The ice winter of 2011/12 on the German North and Baltic Sea coasts and a brief description of ice conditions in the entire Baltic Sea region

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Icebreaker ARKONA operating in Greifswalder Bodden, February 2012.

Courtesy of:
Frank Sakuth

Annex

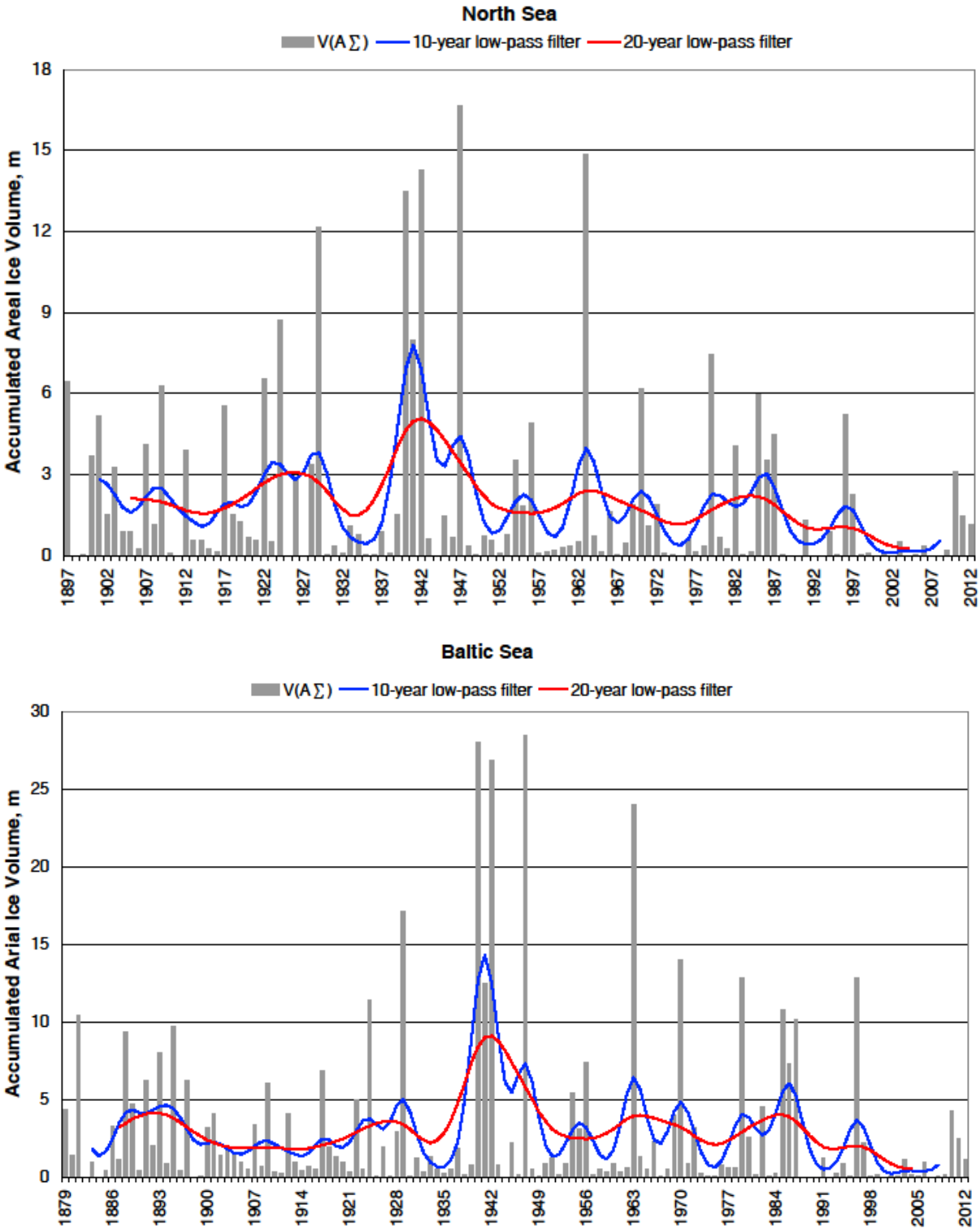


Fig. 1. Distribution of accumulated areal ice volume on the German North Sea coast between 1897 and 2012, and on the German Baltic Sea coast between 1879 and 2012

General

The ice season of 2011/12 was the third consecutive ice season characterised by major ice formation in the German coastal waters. Although ice occurred only for a short period of time (about 3 weeks), the intensity of ice production justified a classification of the winter of 2011/12 as a **moderate** ice winter.

In the ice winter of 2011/2012, the accumulated areal ice volume expressing the severity of ice winters on the German coast, cf. http://www.bsh.de/de/Meeresdaten/Beobachtungen/Eis/Kuesten.jsp, is **1.13 m** for the North Sea, and **1.12 m** for the Baltic Sea, cf. Figs. 1 and 2.

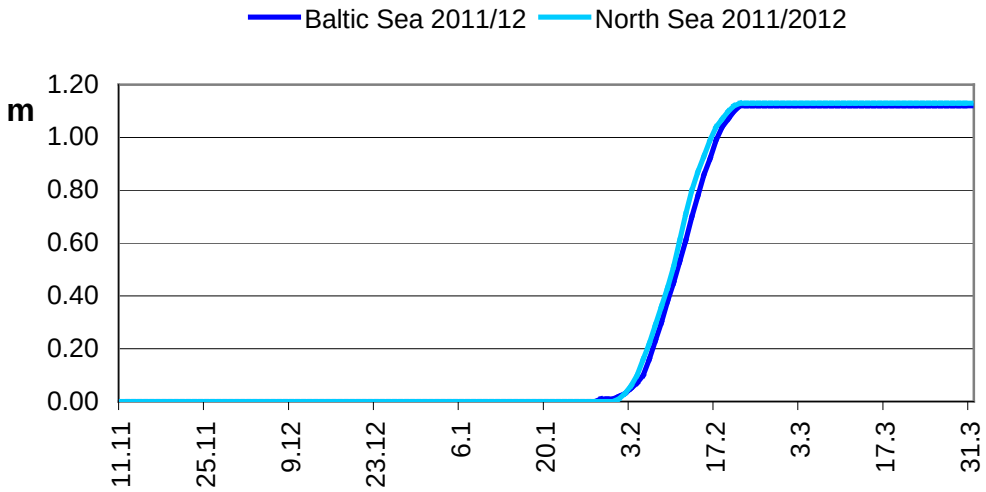


Fig. 2. Accumulated areal ice volume on the German coasts in the winter of 2011/12

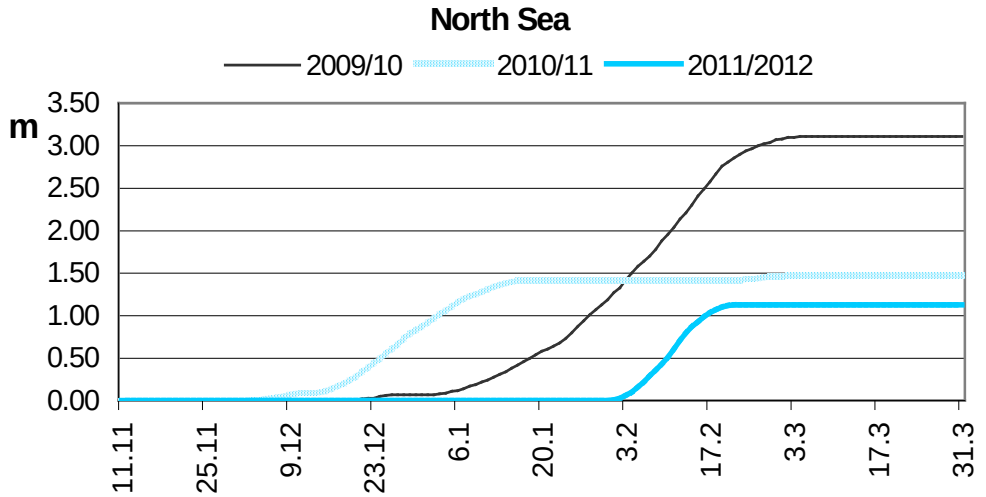


Fig. 3. Accumulated areal ice volume on the German North Sea coast in the winters of 2009/10, 2010/11 and 2011/12

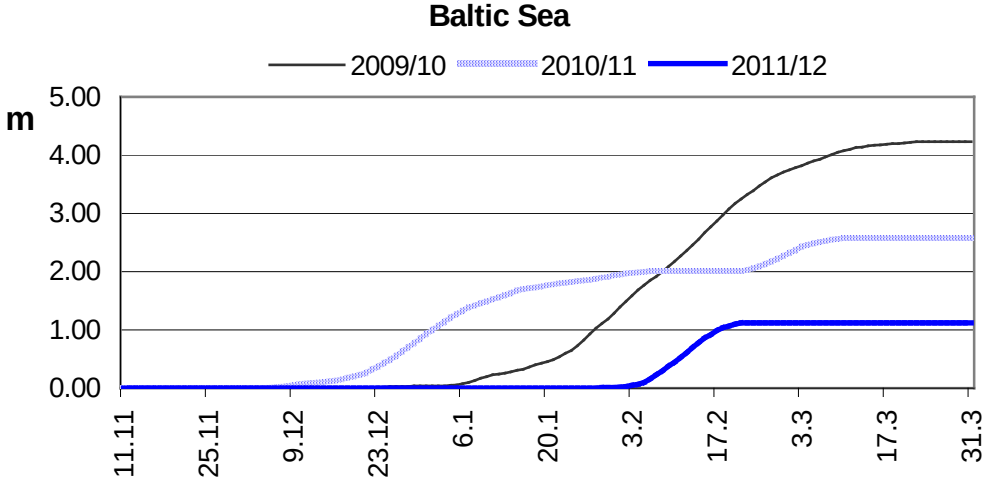


Fig. 4. Accumulated areal ice volume on the German Baltic Sea coast in the winters of 2009/10, 2010/11 and 2011/12

The past three winter seasons on the German North Sea coast were classified as moderate ice winters. The strongest of these ice seasons was 2009/10, while the ice season of 2010/11 was one week shorter and had about 50 % less ice. The ice volume produced in the winter of 2011/12 about equalled that in 2010/11 but formed in about half the time, see Fig. 3, Table 1.

On the German Baltic Sea coast, the ice winter of 2009/10 was classified as severe, and both the winters of 2010/11 and 2011/12 were classified as moderate ice winters. During the past ice winter, a considerable quantity of ice formed within just two weeks also in this region. The ice season of 2011/12 was short but intensive, see Fig. 4 and Table 1.

Table 1. Reduced ice sum (R_E) and accumulated areal ice volume ($V_{A\Sigma}$) on the German North and Baltic Sea coasts in the winters of 2009/10, 2010/11 and 2011/12

	North Sea		Baltic Sea	
	R_E	$V_{A\Sigma}$	R_E	$V_{A\Sigma}$
2009/10	31.2	3.11	45.8	4.22
2010/11	23.2	1.47	35.5	2.45
2011/12	11.9	1.13	14.0	1.12

The comparison clearly shows that coastal ice formation in our latitudes depends primarily on the duration and severity of frost. Other important factors are the time of frost occurrence and the number and length of the frost periods. All other factors are of lesser importance.

In the northern Baltic region, ice formation in the winter of 2011/12 did not begin until early December, which was two to three weeks later than average, and continued very hesitantly until mid-January. Ice coverage at the end of January 2012 corresponded to that normally reached by 1 January. During the last days of January, an extensive, stable high-pressure zone settled over northwest Russia, causing very cold weather conditions in Europe during the three weeks that followed. Based on maximum ice extent in the entire Baltic Sea, which reached 179,000 km^2 between 8 and 15 February, the winter of 2011/12 has been classified as a **moderate** ice winter.

