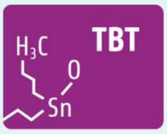
TBT and imposex

INDICATOR TYPE: Core
INDICATOR CATEGORY: State
BSAP SEGMENT: Hazardous substances and litter
MSFD CRITERIA: D8C1



Tributyltin (TBT) and imposex

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1 Key message

This core indicator evaluates the status of the marine environment based on concentrations of tributyltin (TBT) and its breakdown products dibutyltin (DBT) and monobutyltin (MBT) in the Baltic Sea.

Monitoring is carried out in water, biota (marine gastropods) and sediments. Imposex effects of TBT on marine gastropods are used as another source of data on TBT, as a sensitive biological effect caused by organotin. Good status is achieved when the concentrations of TBT are below the threshold value established for each matrix. The indicator presents a status evaluation using all data currently available until 2021 to evaluate the assessment period 2016 – 2021 (Figure 1).

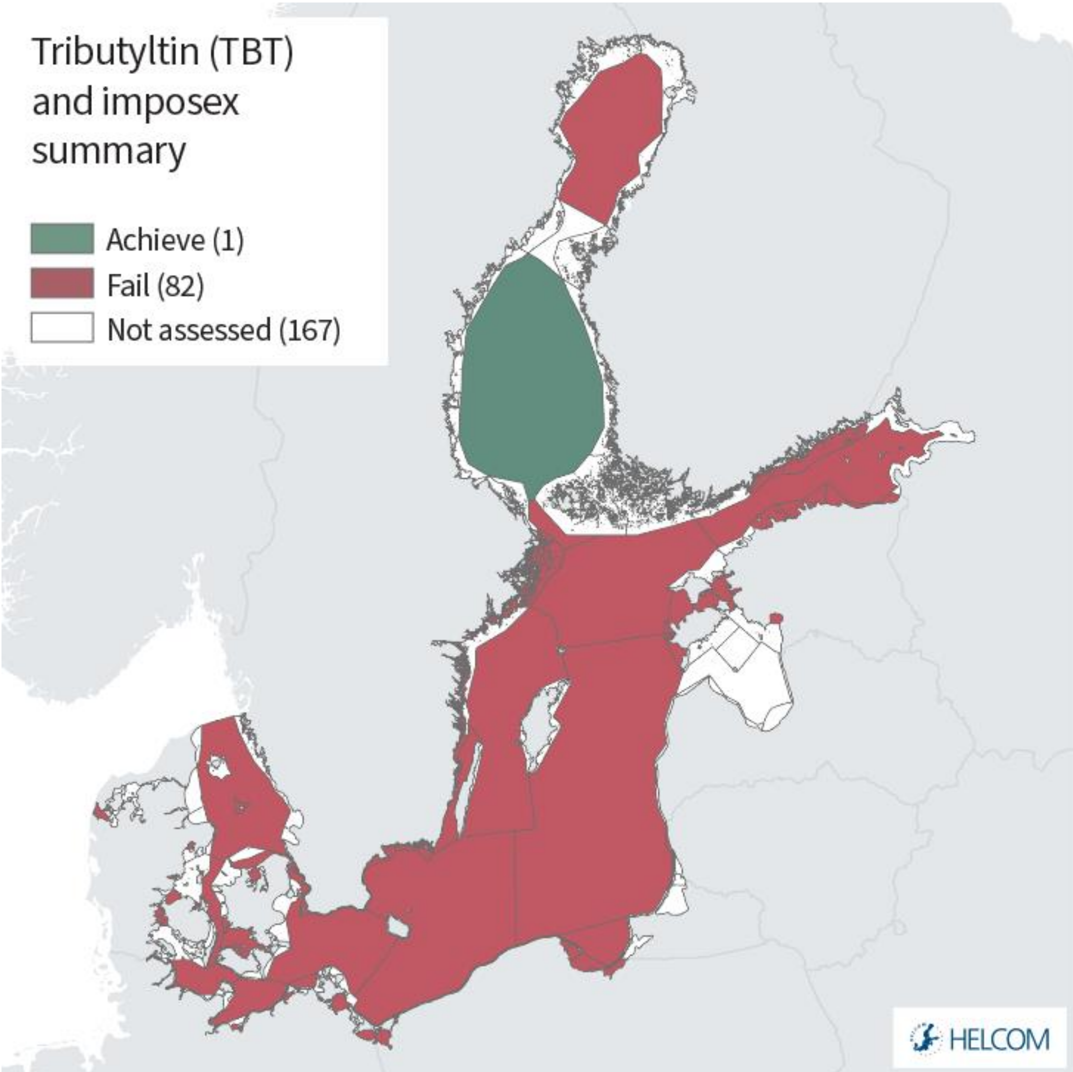

Figure 1. Status evaluation results based on evaluation of the TBT concentrations in sediment and water, and biological effects in biota - marine gastropods (Imposex). One-Out-All-Out (OOAO) method is applied between the three monitored components to provide an overall evaluation of Good Environmental Status (GES). A confidence evaluation is applied in a similar manner. The evaluation is carried out using Level 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.**

Some assessment units achieve good environmental status (GES), for example the Polish coastal area POL-OO2 Bornholm Basin/Pomeranian Bay area for the water monitoring matrix and SEA-015 (Bothnian Sea open sea area) for the sediment monitoring matrix. However, when applying a One-Out-All-Out approach across monitoring matrix types GES is only achieved in SEA-015 (Figure 1). Certain stations within the assessment unit level evaluation presented in Figure 1 also achieved GES, for example Finnish station LL3A in the Gulf of Finland (sediment) or Danish station DMU D14 (biota, Imposex), though achievement of GES at the station level (or vice versa) does not automatically result in GES at the assessment unit level due to compilation of several station level evaluations (as discussed below).

Data in one or more of the monitored components was available from Denmark, Estonia, Finland, Germany, Lithuania, Poland and Sweden, offering a broad spatial coverage in the Baltic Sea region. In general, the majority of evaluated assessment units fail to achieve GES. With one exception all significant trends identified are downwards (all for the Imposex component). This result is not unexpected as the main source of TBT is antifouling paints, which have been banned. However, TBT is highly persistend and might accumulate in sediments. Therefore, sediments still represent a potential source of TBT, especially in harbours and shipping lanes, and these pools can be re-suspended during storm events.

