

Indicator Fact Sheet

(WEU15) Frequency of low bottom oxygen concentrations in coastal and marine waters

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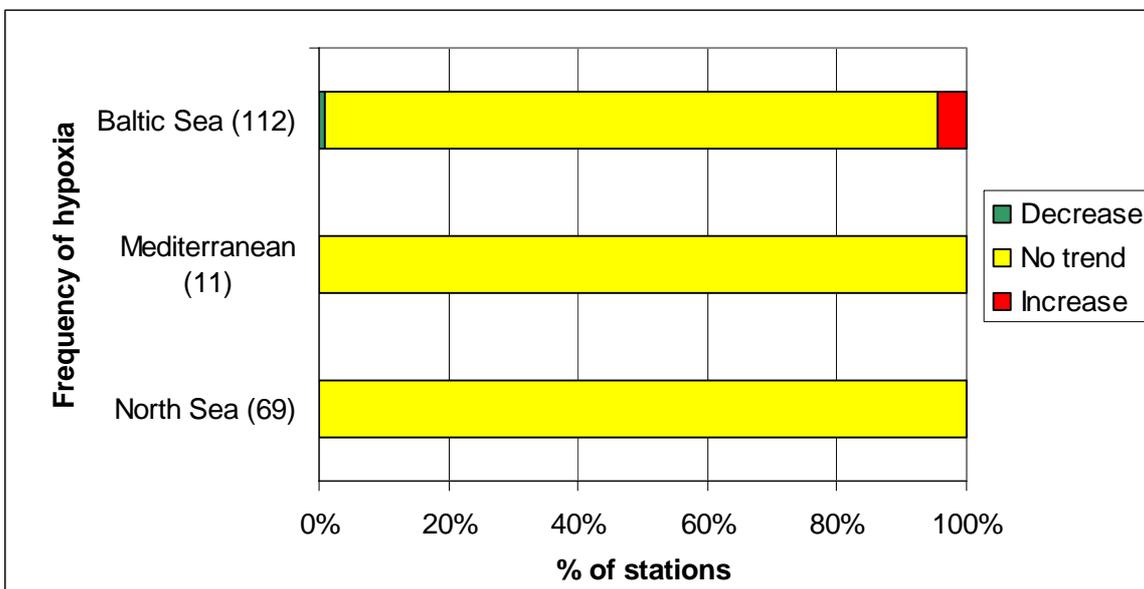
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Key message

☹ Generally no trend is observed in the frequency of low oxygen concentrations (hypoxia) in the Baltic Sea, the North Sea and the Mediterranean Sea.

Figure 1: Trends in the frequency of low oxygen concentrations in bottom waters of the Baltic Sea, the Mediterranean and the North Sea.



Notes

Number of stations in brackets.

North Sea (incl. the Skagerrak): Belgium, Denmark, Norway, Sweden

Baltic Sea (including the Kattegat): Denmark, Estonia, Finland, Germany, Lithuania, Poland, Sweden

Mediterranean Sea: Greece, Italy

Results of trend analyses applied to time series for the period 1985-2002 (stations with at least three years data in the period 1995-2002 and at least five years in total) are shown with a bar chart for each sea region.

Source: Data from HELCOM, OSPAR and EEA member countries compiled by ETC Water.

Results and assessment

Policy relevance:

The objective of this descriptive indicator is to demonstrate the results of measures taken to reduce the nutrient load on the frequency of hypoxia as an indicator of eutrophication. The main governing factor for the occurrence of hypoxia is the physical transport of water to the bottom layer and nutrient inputs enhancing the likelihood of hypoxic conditions.

Policy context:

In order to reduce adverse effects of excess anthropogenic input of nutrients and to protect the marine environment, measures are being taken as a result of various initiatives on all levels (global, European, regional conventions and Ministers Conferences, national), for example, UN Global Programme of Action for the Protection of the Marine environment against Land-Based Activities; Mediterranean Action Plan (MAP) 1975; Helsinki Convention 1992 (HELCOM) on the Protection of the Marine Environment of the Baltic Sea Area; OSPAR Convention 1998 for the Protection of the Marine Environment of the North East Atlantic; Black Sea Environmental Programme (BSEP).