During the ice winter of **2011/2012**, the BSH issued the following information about the ice situation and expected ice development in the entire Baltic Sea region and in the German coastal waters:

102 ice reports (official reports issued Monday – Friday),
26 German Ice Reports (international exchange, issued when ice forms in German shipping lanes),
about 100 NAVTEX reports (in German and English for the German North and Baltic Sea coasts),
21 ice reports “German Baltic Sea coast“ (detailed description of ice situation for German users),
17 ice reports “German North Sea coast“ (detailed description of ice situation for German users),
23 weekly reports (information for the Federal Ministry of Transport, Building and Urban Development and for MURSYS)
23 general ice charts (once a week, as a **reference ice chart** for the entire Baltic Sea)
13 ice charts for the western Baltic Sea, Kattegat, and Skagerrak,
19 special ice charts (German Baltic Sea coast).

The BSH‘s Ice Service also provided information and advice to numerous individual users.

The BSH’s ice reports and ice charts are available free of charge at
http://www.bsh.de/de/Meeresdaten/Beobachtungen/Eis/ and ftp://ftp.bsh.de/outgoing/eisbericht .

The archive containing all ice charts issued up to now is available at
ftp://ftp.bsh.de/outgoing/eisbericht

GIS-compatible data in Shape format comprising all ice parameters available can be provided on request.

General ice chart / reference chart for the Baltic Sea region

The BSH published 23 issues of its general ice chart showing the ice situation in the entire Baltic Sea region. Besides the parameters “ice concentration” and “ice thickness”, also ice deformation (rafting, ridging, jammed brash barriers), formation of channels and cracks, fast ice, and melting stages of ice are documented in the charts. The ice information published in this weekly reference chart will also be used increasingly for climatological studies and as input for model predictions. Work is being carried out at the BSH to include additional ice parameters such as floe size and ice ridge height and to develop automated operational techniques for the evaluation of remote sensing data.

Remote sensing data are an important source of ice information complementing the information provided by observation stations and by other ice services with whom the BSH routinely exchanges information. As the data provided by visual-range and infrared observation systems is affected negatively by cloud formation, continuous coverage of the North and Baltic Sea regions can only be achieved by microwave-based systems. Besides methods using passive microwave sensors (SSMI/AMSR) to measure ice concentration, also active measurement systems have been used increasingly (mainly synthetic aperture radar (SAR) data from the Envisat satellite). Data supplied by the MODIS scanner (Moderate-Resolution Imaging Spectroradiometer) installed on the “Terra” and “Aqua” satellites and AVHRR measurements (Advanced Very High Resolution Radiometer) from the NOAA satellites are used to verify ice parameters derived from SAR data and to complement ice information where areal coverage is incomplete. In comparison with passive methods (SSMI: 15km x 13km, AMSR: 6km x 4km), use of SAR data (150m x 150m resolution) increases the spatial resolution and information depth of ice data considerably and allows the determination of additional ice parameters besides ice concentration.

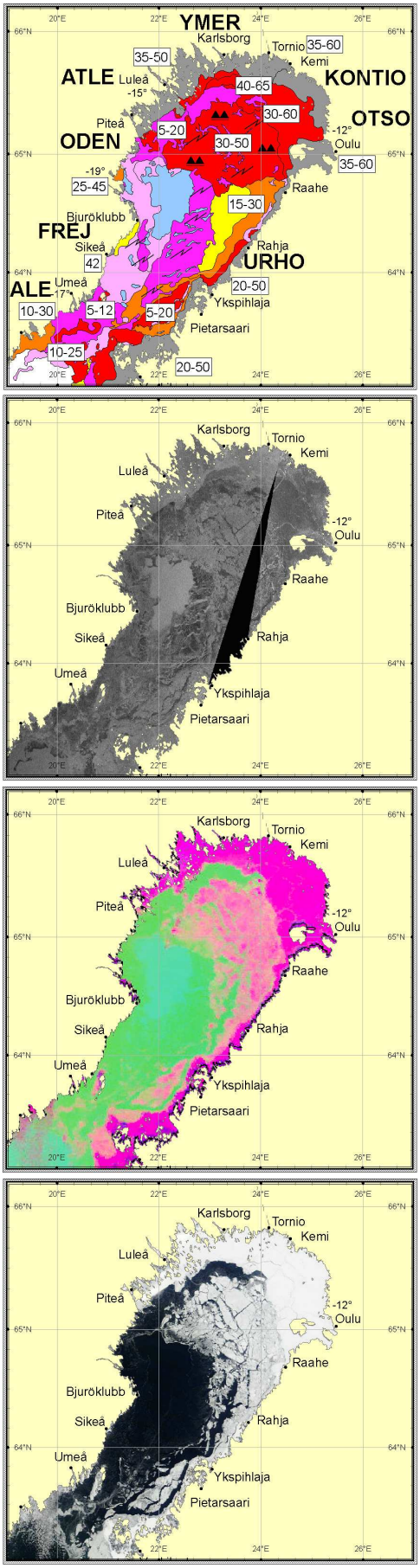


Fig. 5. Ice conditions in the Bay of Bothnia (section of ice chart no. 13) and remote sensing data from Envisat ASAR, NOAA AVHRR and Terra MODIS on 6 March 2012

Weather conditions in the German coastal regions during the winter months

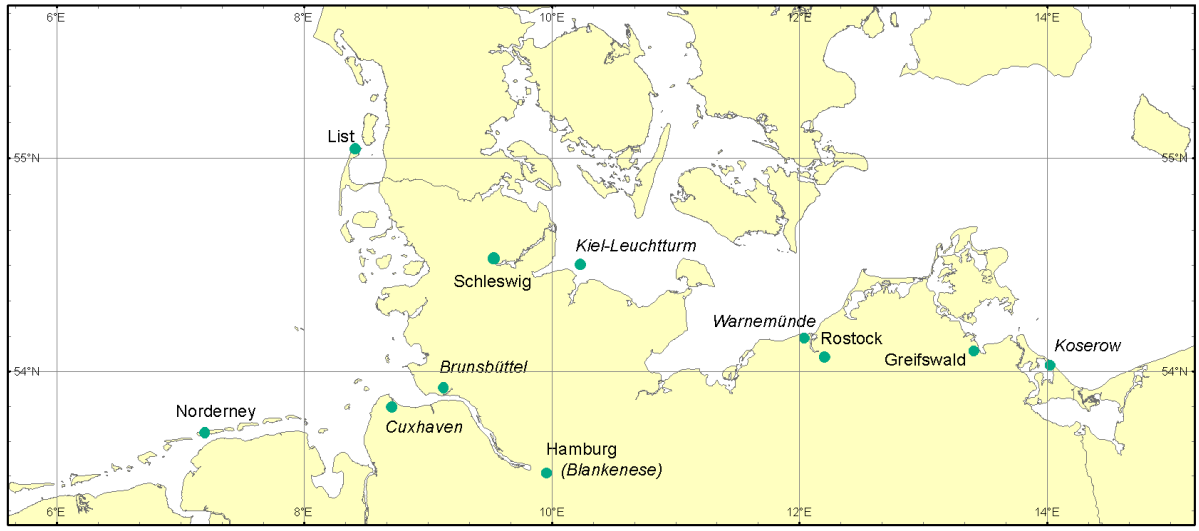


Fig. 6. General chart showing air and water temperature measuring stations

Table 2. Montly mean air temperatures (℃) in the winter of 2011/12 and their deviation from the 1961 – 1990 (K) climate means (courtesy of Deutscher Wetterdienst, www.dwd.de)

Station	November		December		January		February		March	
	℃	K	℃	K	℃	K	℃	K	℃	K
Norderney	6.1	-0.2	5.9	2.7	4.4	2.8	0.5	-1.3	6.5	2.5
Hamburg	5.6	0.0	4.9	2.5	2.8	1.9	0.0	-1.6	7.2	2.8
List (Sylt)	7.0	0.9	5.6	2.8	3.6	2.6	-0.1	-1.0	5.5	2.8
Greifswald	4.9	0.4	4.3	3.2	2.2	2.8	-1.0	-1.0	6.2	3.5
Rostock-Warnemünde	5.6	0.3	4.7	2.8	2.6	2.4	-0.3	-1.0	6.3	3.2
Schleswig	5.9	1.0	4.1	2.4	2.6	2.3	-0.5	-1.1	6.3	3.5

The winter of 2011/12 was characterised by a single frost period lasting about 20 days which led to ice formation in the German coastal waters. November, December, and the first half of January were very mild. Monthly mean values in the coastal regions deviated from the long-term means of the 1961 – 1990 reference period by up to +1 K in November, and up to +3.2 K in December, cf. Table 2 and Fig. 7. Water temperatures at the beginning of January still reached 5 – 6 ℃, cf. Fig. 8a and 8b. Also the mean values in January were above average, which was due to the very mild weather prevailing until the middle of the month, with daily maximum temperatures between 5 and 11 ℃ and frost-free nights. The weather regime changed in the 4th week of January, when Europe came under the influence of a strong high-pressure zone over northwestern Russia. Cold continental air of Siberian origin flowed into the coastal region, causing continuous frost from 27 January. At the end of the month, a complete snow cover of 5 cm thickness formed in the Baltic Sea coastal areas and in the area of the North Frisian coast (Lefebvre, 2012). Water temperatures dropped to 0 - 3℃. The extreme cold, which lasted until mid-February, peaked on 6 February, when temperatures during the day ranged between -5 and -10℃ and dropped below -20 ℃ during the night. In Ueckermünde on the south coast of Szczecin Lagoon, temperatures dropped as low as -28.7 ℃. Toward the middle of the month, the weather regime changed again. Weather conditions in the North and Baltic Sea coastal regions were now determined by low-pressure zones over the Atlantic Ocean transporting mild maritime air into the region. Air temperatures rose markedly, and the nights remained frost-free. The frost period had ended. Compared to the long-term mean, February on the German coasts was 1 – 1.5 K too cold. The warm weather continued in March, which was about 3 K too warm.

