HELCOM core indicator report

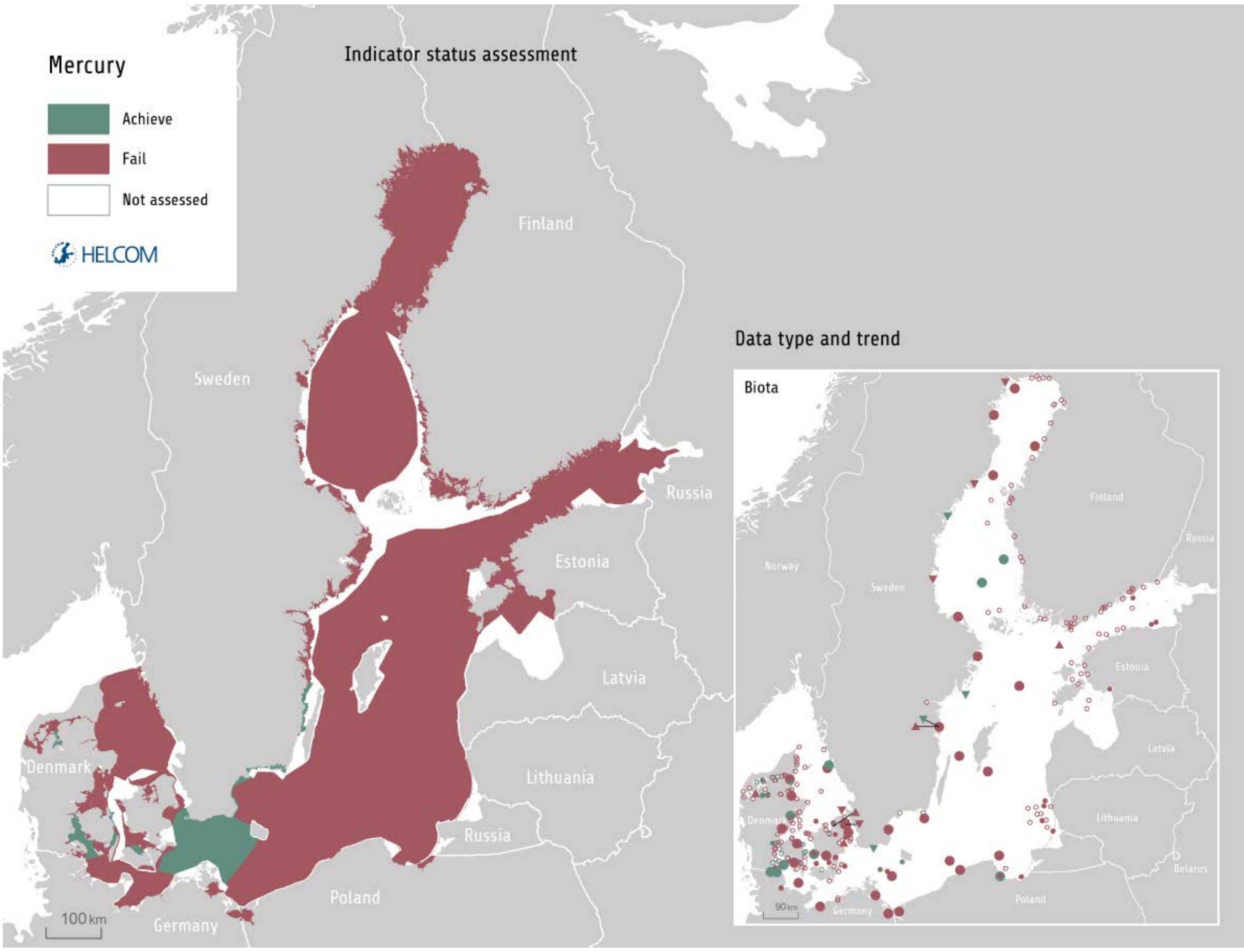
July 2018

Metals (lead, cadmium and mercury)

Key Message

This core indicator evaluates the status of the marine environment based on concentrations of the heavy metals in the Baltic Sea. Lead (Pb), cadmium (Cd) and mercury (Hg) are measured in water, biota (fish and mussels) and sediments. Good status is achieved when the concentrations of heavy metals are below the specific threshold values.

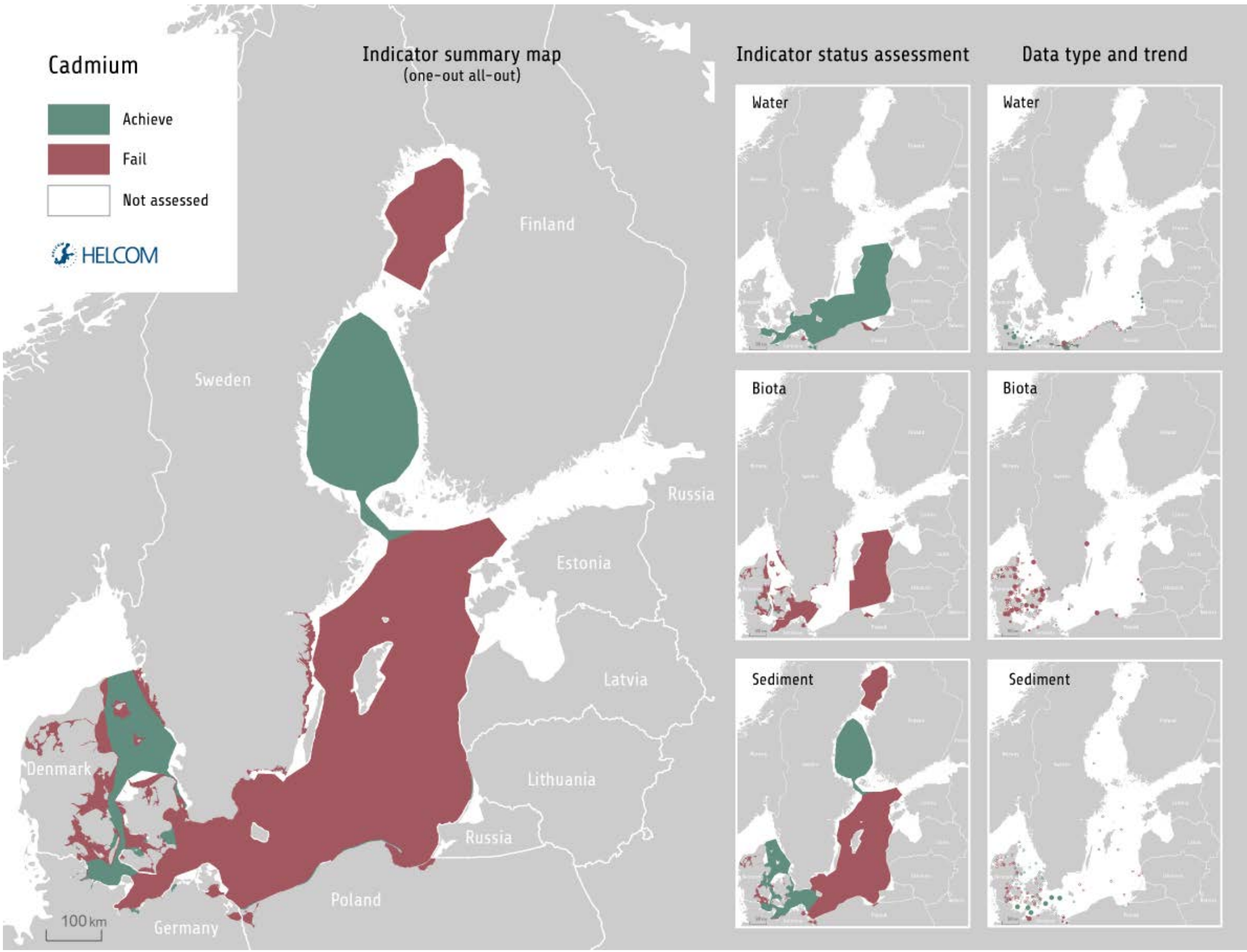
The indicator presents a status evaluation using all available data in the HELCOM region during the assessment period 2011 - 2016.



Key message figure 1. Status assessment results based on evaluation of the mercury concentrations in fish and mussels. The assessment is carried out using Scale 4 HELCOM assessment units (defined in the [HELCOM Monitoring and Assessment Strategy Annex 4]). **Click here to access interactive maps at the HELCOM Map and Data Service: [Mercury].**

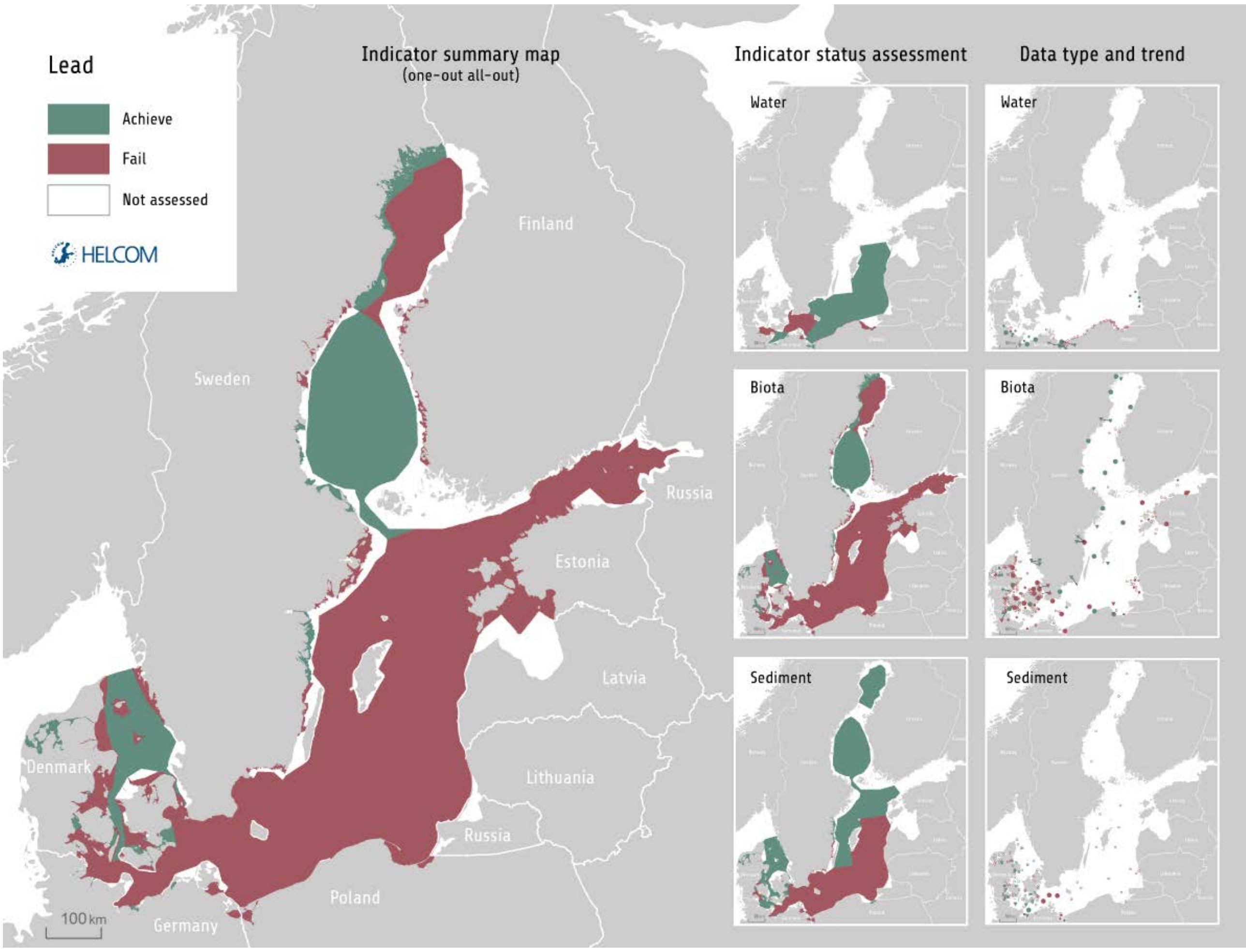
Mercury (Hg) concentrations in fish muscle (used for the assessment) exceeded the threshold level in almost all monitored open sea sub-basins, indicating not good status in the Bothnian Bay, The Quark, Bothnian Sea, Gulf of Finland, Northern Baltic Proper, Western- and Eastern Gotland Basins, Gdańsk Basin, Bornholm Basin, Bay of Mecklenburg, Kiel Bay and Kattegat (Key message figure 1). Good status was not achieved in the majority of coastal areas assessed, including: Finnish, Swedish, Estonian, Polish, German and Danish assessment units. Good status was only achieved in the Arkona Basin open sea assessment unit and few coastal Danish and Swedish coastal areas.