The EU Nitrate Directive and Urban Wastewater Treatment Directive aim at reducing nitrate loads, mainly from agricultural soil leaching and nutrients from point sources to eutrophication sensitive areas.

The recent EU Water Framework Directive aims among other things at obtaining good ecological quality of coastal waters. Nutrient enrichment is a widespread problem in European coastal waters (EEA 2001) therefore nutrient loads to these areas should be reduced. HELCOM member countries have agreed to aim at a 50% reduction in nutrient load to the Baltic Sea area based on mid 1980s levels. Member countries of the North Sea Ministerial Conference has agreed to aim at a 50% reduction of the nutrient load (based on the mid 1980s levels) to areas affected by or likely to be affected by eutrophication. The OSPAR member countries have agreed to reduce the nutrient load to problem areas and potential problem areas with regard to eutrophication. MAP member countries have agreed to aim at a 50% reduction in nutrient loads from industrial sources. Thus the political targets to reduce eutrophication have focused on load reductions. Implementation of the Water Framework Directive will probably extend the targets to include nutrient concentrations in the coastal water, and target concentrations for nutrients in different typologies in the different regional seas are under development. As eutrophication is a widespread problem in certain European coastal waters (EEA 2001), reductions of nutrient loads are necessary in order to improve oxygen conditions in bottom waters.

Environmental context:

The indicator describes the relative frequency of oxygen concentrations in bottom water (May-November) below 2 ml/l, which is defined as hypoxic conditions reported to have adverse effects on the benthic community (Diaz and Rosenberg, 1995). Phytoplankton primary production is in most marine areas nutrient limited and dependent on the general availability of nutrients (eutrophic level) in the specific area. Enhanced primary production increases the sedimentation rate of organic material to the bottom. The fraction of primary production in coastal waters, which is deposited to the sediment, is mostly in the range of 25-50% (Nixon, 1981; Wollast, 1991). Oxygen concentrations in bottom waters depend on consumption of oxygen from degradation of sedimenting organic material and supply of oxygen from vertical mixing and horizontal transport processes. The majority of sedimenting organic material can be related to occurrences of phytoplankton blooms (Smetacek, 1985; Olesen and Lundsgaard, 1995), which accumulate in the sediments and subsequently degrade at a temperature dependent rate. Consequently, oxygen deficiency is mostly observed in summer and autumn when bottom water temperature is high. The supply of oxygen to the bottom water depends on the hydrographical conditions of the specific area (wind conditions, stratification, advection, tidal mixing, etc.). Marine areas with strong stratification of the water column and small advective transport are sensitive to oxygen deficiency. Due to strong inter annual variations in hydrographical conditions of the coastal zone, trends in frequency of hypoxia as such can not be directly related to measures taken for reducing nutrient inputs.

Assessment:

Generally no trend is observed in the frequency of hypoxia in the North Sea or the Mediterranean Sea during the period 1985-2002. Significant trends are observed at a few stations in the Baltic Sea although with no specific pattern. The most drastic change in the frequency of hypoxia in Danish waters occurred from the 1970s to the 1980s (Ærtebjerg et al. 2002). Many stations had too few data to provide sufficient power in the trend analysis.