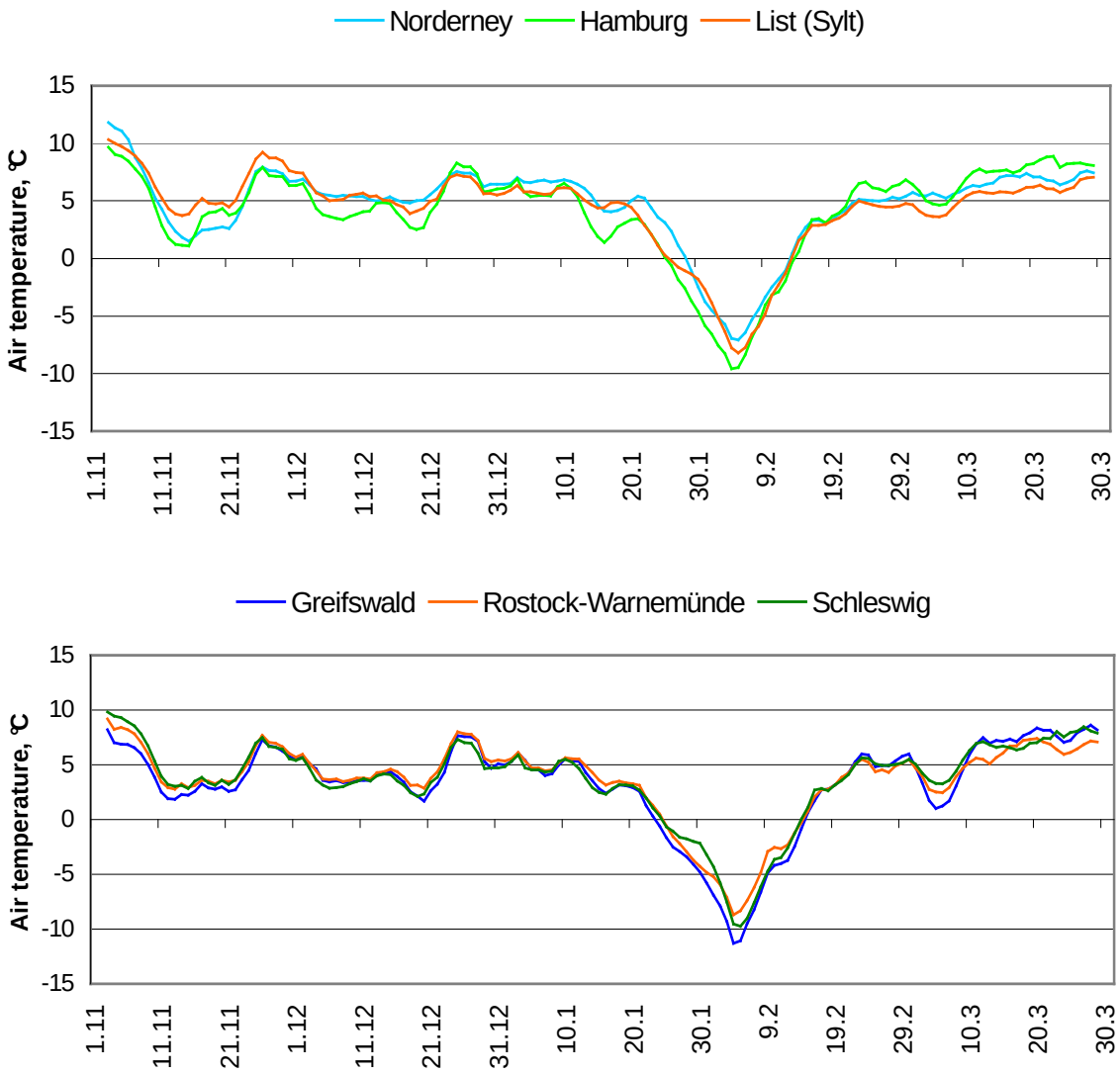


Fig. 7. 5-day running mean of air temperatures in the winter of 2011/12 (courtesy of Deutscher Wetterdienst, www.dwd.de)

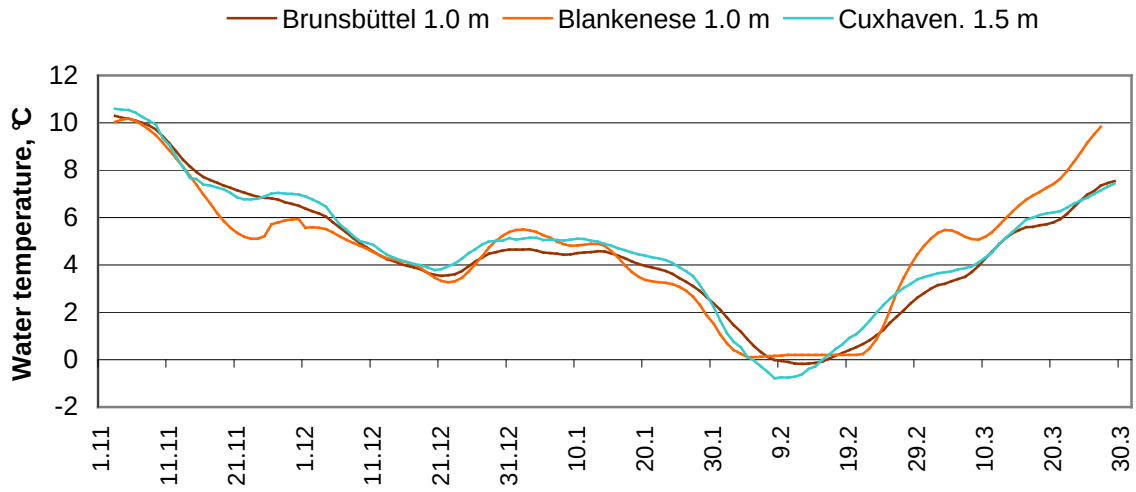


Fig. 8a. Water temperatures on the North Sea coast
Source of measurement data: Brunsbüttel, WSA Brunsbüttel; Cuxhaven, DWD; Blankenese, Institut für Hygiene und Umwelt, Hamburg

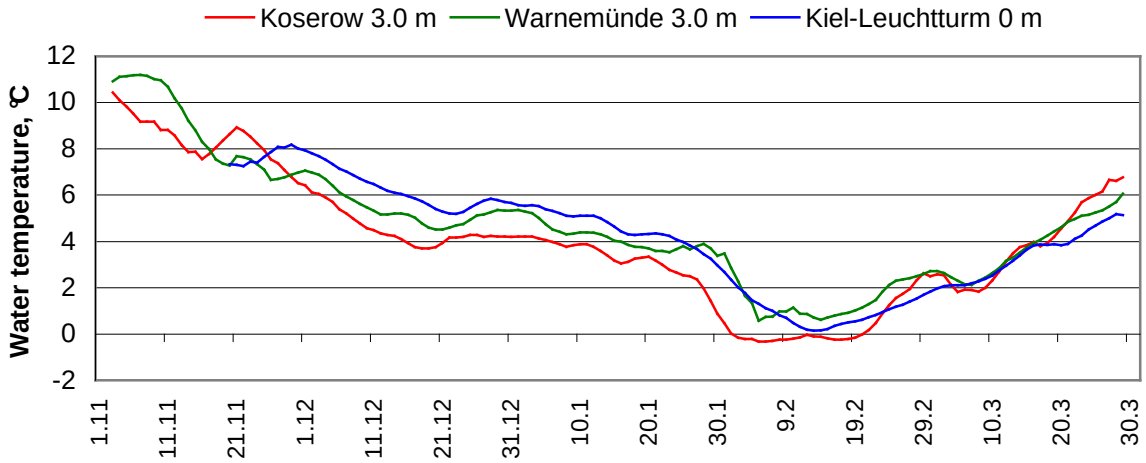
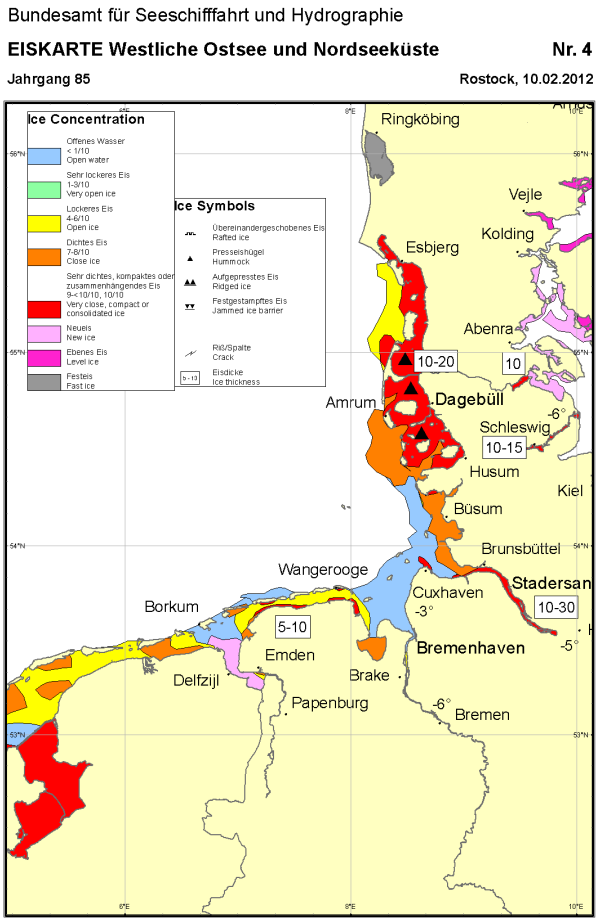


Fig. 8b. Water temperatures in the western and southern Baltic Sea
Source of measurement data: Koserow, StALU Mittleres Mecklenburg, Dienststelle Rostock; MARNET - Messnetz, Bundesamt für Seeschifffahrt und Hydrographie (BSH), Leibniz-Institut für Ostseeforschung Warnemünde (IOW)

Ice conditions and navigation on the German North Sea coast

(Cf. Annex, Tables A1 and A2 and Fig. A1)



Ice formation in the smaller harbours and sheltered areas of the North Frisian coast began at the end of January, in the Wadden Sea tidal areas along the North Frisian coast and in the lower reaches of the North Sea tributaries in early February. In Kiel Canal, ice was observed between 5 and 16 February. The ice season practically consisted of a single ice period, which lasted from a few days to three weeks in the different areas of the German North Sea coast. The ice lasted longest in the tidal flats and upstream sectors of the rivers Ems, Weser, and Elbe. Ice thicknesses quickly grew to 10 – 30 cm, with thicker ice observed in the tidal flats and some harbours, where tidal influences caused ice rafting and ridging. Ice thicknesses of up to 50 – 70 cm were reported. In the tidal flats off Pellworm, ice ridges reached heights between 1 and 4 m.

Large commercial vessels did not encounter any difficulties during this past ice winter, and only smaller vessels had some problems between 4 and 19 February, especially in the North Frisian Wadden Sea, the Lower Elbe, and in parts of Hamburg harbour.

Fig. 9. Ice conditions on the German North Sea coast in the winter of 2011/12 at the time of maximum ice formation

Ice conditions and navigation on the German Baltic Sea coast

Due to the prevailing meteorological conditions, there was only one freezing period on the German Baltic Sea coast, which lasted up to 30 days in the inner coastal waters. The data of ice occurrence at the individual observation stations are given in Table A3 in the Annex. Thicknesses of level ice in the sheltered coastal waters reached their maximum of 10 – 30 cm in mid-February, cf. Fig. 10. In the waters of Greifswalder Bodden, fast ice formed only in the bays and on the northern coast, whereas ice in the central part kept moving. This led to ice rafting and ridging, cf. photographs below. Shipping faced major difficulties also in the navigation channels (Osttief, Landtiefrinne). Between 6 and 24 February, in the approaches to the Stralsund north and south harbours, icebreaker assistance was only provided to vessels having an ice class of 1C as a minimum and at least 1,000 kW propulsion power. The northern approaches to Stralsund and the western bodden waters were closed to shipping for three weeks, cf. Table A4 in the Annex.

