Indicator Fact Sheet

(WEU13) Chlorophyll-a concentrations in transitional, coastal and marine waters

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Key message

⁽²⁾ Generally no trend is observed in summer surface chlorophyll-a concentrations in the Baltic Sea, Greater North Sea or Greek coastal waters.



Figure 1: Trends in mean summer chlorophyll-a concentrations in Europe's Seas

Notes: Number of stations in brackets.

Baltic Sea: Denmark, Finland, Lithuania, Sweden

North Sea: Belgium, Denmark, Netherlands, Norway, Sweden

Mediterranean Sea: Greece

Results of trend analyses applied to time series for the period 1985-2000 (stations with at least 3 years data in the period 1995-2000 and at least 5 years in total) are shown with a bar chart for each sea region.

Source: Data from HELCOM, OSPAR and EEA member countries.

Results and assessment

Policy relevance:

The objective of the indicator is to demonstrate the effects of measures taken to reduce nutrient loads on coastal concentrations of phytoplankton expressed as chlorophyll-a. This is an indicator for eutrophication.

Policy context:

In order to reduce adverse effects of excess anthropogenic input of nutrients and to protect the marine environment against eutrophication, measures are being taken as a result of various initiatives on all levels (global, regional conventions and Ministers Conferences, European, 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.

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. Eutrophication is a widespread problem in European coastal waters (EEA 2001), therefore reductions of nutrient loads and consequently, chlorophyll-a concentrations are necessary in these areas. HELCOM member countries have agreed to aim at a 50% reduction in nutrient loads to the Baltic Sea area based on mid 1980s levels. Member countries of the North Sea Ministerial Conference have agreed to aim at a 50% reduction. 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 to reduce eutrophication have focused on load reductions. Implementation of the Water Framework Directive will probably extend the targets to include chlorophyll-a concentrations in the coastal water, and target concentrations for chlorophyll-a in different typologies in the different regional seas are expected to be development.

Environmental context:

The primary effect of eutrophication is excessive growth of plankton algae increasing the concentration of chlorophyll-a and the amount of organic matter settling to the bottom. The biomass of phytoplankton is most frequently measured as the concentration of chlorophyll-a in the euphotic part of the water column. Measurements of chlorophyll-a are included in most eutrophication monitoring programmes, and chlorophyll-a represents the biological eutrophication indicator with best geographical coverage at the European level.

The excessive settling of plankton algae may be enhanced by changes in species composition and functioning of the pelagic food web by stimulating the growth of small flagellates rather than larger diatoms, which leads to lower grazing by copepods and increased sedimentation. The consequent increase in oxygen consumption can in areas with stratified water masses lead to oxygen depletion and changes in community structure or death of the benthic fauna. Bottom dwelling fish may either escape or die. Eutrophication can also promote the risk of harmful algal blooms that may cause discoloration of the water, foam formation, death of benthic fauna, wild and caged fish, or shellfish poisoning of humans. The shadowing effect of increased phytoplankton biomass will reduce the depth distribution of sea grasses and macroalgae. This will together with increased growth and dominance of fast growing filamentous macroalgae in shallow sheltered areas change the coastal ecosystem, increase the risk of local oxygen depletion and reduce biodiversity and nurseries for fish. Secondary production of benthic fauna is most often food limited and related to the input of phytoplankton settling at the bottom, which in turn is also related to the chlorophyll-a concentration (EEA 2201; Borum, 1996; Conley et al., 1993).

This indicator describes the mean summer surface concentrations (May/June-September, 0-10 m) of the plant pigment chlorophyll-a in the Baltic Sea Area, Greater North Sea, Irish Sea, Mediterranean Sea and Black Sea. In summer, phytoplankton primary production, and consequently chlorophyll-a concentration, is nutrient limited in most areas and dependent on the general availability of nutrients (eutrophic level) in the specific area. Therefore, the indicator is directly related to eutrophication problems due to excess nutrient loads from anthropogenic sources.

Due to variations in freshwater run-off and hydro-geographic variability of the coastal zone and internal cycling processes, trends in chlorophyll-a concentrations as such can not be directly related to measures taken, but must be evaluated in a broader context.

Assessment:

No general trend is observed in summer surface chlorophyll-a concentrations either in the Baltic Sea area, Greater North Sea or coastal waters of Greece. The majority of stations show no trend. A few stations in Danish estuaries and Danish North Sea show a decreasing trend, whilst a few stations in Belgian, Finnish, Lithuanian and Swedish coastal waters show an increasing trend. No trend is observed in the Dutch coastal waters which receive high nutrient inputs from the Rhine river basin, nor in Norwegian and Greek coastal waters. Finland reports that the increasing trend of chlorophyll-a in the eastern Gulf of Finland and in the Archipelago Sea is due to increase in phosphorus released from hypoxic/anoxic sediments (Kauppila & Bäck, 2001; Hänninen et al. 2000). Due to the information available for this indicator the efforts in the reduction of nutrient loads didn't face success yet.