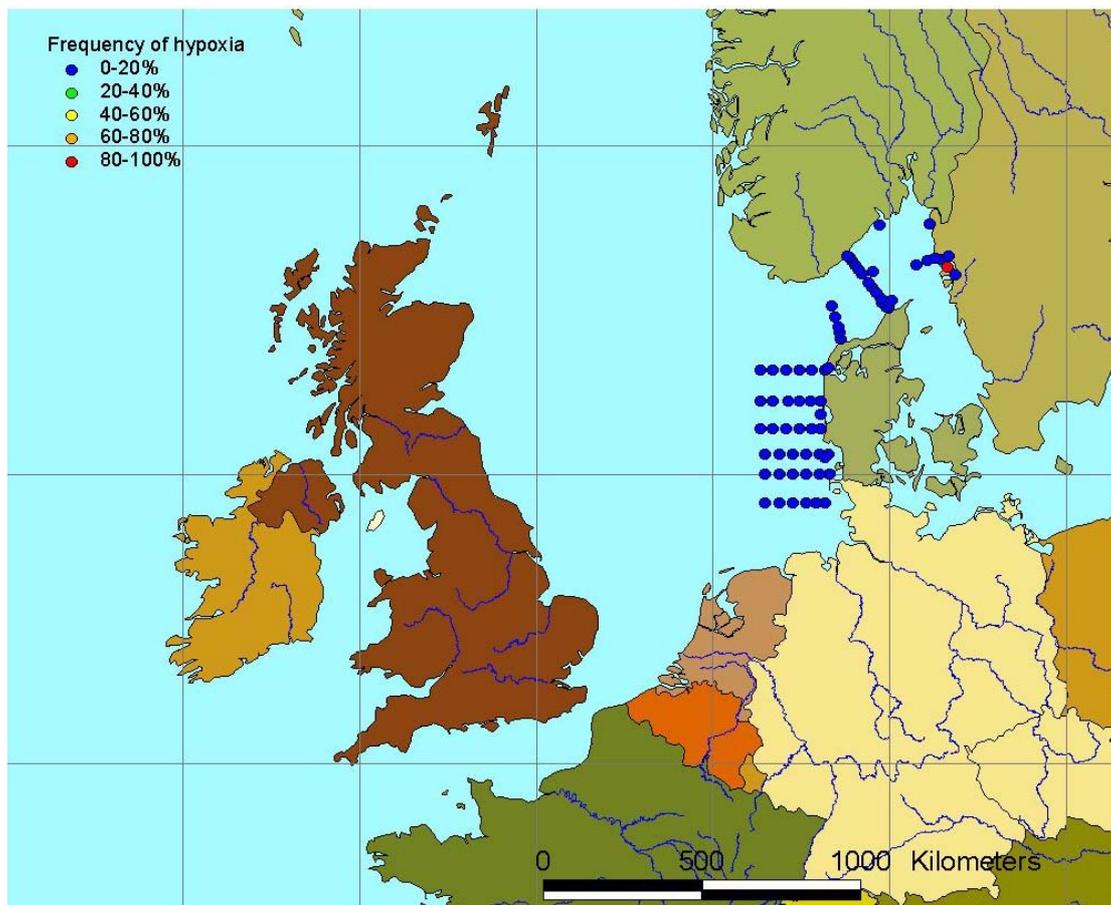
Sub-indicator: Frequency of low bottom oxygen concentrations in marine waters

Key message

☹ Generally no trend is observed in the frequency of low oxygen concentrations (hypoxia) in the Baltic Sea, the North Sea and the Mediterranean Sea.

🔴 Hypoxia is a problem in specific estuaries with large inputs of nutrients and little mixing of the water column as well as in stratified coastal waters and in the deep troughs of the Baltic Sea and the Black Sea.