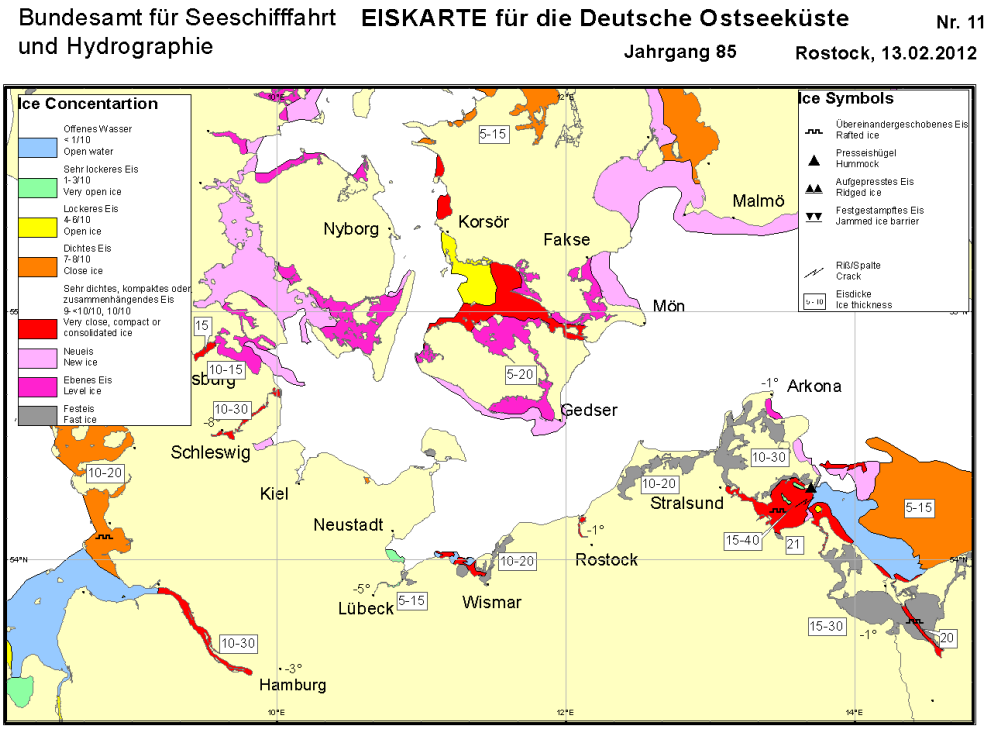


Fig. 10. Ice situation in the western Baltic Sea on 13 February 2012

4-5 m high ice rafting at Thiessow, Südperd

Pack ice at Klein Zicker

Courtesy of: Frank Sakuth

Ice conditions in the German Bight, Kattegat, Skagerrak, and in the Danish and Swedish waters of the western Baltic Sea

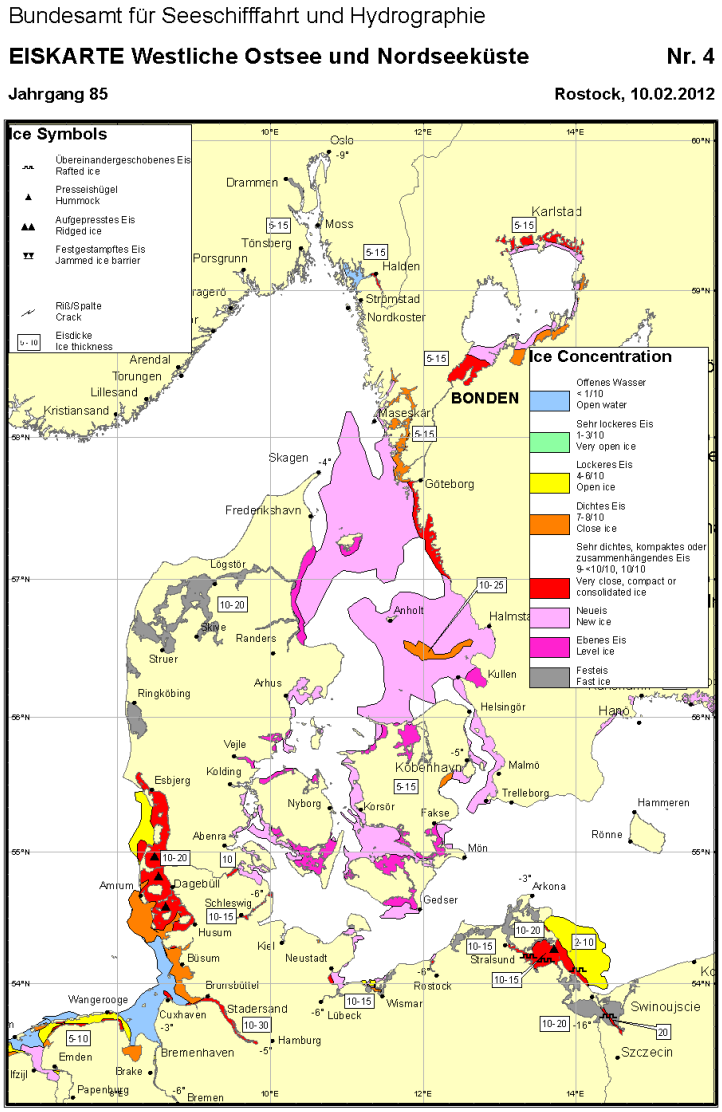


Fig. 11. Ice situation in the German Bight, western Baltic Sea, Skagerrak and Kattegat on 10 February 2012

In the North Sea coastal waters of the Netherlands, ice occurred only in the Wadden Sea south of the West Frisian islands. First ice formed on 6 February or, in smaller harbours, a few days earlier. Between 8 and 10 February, the time of maximum ice development, ice thicknesses reached 5 – 15 cm. Rafted ice locally reached heights of more than 30 cm. The last ice report was received on 16 February, and the Netherlands coast probably was ice-free several days later. In some sheltered areas of Limfjord, ice thickness grew to 40 cm in the course of February. Shipping in Limfjord was assisted by the tug ZENIT until the end of February, when the waters were free of ice again.

In the *Skagerrak*, ice of 5 – 15 cm thickness occurred in some smaller fjords on the Norwegian coast from mid-January to mid-March. In February, ice of 5 -10 cm thickness occurred locally in the harbours of Oslo, and new ice developed in the Oslo navigation channel.

In February, smaller harbours and fjords along the Danish and Swedish coasts of the *Kattegat* were completely covered with ice, with maximum ice thicknesses of 5 – 20 cm. Large areas in the offshore waters and in the Belts and Sounds were covered with thin ice or new ice in the time between 8 and 15 February, cf. Fig. 11.

The ice season in lake *Vänern* lasted about four weeks, from early February to early March. Ice occurred only in the bays and near-shore areas and reached thicknesses between 5 and 15 cm, with variable ice concentrations.

In the course of February, fast ice or level ice developed in the bays and sheltered waters of the Danish and Swedish coasts in the western Baltic Sea. Around the time of maximum ice development, in mid-February, ice thicknesses reached up to 15 cm. Offshore waters remained ice-free.

Ice conditions in the Polish coastal waters in the southern Baltic Sea

Also along the coast of Poland, maximum ice formation was reached in mid-February, when fast ice of 15 – 30 cm thickness covered Szczecin Lagoon and Puck Bay, and up to 15 cm thick ice in variable concentrations occurred in the harbours along the coast between Świnoujście and Gdańsk. Very close 5 – 15 cm thick drift ice and new ice were observed in the Pomeranian Bight, and new ice formed also in the Bay of Gdansk. Vistula Lagoon was covered with 30 – 50 cm thick ice. On 19 and 20 February, ice

drifting eastward from the Pomeranian Bight due to strong westerly winds was observed in the offshore waters off Kołobrzeg, and on 23 February off Ustka. The ice in Szczecin Lagoon disappeared by 26 February, and in Vistula Lagoon by mid-March.

Ice conditions in the northern Baltic Sea region (north of 56 ºN)

Ice formation in the northern Baltic Sea region began in December 2011, about two to three weeks later than normal. Until the end of January, the ice development was very slow, with all the characteristics of a weak ice winter. However, ice formation in all northern Baltic waters intensified when very cold easterly air flowed into the Baltic during the last days of January. In the first and second weeks of February, permanent frost and air temperatures between -15 and -30℃ prevailed on the coasts of the Gulfs of Bothnia, Finland, Riga. Within a relatively short period of about 10 days, the ice increased markedly. With a maximum ice extent of 179 000 km^2, the winter season of 2011/12 briefly met the criteria for a **moderate** ice winter in the time from 8 to 12 February, cf. Fig. 13. In early March, the thickness of fast ice in the skerries reached its maximum of 35 - 65 cm in the Bay of Bothnia, 10 - 50 cm in the Sea of Bothnia (higher values were measured off the coast of Finland), 60-70 cm in the eastern Gulf of Finland, and 10 - 35 cm in its western part. Lake Mälaren near the Swedish coast was covered with 15 - 30 cm of ice, the bay of Pärnu in the Gulf of Riga with 45 - 50 cm, and Moon Sound with 20 - 30 cm thick fast ice, cf. Fig. 13. As in any other winter season, ice rafting and ridging occurred in the offshore waters. Numerous icebreakers providing assistance to shipping in the entire Baltic Sea were deployed throughout the ice season. The ice winter of 2011/12 in the Gulf of Riga ended in the first decade of April, in the Gulf of Finland in early May at about the normal date, and in the Bay of Bothnia in mid-May, about two weeks earlier than the long-term mean.

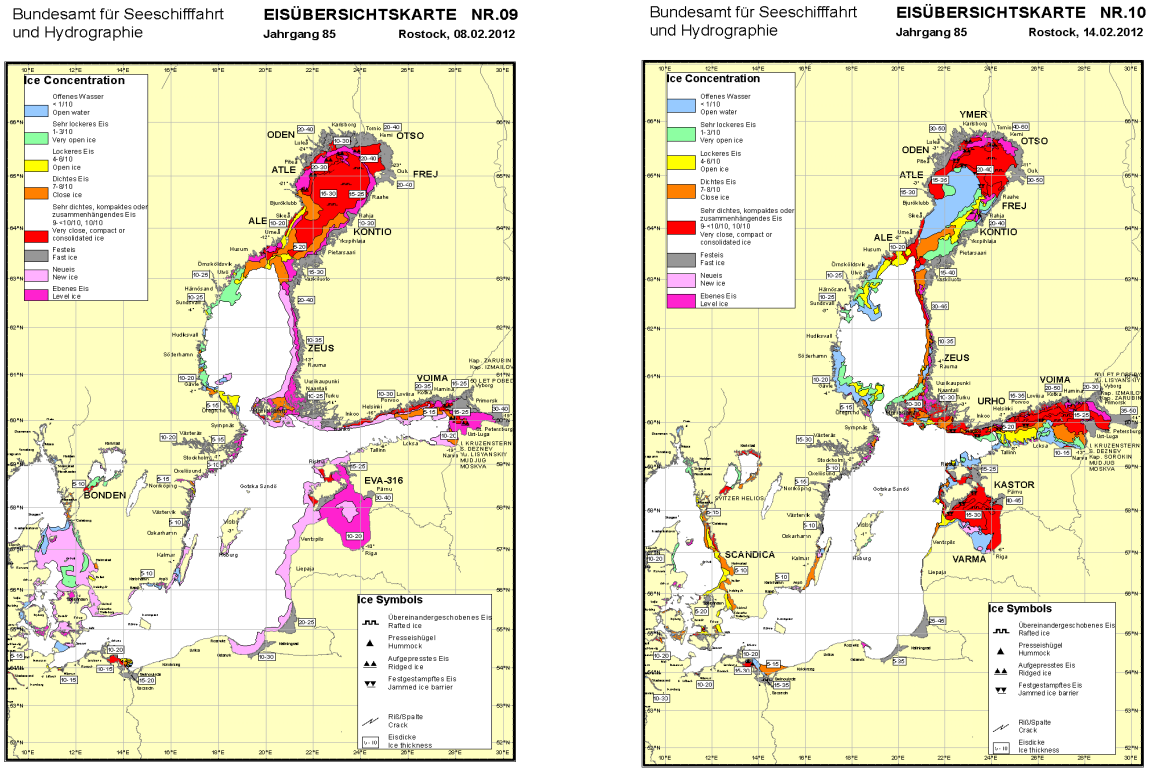


Fig. 12. General ice charts of 8 and 14 February at the time of maximum ice extent in the winter of 2011/12