Sub-indicator: Summer surface chlorophyll-a concentrations

Key message

Generally no trend is observed in summer surface chlorophyll-a concentrations in the Baltic Sea, Greater North Sea or Greek coastal waters.

• The chlorophyll-a concentration is generally highest in estuaries and close to river mouths or big cities, reflecting the land-based inputs of nutrients.

Figure 2: Mean summer surface concentrations of chlorophyll-a in the Baltic Sea Area (1995-2002, May/Jun-Sep, 0-10 m).

Coastal stations are marked by circles and ICES open-water stations by squares. Level classification is based on the 20%, 40%, 60% and 80% percentiles of the chlorophyll-a distribution at coastal stations.



Source: Data from HELCOM and EEA member countries.

Figure 3: Mean summer surface concentrations of chlorophyll-a in the Greater North Sea and Irish Sea (1995-2002, May -Sep, 0-10 m).

Coastal stations are marked by circles and ICES open-water stations by squares. Level classification is based on the 20%, 40%, 60% and 80% percentiles of the chlorophyll-a distribution at coastal stations.



Source: Data from OSPAR and EEA member countries

Figure 4: Mean summer surface concentrations of chlorophyll-a in the Mediterranean Sea (1995-2002, May -Sep, 0-10 m).

Level classification is based on the 20%, 40%, 60% and 80% percentiles of the chlorophyll-a distribution.



Source: Data from EEA member countries

Figure 5: Mean summer surface concentrations of chlorophyll-a in the Black Sea (1995-2002, May -Sep, 0-10 m).

Level classification is based on the 20%, 40%, 60% and 80% percentiles of the chlorophyll-a distribution.



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

Assessment of the sub-indicator

The mean summer surface chlorophyll-a concentration is low (<3 μ g/l) in the Skagerrak and the open North Sea. Higher concentrations (>6 μ g/l) are observed in the Belgian, Dutch, German and Danish coastal North Sea waters and estuaries, and in UK estuaries, reflecting the land-based nutrient loads (Figure 2).

In the Baltic Proper and Gulf of Finland, concentrations $>3\mu g/l$ are seen even in open waters, probably due to summer blooms of cyano-bacteria, which are specific for the Baltic Sea. Concentrations $>4.5 \mu g/l$ are observed along the Finnish coast in the Gulf of Finland, partly due to the Neva River outflow at the eastern end of the Gulf. High concentrations are also seen in the Gulf of Riga, Gulf of Gdansk, at the Lithuanian coast and in a number of Danish and Swedish estuaries due to local nutrient loads (Figure 3).

In the Mediterranean Sea, the lowest concentrations (<0.4 μ g/l) are observed around the Sardinian Island and in southern Italian and in Greek coastal waters. Higher concentrations (>0.7 μ g/l) are observed along the Spanish Costa del Sol, most of the Italian east and west coasts and in the Greek Saronikos Bay. High concentrations (>2.6 μ g/l) are seen in the Gibraltar Bay, northern Adriatic and at the Italian west coast from Napoli to north of Rome (Figure 4).

Very few chlorophyll data are available for the Black Sea. They show the highest level (>1.7 μ g/l) in the Ukrainian waters of the north-western Black Sea (Figure 5).

No general trend is observed in summer surface chlorophyll-a concentrations either in the Baltic Sea area, Greater North Sea or coastal waters of Greece. The far majority of stations

show no trend. A few stations in Danish estuaries and Danish North Sea show a decreasing trend, while a few stations in Belgian, Finnish, Lithuanian and Swedish coastal waters show an increasing trend. No trend is observed in the Dutch coastal waters which receive high nutrient inputs from the Rhine river basin, nor in Norwegian and Greek coastal waters. Finland reports that the increasing trend of chlorophyll-a in the eastern Gulf of Finland and in the Archipelago Sea is due to increase in phosphorus released from hypoxic/anoxic sediments (Kauppila & Bäck, 2001; Hänninen et al. 2000).

Sub-indicator: Chlorophyll a from satellite images

Key message

• Eutrophication effects like phytoplankton blooms, measured as chlorophyll-a from satellite images, occur in several coastal areas of European seas.

Figure 6: Mean spring-summer (April-September) concentrations of chlorophyll-like pigments in European seas as determined from SeaWiFS satellite observations in 1998 and 2000, respectively.

The concentration scale (μ g/l) is valid only for oceanic waters and overestimates to a large and variable degree the chlorophyll concentrations in coastal seas. New regional algorithms for remotely sensed chlorophyll a is undergoing further development and will improve over the years.





Source: JRC 2002.