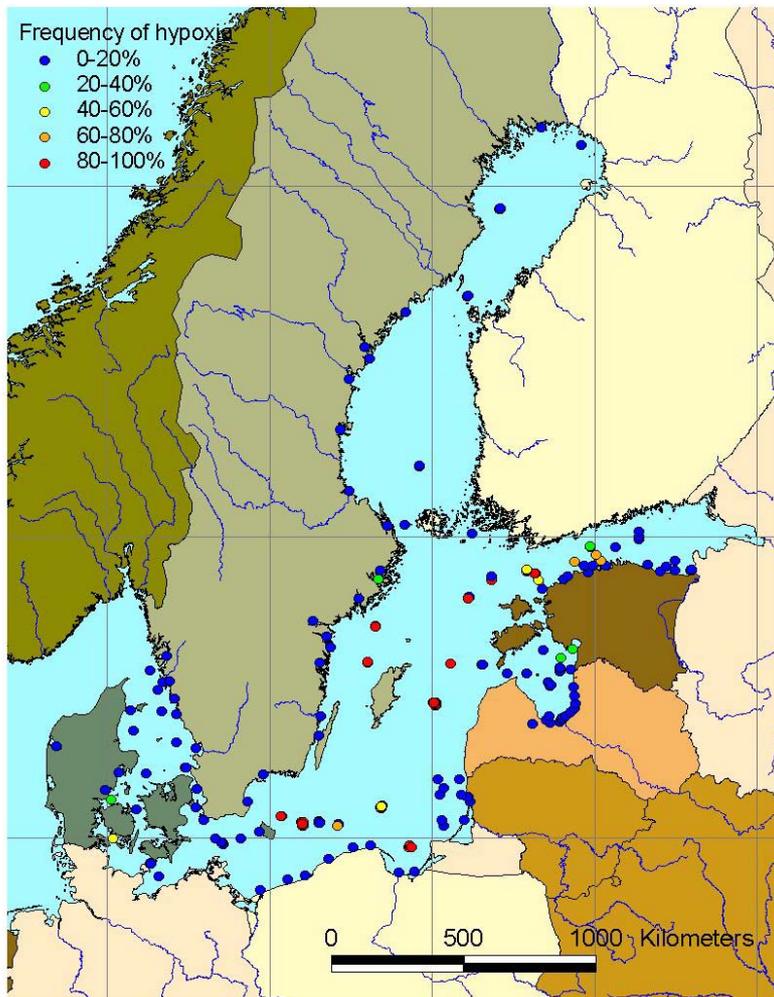
Figure 2: The mean frequency of hypoxia (<2 ml/l) at stations (>10 m) in the Greater North Sea (1995-2002).



Source: Data from OSPAR and EEA member countries.

Note: Hypoxia describes situations when the oxygen concentration in the water column is below 2 ml/l. The frequency of hypoxia is number of oxygen observations below 2 ml/l out of the total number of observations per year.

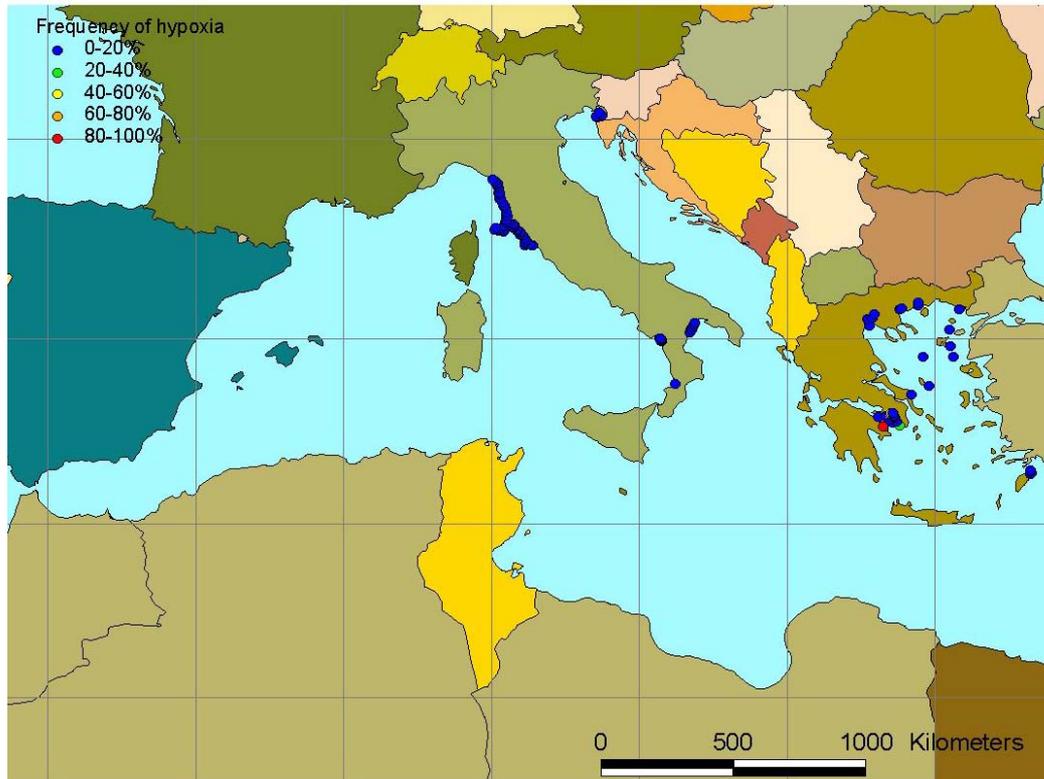
Figure 3: The mean frequency of hypoxia (<2 ml/l) at stations (>10 m) in the Baltic Sea area (1995-2002).