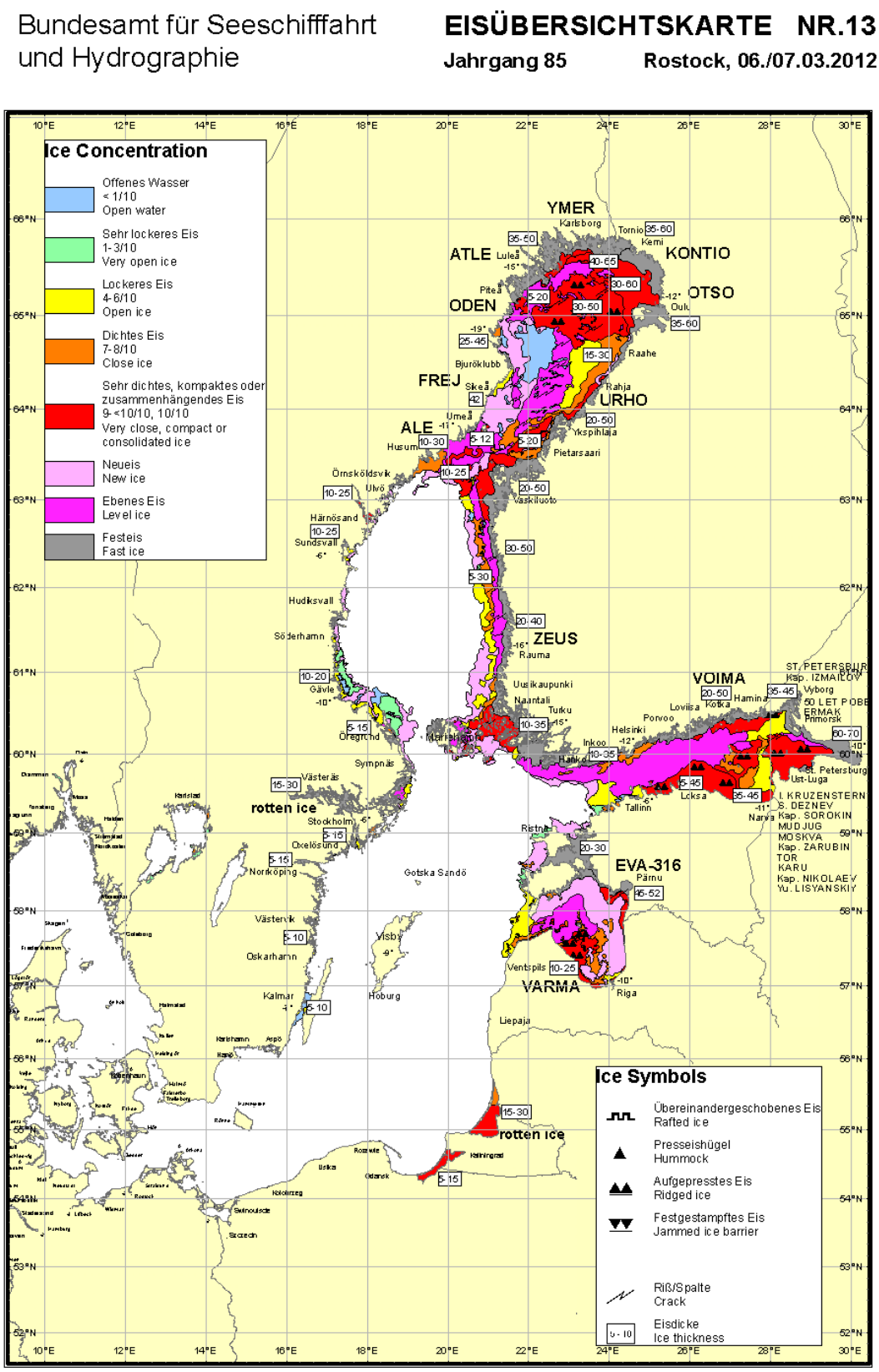


Fig. 13. General ice chart of 6/7 March showing maximum ice thicknesses in the northern Baltic Sea region in the winter of 2011/2012

Annex

Table A1. Ice conditions on the German North Sea coast and in Kiel Canal in the winter of 2011/12

Observation station	Beginning of ice occurrence	End of ice occurrence	Number of days with ice	Max. thickness of level ice, cm
Kiel Canal				
Holtenau, Canal entrance			0	
Canal, Holtenau – Rendsburg	07.02.12	07.02.12	1	< 5
Canal, Rendsburg – Fischerhütte	07.02.12	13.02.12	3	5-10
Canal, Fischerhütte – Brunsbüttel			0	
Brunsbüttel, Canal entrance	05.02.12	16.02.12	9	5-15
German Bight				
Ellenbogen (Sylt), List Deep	07.02.12	20.02.12	13	15-30
Dagebüll, harbour	01.02.12	16.02.12	16	15-30
Dagebüll, fairway	06.02.12	16.02.12	10	15-30
Wyk on Föhr, harbour	03.02.12	17.02.12	15	30
Wyk on Föhr, Norderaue	04.02.12	16.02.12	13	30
Amrum, Wittdün harbour	03.02.12	17.02.12	15	30
Amrum, Vortrapp Deep	03.02.12	17.02.12	15	15-30
Amrum, Schmal Deep	03.02.12	17.02.12	15	15-30
Husum, harbour	01.02.12	18.02.12	18	10-20
Husum, Au	03.02.12	17.02.12	14	10-20
Nordstrand, Hever	05.02.12	16.02.12	12	20-30
Tönning, harbour	30.01.12	21.02.12	23	15-30
Eiderdamm, sea area	31.01.12	20.02.12	21	15
Büsum, harbour	02.02.12	19.02.12	18	20
Büsum, Norderpiep	01.02.12	19.02.12	19	10
Büsum, Süderpiep	01.02.12	19.02.12	19	10-15
Harburg, Elbe	01.02.12	21.02.12	21	30
Hamburg, Landing Pier - Kehrwieder	01.02.12	21.02.12	21	15-30
Hamburg – Landing Pier, Elbe	01.02.12	21.02.12	21	15-30
Altona, Elbe	01.02.12	21.02.12	21	15-30
Stadersand, Elbe	01.02.12	20.02.12	20	15-30
Glückstadt, harbour and entrance	02.02.12	26.02.12	25	30
Glückstadt, Elbe	02.02.12	23.02.12	22	30
Brunsbüttel, Elbe	05.02.12	17.02.12	13	10-15
Cuxhaven, harbour and entries	05.02.12	20.02.12	12	20
Cuxhaven, Elbe	06.02.12	17.02.12	11	30
Cuxhaven – Neuwerk	06.02.12	14.02.12	9	20
Neuwerk, Elbe	31.01.12	14.02.12	11	10-20
Großer Vogelsand	06.02.12	14.02.12	8	10
Elbe, approach buoy	07.02.12	07.02.12	1	10
Helgoland, harbour and entries			0	
Bremen, Weser	04.02.12	15.02.12	12	10-15
Brake, Weser	06.02.12	15.02.12	10	15-30
Bremerhaven, Weser	07.02.12	19.02.12	13	15-30
Hohe Weg lighthouse, fairway			0	
Alte Weser, fairway			0	
Neue Weser, fairway			0	
Wilhelmshaven, harbour entries	04.02.12	13.02.12	8	50-70 (rafting)
Wilhelmshaven, tanker unloading pier	04.02.12	14.02.12	11	10-15
Schillig, Jade area	02.02.12	14.02.12	12	5-10
Wangerooge, fairway	02.02.12	11.02.12	2	5

Table 1, contd.

Wangerooge, Wadden	02.02.12	14.02.12	13	10-15
Wangerooge, Harle	02.02.12	14.02.12	13	10-15
Norderney, Wadden	01.02.12	14.02.12	14	10-15
Norderney, Wadden	07.02.12	13.02.12	6	10-15
Papenburg – Emden	03.02.12	18.02.12	16	10-15
Emden, new inner harbour	02.02.12	15.02.12	14	15
Emden, Ems and outer harbour	02.02.12	16.02.12	15	15
Ems, Emden – Randzelgat	02.02.12	14.02.12	13	5-10
Borkum, Randzelgat	07.02.12	14.02.12	8	5-10
Borkum, Westerems	07.02.12	13.02.12	5	5

Table A2. Navigational conditions on the German North Sea coast and in Kiel Canal in the winter of 2011/12

Observation station	Days with K_B=2*	Days with K_B=3,5,6*	Days with K_B=8,9*
Kiel Canal			
Holtenau, Canal entrance			
Canal, Holtenau – Rendsburg			
Canal, Rendsburg – Fischerhütte			
Canal, Fischerhütte – Brunsbüttel			
Brunsbüttel, Canal entrance			
German Bight			
Ellenbogen (Sylt), List Deep	7		
Dagebüll, harbour	8	2	
Dagebüll, fairway	1	2	
Wyk on Föhr, harbour	9		
Wyk on Föhr, Norderaue	6	2	
Amrum, Wittdün harbour	3	9	
Amrum, Vortrapp Deep	11		
Amrum, Schmal Deep	11		
Husum, harbour	10		
Husum, Au	8		
Nordstrand, Hever	8		
Tönning, harbour	2	16	
Eiderdamm, sea area	9	6	
Büsum, harbour	2	1	
Büsum, Norderpiep	3	1	
Büsum, Süderpiep	6	3	
Harburg, Elbe	13	4	
Hamburg, Landing Pier - Kehrwieder	13	1	
Hamburg – Landing Pier, Elbe	14		
Altona, Elbe	14		
Stadersand, Elbe	15		
Glückstadt, harbour and entrance	8	9	
Glückstadt, Elbe	8	2	
Brunsbüttel, Elbe			
Cuxhaven, harbour and entries	1		
Cuxhaven, Elbe			
Cuxhaven – Neuwerk			
Neuwerk, Elbe			
Großer Vogelsand			
Elbe, approach buoy			
Helgoland, harbour and entries			
Bremen, Weser	2		
Brake, Weser	4		
Bremerhaven, Weser	7		
Hohe Weg lighthouse, fairway			
Alte Weser, fairway			
Neue Weser, fairway			
Wilhelmshaven, harbour entries	1	4	
Wilhelmshaven, tanker unloading pier	5		
Schillig, Jade area			
Wangerooge, fairway	1		

Table 2, contd.

Wangerooge, Wadden	8		
Wangerooge, Harle	5	7	
Norderney, Wadden			
Norderney, Wadden			
Papenburg – Emden	9		
Emden, new inner harbour	6		
Emden, Ems and outer harbour	6		
Ems, Emden – Randzelgat	1		
Borkum, Randzelgat			
Borkum, Westerems			

* According to the Baltic Sea ice code

$K_B = 2$ Navigation difficult for unstrengthened or low-powered vessels built of iron or steel. Navigation for wooden vessels even with ice sheathing not advisable.