Assessment of the sub-indicator

As a first approach to identifying European coastal areas with enhanced chlorophyll levels compared to neighbouring seas (Table 1), maps were produced from satellite (SeaWiFS) images showing the spring-summer mean concentrations of chlorophyll-like pigments in the Baltic, western European, Mediterranean and Black Seas in the years 1998 and 2000 (JRC, 2002).

Differences between 1998 and 2000 are seen in both geographical distribution and in concentration levels of chlorophyll-like pigments, especially in the eastern and southern North Sea, the Sea of Azov and in the Baltic Sea (Figure 6). In the latter case, the concentration generally seems to increase from 1998 to 2000. However, these inter-annual differences are not only due to varying distribution and concentration of phytoplankton blooms related to variations in meteorology and hydrography including runoff, wind direction and wind force, but also to varying distribution of yellow substance and suspended matter. The cyanobacteria bloom in 2000 in the Gulf of Finland was lower than in 1998, even if the satellite images indicate a higher concentration of chlorophyll-like pigments. So it is not possible from comparison of two years satellite images to conclude a general development. This has to be done in a broader context including in situ measurements and meteorological variability from year to year.

It also has to be emphasised that the SeaWIFS algorithm used to determine the chlorophyll-a concentrations is valid only for oceanic waters and overestimates to a large and variable degree the chlorophyll-a concentrations in coastal waters, especially in the Baltic Sea, due to high concentrations of coloured dissolved organic material (CDOM, yellow substance).

References

EEA 2001. Eutrophication in Europe's coastal waters. Topic report 7/2001, 116 pp.

Kauppila, P. & Bäck, S. 2001. The state of Finnish coastal waters in the 1990s. The Finnish Environment 472, 134 pp.

Hänninen, J., Vuorinen, I., Helminen, H., Kirkkala, T. & Lehtilä, K. 2000. Trends and gradients in nutrient concentrations and loading in the Archipelago Sea, Northern Baltic, in 1970-1997. *Estuarine, Coastal and Shelf Science* 50: 153-171.

Data

Spreadsheet: WEU13_ChIA_Marine.xls

Table 1:

Coastal areas with apparently enhanced chlorophyll levels compared to neighbouring seas as deemed from the satellite SeaWIFS spring-summer mean chlorophyll images (Figure 6).

Baltic Sea: North-eastern part and eastern coast of Bothnian Bay; the Quark area; Coastal areas of Bothnian Sea; Gulf of Finland; Gulf of Riga; Coastsal areas off Kaliningrad and Lithuania; Gulf of Gdansk; Pomeranian Bight; Swedish Baltic Proper coast;
Belt Sea and Kattegat: Especially coastal and shallow areas of the Belt Sea and Kattegat;
Skagerrak: North-eastern and south-western parts and coastal areas of Skagerrak.
North Sea: Eastern North Sea; German Bight; Wadden Sea; Southern Bight; UK coast and estuaries.

The Channel: Coastal areas, especially Baie de Somme, Baie de Seine and Baie du Mont St. Michel.

Celtic Seas: Bristol Channel; Liverpool Bay with associated estuaries; Solway Firth; Firth of Clide; Ireland's coast to the Irish Sea

Bay of Biscay and Iberian Coast: French coastal areas and estuaries in Bay of Biscay, especially in the vicinity of the Loire and Gironde estuaries; Spanish and Portuguese Atlantic coasts

Mediterranean Sea: Costa del Sol; Vicinity of the Ebro delta; Gulf of Lyon; Italian west coast, especially Gulf of Gaeta, Napoli Bay and in the vicinity of the rivers Tiber and Arno; Northern Adriatic Sea, especially Gulf of Venice and the areas influenced by the river Po; Northern Aegean Sea, especially Bights of Thessaloniki and Thermaikos and in the Limnos area with inflow from the Black Sea through the Marmara Sea. Outside EU-countries enhanced chlorophyll concentrations are found along the south-east coast of Tunesia and the Egyptian coast from Alexandria to Gaza.

Black Sea, Marmara Sea and Sea of Azov: Marmara Sea, especially close to Istanbul and southern coastal areas; The north-western Black Sea, especially along the Ukrainian and Romanian coasts influenced by the large rivers Danube, Dnipro, Dnister and Southern Bug, and less along the Bulgarian and Turkish coasts; The Sea of Azov.

Source: EEA 2001 and JRC

Table 2:

Number of stations per country showing no trend, decreasing or increasing trend in summer surface concentrations of chlorophyll a in recent years in the North Atlantic, Baltic Sea, Black Sea, Mediterranean and the North Sea, respectively.