Data on concentrations of cadmium (Cd) in seawater, biota (mussels) and sediment was used for the status assessment, and taking into account all matrices by applying the One-Out-All-Out (OOAO) method, good status was achieved in the Bothnian Sea, Åland Sea, Kattegat, Great Belt and Kiel Bay as well as in some of the Danish and German coastal areas (Key message figure 2). Good status was not achieved in the Bothnian Bay, Northern Baltic Proper, Western Gotland Basin, Eastern Gotland Basin, Bornholm Basin, Arkona Basin, Gdańsk Basin, Bay of Macklenburg and in some coastal areas: German, Danish and Polish.



Key message figure 2. Status assessment results based on evaluation of the cadmium concentrations. One-Out-All-Out (OOAO) method (large upper figure), in seawater (lower left), in biota (lower middle) and in sediment (lower right). The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: Cadmium.**

Concentrations of lead (Pb) in seawater, biota (fish and mussel) and sediment were monitored, and when summarised using the OOAO approach good status was only achieved in the Bothnian Bay, Åland Sea, Kattegat and Great Belt open sea assessment units as well as in some Finnish, Swedish, Danish and German coastal areas (Key message figure 3). Areas where good status was not met were the Quark, Northern Baltic Proper, Gulf of Finland, Western Gotland Basin, Eastern Gotland Basin, Gdańsk Basin, Bornholm Basin, Arkona Basin, Kiel Bay and the Bay of Mecklenburg, as well as of the coastal areas: Finnish, Swedish, Estonian, Polish, German and Danish.



Key message figure 3. Status assessment results based on the evaluation of lead concentrations. One-Out-All-Out (OOAO) method (large upper figure), in seawater (lower left), in biota (lower middle) and in sediment (lower right). The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: Lead.**

The confidence of the indicator evaluation is **high**. The data on metal concentrations is spatially adequate and time series are available for several stations.

The indicator is applicable in the waters of all countries bordering the Baltic Sea.

Relevance of the core indicator

The heavy metals cadmium (Cd), lead (Pb) and mercury (Hg) are toxic to marine organisms when encountered at high concentrations.

Metals are bioaccumulated by marine organisms causing harmful effects. The severity of effect mainly depends on the concentration in the tissues. Additionally, both Cd and Hg are also known to biomagnify, i.e. the concentration levels increase upwards through the food chain. When heavy metals bioaccumulate in tissues they can cause different biological effects on the individual organism, which transform into changes at population, then species level, and finally affect biodiversity and ecosystem functioning. Heavy metal accumulation in fish, specifically destined for human consumption, directly affect human health.

Policy relevance of the core indicator

	BSAP segment and objectives	MSFD Descriptor and criteria
Primary link	Hazardous substances • Concentration of hazardous substances close to natural levels. • Healthy wildlife.	D8 Concentrations of contaminants D8C1 Within coastal, territorial and areas beyond territorial waters the concentration of contaminants do not exceed the threshold values.
Secondary link	Hazardous substances • Fish safe to eat.	D9 Contaminants in fish and seafood D9C1 The level of contaminants in edible tissues of seafood caught or harvested in the wild does not exceed maximum levels which are the threshold values.
Other relevant legislation: The Water Framework Directive (Cd, Pb and Hg are listed as priority substances).		

Cite this indicator

HELCOM (2018) Metals (lead, cadmium and mercury). HELCOM Core Indicator Report. Online. [Date Viewed], [Web link].

ISSN: 2343-2543

Download full indicator report

Metals HELCOM core indicator 2018 (pdf)

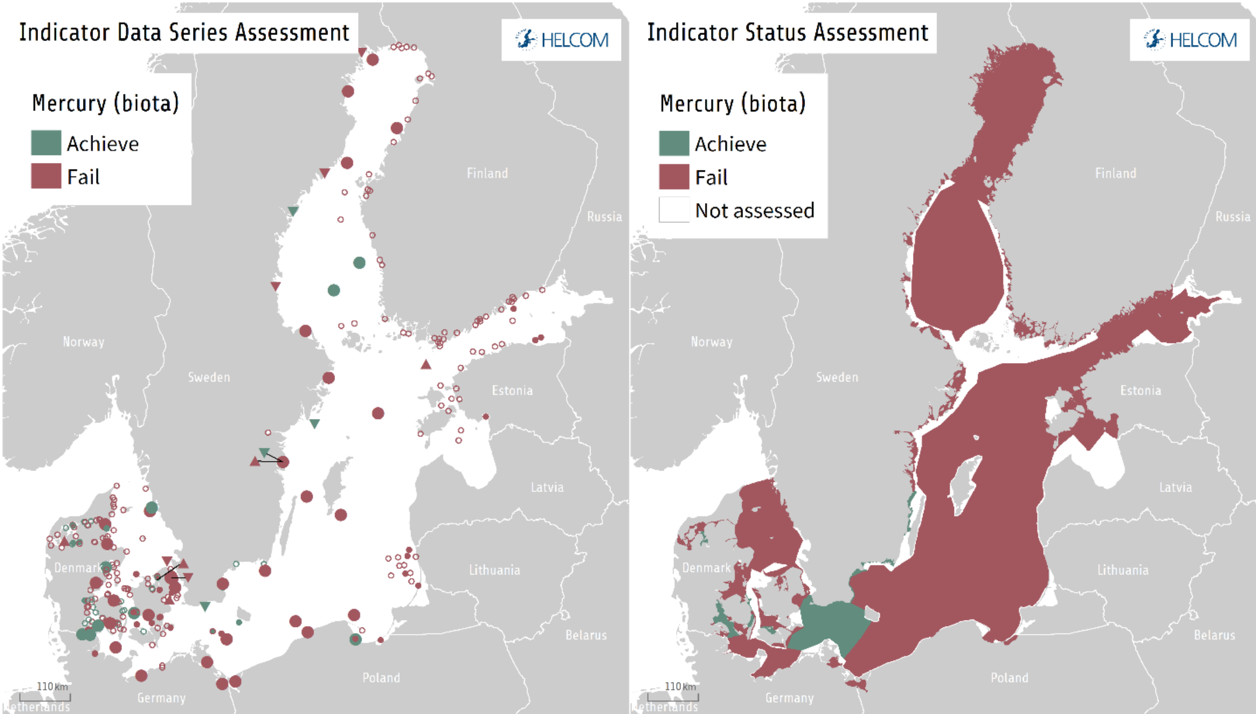
Results and Confidence

The data underlying the core indicator evaluation are based on regular monitoring data gathered by HELCOM Contracting Parties and reported to the HELCOM COMBINE data base (hosted by ICES). The indicator presents information on the current levels of cadmium, lead and mercury concentrations in selected marine matrices: seawater, fish (muscle and liver tissue) soft body of mussels as well as in the bottom sediment for the assessment period 2011-2016, assessed against regionally agreed threshold values. The values presented in the report refer to the concentrations and mean values calculated from them, while the status assessments are based on the so-called representative concentrations assessed against threshold values, which result from data evaluation (see Assessment protocol), and are considered as values representative of status for the given assessment units.

Mercury

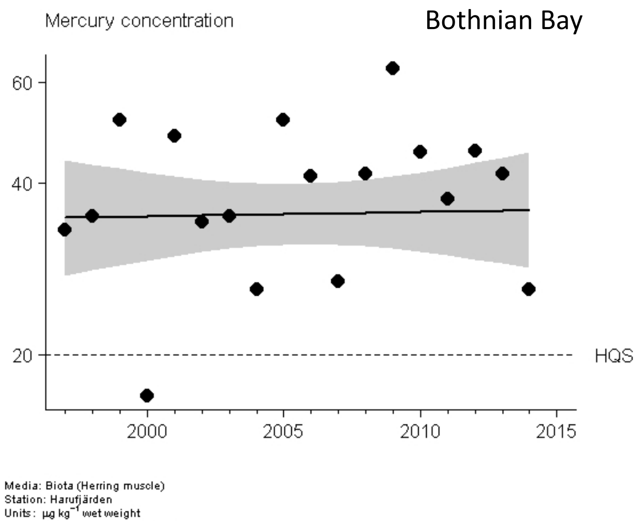
Biota

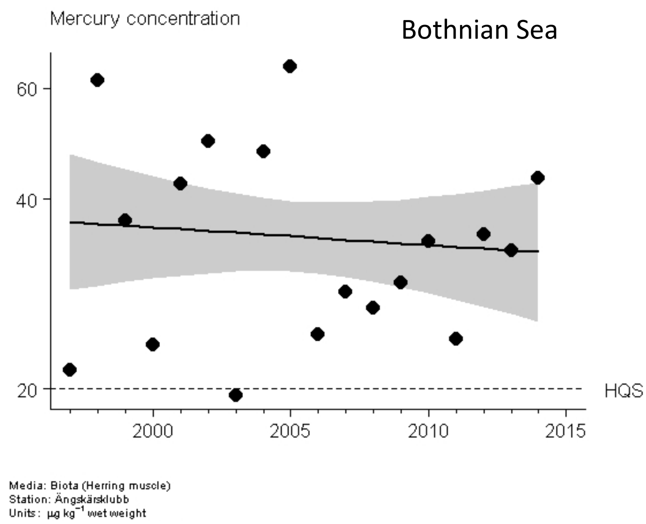
Mercury is analysed in fish muscle as a primary matrix, and the network of sampling station is dense (Results figure 1). The most common species in which Hg is measured are herring and cod in the open sea area and flounder and perch in coastal areas. Concentrations of Hg exceeded the threshold value of 20 µg kg^{-1} wet weight at the majority of the stations. Concentrations were only lower at a few stations. The mean concentrations on a sub-basin level were above the threshold value in all assessed areas, except the Arkona Basin and some of the Danish and Swedish coastal areas (Key message figure 1). The lowest mean concentration in the Arkona Basin was equal to 17.6 µg kg^{-1} wet weight and was below the threshold value (20 µg kg^{-1} wet weight). The Arkona Basin status evaluation, as with all other assessments of each aggregated assessment unit, takes into account data variation within an assessment unit and within the HELCOM region, and this influences the final status assessment (Results figure 1 and Key message figure 1). In the Gulf of Finland and in the Kattegat Hg concentrations in fish muscle were similar, 34.5 and 36.5 µg kg^{-1} respectively and the highest value of 58.0 µg kg^{-1} wet weight was found in the Gdańsk Basin.

