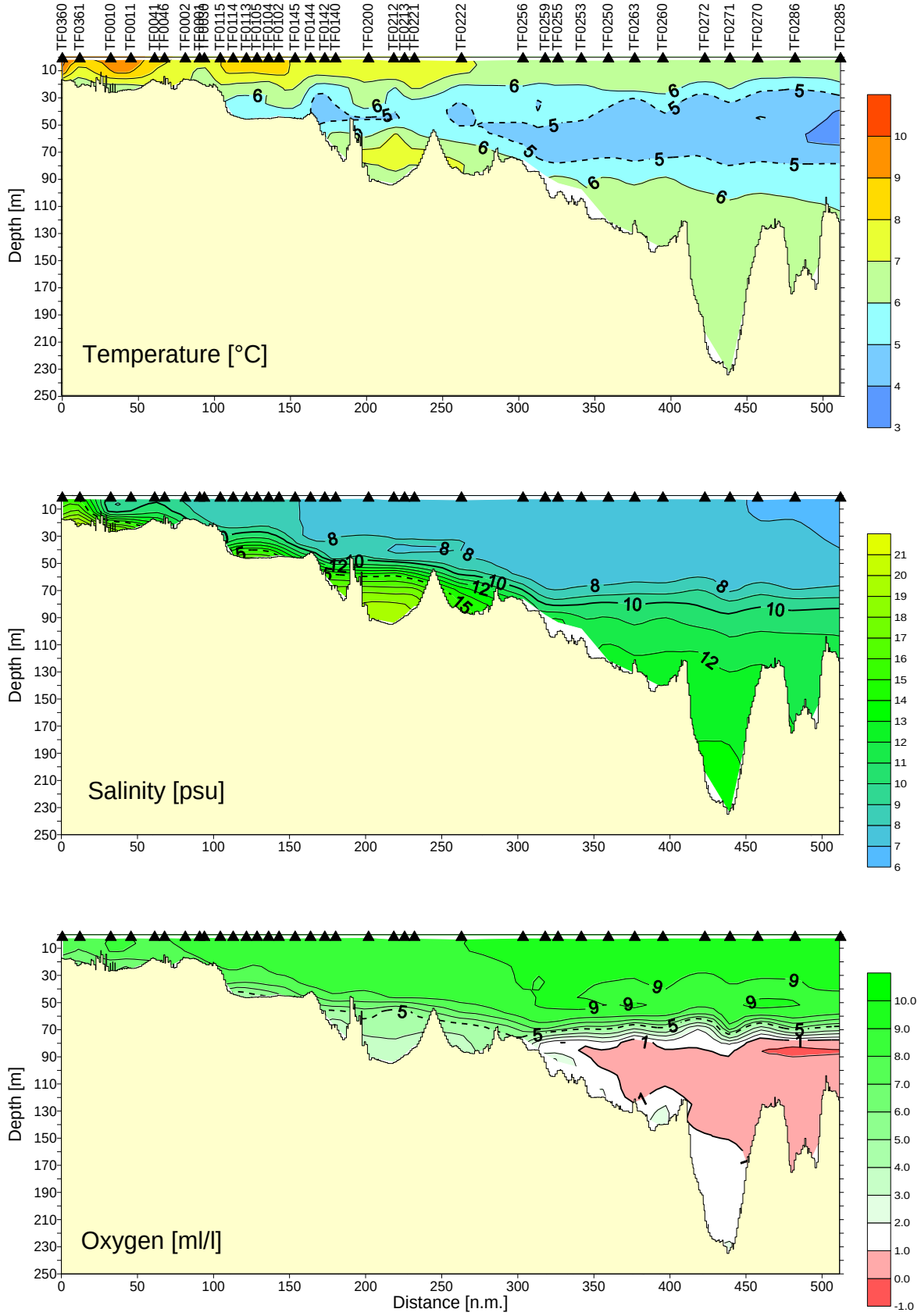


Fig. 4: Oxygen/hydrogen sulphide concentrations in the near-bottom layer (selected stations)

Monitoring EMB102

Kiel Bight - Gotland Sea
05.05.2015 09:26 - 11.05.2015 05:56 UTC



KB-GS.srf

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Fig. 5: Transsect from the Kiel Bight to the Farö Deep for temperature, salinity and oxygen.