Source: Data from HELCOM and EEA member countries

Note: Hypoxia describes situations when the oxygen concentration in the water column is below 2 ml/l. The frequency of hypoxia is number of oxygen observations below 2 ml/l out of the total number of observations per year.

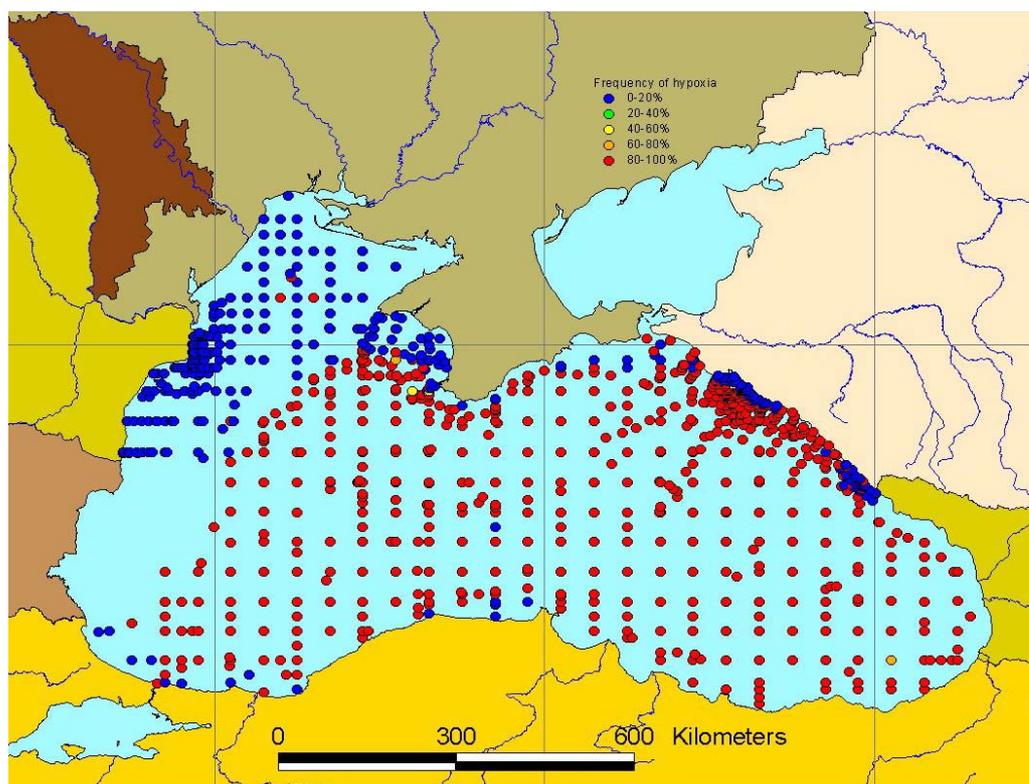
Figure 4: The mean frequency of hypoxia (<2 ml/l) at stations (>10 m) in the Mediterranean Sea (1995-2002).



Source: Data from EEA member countries

Note: Hypoxia describes situations when the oxygen concentration in the water column is below 2 ml/l. The frequency of hypoxia is number of oxygen observations below 2 ml/l out of the total number of observations per year.

Figure 5: The mean frequency of hypoxia (<2 ml/l) at stations (>10 m) in the Black Sea (1990-2006).



