HELCOM

Mercury

INDICATOR TYPE: Core

INDICATOR CATEGORY: State

BSAP SEGMENT: Hazardous substances and litter

MSFD CRITERIA: D8C1

Hg

Mercury

Table of Contents

1 Key message

This core indicator evaluates the status of the marine environment based on concentrations of mercury in biota (fish muscle and mussel soft tissue) in the Baltic Sea. Good status is achieved when the concentrations of mercury are below the regionally agreed threshold values.

The indicator presents a status evaluation using all monitoring data for the HELCOM region during the assessment period 2016 – 2021 (Figure 1).

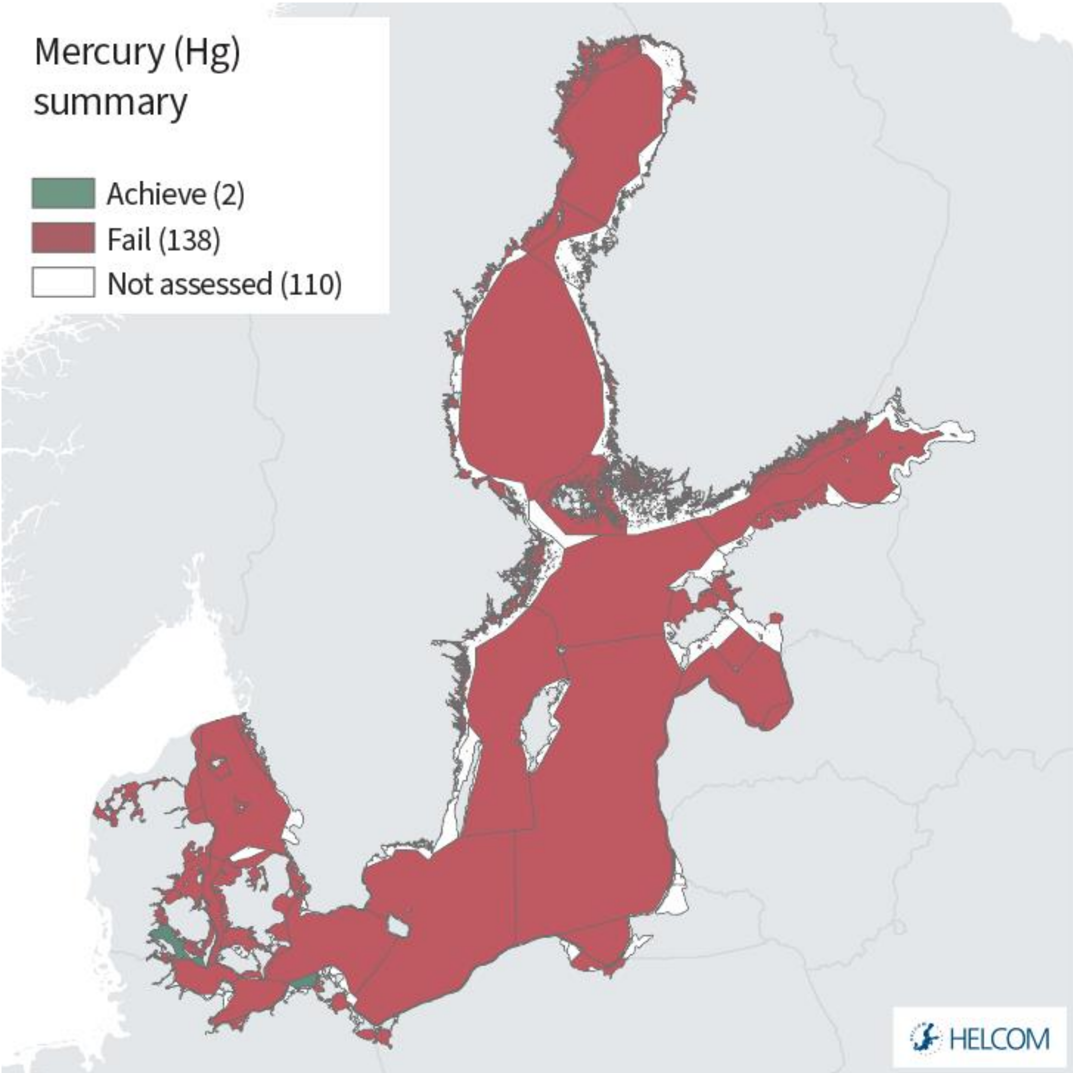

Figure 1. Status evaluation results based for mercury concentrations in fish and mussels. The evaluation is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **See 'data chapter' for interactive maps and data at the HELCOM Map and Data Service.**

Mercury (Hg) concentrations in fish muscle exceeded the threshold level in all 16 (of 17) evaluated open sea assessment units. In addition, of the 124 coastal assessment units evaluated all but 2 failed to achieve the threshold value (i.e. only two were in Good

Environmental Status, GES). The assessment units where GES was recorded were GER-010 and DEN-216, coastal areas of the Great Belt and Bornholm Basin, respectively.

The confidence of the indicator evaluation is moderate, with high confidence in certain assessment units. The data on mercury concentrations is spatially adequate and time series are available for several stations across the region.

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

1.1. Citation

The data and resulting data products (e.g. tables, figures and maps) available on the indicator web page can be used freely given that it is used appropriately and the source is cited. The indicator should be cited as follows:

HELCOM (2023) Mercury. HELCOM Core Indicator Report. Online. [Date Viewed], [Web link].

ISSN: 2343-2543

2. Relevance of the indicator

Mercury has historically entered the Baltic Sea at elevated levels due to human activities and has known negative environmental impacts where concentrations exceed acceptable levels. There remain key inputs for example due to combustion activities and also from other relevant global processes that result in current inputs to the Baltic Sea.

2.1. Ecological relevance

Metals are naturally occurring substances that have been used by humans since the Iron Age. Heavy metals, including mercury (Hg) are toxic to wildlife and humans, and even at low levels, they can be harmful to organisms. The severity of the effect mainly depends on the concentration in the tissues. When heavy metals bioaccumulate in tissues they can cause different biological effects on the individual organism, which transform into changes at the population, then species level, and finally affect biodiversity and ecosystem functioning.

Mercury (Hg) is one of the most toxic metals (UNEP 2013, 2019) and it has no known essential biological function. Even low levels of Hg in the body can lead to disruptions of important biochemical processes, and irreversible damage to the nervous system and brain functions (Axelrad *et al*. 2007). The metal has also hepatotoxic, embryotoxic and mutagenic properties and may lead to cardiovascular disorders (Roman *et al*. 2011).