$K_B = 3,5,6$ Navigation without icebreaker assistance possible only for high-powered vessels of strong construction and suitable for navigation in ice (with or without icebreaker assistance)

$K_B = 8,9$ Navigation temporarily closed or ceased

Table A3. Ice conditions on the German Baltic Sea coast in the winter of 2011/12

Observation station	Beginning of ice occurrence	End of ice occurrence	Number of days with ice	Max. thickness of level ice, cm
Kamminke, harbour and environment	29.01.12	25.02.12	28	18
Ueckermünde, harbour	30.01.12	22.02.12	24	15
Ueckermünde, harbour to Uecker mouth	30.01.12	20.02.12	22	10-15
Ueckermünde, Szczecin Lagoon	30.01.12	25.02.12	27	28
Karnin, Szczecin Lagoon	01.02.12	26.02.12	26	20
Karnin, Peenestrom	01.02.12	26.02.12	26	20
Anklam, harbour	30.01.12	23.02.12	25	13
Anklam, harbour – Peenestrom	30.01.12	23.02.12	25	14
Brücke Zecherin, Peenestrom	29.01.12	23.02.12	26	25
Rankwitz, Peenestrom	29.01.12	25.02.12	28	16
Warthe, Peenestrom	26.01.12	25.02.12	31	17
Wolgast – Peenemünde	29.01.12	21.02.12	24	15-20
Peenemünde – Ruden	01.02.12	22.02.12	22	15-30
Koserow, sea area	03.02.12	18.02.12	16	15-30
Stralsund, harbour	31.01.12	21.02.12	22	25
Stralsund – Palmer Ort	31.01.12	22.02.12	23	20-30
Palmer Ort – Freesendorfer Haken	01.02.12	22.02.12	22	15-30
Greifswald-Wieck, harbour	26.01.12	24.02.12	29	15
Dänische Wiek	26.01.12	07.03.12	31	22
Greifswald-Ladebow, harbour	03.02.12	23.02.12	21	30
Osttief	01.02.12	22.02.12	22	20
Landtief channel	01.02.12	17.02.12	17	30
Thiessow, bodden area	31.01.12	26.02.12	27	18
Thiessow, sea area	01.02.12	24.02.12	23	15
Lauterbach, harbour and vicinity	31.01.12	23.02.12	24	20
Greifswalder Oie, eastern sea area	06.02.12	14.02.12	9	5
Sassnitz ferry, harbour and vicinity	04.02.12	14.02.12	8	5-10
Sassnitz ferry harbour, sea area	04.02.12	14.02.12	7	5
Sassnitz, harbour and environment	04.02.12	18.02.12	15	10-15
Sassnitz, sea area	04.02.12	16.02.12	11	10-15
Arkona, sea area	06.02.12	07.02.12	2	< 5
Stralsund – Bessiner Haken	26.01.12	22.02.12	25	15-30
Vierendehlrinne	26.01.12	22.02.12	25	15-30
Barhöft – Gellen, fairway	26.01.12	22.02.12	27	15-30
Neuendorf, harbour and vicinity	28.01.12	23.02.12	27	11
Neuendorf, sea area	06.02.12	15.02.12	6	< 5
Kloster, sea area	07.02.12	07.02.12	1	< 5
Kloster, bodden area	28.01.12	23.02.12	27	13
Schaprode – Hiddensee, fairway	31.01.12	23.02.12	24	15
Dranske, Libben fairway			0	
Dranske, bodden area	31.01.12	24.02.12	25	15-30
Wittow, ferry	31.01.12	23.02.12	24	15
Althagen, harbour and vicinity	28.01.12	23.02.12	27	13
Zingst, Zingster Strom	29.01.12	16.02.12	19	18
Zingst, sea area	01.02.12	15.02.12	15	5
Barth, Harbour and vicinity	27.01.12	22.02.12	27	16
Rostock, city harbour	24.01.12	22.02.12	23	20-25
Rostock – Warnemünde	26.01.12	22.02.12	28	20
Rostock overseas port	26.01.12	22.02.12	28	20

Table 3, contd.

Warnemünde, sea canal	03.02.12	16.02.12	14	5-10
Warnemünde, sea area	06.02.12	15.02.12	10	5-10
Rostock, approach buoy			0	
Wismar, Harbour	25.01.12	23.02.12	26	18
Wismar – Walfisch	01.02.12	22.02.12	22	10-15
Walfisch – Timmendorf	01.02.12	22.02.12	20	10-12
Timmendorf –Wismar, approach buoy	06.02.12	14.02.12	7	7
Lübeck – Travemünde	01.02.12	22.02.12	22	15
Travemünde, harbour	01.02.12	18.02.12	16	15
Travemünde, sea area	07.02.12	10.02.12	4	15
Neustadt, harbour	30.01.12	14.02.12	16	6
Neustadt, sea area	02.02.12	07.02.12	5	5-15
Dahmeshöved, sea area	06.02.12	07.02.12	2	2
Fehmarn Sound	05.02.12	07.02.12	3	< 5
Kiel, inner harbour	25.01.12	16.02.12	20	7
Holtenau – Laboe	04.02.12	06.02.12	3	< 5
Bülk, sea area	04.02.12	04.02.12	1	< 5
Kiel lighthouse, sea area NE			0	
Kiel lighthouse, sea area NE			0	
Heiligenhafen, harbour	03.02.12	19.02.12	17	14
Fehmarn Sound, western entrance	05.02.12	07.02.12	3	< 5
Westermarkelsdorf, sea area	07.02.12	08.02.12	2	< 5
Marienleuchte, sea area			0	
Fehmarn Belt, eastern entrance	04.02.12	13.02.12	7	5-10
Eckernförde, harbour	30.01.12	15.02.12	17	7
Eckernförde, bay	07.02.12	15.02.12	9	5
Schlei, Schleswig – Kappeln	26.01.12	22.02.12	27	15-30
Schlei, Kappeln – Schleimünde	02.02.12	21.02.12	20	10
Flensburg – Holnis	04.02.12	21.02.12	18	15
Holnis – Neukirchen	08.02.12	19.02.12	12	10-15
Neukirchen – Kalkgrund lighthouse	08.02.12	18.02.12	11	10-15
Falshöft, sea area	11.02.12	11.02.12	1	< 5

Table A4. Navigational conditions on the German Baltic Sea coast in the winter of 2011/12

Observation station	Days with K_B=2*	Days with K_B=3,5,6*	Days with K_B=8,9*
Kamminke, harbour and environment	2	19	2
Ueckermünde, harbour	8	11	
Ueckermünde, harbour to Uecker mouth	11		
Ueckermünde, Szczecin Lagoon	5	19	
Karnin, Szczecin Lagoon	4	20	
Karnin, Peenestrom	4	20	
Anklam, harbour	8	16	
Anklam, harbour – Peenestrom	5	18	
Brücke Zecherin, Peenestrom	3	19	
Rankwitz, Peenestrom	3	19	
Warthe, Peenestrom	1	23	
Wolgast – Peenemünde	5	16	
Peenemünde – Ruden	2	17	
Koserow, sea area	6	1	
Stralsund, harbour	5	15	
Stralsund – Palmer Ort	3	17	
Palmer Ort – Freesendorfer Haken	2	17	
Greifswald-Wieck, harbour	2	14	2
Dänische Wiek	3	18	1
Greifswald-Ladebow, harbour	3	17	
Osttief	2	17	
Landtief channel	1	10	
Thiessow, bodden area	1	18	
Thiessow, sea area	1	10	
Lauterbach, harbour and vicinity	2	18	
Greifswalder Oie, eastern sea area	1		
Sassnitz ferry, harbour and vicinity			
Sassnitz ferry harbour, sea area			
Sassnitz, harbour and environment			
Sassnitz, sea area			
Arkona, sea area			
Stralsund – Bessiner Haken			21
Vierendehlrinne	1		21
Barhöft – Gellen, fairway	1		21
Neuendorf, harbour and vicinity	2		21
Neuendorf, sea area			
Kloster, sea area			
Kloster, bodden area			22
Schaprode – Hiddensee, fairway	7	9	
Dranske, Libben fairway			
Dranske, bodden area	2	3	18
Wittow, ferry	17		
Althagen, harbour and vicinity			22
Zingst, Zingster Strom	3		13
Zingst, sea area			
Barth, Harbour and vicinity	4		21
Rostock, city harbour	7	10	
Rostock – Warnemünde	16		
Rostock overseas port	6		

Table 3, contd.

Warnemünde, sea canal			
Warnemünde, sea area			
Rostock, approach buoy			
Wismar, Harbour	4	5	
Wismar – Walfisch	17		
Walfisch – Timmendorf	4		
Timmendorf –Wismar, approach buoy	1		
Lübeck – Travemünde			
Travemünde, harbour			
Travemünde, sea area			
Neustadt, harbour			
Neustadt, sea area	1		
Dahmeshöved, sea area			
Fehmarn Sound			
Kiel, inner harbour			
Holtenau – Laboe			
Bülk, sea area			
Kiel lighthouse, sea area NE			
Kiel lighthouse, sea area NE			
Heiligenhafen, harbour			
Fehmarn Sound, western entrance			
Westermarkelsdorf, sea area			
Marienleuchte, sea area			
Fehmarn Belt, eastern entrance			
Eckernförde, harbour			
Eckernförde, bay			
Schlei, Schleswig – Kappeln	2	17	
Schlei, Kappeln – Schleimünde		9	
Flensburg – Holnis	5		
Holnis – Neukirchen			
Neukirchen – Kalkgrund lighthouse			
Falshöft, sea area			

* According to the Baltic Sea ice code

KB = 2	Navigation difficult for unstrengthened or low-powered vessels built of iron or steel. Navigation for wooden vessels even with ice sheathing not advisable.
KB = 3,5,6	Navigation without icebreaker assistance possible only for high-powered vessels of strong construction and suitable for navigation in ice (with or without icebreaker assistance)
KB = 8,9	Navigation temporarily closed or ceased

Fig. A1. Daily ice occurrence on the German North and Baltic Sea coasts in the ice winter of 2011/112 2

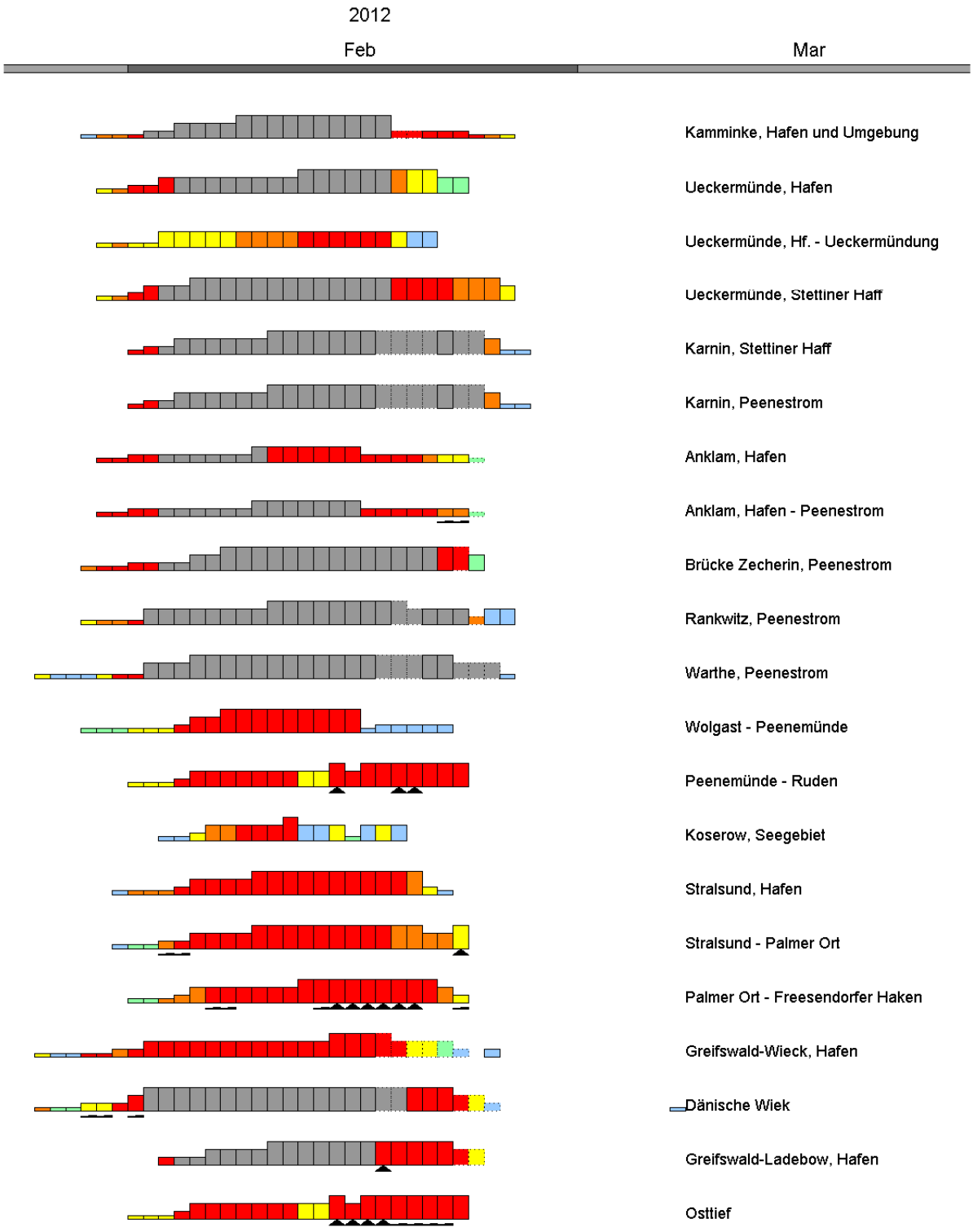


Fig. A1 contd.