The confidence of the indicator evaluation is generally moderate in those assessment units evaluated, with some assessment units in the sediment evaluation showing high confidence and others for the water evaluation showing low confidence. Overall a moderate confidence is deemed to be a suitable reflection of the overall evaluation provided.

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) TBT and imposex. HELCOM core indicator report. Online. [Date Viewed], [Web link].

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2 Relevance of the indicator

Organotin, and in particular TBT, has been shown to be very toxic to marine life, resulting in changes in oyster shells and interfering with the marine gastropods female reproductive organ, an effect known as imposex, causing sterility in some sensitive species. TBT is bioaccumulated by marine organisms causing harmful effects that mainly depend on the level of its final concentration in the tissues. Mussels are not able to degrade TBT by de-butylation, as fish and some marine gastropods are. Levels can be high in top-predators (Strand *et al*, 2005; Law *et al*, 2012). That is why the concentrations of TBT, especially those of importance to ecosystem or human health, have to be monitored.

TBT and triphenyltin (TPT) were introduced in antifouling paints in the 1960s, but soon after, effects on growth and shell formation were found in French oyster grounds, and shortly after, also the effect on marine gastropods reproductive system was discovered. This led to a ban on use of these paints on pleasure boats, and eventually followed up by a total ban on TBT in antifouling paints (782/2003/EC (EC, 2003)) effective from 2008 (OSPAR, 2014).

2.1 Ecological relevance

Since 1960, the tri-substituted OTC (TBT and TPT) has been used extensively as biocide in antifouling paints for boats. It was very efficient and considered to have a low toxicity to mammals. The use has been restricted in many countries, starting in France 1982, because of the recognised adverse effects of these compounds on the aquatic ecosystem. The European Union, Regulation 782/2003/EC requires TBT-free anti-fouling systems to be used from 1 July 2003, and removal of TBT containing paints from 2008.

The uses of TBT and TPT, their persistence, their tendency to bioaccumulate through the food chain (in particular fish and seafood), their high toxicity to aquatic organisms even at levels below 1 ng/l in water, and their complex toxicity profile in experimental animals cause concerns about risks to humans and non-human organisms. Apart from the discovery that organotins were causing deformation and reproductive failure for oysters in France in the 1970s, and at the same time discovery of the imposex effect of masculinisation of female gastropods, these were later followed by observation of masculinisation of fish (Shimasaki *et al.*, 2003), suggesting that these compounds are strong endocrine disruptors (WHO-IPCS, 1999a, b).