Mercury is a stable and mobile element that accumulates in living organisms and biomagnifies in the food chain, thus exposure to Hg may be enhanced at higher levels of the food chain (Kwasigorch *et al*. 2020). The toxicity of Hg depends on the form in which the element occurs. Its labile forms can be more easily transformed and absorbed by organisms, whereas stable forms are not bioavailable (Kwasigorch *et al*. 2020). The most toxic form of this metal is highly bioavailable methylmercury (MeHg), which is formed in the presence of bacteria by the process of methylation (Boeing 2000; Kwasigorch *et al*. 2020). This mercury form has a high affinity for protein and is stored in protein rich tissues like muscle tissue.

2.2. Policy relevance

The core indicator evaluating concentrations of the metal Mercury (Hg) addresses a major goal and various ecological objectives of the Baltic Sea Action Plan (BSAP 2021). This includes the goal of the hazardous substances and litter segment of a 'Baltic Sea unaffected by hazardous substances (and litter)', and key ecological objectives of: 'Marine life is healthy', 'Concentrations of hazardous substances are close to natural levels', and 'All sea food is safe to eat'. There is also relevance for the BSAP biodiversity goals (Table 1).

The core indicator also addresses the following qualitative descriptors of the MSFD for determining good environmental status (European Commission 2008a), in particular being of direct relevance to Descriptor 8 and of significance for Descriptor 9 as set out under the specific Descriptors and Criteria in Commission Decision (EU) 2017/848.

Mercury is listed as a priority substance (European Commission 2013), monitoring under the EU Water Framework Directive is done in the biota matrix (European Commission 2000). As highly toxic, mercury is included in the recommendations concerning the acceptable levels in products for consumption including seafood (Commission Regulation (EC) No 1881/2006, European Commission 2006a).

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 2008b).

Table 1. Overview of key policy relevance elements.

<table>
<tr><th></th><th>Baltic Sea Action Plan (BSAP)</th><th>Marine Strategy Framework Directive (MSFD)</th></tr>
<tr><td>Fundamental link</td><td>Segment: Hazardous substances and litter goal
Goal: “Baltic Sea unaffected by hazardous substances and litter”
• Ecological objective: “Marine life is healthy”, “Concentrations of hazardous substances are close to natural levels” and “All sea food is safe to eat”.
• Management objective: “Minimize input and impact of hazardous substances from human activities”.</td><td>Descriptor 8 Concentrations of contaminants are at levels not giving rise to pollution effects.
• Criteria 1 The health of species and the condition of habitats (such as their species composition and relative abundance at locations of chronic pollution) are not adversely affected due to contaminants including cumulative and synergetic effects.
• Feature – Contaminants list.
• Element of the feature assessed – Contaminants list.</td></tr>
<tr><td>Complementary link</td><td>Segment: Biodiversity
Goal: “Baltic Sea ecosystem is healthy and resilient”
• Ecological objective: “Viable populations of all native species”, “Natural distribution, occurrence and quality of habitats and associated communities”, and “Functional, healthy and resilient food webs”.
• Management objective: “Reduce or prevent human pressures that</td><td>Descriptor 9 Contaminants in fish and other seafood for human consumption do not exceed levels established by Union legislation or other relevant standards.
• Criteria 1 The level of contaminants in edible tissues (muscle, liver, roe, flesh or other soft parts, as appropriate) of seafood (including fish, crustaceans, molluscs, echinoderms, seaweed and other marine plants) caught or harvested in the wild (excluding fin-fish from mariculture) does not exceed:
(a) for contaminants listed in Regulation (EC) No 1881/2006, the</td></tr>
</table>

	lead to imbalance in the foodweb".	maximum levels laid down in that Regulation, which are the threshold values for the purposes of this Decision; (b) for additional contaminants, not listed in Regulation (EC) No 1881/2006, threshold values, which Member States shall establish through • Feature – Contaminants in seafood. • Element of the feature assessed – Contaminants in Foodstuffs Regulation.
Other relevant legislation:	• The Water Framework Directive (Hg is listed as priority substances). • UN Sustainable Development Goal 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) is most clearly relevant, though SDG 12 (Ensure sustainable consumption and production patterns) and 13 (Take urgent action to combat climate change and its impacts) also have relevance.	

2.3. Relevance for other assessments

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 mercury in the marine environment, this indicator also contributes to the overall hazardous substances assessment along with the other hazardous substances core indicators. This indicator along with the other hazardous substances core indicators is used to develop an overall assessment of contamination status by inclusion in the integrated assessment of hazardous substances.

3. Threshold values

Good Environmental Status (GES) is achieved when the concentrations of metals are below the specified threshold value, as illustrated in Figure 2.

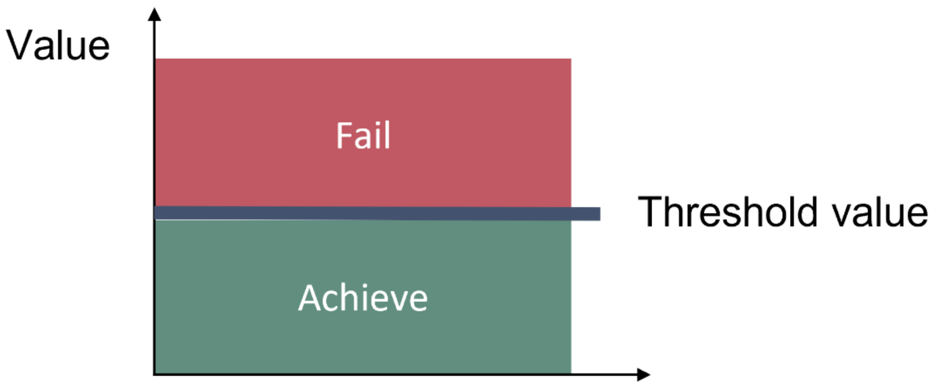

Figure 2. Good Environmental Status (GES) is achieved if the concentrations of metals are below the agreed threshold value.

The threshold value for mercury in biota is based on Environmental Quality Standards (EQS) (Table 2) 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 only for the primary matrix. In the case of mercury, a threshold value is defined only for primary matrix which is fish muscle and mussel soft tissue.

Table 2. Threshold value for Mercury (EQS – Environmental Quality Standard, AA- Annual Average Concentration, QS – Quality Standard, BAC = Background Assessment Criteria). Underlined supporting parameters represent parameters without which the indicator evaluation cannot be applied. MU = muscle, SB = soft body. Source for threshold value:
EC (2008): Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. OJ L 348:84

Indicator	**Threshold value**	**Parameters (PARAM) / Parameter groups (PARGROUP) (see also http://vocab.ices.dk/)**	**Matrix**	**Species**	**Matrix**	**Basis**	**Supporting parameters and information**
Metals (Hg)	Primary threshold EQS biota secondary poisoning: 20 µg/kg ww	PARAM = HG	Biota	Herring & cod (open sea) Flounder, sole, eelpout & Perch (coastal)	MU ('fillet')	W	Dry weight
				Molluscs (M edulis, + M. baltica + Dreissena polymorpha)	SB	W	Dry weight

3.1. Setting the threshold value(s)

The threshold value for mercury in biota is based on Environmental Quality Standards (EQS) which have been defined at EU level for substances included in the priority list under the Water Framework Directive, WFD (European Commission 2000, 2013).