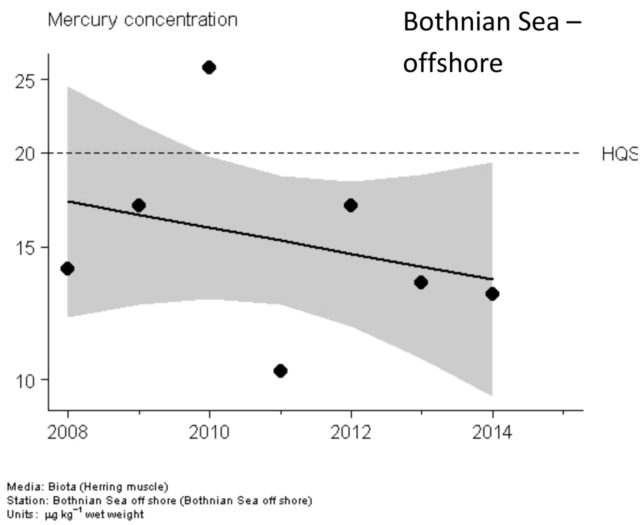


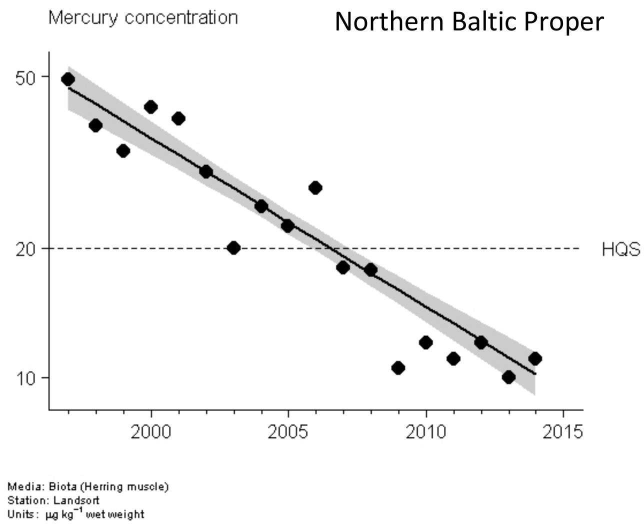
Results figure 1. Map presenting station based status of mercury concentrations in biota - fish muscle and mussels (left), and assessment unit based status for mercury in biota. Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Mercury.**

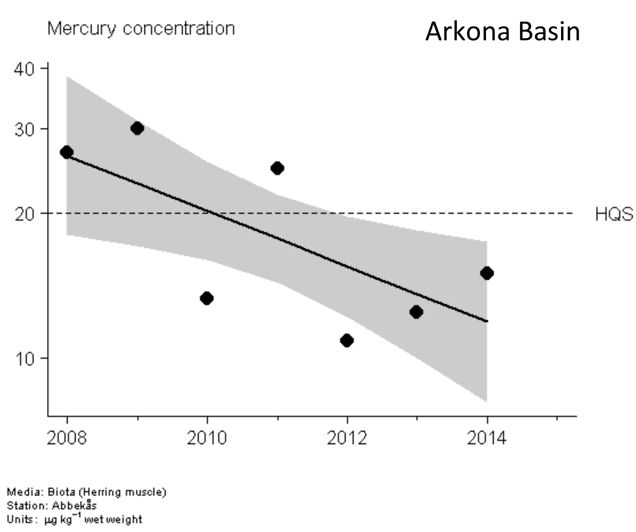
Taking into account the temporal changes in Hg concentrations in biota, downward trends were recorded for 18 data series, in the case of 43 data series trends were not detectable, and in the 5 data series there were upward trends. Some examples are presented in Results figure 2.

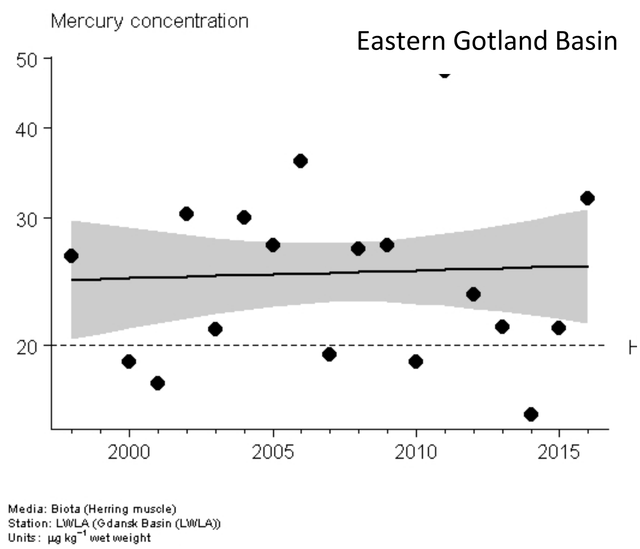

Mercury concentration
Bothnian Bay
60
40
20
HQS
2000
2005
2010
2015
Media: Biota (Herring muscle)
Station: Harufjärden
Units : µg kg^{-1} wet weight

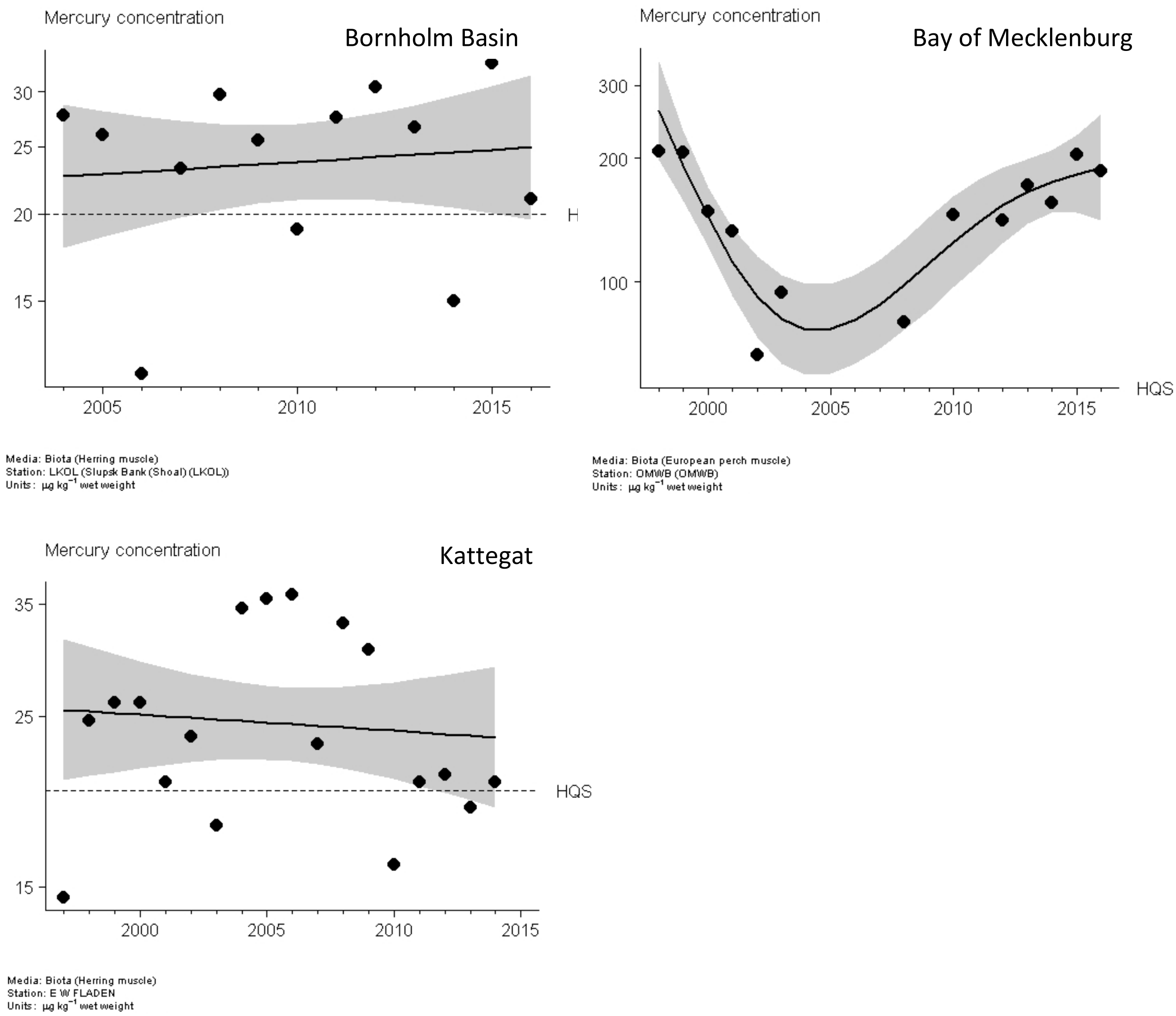

Mercury concentration
Bothnian Sea
60
40
20
HQS
2000
2005
2010
2015
Media: Biota (Herring muscle)
Station: Ängskärsklubb
Units : µg kg^{-1} wet weight


Mercury concentration
Bothnian Sea – offshore
25
20
15
10
HQS
2008
2010
2012
2014
Media: Biota (Herring muscle)
Station: Bothnian Sea off shore (Bothnian Sea off shore)
Units : µg kg^{-1} wet weight


Mercury concentration
Northern Baltic Proper
50
20
10
HQS
2000
2005
2010
2015
Media: Biota (Herring muscle)
Station: Landsort
Units : µg kg^{-1} wet weight


Mercury concentration
Arkona Basin
40
30
20
10
HQS
2008
2010
2012
2014
Media: Biota (Herring muscle)
Station: Abbekås
Units : µg kg^{-1} wet weight


Mercury concentration
Eastern Gotland Basin
50
40
30
20
2000
2005
2010
2015
Media: Biota (Herring muscle)
Station: LWLA (Gdansk Basin (LWLA))
Units : µg kg^{-1} wet weight



Results figure 2. Long-term trends of mercury concentrations in fish muscle at chosen stations (HQS –threshold value, grey colour-confidence level 95% range (see Assessment protocol)).