		Atlant	ic		
Country		Chlorophy	11	Number of stations	
	Decrease	No trend	Increase	Total	
Open water	0	19	1		20

Baltic Sea Area												
Country		Chlorophy	Number of stations									
	Decrease	No trend	Increase	Total								
Open water	0	17	1	18								
Denmark	4	11	0	15								
Finland	0	9	0	9								
Lithuania	0	9	2	11								
Sweden	0	20	3	23								

Country		Chlorophy	Number of stations	
	Decrease	No trend	Increase	Total
Greece	0	6	0	6
Italy	5	95	0	100

North Sea Area												
Country		Chlorophy	Number of stations									
	Decrease	No trend	Increase	Total								
Open water	0	28	0	28								
Belgium	0	13	2	15								
Denmark	2	22	0	24								
Netherlands	0	5	0	5								
Norway	0	10	0	10								

	Sweden	0	4	3	7
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Table 3:

The number of stations included in the chlorophyll-a analysis per 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	Open water	45	233	. 14	151	440	· 241	· 502	95	304	126	475	404	113	· 46	175	24	13	
	France	_			3	-		1			-	_	-	-	-	-		-	
	UK	36	58	5		6		7	3	4		56	114	7	173	7	2	1	
Baltic Sea	Open water	17	74	21	14	8	98	91	25	36	24	19	21	40	26	34	33	3	
	Denmark	8	8	10	11	11	9	11	10	12	10	10	10	10	15	15	16	16	16
	Finland	10	10	14	6	6	17	19	25	10	12	11	12	10	14	19	16	7	
	Germany						6												
	Lithuania											11	11	11	11	11	11	11	
	Poland						20	5									8	10	
	Russia	2	2		2		21	7											
	Sweden					1	15	41	34	34	23	25	25	38	30	25	25	1	
Black Sea	TUBS project	3	17			28		8	2										
Mediter-	Greece									5	14	19	22	24	8	3			
ranean	Italy												80	677	747	136	800	176	192
Sea																9			
	Slovenia																	4	
	Spain														23	40			
North Sea	Open water	18	2	2	16	27	27	5	3	4	1	3	3	3	30	30	30	22	
(Greater)	Belgium									26	23	28	19	23		9	23		
	Denmark	7	2	3	18	18	18	4	3	4	2	3	8	8	24	24	24	23	7
	Germany											4		1	3				
	Netherlands	5	4	4	5	5	5	5	5	5	5	52	29	32	5	5	5		
	Norway	5	5		16	6	40	71	47	7	10	49	13	19	20	9	20	4	
	Sweden						33	23	5	9	19	7	7	7	10	8	8		
	UK	12	4		39	104	80		35	217	28	34	23	7	1	35		4	

Meta data

Web presentation information

1. Abstract / description / teaser:

Demonstrates the effects of nutrient load trends on coastal concentrations of phytoplankton expressed as chlorophyll a (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 HELCOM and OSPAR monitoring results from the Baltic Sea Area, Greater North Sea and Irish Sea reported from individual countries to ICES data centre. Additional monitoring data was provided from NRCs in Denmark, Finland, Greece, Italy, Latvia, Lithuania, The Netherlands, Norway, Slovenia, Spain, Sweden and U.K.

6. Description of data:

Data were provided as measurements of chlorophyll-a sampled at discrete depths except NRC data from Finland, Latvia and The Netherlands that provided seasonally aggregated values.

7. Geographical coverage:

HELCOM and OSPAR stations and regional stations from Denmark, Finland, Greece, Italy, Latvia, Lithuania, The Netherlands, Norway, Slovenia, Spain, Sweden, U.K.

8. Temporal coverage:

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

Summer chlorophyll-a levels were calculated from averages 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:

In the Baltic and north-east Atlantic 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 NRCs, and stations were identified by their geographical reference. Surface concentrations of chlorophyll-a were obtained by averaging data from the top 10 m.

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 surface water quality values for each station in each region, per country.

For each station yearly summer mean concentrations of chlorophyll-a were obtained by averaging observations in May to September, for the northern Baltic Sea Area June to September.

Trend analysis was carried out for each station in a region. Trend detection for each time series was done with the Mann-Kendall Statistics using a two-sided test with a significance level of 5%.

Qualitative information

- 11. Strength and weakness (at data level). The accuracy on regional level is of course largely influenced by the number of stations for which data are available.
- 12. Reliability, accuracy, robustness, uncertainty (at data level). The Mann-Kendall test is a robust and accepted approach. Due to the multiple trend analyses approximately 5% of the conducted tests will turn out significantly if in fact there is no trend.

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 were only consistent for the North Sea and Baltic Sea, where

sufficiently long time series were available with a reasonable spatial coverage. In order to improve the assessment it is crucial to get access to more data, in terms of both better spatial coverage and longer time series. 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 chlorophyll levels over the entire region should be investigated. Thirdly, indicators could make use of salinity data at stations as covariate in order to compensate for interannual variations in salinity. It might also be necessary that data are accompanied by information on methodology and estimated uncertainty.