4 Results and discussion

The results of the indicator evaluation that underlie the key message map and information are provided below.

4.1. Status evaluation

The data utilised in this core indicator is 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 mercury concentrations in selected marine matrices: fish (muscle and liver) and soft body of mussels for the assessment period 2016-2021, evaluated against a regionally agreed threshold value. The values presented in the report refer to the concentrations and mean values calculated from them, while the status evaluations are based on the so-called representative concentrations assessed against threshold values, which result from data evaluation (see Methodology), and are considered as values representative of status for the given assessment units.

Biota

The evaluation of the core indicator status is based on data on Hg concentrations in the muscles of fish of the following species: herring, cod, perch, flatfish, viviparous eelpout and soft tissues of mussels of the species: *Mytilus edulis* and *Macoma balthica*.

An evaluation was possible for 140 assessment units, of which 16 were open sea HELCOM sub-basins. All open sea assessment units failed to achieve the threshold value (i.e. were sub-GES) and all but two of the 134 coastal assessment units evaluated also failed to achieve GES (sub-GES) (Figure 3).

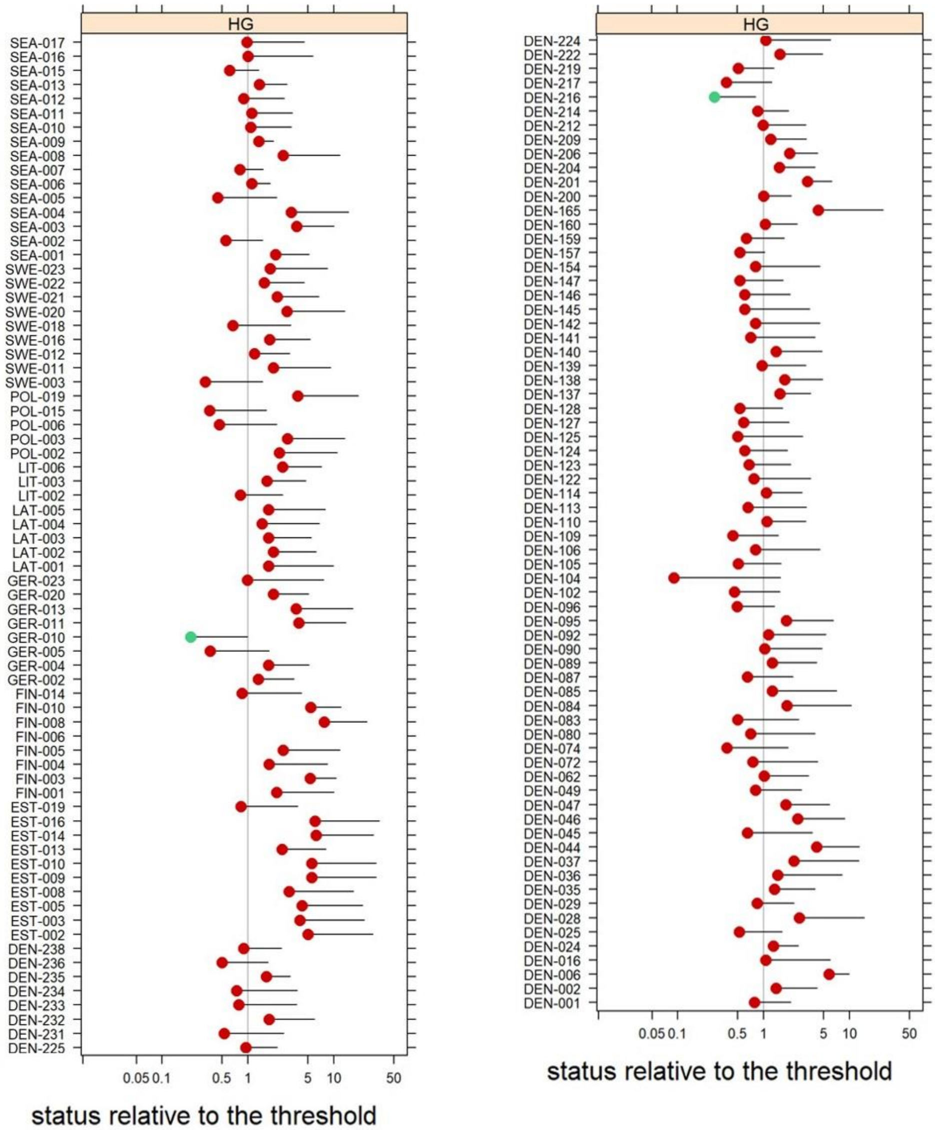

Figure 3. Overview of HELCOM Level 4 assessment units evaluated for Mercury (Hg) in biota. The 95% confidence limit on the mean concentration is presented. Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.

The concentration in the last year of the evaluation (i.e. the most recent concentration in any given data series) is informative of latest reference point and will occur in the current assessment period. At the station level (i.e. per data series) the concentrations in the last year of evaluation (μg kg^{-1} ww) varied, in cases somewhat widely even within a single sub-basin. This varied between and within the 17 HELCOM sub-basins when comparing all stations, inclusive of open sea and coastal, within each sub-basin. (Table 3). These values show the variation across sub-basins and also the latest station level concentrations in the assessment period but do not themselves reflect status as status is derived from the entire assessment period and is also influenced the 95% confidence limit on the mean concentration (as in Figure 3).

Table 3. Overview of number of stations within each HELCOM sub-basin (coastal and open sea), the mean value of the concentrations in the last year of evaluation across the stions and the lowest and largest of these values within each sub-basin.

HELCOM sub-basin	Mean (µg kg^{-1} ww)	Number of stations	Lowest concentration (µg kg^{-1} ww)	Largest concentration (µg kg^{-1} ww)
Kattegat (SEA-001)	30	69	6	166
Great Belt (SEA-002)	22	95	0	268
The Sound (SEA-003)	144	117	29	468
Kiel Bay (SEA-004)	42	2	20	64
Bay of Mecklenburg (SEA-005)	51	9	14	142
Arkona Basin (SEA-006)	160	31	6	1529
Bornholm Basin (SEA-007)	31	12	4	75
Gdansk Basin (SEA-008)	39	3	9	58
Eastern Gotland Basin (SEA-009)	32	28	6	70
Western Gotland Basin (SEA-010)	27	5	9	49
Gulf of Riga (SEA-011)	55	14	15	124
Northern Baltic Proper (SEA-012)	46	4	15	110
Gulf of Finland (SEA-013)	74	16	12	144
Åland Sea (SEA-014)	34	2	17	51
Bothnian Sea (SEA-015)	41	8	7	190
The Quark (SEA-016)	44	4	20	72
Bothnian Bay (SEA-017)	75	8	19	164

The status evaluation is derived based on the station level evaluation of 321 individual stations across the Baltic Sea region. 95 of these stations represented ‘full data’ and of these distinct downward trends (e.g. decreasing concentrations) were recorded in 13 instances (6 which were also in GES). These stations were located in the Kattegat, Arkona Basi, Bay of Mecklenburg, Gulf of Riga, The Quark, Western Gotland Basin, Bornholm Basin, Bothnian Sea and Bothnian Bay sub-basins. While other stations showed either no distinct trends or were evaluated as ‘initial’ data series due to the data available 8 stations also showed trends of increasing concentrations (i.e. upward pointing triangles, increasing Hg concentrations), these stations being located in the Arkona Basin (3), Bornholm Basin, Kattegat (2), Kiel Bay and Northern Baltic Proper sub-basins (Figure 4).