Cadmium

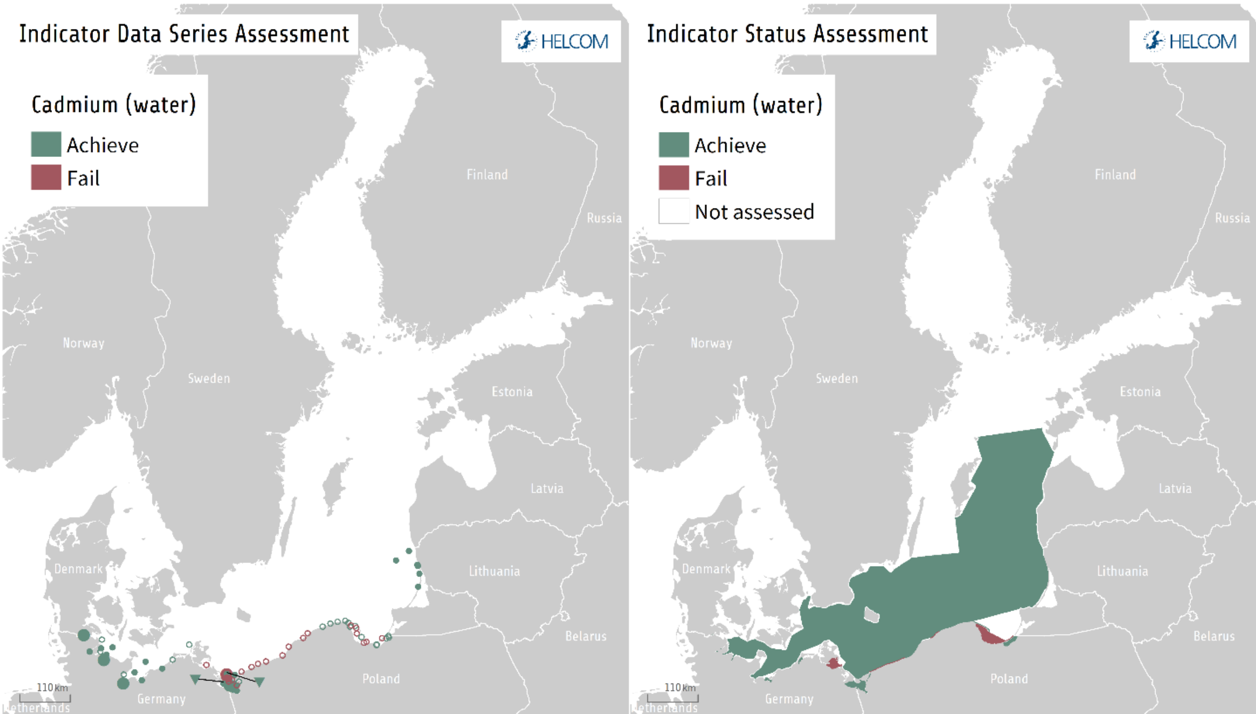
Seawater

The primary matrix for cadmium is water, as the primary threshold value for the core indicator is agreed to be the EQS value for water. This is in conflict with the HELCOM COMBINE monitoring program, where the preferred matrix for monitoring is biota and sediment. As a result, very little data is available for cadmium in water.

Cadmium concentrations in the seawater have been measured by Russia (1995–1998), Germany (1998–2016), Lithuania (2007–2016) and Poland (2011-2016).

The assessment of Cd concentrations in seawater showed that good status was achieved in five open sea basins: Eastern Gotland Basin, Bornholm Basin, Arkona Basin, Bay of Mecklenburg and Kiel Bay (Key message figure 2). Only in a few of the Polish and German coastal areas was good status not achieved, but it should be emphasized that the assessment is widely based on short data series (initial data – see Assessment protocol and Results figures 3-6).

The map shown in Results figure 3 presents monitoring stations and the data series for Cd in seawater (for method description see Assessment protocol). In most cases the representative concentrations of Cd were below the threshold value. Only at some stations in the coastal waters of Gdańsk Basin and the Bornholm Basin the concentrations exceeded 0.2 µg l^{-1}. The representative concentrations aggregated per assessment unit were 0.10 µg l^{-1} in the Eastern Gotland Basin and in the Bornholm Basin, 0.07 µg l^{-1} in the Arkona Basin, and 0.02 µg l^{-1} in the Bay of Mecklenburg and Kiel Bay.



Results figure 3. Map presenting station based status of cadmium concentrations in seawater (left) and assessment unit based status for cadmium in seawater (right). Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Cadmium.**

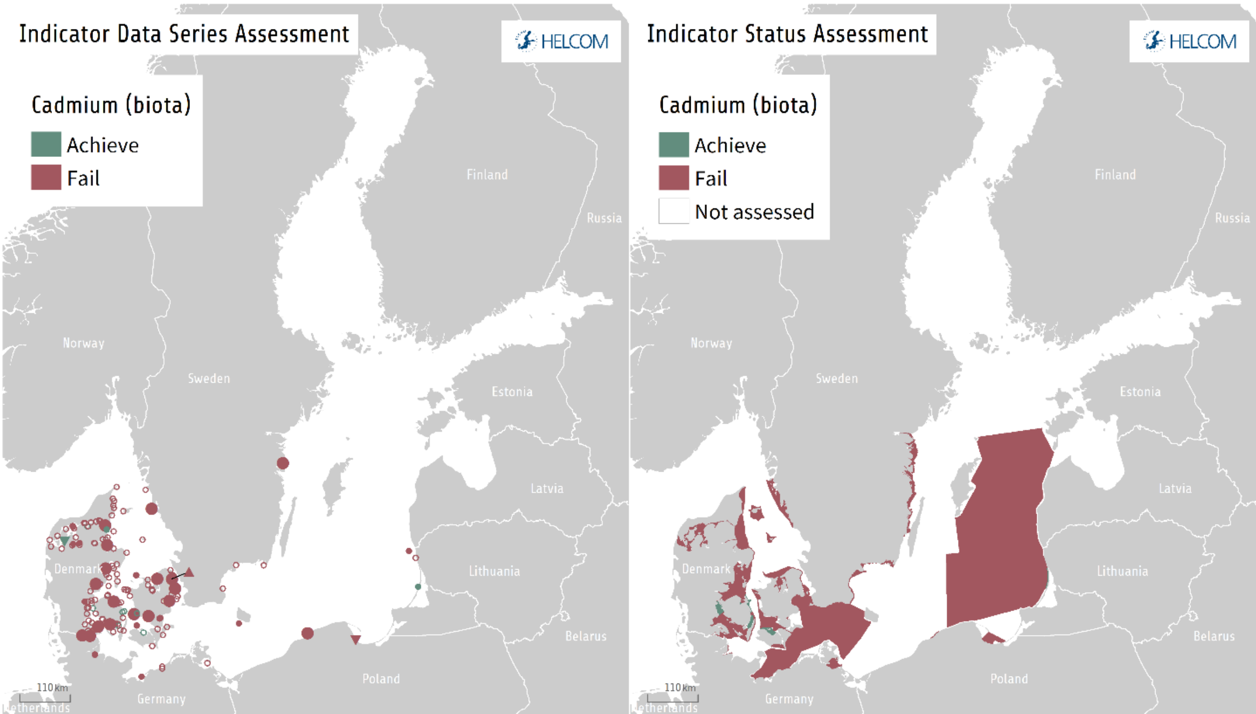
Biota - Mussels

The assessment of Cd levels in biota was carried out only on the basis of Cd concentrations in the mussel tissue. Soft body tissue of mussel is a secondary matrix for the Cd status assessment. There is no data available in northern part of the Baltic Sea, while in the western part the coverage of sampling stations is more dense (Results figure 4).

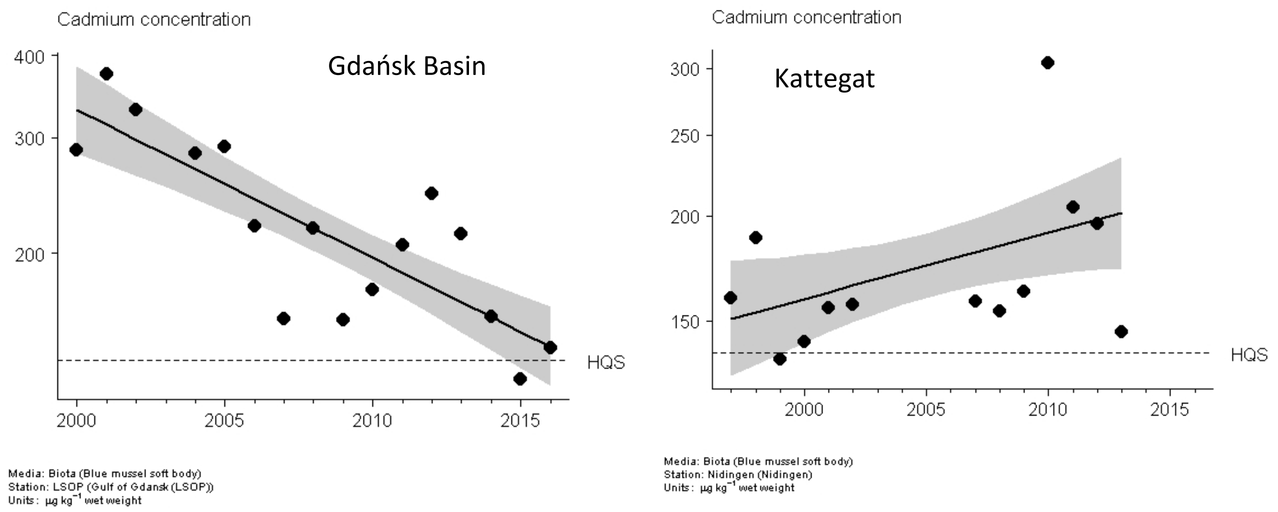
At most sampling stations the representative concentrations of Cd in mussel exceeded the threshold value (960 µg kg^{-1} dry weight), which was recalculated to wet weight (137.3 µg kg^{-1} wet weight) as the majority of data is reported as concentration expressed in wet weight.

The mean concentrations calculated for three open sea sub-basins exceeded the threshold level in the Bay of Mecklenburg (351.2 µg kg^{-1} wet weight), the Arkona Basin (186.4 µg kg^{-1} wet weight) and in the Eastern Gotland Basin (297.0 µg kg^{-1} wet weight) (Key message figure 2).

In some areas statistically significant decreasing and increasing trends could be detected, some examples of which are presented in the Results figure 5.