2.2 Policy relevance

The core indicator on TBT concentrations and imposex addresses the Baltic Sea Action Plan's (BSAP) Hazardous substances and litter segment goal of a “Baltic Sea unaffected by hazardous substances and litter” and also has relevance for elements of the Biodiversity and Maritime activities segment goals: “The Baltic Sea ecosystem is healthy and resilient” and “Environmentally sustainable sea-based activities”, respectively.

In addition, the indicator is of direct relevance to Descriptor 8 and of significance for Descriptor 9 or the EU Marine Strategy Framework Directive (MSFD) as set out under the specific Descriptors and Criteria in Commission Decision (EU) 2017/848.

TBT and its compounds are included in the EU WFD (in water). 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), TBT and imposex are to be measured on a mandatory basis in sediment and marine gastropod (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).

An overview of policy relevance is provided in Table 1.

Table 1. Overview of key policy relevance elements.

	Baltic Sea Action Plan (BSAP)	**Marine Strategy Framework Directive (MSFD)**
Fundamental link	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”.	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.
Complementary link	Segment: Biodiversity Goal: “Baltic Sea ecosystem is healthy and resilient” • Ecological objective: “Viable populations of all native species”,	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,

	"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 lead to imbalance in the foodweb". Segment: Sea-based activities Goal: "Environmentally sustainable sea-based activities" • Ecological objective: "No or minimal disturbance to biodiversity and the ecosystem". • Management objective: "Minimize the input of nutrients, hazardous substances and litter from sea-based activities" and "Enforce international regulations – no illegal discharge".	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 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:	• For some Contracting Parties also Water Framework Directive Tributyltin is listed as no. 30 on the priority substances list in directive 2013/39/EU. • 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 this complex issue. In addition to providing an indicator-based evaluation of the status of the Baltic Sea in terms of concentrations of TBT in the marine environment, this indicator along with the other hazardous substances core indicators contributes to the overall assessment of hazardous substances via inclusion in the integrated assessment of hazardous substances (though only the TBT concentrations part are included, with Imposex included in the Biological Effects overview).

3 Threshold values

Good Status is achieved if the concentrations of TBT are below the specified threshold values, as visualised in the conceptual figure below (Figure 2).

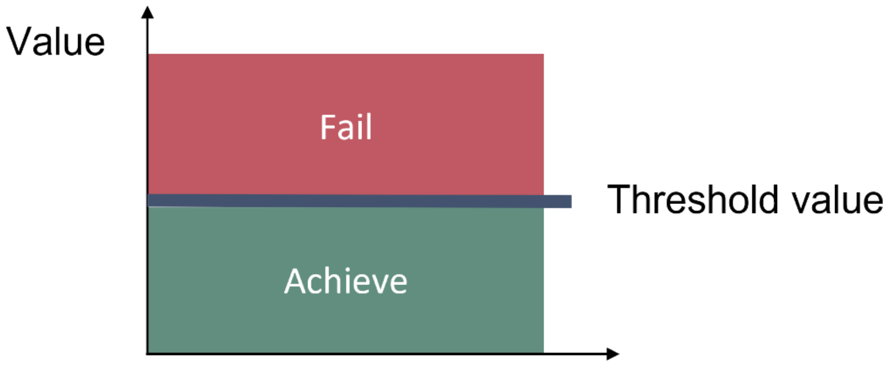


Figure 2. Good status is achieved for each monitored matrix if the concentrations of TBT are below the threshold values listed in Table 2.

The good status thresholds for TBT are based on Environmental Quality Standards (EQS) for water and biota (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 value is applicable 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 (sediment). However, if suitable monitoring data is not available in a region the secondary threshold value can be used for the evaluation of alternative matrices (biota, water) (Table 2). 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).

It is important to note, especially when comparing between this and prior indicator evaluations, that as part of the process to achieve regional agreement and move this indicator to a core indicator that would be included in the integrated assessment for HOLAS 3 the threshold value applied for sediment has changed between the two assessment periods. The primary threshold value for sediment was lowered from 1.6 (in HOLAS 2) to 1.3 µg /kg dw sediment (5% TOC) based on new analyses carried out.