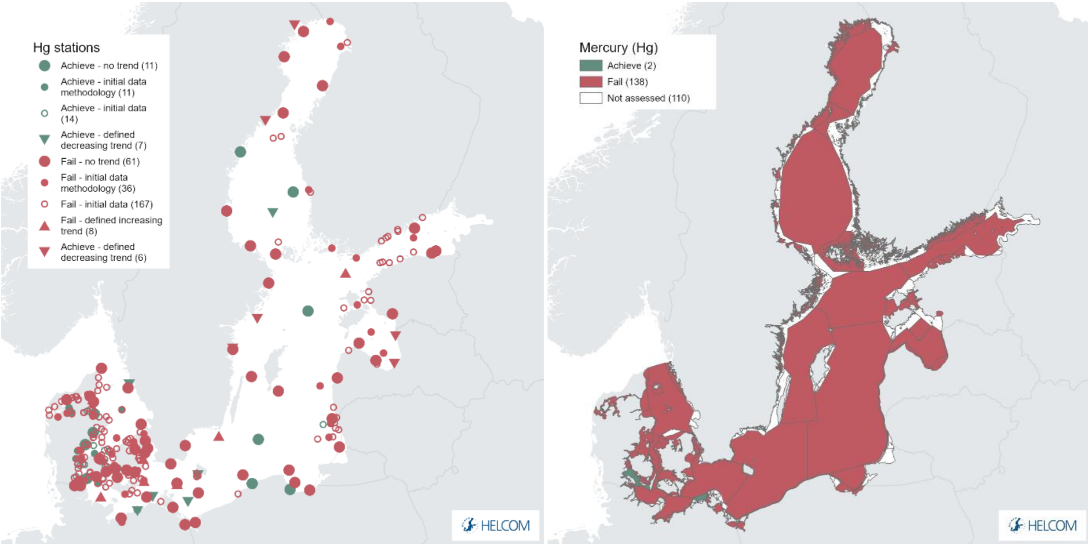

Figure 4. Map presenting station-based status evaluation of mercury concentrations in biota - fish muscle and mussels by station (left), and assessment unit based status for mercury in biota (right). Green colour represents good status and red colour represents not good status. Large, filled triangles 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 Methodology) 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 evaluation (see Methodology). **See 'data chapter' for interactive maps and data at the HELCOM Map and Data Service.**

Stations with 'full' (>3 years of data in the assessment period) and 'initial' data (<2 years of data in the assessment period), the latter which limits the application of the full statistical analyses, were available and widely distributed across the region. Examples of different trend patterns at the station level (station time series) are presented in Figure 5.

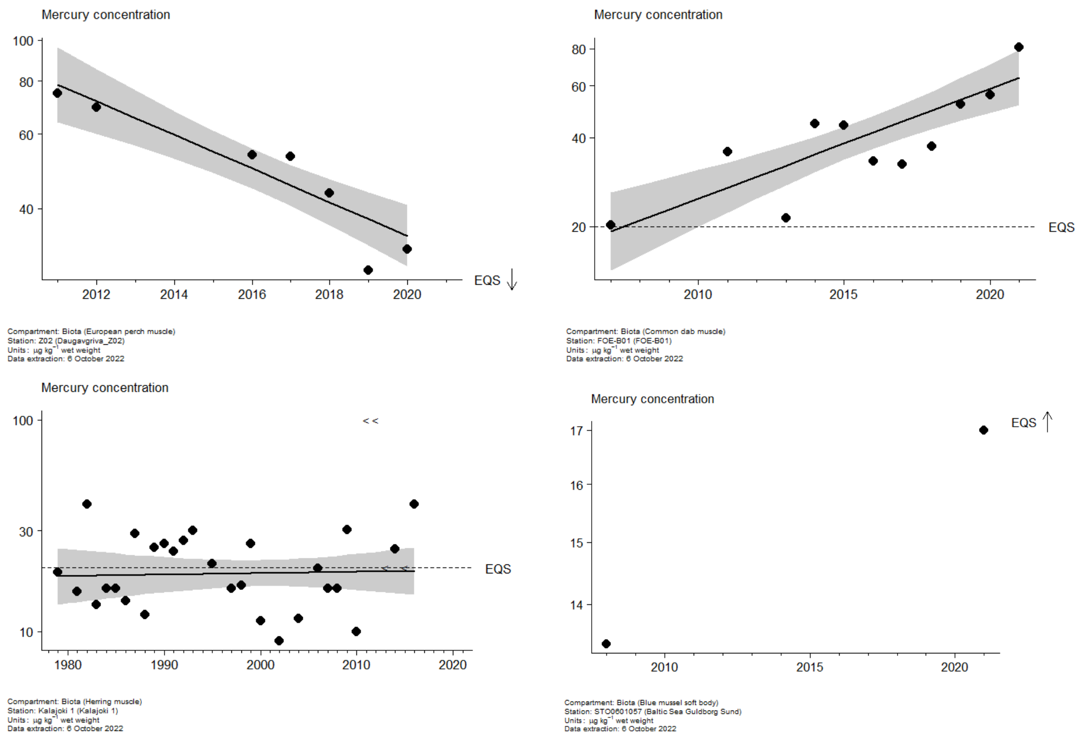

Figure 5. Examples of Mercury concentration in biota at stations in the Gulf of Riga (top left – distinct decreasing trend, 'full data'), Kiel Bay (top right – distinct increasing trend, 'full' data), Bothnian Bay Riga (bottom left – no distinct directional trend, 'full data'), and the Belt Sea (bottom right – 'initial' data).

4.2. Trends

Examples of key station level trends at selected stations are provided above (Figure 5). The evaluation of mercury includes a large number of high-quality datasets with long trends and the possibility to assign statistical trends. Distinct downward trends (e.g. decreasing concentrations) were recorded at 13 stations and 8 stations showed trends of increasing concentrations.