Results figure 4. Map presenting station based status of cadmium concentrations in biota - mussels (left) and assessment unit based status for cadmium in biota (right). Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Cadmium.**

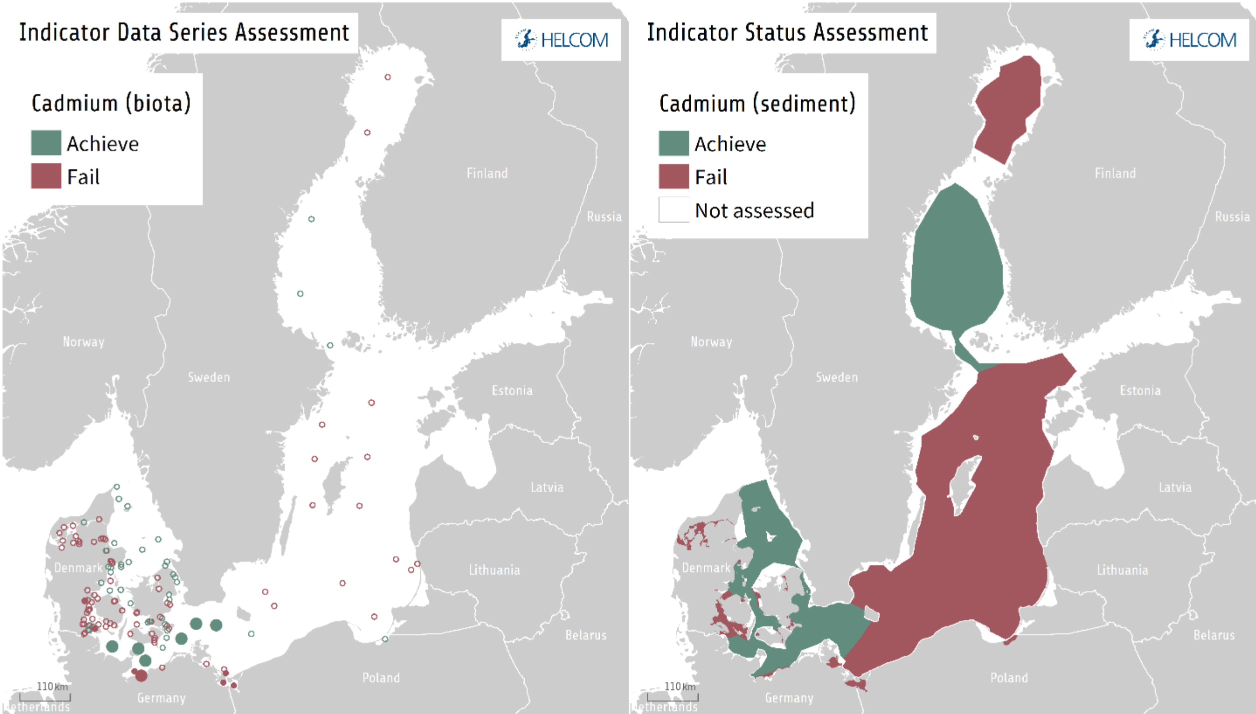


Results figure 5. Long-term trends of cadmium concentrations in mussel at chosen stations (HQS – threshold level, grey colour-confidence level 95% range (see Assessment protocol)).

Sediment

The assessment based on the Cd concentrations in bottom sediments showed that good status was achieved in the Bothnian Sea and in the Åland Sea in the north, and in the Arkona Basin, Bay of Mecklenburg, Kiel Bay, Great Belt, The Sound and Kattegat in the west (Key message figure 2). Good status was not achieved in five main open sea sub-basins: the Northern Baltic Proper, Western Gotland Basin, Eastern Gotland Basin, Gdańsk Basin and Bornholm Basin, nor in some Polish, German and Danish coastal areas.

Taking into account individual stations (Results figure 6), the lowest mean concentration of Cd in sediments (0.1 mg kg^{-1} dry weight) was found in at the Great Belt. The concentrations at the levels between 0.2 and 0.4 mg kg^{-1} dry weight were specific to the Kattegat, The Sound, Kiel Bay, Bothnian Sea and the Åland Sea. The highest mean concentrations, markedly exceeding the threshold value of 2.3 mg kg^{-1} dry weight, were found in the Eastern Gotland Basin (8.1 mg kg^{-1} dry weight), Western Gotland basin (7.5 mg kg^{-1} dry weight) and Northern Baltic Proper (6.1 mg kg^{-1} dry weight).



Results figure 6. Map presenting station based status of cadmium concentrations in sediment (left) and assessment unit based status for cadmium in sediment (right). Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Cadmium.**

Lead

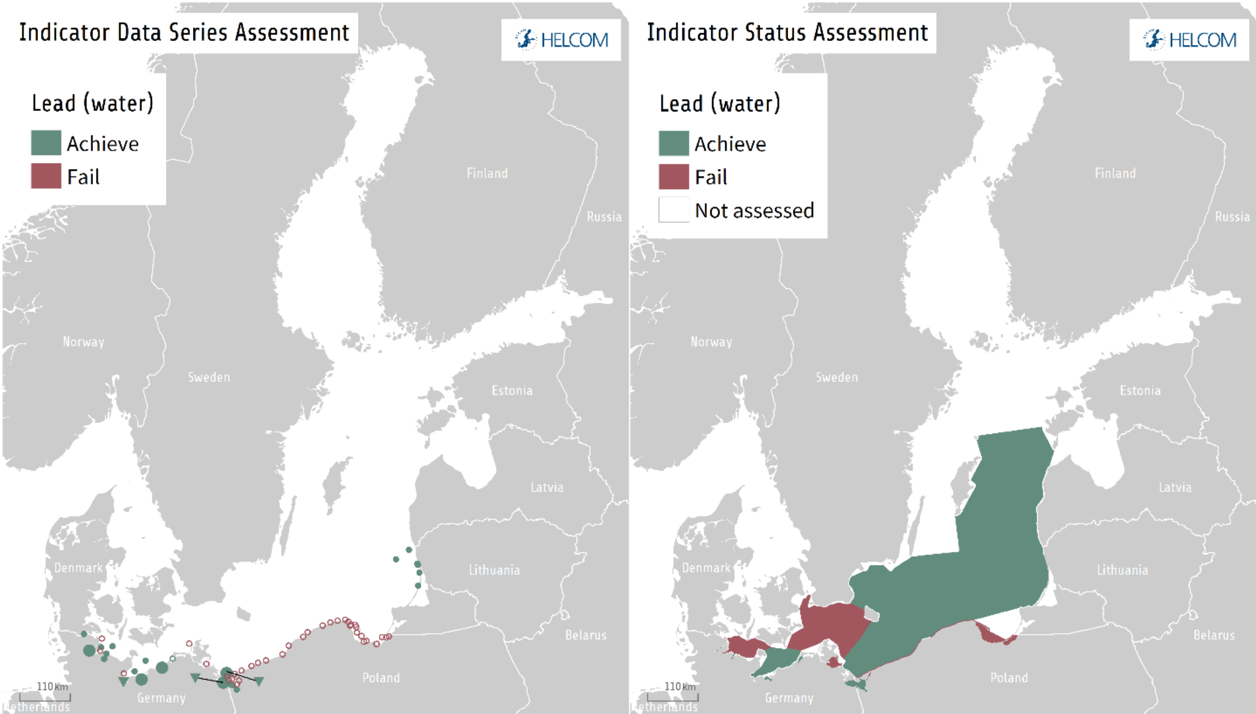
Seawater

The primary matrix for lead (Pb) is water, thus an EQS value has only been suggested for water. This is in conflict with the HELCOM Combine monitoring program, where the preferred matrix is biota and sediment (see discussion on Good Environment Status). As a result, very little data is available for lead in water.

Some long-term results for lead concentrations in seawater exist, as measurements by Russia (1995–1998), Germany (1998–2016), Lithuania (2007–2016) and Poland (2011-2016).

The assessment based on Pb concentrations in seawater showed that good status was achieved in three open sea sub-basins: Eastern Gotland Basin, Bornholm Basin and in Bay of Mecklenburg, as opposed to Kiel Bay and Arkona Basin that failed to achieve the threshold (Key message figure 3). Good status was also not achieved in the some Polish coastal areas and in one German coastal area, but it should be pointed out that status assessment is based on relatively short data series, as was the case for Cd.

In the Lithuanian coastal area the concentrations of Pb in seawater were below the threshold value, while in Polish coastal areas concentrations exceeded the threshold value of 1.3 µg l^{-1} (Results figure 7). The average concentrations of Pb in seawater were below the threshold value in the Bornholm Basin – 1.05 µg l^{-1}, the Bay of Mecklenburg - 0.24 µg l^{-1} and the Eastern Gotland Basin, 1.00 µg l^{-1}. In the Arkona Basin and in the Kiel of Bay the average representative Pb concentrations exceeded slightly the threshold value and were at the level of 1.6 µg l^{-1} indicating that good status was not achieved (Key message 3).



Results figure 7. Map presenting station based status of lead concentrations in water (left) and assessment unit based status for lead in water (right). Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Lead.**

Biota

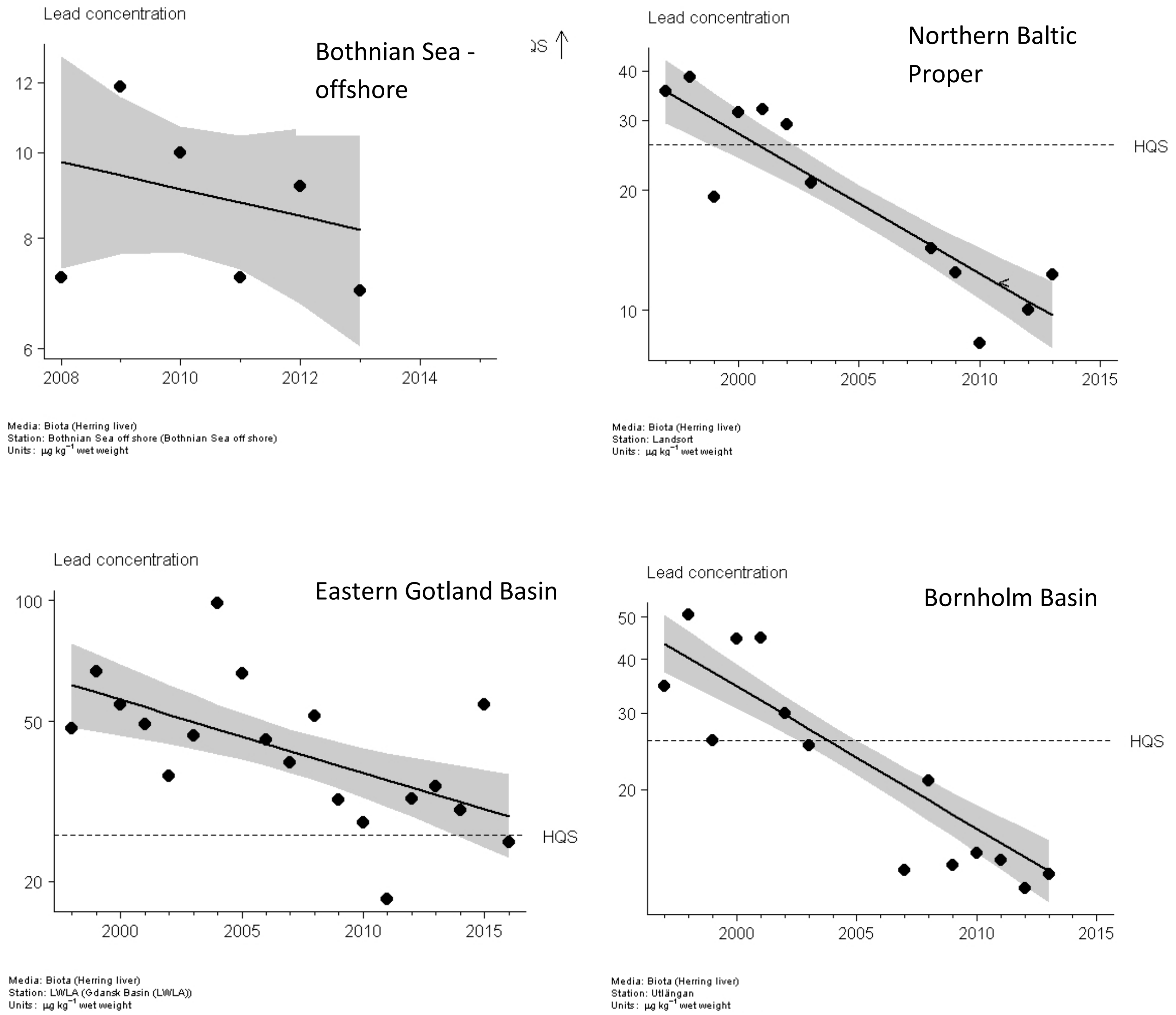
The assessment of Pb levels in organisms was carried out on the basis of Pb concentrations in fish liver and the mussel tissue (Key message figure 3). Taking into account main open sea sub-basins good status was achieved only in Bothnian Sea and in Kattegat, while in the Bothnian Bay, The Quark, Gulf of Finland, Western Gotland Basin, Eastern Gotland Basin, Gdańsk Basin, Bornholm Basin, Arkona Basin, Bay of Mecklenburg and in the Kiel Bay good status requirements have not been met.