Table 2. Threshold value for TBT and imposex (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 can not be applied. SED – sediment, CORG – organic carbon, AL – Aluminium, LI – Lithium, D- dry weight. Gercken & Sordyl 2009; Magnusson *et al.* 2016; OSPAR (2010a) EcoQO and EG HAZ 16-2021 document 3-4.

Indicator	**Threshold value**	**Parameters (PARAM) / Parameter groups (PARGROUP) (see also http://vocab.ices.dk/)**	**Matrix**	**Species**	**Matrix**	**Basis**	**Supporting parameters and information**
TBT	Primary threshold QS 1.3 µg /kg dw sediment (5% TOC)	PARAM = TBSN+	Sediment		All (surface, ICES 'upper sediment layer - 0-X cm')	D	CORG Al Li Grain size
	Secondary threshold EQS water (AA): 0.2 ng/l water	PARAM = TBSN+	Water		(All – unfiltered is preference)		Surface water layer (≤ 5.5 m)
TBT and imposex	Primary threshold Gercken & Sordyl 2009; Magnusson et al 2016[k] EAC: *Peringia ulvae*: 0.1 VDSI *Nucella lapillus*: 2.0 VDSI *Neptunea antiqua*: 2.0 VDSI *Hinia reticulata*: 0.3 VDSI *Buccinum undatum*: 0.3 VDSI Littorina littorea: <0.3 ISI	Imposex: PARAM = VDS, VDSI, INTS, INTSI, IMPF%, IMPS, IMPSI, PCI, %FemalePOP Assisting parameters: PARAM = MBSN+, DBSN+, TBSN+, TPSN+	Biota	Gastropods	All	D	

3.1 Setting the threshold value(s)

The threshold values are based on established threshold value setting approaches or published parameters required for carrying out such evaluations. Environmental Quality Standards (EQS) and Quality Standards (QS) are developed following the approach set out in the Derivation of environmental quality standards (EQS) for the aquatic environment following the EU Guidance Document No. 27. Technical Guidance Document for Deriving Environmental Quality Standards (EU, 2018). The application of this approach to develop the primary threshold value applied for sediment is set out in EG HAZ 16-2021 document 3-4 and its application was subsequently approved in HOD 61-2021 (document 5-1-Rev.1 and Workspace ATT. 21 Rev.1).

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 presented in this core indicator report were collected in the HELCOM COMBINE data base, a compilation of data from the monitoring activities reported by all Baltic Sea countries. The report presents information on the current levels of TBT concentrations in selected marine monitoring matrices: seawater, biota (mussels, marine gastropods) and sediments. Fish data have not been used, as currently no thresholds have been defined or agreed for TBT in this matrix.

Seawater

The agreed secondary threshold value for TBT in water is the EQS value (AA-EQS) of 0.2 ng/l. This monitoring matrix is a secondary one since the preferred matrices for monitoring in the HELCOM COMBINE monitoring programme are biota and sediment.. As a result, relatively little data is available for TBT in water.

Of the 42 Level 4 HELCOM assessment units evaluated for seawater only one achieved the threshold value and represents Good Environmental Status, assessment unit POL-002, situated in the Bornholm Basin/Pomeranian Bay area (Figure 3). Data is available from Estonia, Germany, Lithuania and Poland.