4.3. Discussion text

Mercury accumulates in biota and has detrimental effects. While there are positive signs of stations showing decreasing trends the general status is sub-GES, GES being achieved only in two assessment units. Local variation can clearly be seen at the station level and the influence of this on the assessment unit level evaluation is relevant, as some assessment units have stations that are in GES and also those that are sub-GES. When evaluations take place in areas where stations are close to the threshold value the regional uncertainty and quality of the data set is an important factor. In addition, some variation in the results may be generated due to the different monitoring matrices applied (Figure 6), an issue that may be relevant for further study beyond HOLAS 3.

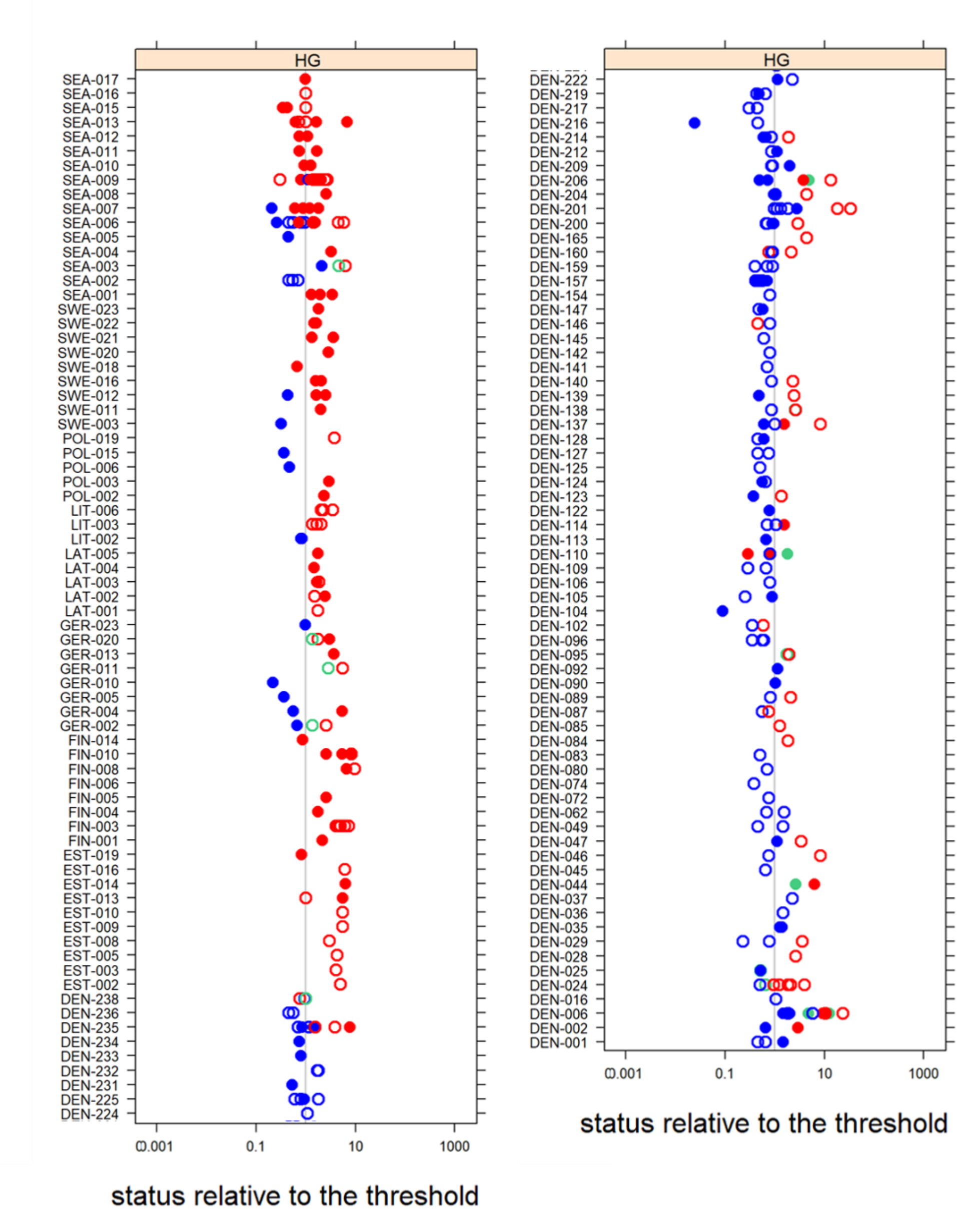

Figure 6. The same assessment units as shown in Figure 3 are presented but each assessment unit visualises the individual stations included in making the assessment unit level status evaluation. Potential difference in evaluation outcome due to different sampling matrices are highlighted: Red = fish muscle, blue = mussel soft body, and green = fish liver.

An overview of the outcomes for the open sea sub-basins is provided below (Table 4).

Table 4. Overview of evaluation outcomes and comparison with previous evaluation (using the OOAO evaluation outcomes per assessment unit). Currently this approach is only applied for open sea assessment units.

HELCOM Assessment unit name (and ID)	Threshold value achieved/failed – HOLAS II	Threshold value achieved/failed – HOLAS 3	Distinct trend between current and previous evaluation.	Description of outcomes, if pertinent.
Kattegat (SEA-001)	Failed	Failed	No change in status between the two assessment periods.	The threshold value is not achieved (sub-GES). All stations fail the threshold value.
Great Belt (SEA-002)	Not evaluated	Failed	NA	The threshold value is not achieved (sub-GES). A single stations achieves the threshold value.
The Sound (SEA-003)	Not evaluated	Failed	NA	The threshold value is not achieved (sub-GES). All stations fail the threshold value.
Kiel Bay (SEA-004)	Failed	Failed	No change in status between the two assessment periods.	The threshold value is not achieved (sub-GES). The single station in this area shows an increasing trend.
Bay of Mecklenburg (SEA-005)	Failed	Failed		The threshold value is not achieved (sub-GES). The single station in this area achieves the threshold value but the regional psi values result in sub-GES.
Arkona Basin (SEA-006)	Achieved	Failed	Deterioration. The condition has deteriorated with sub-GES recorded in the current assessment period. The change is driven by the inclusion of more relevant stations in the current period.	The threshold value is not achieved (sub-GES). All stations but one fail the threshold value.