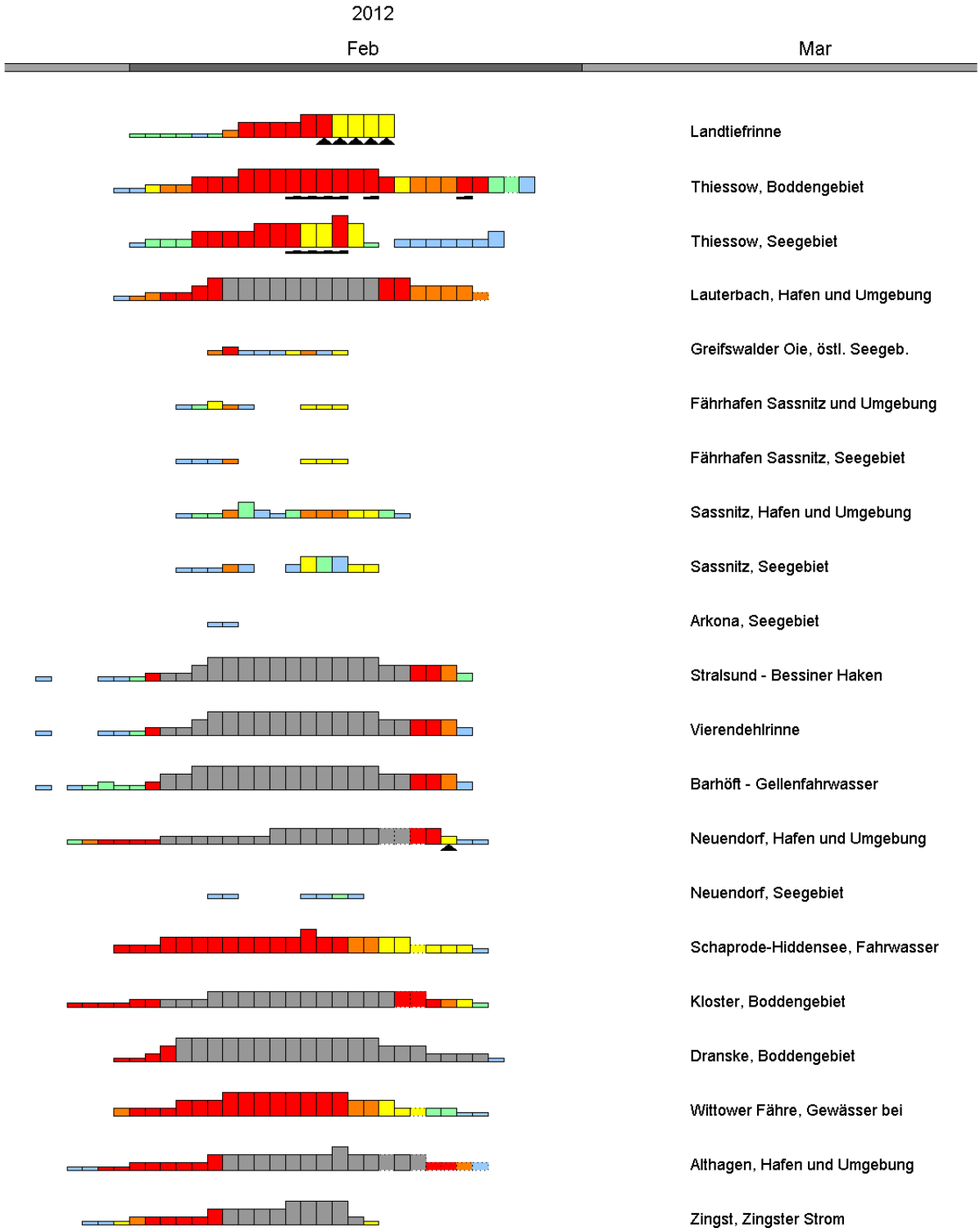

2012
Feb
Mar
Landtiefrinne
Thiessow, Boddengebiet
Thiessow, Seegebiet
Lauterbach, Hafen und Umgebung
Greifswalder Oie, östl. Seegeb.
Fährhafen Sassnitz und Umgebung
Fährhafen Sassnitz, Seegebiet
Sassnitz, Hafen und Umgebung
Sassnitz, Seegebiet
Arkona, Seegebiet
Stralsund - Bessiner Haken
Vierendehlrinne
Barhöft - Gellenfahrwasser
Neuendorf, Hafen und Umgebung
Neuendorf, Seegebiet
Schaprode-Hiddensee, Fahrwasser
Kloster, Boddengebiet
Dranske, Boddengebiet
Wittower Fähre, Gewässer bei
Althagen, Hafen und Umgebung
Zingst, Zingster Strom

Fig. A1 contd.

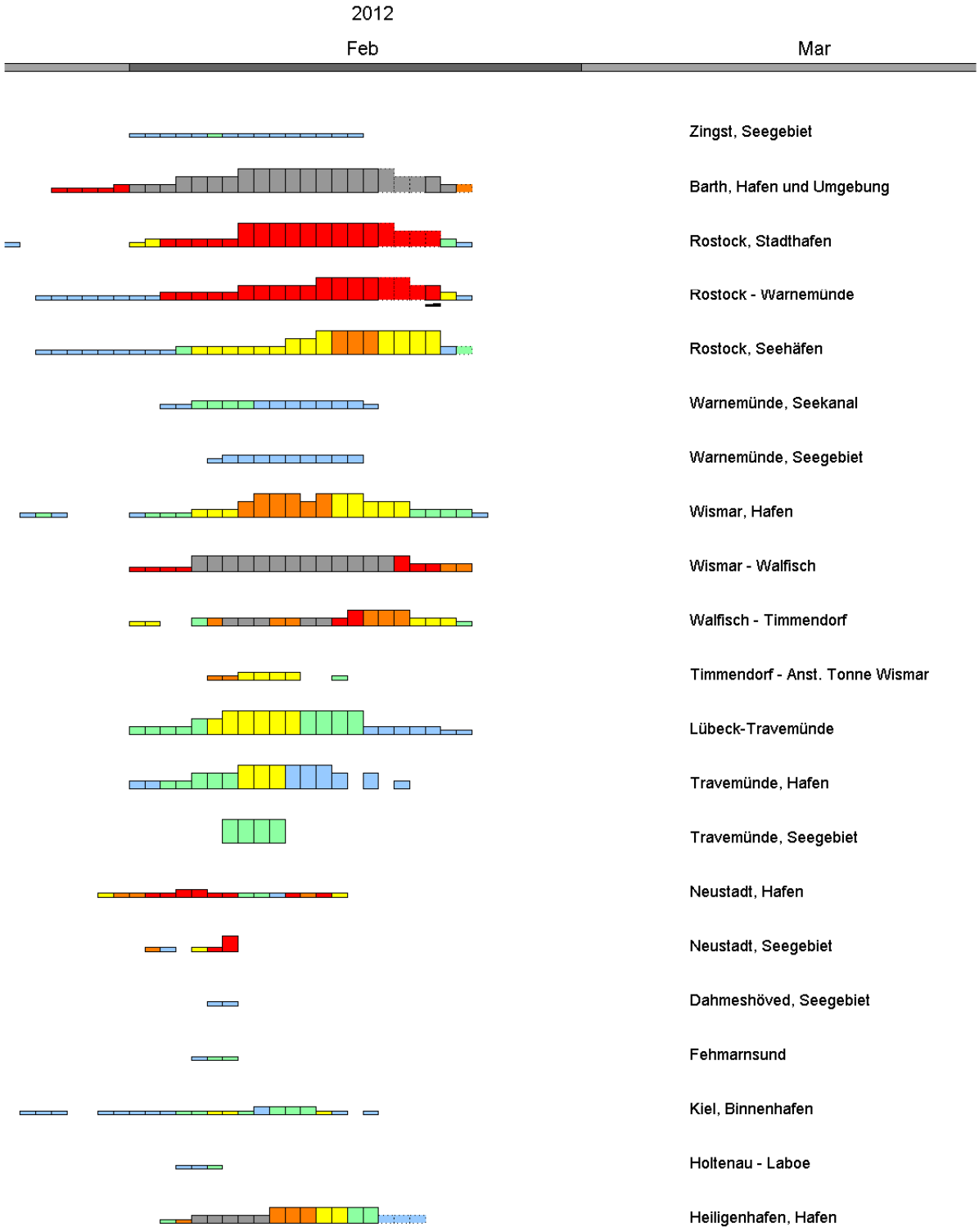

2012
Feb
Mar
Zingst, Seegebiet
Barth, Hafen und Umgebung
Rostock, Stadthafen
Rostock - Warnemünde
Rostock, Seehäfen
Warnemünde, Seekanal
Warnemünde, Seegebiet
Wismar, Hafen
Wismar - Walfisch
Walfisch - Timmendorf
Timmendorf - Anst. Tonne Wismar
Lübeck-Travemünde
Travemünde, Hafen
Travemünde, Seegebiet
Neustadt, Hafen
Neustadt, Seegebiet
Dahmeshöved, Seegebiet
Fehmarnsund
Kiel, Binnenhafen
Holtenau - Laboe
Heiligenhafen, Hafen

Fig. A1 contd.