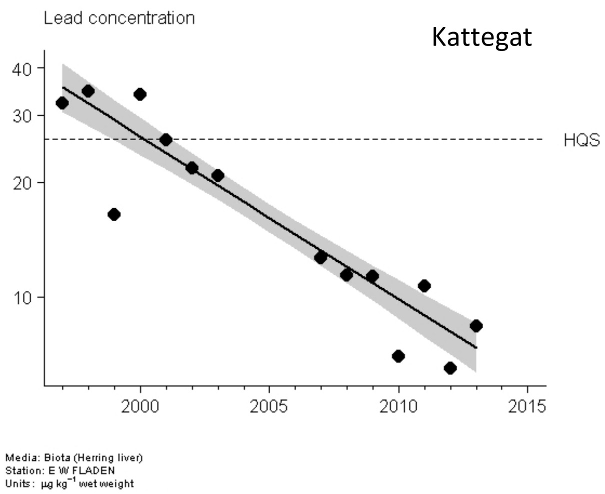
Fish

Fish liver is used as a secondary matrix for Pb assessment. The number of data on Pb in fish liver reported by HELCOM Contracting Parties is quite large and guaranties good coverage of the Baltic Sea (Results figure 10).

The lowest mean concentration of Pb in fish liver was found in the Kattegat (10.4 µg kg^{-1} wet weight), while the highest value, exceeding the 26 µg kg^{-1} wet weight several threshold value almost ten-fold, was specific to the Gulf of Finland (203.3 µg kg^{-1} wet weight). Relatively high concentrations were also found in the Eastern Gotland Basin (70.1 µg kg^{-1} wet weight) and in the Kiel Bay (49.9 µg kg^{-1} wet weight).

Considering temporal changes in Pb concentrations in liver of common Baltic fish species – herring and flounder, statistically significant decreasing trends were observed for fish from many of the Baltic Sea assessment areas (Result figure 8). This decrease is most probably the result of the ban on leaded fuels imposed in the 1980s.

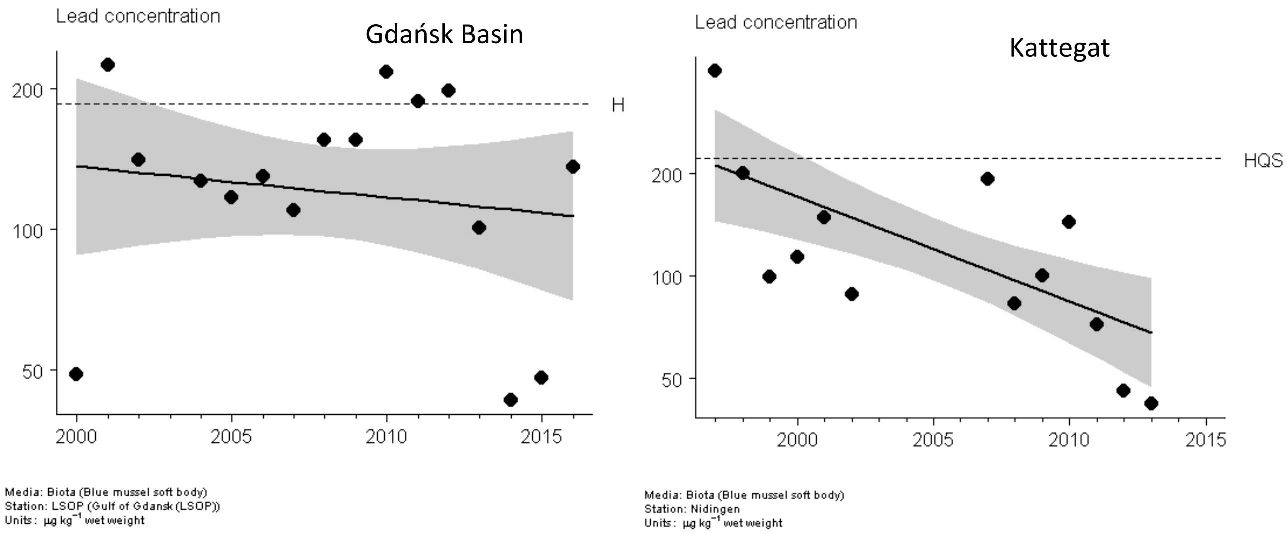




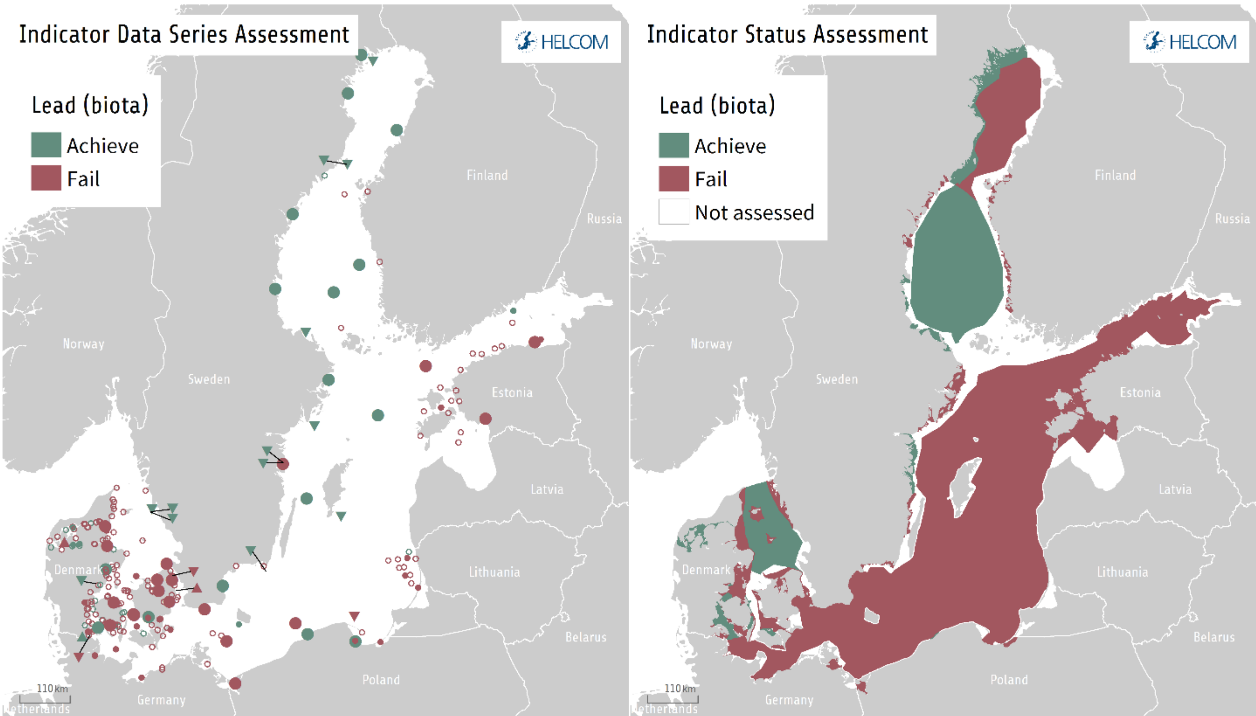
Results figure 8. Long-term trends of lead concentrations in fish liver at chosen stations (HQS –threshold value, grey colour- confidence level 95% range (see Assessment protocol)).

Mussels

Mussel soft body is another secondary matrix for monitoring of Pb levels in the Baltic Sea. Most of the stations, where this monitoring is carried out are located in the western part of the Baltic Sea (Results figure 10). Concentrations of Pb in mussel soft tissues found at that at certain single stations in the Polish coastal areas and in the Danish Straights good status was indicated, as they were below the threshold value (1300 µg kg^{-1} dry weight and 185.9 µg kg^{-1} wet weight after recalculation to the wet weight). However, at most locations good status was not achieved. At the same time, in some areas where the long-term measurements are being carried out, a downward trend is observed (Result figure 9).



Results figure 9. Long-term trends of lead concentrations in mussel at chosen stations (HQS –threshold value, grey colour- confidence level 95% range (see Assessment protocol)).

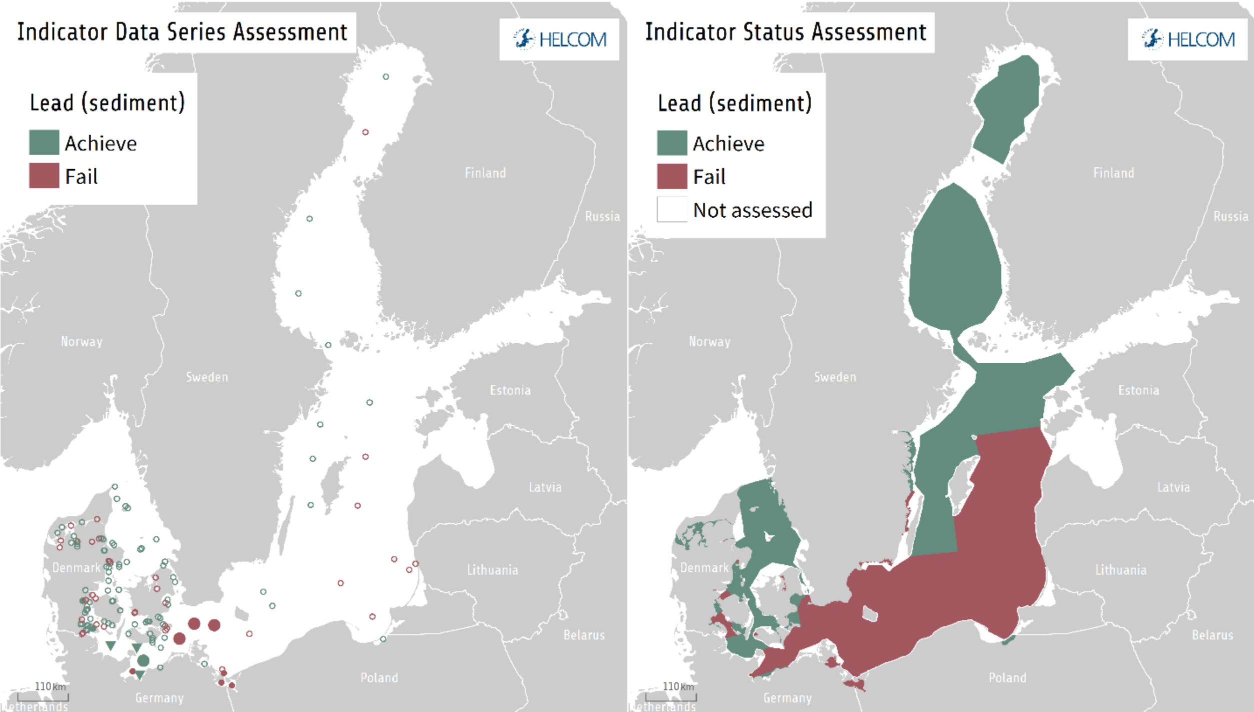


Results figure 10. Map presenting station based status of lead concentrations in biota - fish liver and mussels (left) and assessment unit based status for lead in all biota (right, see also figure 9). Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Lead.**

Sediment

The assessment based on the Pb concentrations in bottom sediments showed that good status was achieved in the Bothnian Bay, Bothnian Sea, Åland Sea, Northern Baltic Proper, Western Gotland Basin, Kiel bay, Great Belt and in the Kattegat, as well as in some of the German and Danish coastal areas (Key message figure 3 and Results figure 11). Good status was not achieved in five main open sea sub-basins: the Eastern Gotland Basin, Gdańsk Basin, Arkona Basin and Bay of Mecklenburg and in some Polish, German and Danish coastal areas.