Bornholm Basin (SEA-007)	Failed	Failed	No change in status between the two assessment periods.	The threshold value is not achieved (sub-GES). Stations exhibit GES conditions and sub-GES conditions, including increasing concentration trends.
Gdansk Basin (SEA-008)	Failed	Failed		The threshold value is not achieved (sub-GES). The single stations but one fail the threshold value.
Eastern Gotland Basin (SEA-009)	Failed	Failed		The threshold value is not achieved (sub-GES). The vast majority of stations fail the threshold value.
Western Gotland Basin (SEA-010)	Failed	Failed		The threshold value is not achieved (sub-GES). One stations but shows a decreasing trend.
Gulf of Riga (SEA-011)	Not evaluated	Failed	NA	The threshold value is not achieved (sub-GES). Both stations fail the threshold value.
Northern Baltic Proper (SEA-012)	Failed	Failed	No change in status between the two assessment periods.	The threshold value is not achieved (sub-GES). One station achieves GES the other shows an increasing trend.
Gulf of Finland (SEA-013)	Failed	Failed		The threshold value is not achieved (sub-GES). All stations fail the threshold value.
Bothnian Sea (SEA-015)	Failed	Failed		The threshold value is not achieved (sub-

				GES). Stations evaluated as ‘full’ are GES but ‘initial’ fail the threshold value.
The Quark (SEA-016)	Failed	Failed		The threshold value is not achieved (sub-GES). The evaluated station fails the threshold value.
Bothnian Bay (SEA-017)	Failed	Failed		

5. Confidence

The overall confidence of the indicator evaluation is moderate, with high in certain assessment units (Figure 7 and further details in Annex 1).

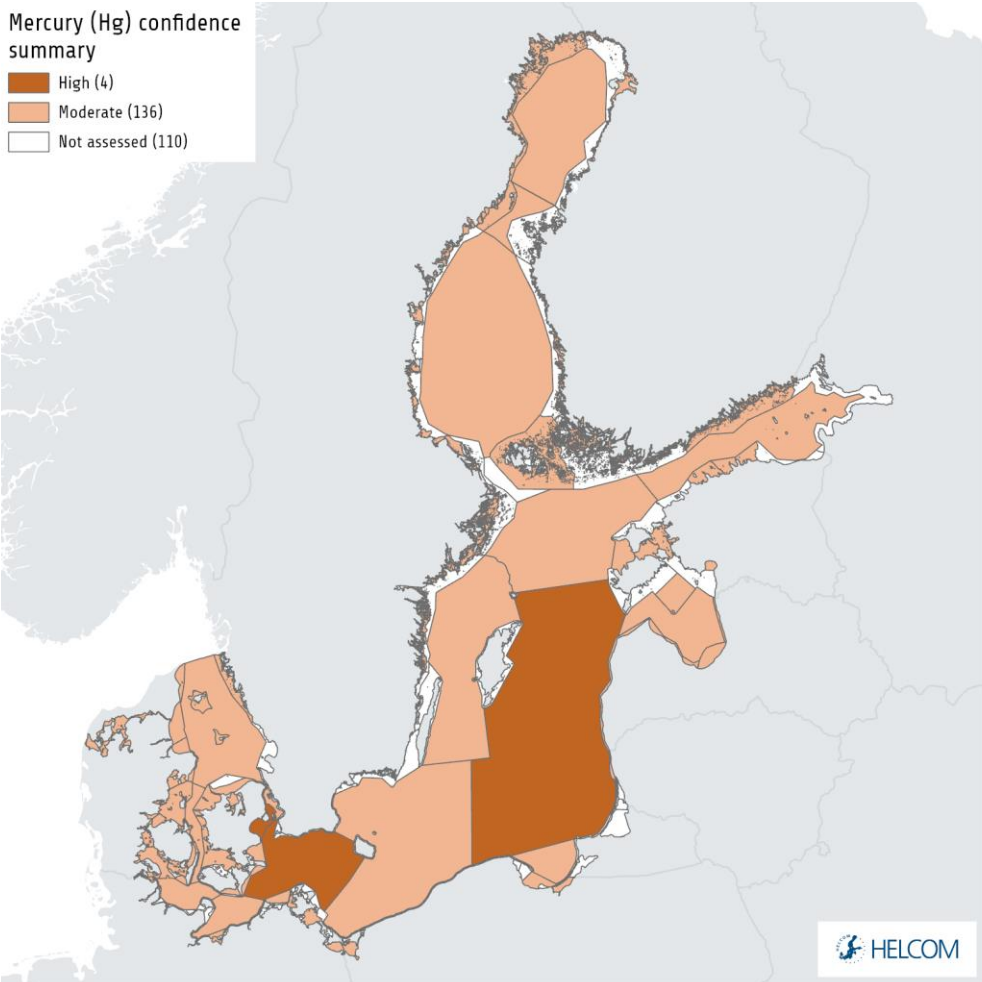

Figure 7. Map presenting the confidence in the overall evaluation based on a OOAO summary of confidence across all monitored matrices (see Annex 1). The evaluation is carried out using Level 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4).

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 overall confidence evaluation, when exploring and averaging the separate components evaluated (see Annex 1) is however moderate as in most assessment units there is scope for either improved spatial or temporal development relative to other coastal or open sea assessment units within this evaluation (i.e. generally only those assessment units with the most optimised input data and evaluation score the highest ranking confidence).

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

6. Drivers, Activities, and Pressures

Drivers are often large and complex issues that are difficult to quantify, though in certain instances proxies can be utilised to express them or changes in them. A driver for example may relate to globalisation or political will and, while difficult to quantify in terms of specific relevance to an indicator, changes in drivers can catalyse changes in activities that will consequently influence pressures for example resulting in altered levels of shipping and the subsequent pressures for that activity. A brief overview of key pressures and activities is provided in Table 5.

Mercury has been used for centuries. One of the biggest sources of environmental pollution, including the marine environment, with mercury, is the combustion of solid fuels - such as coal- both in industrial and domestic conditions but also the small scale mining of gold. Historically there have been large local releases of mercury to the Baltic Sea from industry located along the coastline and further inland (river transport to the coast). Examples of historic sources are sewage sludge and smelting facilities. Today, most mercury enters the Baltic Sea through atmospheric deposition (Soerensen et al. 2016). 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).

Combustion of solid fuels are mainly used for energy generation, cement and metal production. In the last decades, EU or worldwide legislation has been put in place banning most uses of mercury. The Minamata Convention on Mercury is a global treaty focused on reducing mercury releases to the environment. The convention was established in 2013, entered into force in 2017 and has currently been signed by 128 countries (UNEP 2013). The main EU regulation relating to the use and limitation of mercury in the environment is REGULATION (EU) 2017/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 on mercury, and repealing Regulation (EC) No 1102/2008. This Regulation establishes measures and conditions concerning the use and storage of and trade in mercury, mercury compounds and mixtures of mercury, and the manufacture and use of and trade in mercury-added products, and the management of mercury waste, in order to ensure a high level of protection of human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

Table 5. Brief summary of relevant pressures and activities with relevance 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		

7. Climate change and other factors

The observed climate change may impact the distribution and levels of mercury in the marine environment. Among the direct parameters of climate change, the fate of mercury in the Baltic Sea environment may be affected by the following:

1. Seawater temperature - an increase in water temperature may affect the metabolism of marine organisms and increase the efficiency of bioaccumulation of mercury
2. Large-scale atmospheric circulation - it can affect the transport of pollutants, including mercury over long distances and thus influence the amount of deposition to the waters of the Baltic Sea
3. Precipitation - changes in the precipitation regime may affect the amount of atmospheric mercury deposition to the Baltic Sea
4. River run-off - may be an important source of mercury entering the Baltic Sea; increasing the inflow in flood situations increases the inflow of mercury
5. Carbonate chemistry - changes in the pH of the aquatic environment may affect the transformations and thus the chemical forms of mercury in the marine environment; they may affect also metabolism of organisms and thus the efficiency of bioaccumulation of mercury
6. Sediment transportation - due to significant amounts of mercury deposited in bottom sediments, dynamics at the bottom and transport of sediments may lead to secondary isotope release (e.g. from new or historic processes, Obrist et al., 2018)

Among the indirect parameters of climate change affecting mercury fate in the marine environment are changes in oxygen levels and changes in the microbial community structure (Capo et al. 2022). Projected warming may enhance oxygen depletion in the Baltic Sea, which may influence the biogeochemical processes involving mercury. Due to the participation of microorganisms in the transformation processes of individual mercury forms, the change of the microbial structure may also be important for these processes (HELCOM and Baltic Earth 2021).

8. Conclusions

In general, the indicator is fully operational, and a wide-ranging evaluation can be made across the region. Mercury is persistent and despite apparent reductions in inputs and also decreasing trends (i.e. lower concentrations) at some stations where distinct trends could be assigned status is still failed in almost all evaluated areas - all but two coastal areas and all open sea assessment units evaluated fail to achieve GES (are sub-GES). In addition, there are some records of increasing concentrations at some stations.

8.1. Future work or improvements needed

The current annual sampling of biota is considered to be of adequate frequency for the core indicator. The biota monitoring in each sub-basin depends on the availability of certain species during the time of monitoring cruises and cannot be secured at all times. Some sub-basins and assessment units may benefit from longer-term time series data to support a stronger and more statistically robust evaluation. Exploring the assessment scale and appropriate way to address gaps where no monitoring occurs may also be relevant. In addition, careful review of data at the regional scale is needed as the general data quality and variation within the data set is utilised in the assessment unit level evaluation. Beyond HOLAS 3 it would be valuable to evaluate the harmonisation between the different sampling matrices applied (i.e. tissue types) to ensure the threshold value is evenly applied across all components.

Exploring the benefits of including information on dated sediment cores in the future, in particular to examine longer-term trends, would be valuable.

9. Methodology

The overall methodology is set out below.

9.1. Scale of assessment

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 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.

9.2. Methodology applied

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 metal to the specified concentration (threshold) levels is used for each biotic and abiotic element (matrix) of the marine environment. A ratio above 1, therefore, indicates non-compliance (failure to meet the 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.

All available data on mercury concentrations in biota: fish muscle, and mollusc soft tissue up to 2021, reported by HELCOM Contracting Parties to the HELCOM COMBINE database, was used to assess the state of the Baltic Sea environment.

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

The basis for the evaluation 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 a 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 the 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 2016-2021 (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: $\exp\left(\mathrm{meanLY} + \mathrm{qnorm}(0.95) \cdot \frac{\Psi}{\mathrm{sqrt}(n)}\right)$, where n is the number of years with data in the period 2016-2021 (HELCOM 2018).

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 Table 2.

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

9.3. Monitoring and reporting 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

Concentrations of mercury 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

Mercury concentrations may spatially highly vary 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).

Monitoring of mercury is relevant in the entire sea area.

10. Data

The data and resulting data products (e.g. tables, figures and maps) available on the indicator web page can be used freely given that it is used appropriately and the source is cited.

Results: Mercury in biota

Data: Hazardous substances in biota

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

11. Contributors

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12. Archive

This version of the HELCOM core indicator report was published in April 2023:

The current version of this indicator (including as a PDF) can be found on the HELCOM indicator web page.

Older versions of the core indicator report are available:

Metals HELCOM core indicator 2018 (pdf)

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

HELCOM-CoreIndicator-Metals(Lead, Cadmium, Mercury) 2013 (pdf)

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Annex 1 Assessment unit level confidence summary

Confidence is evaluated per assessment unit based on a relative evaluation of following parameters for the copper indicator: 1) spatial component, 2) temporal component, 3) methodological component, and 4) the evaluation component. Despite the common approach applied with other indicators the information set out here is not directly comparable as it only focusses on an evaluation within each indicator (i.e. is relative only between the evaluated assessment units for copper) and it furthermore only addresses the evaluated units. More general information related to overarching confidence and required improvements are detailed in the main report.

The confidence for each component was applies based on a categorical approach using high, moderate and low. To achieve the overall summary confidence a score of 0.25 was applied to low, 0.5 to moderate and 1.0 to high with an average value calculated across the components and the same scores used to then select he final overall category.

Spatial component: Open sea and coastal areas were treated separately due to the scale of sea area being vastly different. The area (km^2) for each evaluated assessment unit was divided by the total number of stations in the assessment unit and the resulting area per station was used to divide into three categories, roughly interpreted as stations addressing small, medium or large areas. If a large number (relatively) of stations were still available despite the area being large an increase of 1 category was applied.

Temporal component: The presence of ‘full’ and/or ‘initial’ data series was utilised to evaluate this. Where only a single initial data series/station was present a category of low was applied, where two initial data series were available a category of moderate was applied, where a single full data series was present a category of moderate was applied, and where two or more full data series were present a category of high was applied.

Methodological component: A score of high is applied to all evaluated assessment units since the indicator is evaluated using the MIME tool and applies a regionally agreed methodology and threshold values on national monitoring data.

Evaluation component: The standard error generated within the MIME assessment tool is utilised as a proxy for this component. In simple terms the basis of this evaluation is that standard error can be roughly equated to a coefficient of variance. This therefore provides a general confidence evaluation of the underlying data and variation within it. A categorical approach was applied where standard error values >0.70 were scored as low, 0.4-0.7 were scored as moderate and <0.4 were scored as high.

The confidence is provided for biota below (Annex 1 - Table 1).

The overall confidence for the OOAO status evaluation is also generated using a OOAO approach from these tables below, suing the overall category.

Annex 1 – Table 1. Summary table showing categorical confidence per component and overall for mercury in biota.