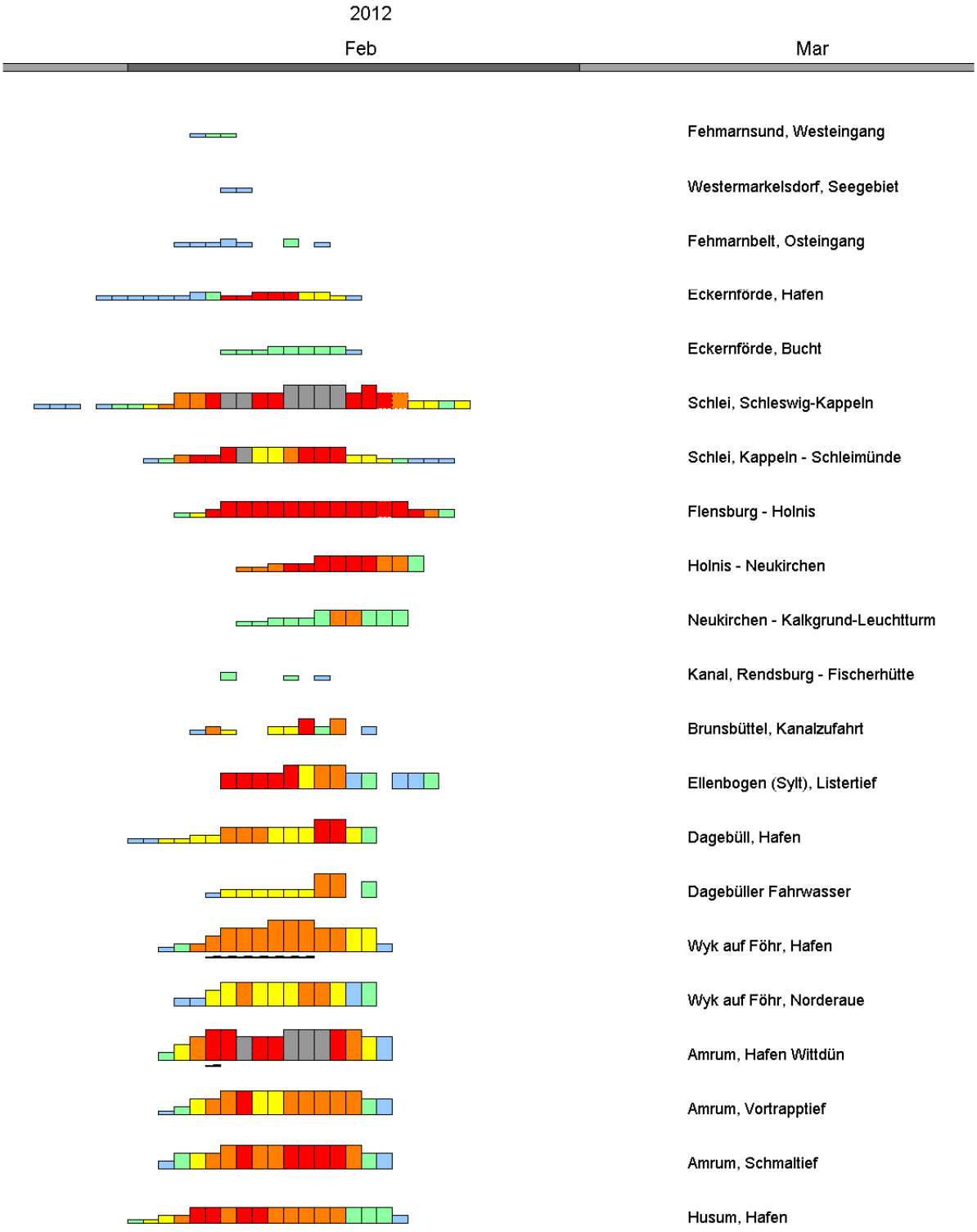

2012
Feb
Mar
Fehmarnsund, Westeingang
Westermarkelsdorf, Seegebiet
Fehmarnbelt, Osteingang
Eckernförde, Hafen
Eckernförde, Bucht
Schlei, Schleswig-Kappeln
Schlei, Kappeln - Schleimünde
Flensburg - Holnis
Holnis - Neukirchen
Neukirchen - Kalkgrund-Leuchtturm
Kanal, Rendsburg - Fischerhütte
Brunsbüttel, Kanalzufahrt
Ellenbogen (Sylt), Listertief
Dagebüll, Hafen
Dagebüller Fahrwasser
Wyk auf Föhr, Hafen
Wyk auf Föhr, Norderaue
Amrum, Hafen Wittdün
Amrum, Vortrapptief
Amrum, Schmaltief
Husum, Hafen

Fig. A1 contd.

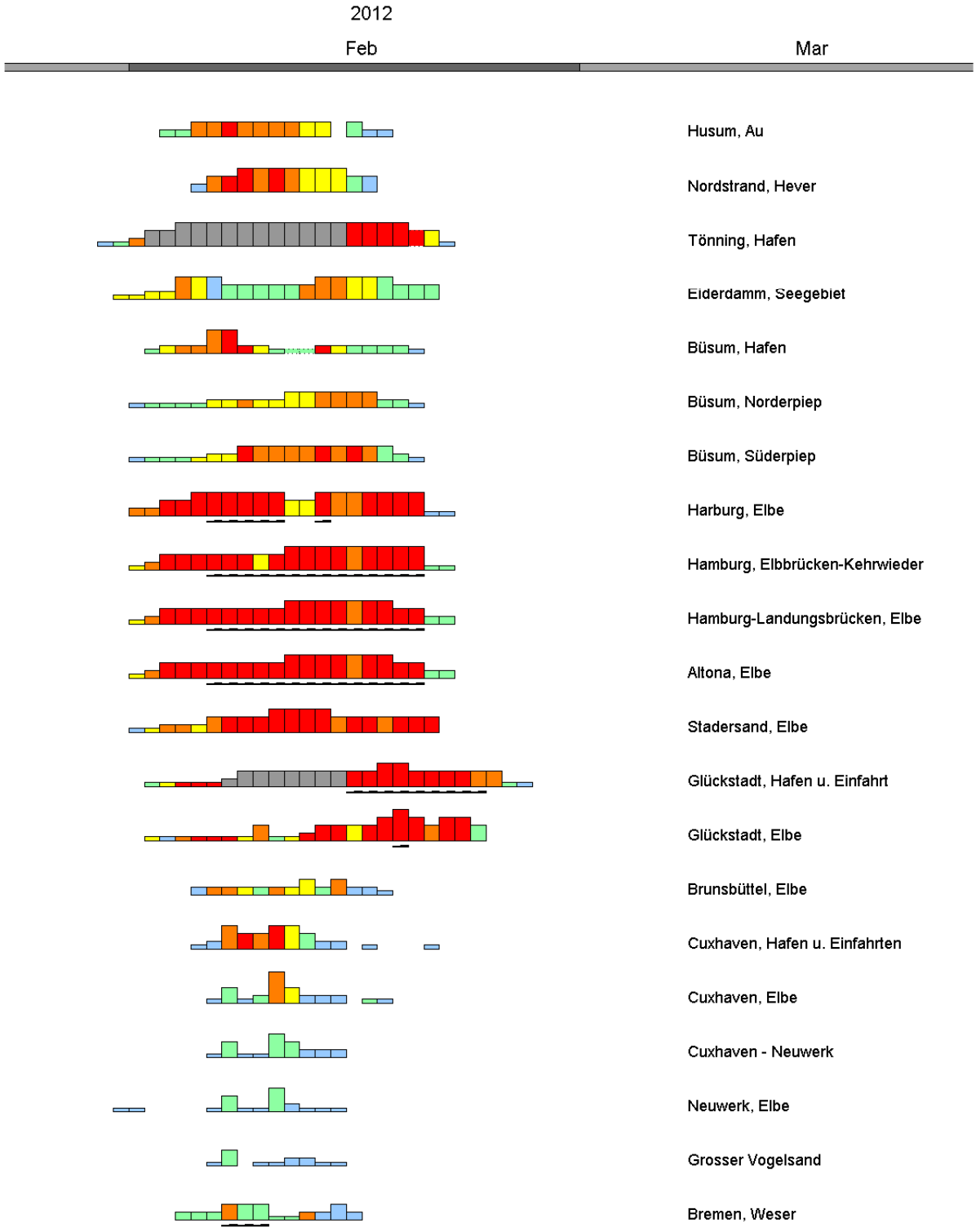
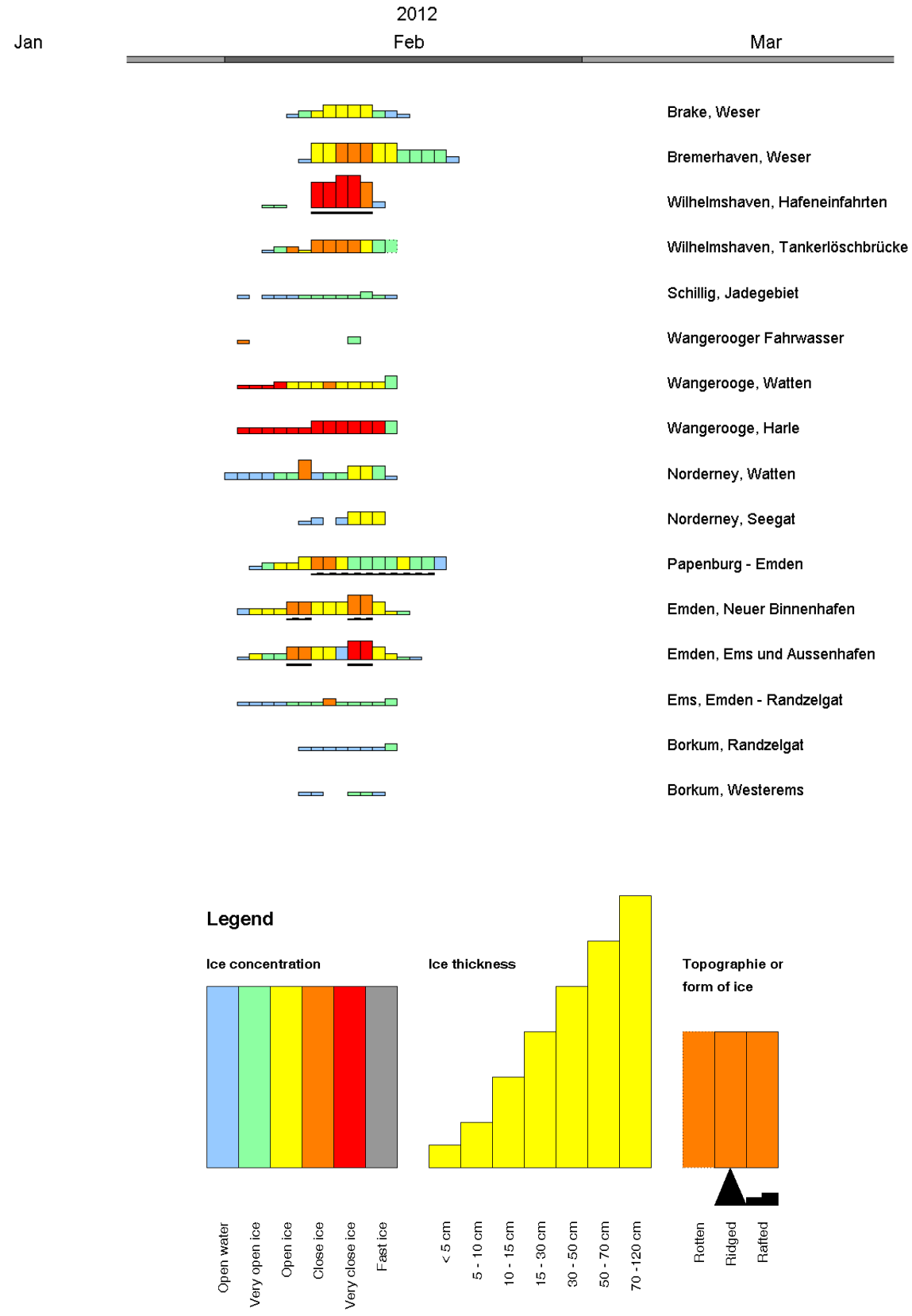

2012
Feb
Mar
Husum, Au
Nordstrand, Hever
Tönning, Hafen
Eiderdamm, Seegebiet
Büsum, Hafen
Büsum, Norderpiep
Büsum, Süderpiep
Harburg, Elbe
Hamburg, Elbbrücken-Kehrwieder
Hamburg-Landungsbrücken, Elbe
Altona, Elbe
Stadersand, Elbe
Glückstadt, Hafen u. Einfahrt
Glückstadt, Elbe
Brunsbüttel, Elbe
Cuxhaven, Hafen u. Einfahrten
Cuxhaven, Elbe
Cuxhaven - Neuwerk
Neuwerk, Elbe
Grosser Vogelsand
Bremen, Weser

Fig. A1 contd.


2012
Jan
Feb
Mar
Brake, Weser
Bremerhaven, Weser
Wilhelmshaven, Hafeneinfahrten
Wilhelmshaven, Tankerlöschbrücke
Schillig, Jadegebiet
Wangerooger Fahrwasser
Wangerooge, Watten
Wangerooge, Harle
Norderney, Watten
Norderney, Seegat
Papenburg - Emden
Emden, Neuer Binnenhafen
Emden, Ems und Aussenhafen
Ems, Emden - Randzelgat
Borkum, Randzelgat
Borkum, Westerems
Legend
Ice concentration
Open water
Very open ice
Open ice
Close ice
Very close ice
Fast ice
Ice thickness
< 5 cm
5 - 10 cm
10 - 15 cm
15 - 30 cm
30 - 50 cm
50 - 70 cm
70 -120 cm
Topographie or form of ice
Rotten
Ridged
Rafted