The lowest mean concentrations of Pb in sediments, remaining significantly below the threshold value (120 mg kg^{-1} dry weight) were found in the Great Belt (21.3 mg kg^{-1} dry weight), Bothnian Sea (23.2 mg kg^{-1} dry weight) and in Åland Sea (25.8 mg kg^{-1} dry weight), while the highest value was specific to the Bornholm Basin (125.8 mg kg^{-1} dry weight).



Results figure 11. Map presenting station based status of lead concentrations in sediment (left) and assessment unit based status for lead in sediment (right). Map presenting status based on lead concentrations in sediment at each sampling station. Green colour represents good status and red colour represents not good status. Large filled triangles indicate data series of three or more years for which statistical trends could be assigned (upwards-increasing concentrations or downwards-decreasing concentrations), large filled circles triangles indicate data series of three or more years for which statistical trends could be assigned but where no detectible trend was observed, and full evaluation with MIME Script (see Assessment protocol) was carried out. Small filled circles represent data series of three or more years for which statistical trends could not be assigned due to specific data factors and open circles represent data series of less than three for which statistical trends could not be assigned due to data series length, and these data types are treated with initial status assessment (see Assessment protocol). **Click here to access interactive maps at the HELCOM Map and Data Service: Lead.**

Confidence in indicator status evaluation

The overall confidence of the indicator evaluation is **high**.

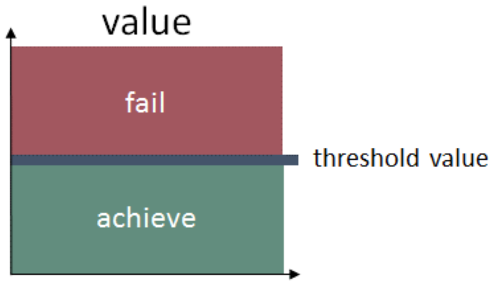
The accuracy of the estimation method is considered to be high, and the risk of false status classifications is considered to be very low. The underlying monitoring data is of high quality and regionally comparable.

The data on metal concentrations in seawater is not spatially adequate. Time series are available only for the German area: Bay of Mecklenburg, Bornholm Basin, Great Belt and Kiel Bay. For Eastern Gotland Basin (Lithuanian data) there are available data only for the period 2012-2014. The confidence of the results is low.

The data on metal concentrations in fish and bivalves is spatially adequate and time series are available for several stations, therefore the confidence in the results is high.

Thresholds and Status evaluation

Good Status is achieved if the concentrations of metals are below the specified threshold values boundary of (Thresholds figure 1).



Thresholds figure 1. Good status is achieved if the concentrations of metals are below the threshold values listed in Good status table 1.

The threshold values for metals are based on Environmental Quality Standards (EQS) for water and biota (Thresholds table 1) which have been defined at EU level for substances included in the priority list under the Water Framework Directive, WFD (European Commission 2000, 2013). The threshold can only be evaluated if concentrations are measured in the appropriate matrix. For historical reasons, the countries around the Baltic Sea have differing monitoring strategies. As a pragmatic approach, a threshold value is defined for primary matrix for each metal. However, if suitable monitoring data is not available in a region to evaluate the primary threshold, then the secondary threshold value can be used for the evaluation of alternative matrices (Good environmental status table 1). Under the WFD, Member States may establish other values than EQS for alternative matrices if specific criteria are met (see Art 3.3. in European Commission 2008a, revised in European Commission 2013).

Thresholds table 1. Threshold value for the included metals (EQS – Environmental Quality Standard, AA- Annual Average Concentration, QS – Quality Standard, BAC = Background Assessment Criteria).

	Threshold values					
Metal	Primary			Secondary		
	Matrix	Concentration	References	Matrix	Concentration	References
Cadmium	Water	AA 0.2 µg l^{-1}	EQS $_{water}$	Sediment	2.3 mg kg^{-1} d.w.	QS $_{sediment}$[1]
				Mussel	960 µg kg^{-1} d.w	OSPAR BAC
Mercury	Fish, mussel	20 µg kg^{-1} ww	EQS $_{biota}$ secondary poisoning	-	-	-
Lead	Water	AA 1.3 µg l^{-1}	EQS $_{water}$	Sediment	120 mg kg^{-1} d.w.	QS $_{sediment}$[1]
				Mussel	1300 µg kg^{-1} d.w	OSPAR BAC
				Fish	26 µg kg^{-1} w.w.	OSPAR BAC

[1] Applies to freshwater sediment (standard for marine sediment is currently not available). Sweden however considers this standard to be applicable also for assessment of the marine environment.

Assessment Protocol

The evaluation is carried out using an agreed R-script (MIME) that applies the statistical analysis.

To evaluate the contamination status of the Baltic Sea, the ratio of the concentration of a metal to the specified concentration (threshold) levels is used for each biotic and abiotic elements (matrix) of the marine environment. A ratio above 1 therefore indicates non-compliance (failure to meet threshold). Taking into account the scope of monitoring programmes implemented by the EU MS regarding heavy metals, and the target concentrations of individual elements, the appropriate measurement matrices were recommended to allow the use of results in Descriptor 8 (Assessment protocol table 1).

All available data on cadmium (in seawater, biota-mussels and bottom sediments), mercury (in biota-fish muscle) and lead (in seawater, fish liver and bottom sediments) concentrations up to 2016, reported by HELCOM Contracting Parties to the HELCOM COMBINE database, were used to assess the state of the Baltic Sea environment.

The assessment of the present environmental status in respect of heavy metal content has been carried out in all assessment units at scale 4, where data availability was sufficient.

The basis for the assessment carried out in the sub-basins was the determination of the concentrations of individual metals in the respective matrices for each station, which were then compared with threshold values to determine the contamination ratio (CR). Good status in respect of single element is scored if CR ≤1.

A two-way approach was used to determine the **representative concentrations** of the individual metals in the individual matrices. In the case of stations where long-term data series exist, the agreed script (MIME Script) was used. This method allows determination of the upper value of the 95% confidence level which is regarded as a **representative concentration**. In the case of stations where data are from 1-2 years only or 'less-than' values make the correct assignment of the above statistical procedures impossible then data are treated as 'initial' data. All initial data is handled in a highly precautionary manner to further ensure that the risk of false positives is minimalised. For all initial data the 95% confidence limit on the mean concentration, based on the uncertainty seen in longer time series throughout the HELCOM area, is used. Applying a precautionary approach, the 90% quantile (psi value, Ψ) of the uncertainty estimates in the longer time series from the entire HELCOM region are used. The same approach is used for time series with three or more years of data, but which are dominated by less-than values (i.e. no parametric model can be fitted). The mean concentration in the last monitoring year (meanLY) is obtained by: restricting the time series to the period 2011-2016 (the last six monitoring years), calculating the median log concentration in each year (treating 'less-than' values as if they were above the limit of detection), calculating the mean of the median log concentrations, and then back-transforming (by exponentiating) to the concentration scale. The upper one-sided 95% confidence limit (clLY) is then given by: exp(meanLY + qnorm(0.95) * Ψ / sqrt(n)), where n is the number of years with data in the period 2011-2016 (HELCOM 2018).

The detailed description of MIME Script method can be found:
for biota http://dome.ices.dk/osparmime/help_methods_biota_metals.html

for sediment http://dome.ices.dk/osparmime/help_methods_sediment_metals.html

In order to ensure comparability of the measurements to the core indicator threshold value, the data to be extracted from the HELCOM COMBINE database has been defined in a so called 'extraction table'. Relevant sections of the extraction table are presented in Assessment protocol Table 1.

Assessment protocol Table 1. HELCOM COMBINE 'extraction table' relevant to the Metals core indicator. Overview table of the parameters, matrices, basis and supporting parameters selected for extraction from the COMBINE database to evaluate the core indicators

Supporting parameters or parameters underlined within the table are those used for the current indicator assessment.

WT = water, MU = muscle, SB = soft body, LI = liver, MU&EP = muscle and epidermis, WW = wet weight, DW = dry weight.

Indicator, threshold value and parameter			Primary matrix or primary threshold					Secondary matrix or secondary threshold				
Indicator	**Threshold value** (previously GES boundary)	**Parameters (PARAM) / Parameter groups (PARGROUP)** (see also http://vocab.ices.dk/)	**Primary matrix / GES**	**Species**	**Matrix**	**Basis**	***Supporting parameters and information***	***Secondary matrix / GES***	***Species***	***Matrix***	***Basis***	***Supporting parameters and information***
Metals (Cd)	**Primary threshold** EQS water 0.2 µg/l	PARAM = CD	Water		WT filtered or unfiltered NOTE 1		Surface water layer (≤ 5.5 m)					
	Secondary threshold OSPAR BAC 960 µg/kg dw mussels.	PARAM = CD						Biota	Molluscs (M edulis + M. baltica)	SB	WW	DW
	Secondary threshold QS from EQS dossier 2.3 mg/kg sediment	PARAM = CD						Sediment (surface, ICES 'upper sediment layer - 0-X cm')		All	DW	Al NOTE 2 Li CORG Grain size
Metals (Pb)	**Primary threshold** EQS water 1.3 µg/l	PARAM = PB	Water		WT filtered or unfiltered NOTE 1		Surface water layer (≤ 5.5 m)					

	Secondary threshold OSPAR BAC 26 µg/kg ww fish liver OSPAR BAC 1300 µg/kg dw mussels	PARAM = PB						Biota	Herring & cod (open sea) Flounder, dab, eelpout & perch(coastal) Molluscs (M edulis + M. baltica)	LI SB	WW WW	DW DW
	Secondary threshold QS from EQS dossier 120 mg/kg sediment	PARAM = PB						Sediment (surface, ICES 'upper sediment layer - 0-X cm')		All	DW	Al [NOTE 2] Li CORG Grain size
Metals (Hg)	**Primary threshold** EQS biota secondary poisoning 20 µg/kg ww	PARAM = HG	Biota	Herring & cod (open sea) Flounder, dab, eelpout & perch (coastal) Molluscs (M. edulis + M. baltica)	MU ('fillet') SB	WW WW	DW DW					

NOTE 1: Filtered and unfiltered samples for Cd and Pb are currently used. Filtered and unfiltered data are never combined and, when pressent in the same assessmnet two assessments are run in parallel. When aggregating data from different assessments (i.e. aggregating multiple data sets for a single HELCOM assessment unit) the most abundant data set (i.e. filtered or unfiltered) is used, and the other excluded. This process results in minimal exclusion of samples when aggregating at the assessment unit level.