Assessment Unit	Spatial	Temporal	Methodological	Evaluation	Overall
DEN-001	High	High	High	Moderate	Moderate
DEN-002	High	High	High	Moderate	Moderate
DEN-006	High	High	High	High	High
DEN-016	High	Low	High	Low	Moderate
DEN-024	High	Moderate	High	Moderate	Moderate
DEN-025	High	High	High	Moderate	Moderate
DEN-028	Moderate	Low	High	Low	Moderate
DEN-029	High	Moderate	High	Moderate	Moderate
DEN-035	High	High	High	Moderate	Moderate
DEN-036	High	Low	High	Low	Moderate
DEN-037	High	Low	High	Low	Moderate
DEN-044	High	High	High	Moderate	Moderate
DEN-045	High	Low	High	Low	Moderate
DEN-046	High	Moderate	High	Low	Moderate
DEN-047	High	High	High	Low	Moderate
DEN-049	High	Moderate	High	Low	Moderate
DEN-062	High	Moderate	High	Low	Moderate
DEN-072	High	Low	High	Low	Moderate
DEN-074	High	Low	High	Low	Moderate
DEN-080	High	Low	High	Low	Moderate
DEN-083	High	Low	High	Low	Moderate
DEN-084	High	Low	High	Low	Moderate
DEN-085	High	Low	High	Low	Moderate
DEN-087	High	Moderate	High	Low	Moderate
DEN-089	High	Moderate	High	Low	Moderate
DEN-090	High	Moderate	High	Low	Moderate
DEN-092	High	Moderate	High	Low	Moderate
DEN-095	High	Moderate	High	Low	Moderate
DEN-096	High	Moderate	High	Moderate	Moderate
DEN-102	High	Moderate	High	Low	Moderate
DEN-104	High	Moderate	High	Low	Moderate
DEN-105	High	High	High	Moderate	Moderate
DEN-106	High	Low	High	Low	Moderate
DEN-109	High	Moderate	High	Low	Moderate
DEN-110	High	High	High	Moderate	Moderate
DEN-113	High	High	High	Low	Moderate
DEN-114	High	High	High	Moderate	Moderate
DEN-122	High	High	High	Moderate	Moderate
DEN-123	High	High	High	Moderate	Moderate
DEN-124	High	High	High	Moderate	Moderate
DEN-125	High	Low	High	Low	Moderate
DEN-127	High	Moderate	High	Low	Moderate

DEN-128	High	High	High	Low	Moderate
DEN-137	High	High	High	Moderate	Moderate
DEN-138	High	Moderate	High	Moderate	Moderate
DEN-139	High	High	High	Low	Moderate
DEN-140	High	Moderate	High	Low	Moderate
DEN-141	High	Low	High	Low	Moderate
DEN-142	High	Low	High	Low	Moderate
DEN-145	High	Low	High	Low	Moderate
DEN-146	High	Moderate	High	Low	Moderate
DEN-147	High	High	High	Moderate	Moderate
DEN-154	Moderate	Low	High	Low	Moderate
DEN-157	High	High	High	Moderate	Moderate
DEN-159	High	Moderate	High	Moderate	Moderate
DEN-160	High	Moderate	High	Moderate	Moderate
DEN-165	High	Low	High	Low	Moderate
DEN-200	High	High	High	Moderate	Moderate
DEN-201	High	High	High	High	High
DEN-204	High	High	High	Moderate	Moderate
DEN-206	High	High	High	Moderate	Moderate
DEN-209	High	High	High	Moderate	Moderate
DEN-212	High	High	High	Moderate	Moderate
DEN-214	High	High	High	Moderate	Moderate
DEN-216	High	High	High	Moderate	Moderate
DEN-217	High	Moderate	High	Low	Moderate
DEN-219	Moderate	High	High	Moderate	Moderate
DEN-222	Moderate	High	High	Low	Moderate
DEN-224	High	Low	High	Low	Moderate
DEN-225	High	High	High	Moderate	Moderate
DEN-231	High	High	High	Low	Moderate
DEN-232	High	Moderate	High	Low	Moderate
DEN-233	High	High	High	Low	Moderate
DEN-234	High	High	High	Low	Moderate
DEN-235	High	High	High	Moderate	Moderate
DEN-236	High	Moderate	High	Low	Moderate
DEN-238	High	Moderate	High	Moderate	Moderate
EST-002	Moderate	Low	High	Low	Moderate
EST-003	Moderate	Low	High	Low	Moderate
EST-005	Moderate	Low	High	Low	Moderate
EST-008	High	Low	High	Low	Moderate
EST-009	High	Low	High	Low	Moderate
EST-010	Moderate	Low	High	Low	Moderate
EST-013	High	High	High	Low	Moderate
EST-014	Moderate	Moderate	High	Low	Moderate
EST-016	Moderate	Low	High	Low	Moderate
EST-019	Moderate	Moderate	High	Low	Moderate
FIN-001	Moderate	Moderate	High	Low	Moderate

FIN-003	High	Moderate	High	Moderate	Moderate
FIN-004	Low	Moderate	High	Low	Moderate
FIN-005	Moderate	Moderate	High	Low	Moderate
FIN-008	High	High	High	Moderate	Moderate
FIN-010	High	High	High	Moderate	Moderate
FIN-014	Low	Moderate	High	Low	Moderate
GER-002	High	High	High	Moderate	Moderate
GER-004	High	High	High	Moderate	Moderate
GER-005	High	Moderate	High	Low	Moderate
GER-010	High	Moderate	High	Low	Moderate
GER-011	High	Moderate	High	Low	Moderate
GER-013	High	High	High	Low	Moderate
GER-020	High	High	High	Moderate	Moderate
GER-023	High	Moderate	High	Low	Moderate
LAT-001	High	Low	High	Low	Moderate
LAT-002	High	High	High	Moderate	Moderate
LAT-003	High	High	High	Moderate	Moderate
LAT-004	High	High	High	Low	Moderate
LAT-005	Moderate	Moderate	High	Low	Moderate
LIT-002	High	High	High	Moderate	Moderate
LIT-003	High	Moderate	High	Moderate	
LIT-006	High	Moderate	High	Moderate	
POL-002	High	Moderate	High	Low	
POL-003	High	Moderate	High	Low	
POL-006	Moderate	Moderate	High	Low	
POL-015	High	Moderate	High	Low	
POL-019	High	Low	High	Low	
SWE-003	Moderate	Moderate	High	Low	
SWE-011	Low	Moderate	High	Low	
SWE-012	High	High	High	Moderate	
SWE-016	Moderate	High	High	Moderate	
SWE-018	Moderate	Moderate	High	Low	
SWE-020	High	Moderate	High	Low	
SWE-021	Moderate	High	High	Moderate	
SWE-022	Moderate	High	High	Moderate	
SWE-023	Low	Moderate	High	Low	
SEA-001	Moderate	High	High	Moderate	
SEA-002	High	High	High	Moderate	
SEA-003	High	High	High	Moderate	
SEA-004	High	Moderate	High	Low	
SEA-005	Moderate	Moderate	High	Low	
SEA-006	High	High	High	High	
SEA-007	Moderate	High	High	High	
SEA-008	Moderate	Moderate	High	Low	
SEA-009	High	High	High	High	
SEA-010	Low	High	High	Moderate	

SEA-011	Moderate	High	High	Moderate	
SEA-012	Low	High	High	Moderate	
SEA-013	Moderate	High	High	Moderate	
SEA-015	Moderate	High	High	Moderate	
SEA-016	High	Low	High	Low	
SEA-017	Low	Moderate	High	Low	