Source: Data were extracted from OceanBase Version 2.02 TU-BS developed within the framework of the NATO-TU - Black Sea Project

Note: Hypoxia describes situations when the oxygen concentration in the water column is below 2 ml/l. The frequency of hypoxia is number of oxygen observations below 2 ml/l out of the total number of observations per year.

Assessment of the sub-indicator

The coastal waters of the North Sea are generally not impacted by hypoxic conditions due to strong tidal mixing, particularly in the southern part (Figure 2), except for a few fjords that are prone to hypoxia.

The deeper parts of the Baltic Sea are characterised by frequent or permanent hypoxic conditions (Figure 3), which can be ascribed to the low exchange of bottom waters. In the Kattegat, the Belt Sea and the Western Baltic hypoxia is observed regularly due to the strong stratification. Oxygen deficiency in these areas are found to be significantly linked to both physical transport and nitrogen input (Henriksen et al., 2001).

In the Mediterranean Sea (Figure 4), both the Italian and Greek coasts appear to have a low frequency of hypoxia except for the Gulf of Saronicos, where hypoxic conditions were observed (>20%) at 5 stations, 4 of these at depths below 200 m. The reason for this is little renewal of bottom water combined with a high input of nutrients from point sources.

In the Black Sea (Figure 5), hypoxic conditions prevail at depths below 150 m, which is due to the low exchange of water through the strait of Bosphorus resulting in virtually no renewal of the bottom water.

Generally no trend is observed in the frequency of hypoxia in the North Sea or the Mediterranean Sea during the period 1985-2000. Significant trends are observed at a few stations in the Baltic Sea although with no specific pattern. The most drastic change in the frequency of hypoxia in Danish waters occurred from the 1970s to the 1980s (Ærtebjerg et al. 2002). Many stations had too few data to provide sufficient power in the trend analysis.

References

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Data

Spreadsheet: WEU15_Hypoxia.xls

Table 1:

Number of stations per country showing no trend, decreasing or increasing trend in frequency of hypoxia in recent years in the Greater North Sea, the Baltic Sea Area and the Mediterranean Sea, respectively.

Trend of hypoxia Sub-region	number of stations			total stations
	decreasing	no/limited trend	increasing	
North Sea				
Danish west coast	0	49	0	49
Norwegian coast	0	13	0	13
Swedish west coast	0	7	0	7
Baltic Sea				
Danish coast	0	7	2	9
Estonian coast	0	22	1	23
Finnish coast	0	8	0	8
German coast	1	15	0	16
Lithuanian coast	0	10	0	10
Polish coast	0	3	1	4
Swedish coast	0	41	1	42
Mediterranean Sea				
Greek coast	0	4	0	4

Italian coast	0	7	0	7
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Table 2:

The number of stations included in the analysis per sea area, country and year 1985-2002.

Sub-region	Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Atlantic	UK	1	1	1	1	1	1	1												
Baltic Sea	Denmark	4	5	6	7	7	7	7	6	7	6	7	7	9	9	11	11	10	11	
	Estonia									40	40	32	43	29	32	33				
	Finland	16	16	25	20	2	19	12	15	18	9	11	11	11	11	19				
	Germany	24	25	24	30	26	21	23	25	26	29	41	32	32	25					
	Latvia												1	3	3	2			16	
	Lithuania											1	10	10	10	11	11	10	11	6
	Poland	3	2	5	4	5	15	6	6	8	8	9	8	6	3				11	
	Russia	5	5	3	6	11	17	9	3											
	Sweden	24	23	23	22	22	37	36	35	42	41	45	45	42	42	39	35	21		
Black Sea	TUBS project	112	130	61	204	232	273	331	298	139	268	55	99							
Mediterranean Sea	Greece									4	3	4	5	12	6	21	15			
	Italy													9	86	80	81	80		
	Slovenia																		4	
North Sea (Greater)	Denmark	24	3	6	34	46	43	9	7	9	4	9	9	10	49	52	52	43	5	
	Germany					1	3	1	1	1										
	Norway	7	7	7	8	9	10	13	13	13	13	13	13	13	13	13	13	13	3	
	Sweden	2	2	5	5	5	11	10	10	8	8	8	8	8	8	8	9	6	6	

Meta data

Web presentation information

1. Abstract / description / teaser:

Demonstrates the results of measures taken to reduce the nutrient load by human activity on the frequency of hypoxia in bottom marine water as an indicator of eutrophication.