NOTE 2: Metals should be normalized to 5% Al.

The assessment of the present environmental status in respect of heavy metal content should be carried out, if possible – regarding data availability, in all assessment units (assessment units at scale 4).

Assessment units

The core indicator evaluates the status with regard to concentrations of metals using HELCOM assessment unit scale 4 (division of the Baltic Sea into 17 sub-basins division into coastal and offshore areas, and the coastal areas further divided into WFD water types or bodies).

The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

Relevance of the Indicator

Hazardous substances assessment

The status of the Baltic Sea marine environment in terms of contamination by hazardous substances is assessed using several core indicators. Each indicator focuses on one important aspect of the complex issue. In addition to providing an indicator-based evaluation of the status of the Baltic Sea in terms of concentrations of metals in the marine environment, this indicator also contributes to the overall hazardous substances assessment along with the other hazardous substances core indicators.

Policy relevance

The core indicator on metal concentrations addresses the Baltic Sea Action Plan's (BSAP) hazardous substances segment's ecological objectives 'Concentrations of hazardous substances close to natural levels' and 'All fish safe to eat'. Mercury and cadmium are included in the HELCOM list of substances or substance groups of specific concern to the Baltic Sea.

The core indicator also addresses the following qualitative descriptors of the MSFD for determining good environmental status (European Commission 2008b):

- Descriptor 8: 'Concentrations of contaminants are at levels not giving rise to pollution effects' and
- Descriptor 9: 'Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards'

and the following criteria of the Commission Decision (European Commission 2017):

- D8C1 Within coastal, territorial and areas beyond territorial waters the concentration of contaminants do not exceed the threshold values
- D9C1 The level of contaminants in edible tissues of seafood caught or harvested in the wild does not exceed maximum levels which are the threshold values.

All three metals are included in the EU WFD (Pb and Cd in water, Hg in biota) and EU Shellfish directive (in shellfish) (European Commission 2000, 2006b). Part of the EU food directives set limits in a range of fish species, shellfish and other seafood. In the OSPAR Coordinated Environmental Monitoring Programme (CEMP), metals are to be measured on a mandatory basis in fish, shellfish and sediment (OSPAR 2010).

Article 3 of the EU directive on environmental quality standards states that also long-term temporal trends should be assessed for substances that accumulate in sediment and/or biota (European Commission 2008a).

Role of metals in the ecosystem

Metals are naturally occurring substances that have been used by humans since the Iron Age. The metals cadmium (Cd), lead (Pb) and mercury (Hg) are the most toxic and they have no known essential biological function. Furthermore, mercury and cadmium biomagnify, implying that the toxic effect may be enhanced at higher levels in the food web. For mercury, the organic form methyl-mercury (MeHg) is more toxic than elemental mercury and this form is readily bioaccumulated, i.e. activity transferred to lipid containing organs. Due to its high evaporation pressure, the net transport is from soils in the tropics up to Scandinavia to the Baltic Sea, and further north until concentrating in the Arctic due to the low temperatures and the resulting low evaporation - a process known as global distillation or the grasshopper effect.

Lead and mercury have been connected to impaired learning curves for children, even at small dosage. Lead can cause increased blood pressure and cardio-vascular problems in adults. Acute metal poisoning generally results in vomiting. Long term exposures of high levels of lead and mercury can affect the neurological system. Mercury can lead to birth defects as seen in Minamata Bay among fishermen in a mercury polluted area, and also after ingestion of methylmercury treated corn in Iran. Cadmium is concentrated in the kidney, and can result in impaired kidney function, and cadmium can exchange for calcium in bones and produce bone fractures (Itai-Itai disease).

Human pressures linked to the indicator

	General	MSFD Annex III, Table 2a
Strong link		Substances, litter and energy • Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events
Weak link		

The main source of all three metals is burning of fossil fuels. The atmospheric deposition to the Baltic Sea mainly originates from long range transport of the metals from outside the Baltic Sea catchment area (details available through the Baltic Sea Environment Fact Sheet Atmospheric deposition of heavy metals on the Baltic Sea). All three metals have been used for centuries, but in the last decades EU or world-wide legislation has been put in place banning most uses.

Current legal use of cadmium and lead includes rechargeable Ni-Cd batteries and for lead car batteries. For mercury current legal use includes low energy light sources. Sources of mercury include use in amalgams for dentistry (the loss from this use have been reduced by installing mercury traps in sinks and generally reducing the use of amalgams in dental works), as electrodes in paper bleaching, in thermometers and mercury switches and a range of other products that have been phased out. For lead, the main source was leaded fuels until their ban in Europe in the 1990s. Both cadmium and lead have pollution hotspots in connection with metal processing facilities, and cadmium coexists with all zinc ores, and is typically present at levels of 0.5–2% in the final products. Weathering of outdoor zinc-products thus leads to cadmium pollution.

Monitoring Requirements

Monitoring methodology

HELCOM common monitoring of relevance to the indicator is described on a general level in the **HELCOM Monitoring Manual** in the **programme topic: Concentrations of contaminants.**

Quality assurance in the form of international workshops and proficiency testing has been organized annually by QUASIMEME since 1993, with two rounds each year for water, sediment and biota.

Current monitoring

The monitoring activities relevant to the indicator that is currently carried out by HELCOM Contracting Parties are described in the **HELCOM Monitoring Manual** in the relevant Monitoring Concept Tables.

Sub-programme: Contaminants in biota
Monitoring Concept Table

Sub-programme: Contaminants in water
Monitoring Concept Table

Sub-programme: Contaminants in sediment
Monitoring Concept Table

Concentrations of cadmium, mercury and lead are being monitored by all the Baltic Sea countries. In addition to long-term monitoring stations of herring, cod, perch, flounder and eelpout, there is a fairly dense grid of monitoring stations for mussels and perch at the shoreline, but very few stations in the open areas of the Baltic Sea. The monitoring is, however, considered to be representative.

Description of optimal monitoring

Cadmium, mercury and lead concentrations are spatially highly varying in the Baltic Sea. Therefore, a dense network of monitoring stations is needed to have reliable overviews of the state of the environment. The monitoring should contain both long-lived and mobile species (herring, cod, flounder) and more local species (perch and shellfish).

Sediment monitoring can complement the assessment. Sediment represents longer timespans than biota (typically years vs. months), and are available in all places, whereas especially local species are not always available for spatial surveys. Time-trends from dated sediment cores in undisturbed (anoxic) areas can be a valuable source of information on the development in concentrations from before monitoring was started and even back to pre-industrialized times.

Monitoring of cadmium, mercury and lead is relevant in the entire sea area.

Data and updating

Access and use

The data and resulting data products (tables, figures and maps) available on the indicator web pages can be used freely given that the source is cited. The indicator should be cited as following:

HELCOM (2018) Metals (lead, cadmium and mercury). HELCOM core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543

Metadata

Result: Heavy metals - Cadmium (Cd)

Data: Heavy metals - Cadmium (Cd) sediment data

Data: Heavy metals - Cadmium (Cd) water data

Data: Heavy metals - Cadmium (Cd) biota data

Result: Heavy metals – Lead (Pb)

Data: Heavy metals – Lead (Pb) sediment data

Data: Heavy metals – Lead (Pb) water data

Data: Heavy metals – Lead (Pb) biota data

Result: Heavy metals – Mercury (Hg)

Data: Heavy metals – Mercury (Hg) biota data

The indicator is based on data held in the HELCOM COMBINE database, hosted at the International Council for the Exploration of the Seas (ICES).

Contributors and references

Contributors

Tamara Zalewska, Martin M. Larsen, Rob Fryer, Sara Danielsson, Elisabeth Nyberg, and HELCOM EN-HZ (HELCOM Expert Group on hazardous substances).

Archive

This version of the HELCOM core indicator report was published in July 2018

Metals HELCOM core indicator 2018 (pdf)

Older versions of the core indicator report are available:

HOLAS II component - core indicator report – web-based version July 2017 (pdf)

2013 Indicator report (pdf)

References

Bignert, A., Berger, U., Borg, H., Danielsson S., Eriksson, U., Faxneld, S., Haglund, P., Holm, K., Nyberg, E., Nylund, K. (2012) Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota. Report to the Swedish Environmental Protection Agency 2012. 228 pp.

European Commission (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Off. J. Eur. Union L 327.

European Commission (2006a) Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Off. J. Eur. Union L 364.

European Commission (2006b) Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters. Off. J. Eur. Union L 376.

European Commission (2008a) Directive 2008/105/EC of the European Parliament and the Council on environmental quality standards in the field of water policy (Directive on Environmental Quality Standards). Off. J. Eur. Union L 348.

European Commission (2008b) Directive 2008/56/EC of the European Parliament and the Council establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Off. J. Eur. Union L 164: 19-40.

European Commission (2010) Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU). Off. J. Eur. Union L232: 12-24.

European Commission (2013) Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. Off. J. Eur. Union L 226: 1-17.

Grasshoff, K., Kremling, K., Ehrhardt, M. (eds) (1999) Methods of Seawater Analysis, Weinheim. Wiley-VCH. 600 pp.

HELCOM (2010) Hazardous substances in the Baltic Sea – An integrated thematic assessment of hazardous substances in the Baltic Sea. Balt. Sea Environ. Proc. No. 120B.

Law, R., Hanke, G., Angelidis, M., Batty, J., Bignert, A., Dachs, J., Davies, I., Denga, Y., et al. (2010) MARINE STRATEGY FRAMEWORK DIRECTIVE Task Group 8 Report Contaminants and pollution effects. JRC Scientific and Technical Reports.

OSPAR (2008) Monitoring and Assessment Series Publication Number No. 379

OSPAR (2010) OSPAR Quality Status Report 2010. OSPAR Commission, London. 176 pp. Available at: http://qsr2010.ospar.org/en/downloads.html

Additional relevant publications

Bignert, A., Danielsson, S., Faxneld, S., Nyberg, E., Vasileiou, M., Fång, J., Dahlgren, H., Kylberg, E., Staveley Öhlund, J., Jones, D., Stenström, M., Berger, U., Alsberg, T., Kärsrud, A.-S., Sundbom, M., Holm,K., Eriksson, U., Egebäck, A.-L., Haglund, P., Kaj, L. (2015) Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota 2015, 2:2015. Swedish Museum of Natural History, Stockholm, Sweden.

Jensen, J.N. (2012) Temporal trends in contaminants in Herring in the Baltic Sea in the period 1980-2010. HELCOM Baltic Sea Environment Fact Sheet 2012.

OSPAR CEMP Assessment Manual. Co-ordinated Environmental Monitoring Programme Assessment Manual for contaminants in sediment and biota. OSPAR Commission, London. 39 pp.

OSPAR (2009) Draft Agreement on CEMP Assessment Criteria for the QSR 2010. Meeting of the Environmental Assessment and Monitoring Committee (ASMO), Bonn, Germany, 20 - 24 April 2009.

HELCOM core indicator report
ISSN: 2343-2543