2. Policy issue / question:

Is the condition regarding eutrophication of Europe's seas improving?

3. EEA dissemination themes:

Coasts and seas

4. DPSIR:

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Technical information

5. Data source:

Sources are OSPAR and HELCOM monitoring results from the Baltic Sea Area, Skagerrak and North Sea reported from individual countries to ICES data centre. Additional monitoring data were provided from Denmark, Finland, Estonia, Greece, Italy, Latvia, Lithuania, the Netherlands, Norway, Slovenia, Spain, Sweden, and the UK. For the Black Sea data were extracted from OceanBase version 2.02 TU-BS developed within the framework of the NATO-TU – Black Sea Project.

6. Description of data:

Data were provided as measurements of oxygen sampled at discrete depths except data from Finland, Latvia and the Netherlands that provided seasonally aggregated values. Data from these three countries could not be used for the present indicator, because data was not aggregated appropriately for the analysis. Data from Spain, Slovenia and the UK included surface samples only and were not used for the present indicator.

7. Geographical coverage:

HELCOM and OSPAR stations and regional stations from Denmark, Estonia, Greece, Italy, Latvia, Lithuania, Norway and Sweden.

8. Temporal coverage:

The period covered ranges from 1985 - 2002. However, less than 10% of the stations have ongoing years since 1985.

Frequency of hypoxia levels were calculated as the average frequency over the period 1995-2002 and 1990-1996 for the Black Sea to give a picture of recent levels with a reasonable spatial coverage.

The two criteria used separately for the selection of time series for trend detection were:

- a. five or more years period since 1985;
- b. To ensure the use of recent data: Series including at least three years in the period 1995-2002 and at least one year in the period 1997-2002.

9. Methodology and frequency of data collection:

Only samples at depths greater than 10 m are considered, since some deliveries contained oxygen concentrations in the surface layer only.

In the Baltic and the North-east Atlantic areas the methodology and frequency of data collection follow OSPAR and HELCOM requirements, subject to ICES reporting formats.

10. Methodology of data manipulation:

Manipulation of the data and trend analysis was carried out using the software SAS®.

Geographical referenced monitoring data has been received from ICES and EEA member countries, and stations were identified by their geographical reference. The minimum oxygen concentration in the water column was selected to be the bottom water sample as there was no information about water depths at stations.

Stations were divided into regions per country. The water quality data was selected and retrieved for each of the resulting regions. This resulted in a database with water quality values for each station in each region, per country.

For each station and each year the number of oxygen concentrations in the bottom water sample below 2 ml/l and the total number of oxygen observations from May through November was determined.

Trend analysis was carried out for each station per country in a region. Trend detection for each time series was done from a logistic regression with a significance level of 5%.

Qualitative information

11. Strength and weakness (at data level). The number of stations for which data are available of course largely influences the accuracy on country level. The amount of data available for trend analysis is too scarce for a great number of stations.
12. Reliability, accuracy, robustness, uncertainty (at data level). The trend analysis is a robust and accepted approach. The accuracy of trend detection per station per region per country of the data gives the most reliable trend information per region.

Further work required

Data for this assessment are still scarce considering the large spatial and temporal variations inherent to these data. Long stretches of European coastal waters are not covered due to lack of data. Trend analyses are only consistent for the North Sea and Baltic Sea. It will be necessary to get access to more data, in terms of better spatial coverage and longer time series, in order to improve the assessment. In order to obtain longer time series it is also important that data are associated with unique station identifiers such that observations within a specific area can be merged. Secondly, methods for comparing data from the same region over different years should be developed to improve the assessment, and techniques for visualising the differences in frequencies of hypoxia over the entire region should be investigated, e.g. by combination with bathymetry data. Thirdly, future work for presenting these indicators could make use of output from hydrographical models to describe the variations in the supply of oxygen to bottom waters.