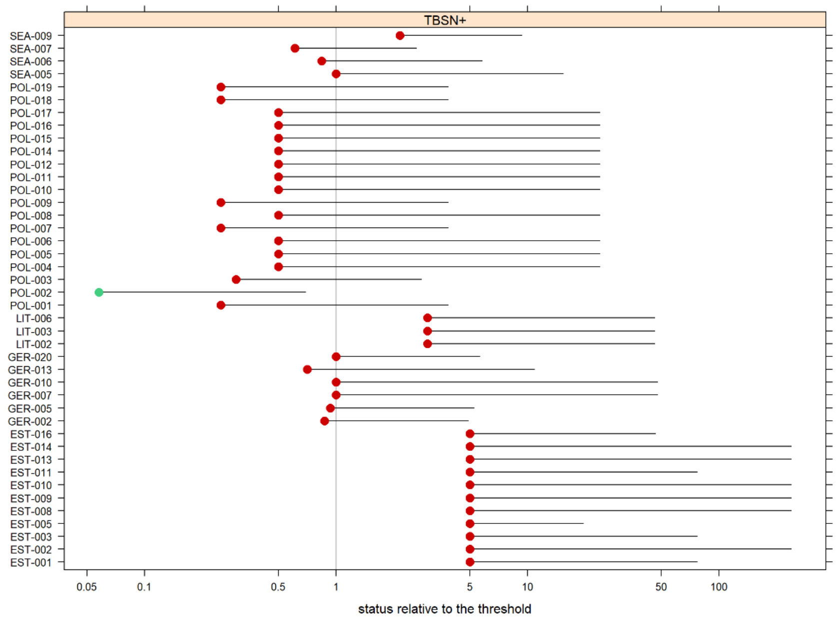


Figure 3. Overview of HELCOM Level 4 assessment units evaluated for TBT in water. Only POL-002 achieved GES, see discussion below. Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.

Most samples were above the average annual concentration EQS (AA-EQS) of 0.2 ng/l. The AA-EQS is considered to be high. For example, compared to the OSPAR (Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic) Environmental Assessment Criteria (EACs) in seawater (0.01-0.1 ng/l). The 2004 revision of OSPAR EACs suggested using the AA-EQS as the lower and MAC-EQS as the upper EAC value. Hence, the AA-EQS is considered to be the relevant threshold value, not MAC-EQS that would normally be used for spot samples.

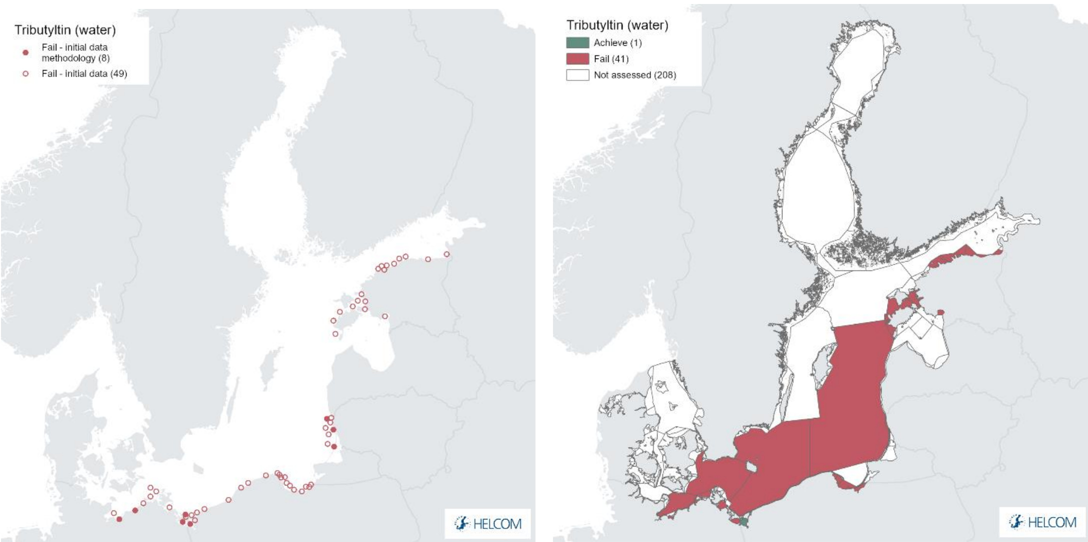


Figure 4. Station based evaluation of TBT in seawater (left) and assessment unit status evaluation (right). Small filled circles represent results based on three-four years and empty circles represent results based on <3 years, initial status evaluation. The evaluation is carried out using Level 4 HELCOM 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.**

The evaluation in water covers 38 coastal assessment units (HELCOM Level 4) and 4 open sea assessment units, totalling 57 individual monitoring stations (Figure 4). It should also be noted that the POL-002 assessment unit fails to achieve the threshold value at the individual station level but when the assessment unit level evaluation is applied the assessment unit achieves GES. This deviation between the two evaluations is due to the methodology where a re-scaling of the results occurs between the two components to take into account the regional uncertainty estimates when evaluatinh assessment unit level status. In such instances, the final evaluation should be considered with caution as there are significant uncertainties in the final outcome.

It is important to note that with a quantification limit (QL) around 0.06-1 ng/l, even the newest, best method with QL at 0.06 ng/l is at 30% of the AA-EQS, which is the minimum performance criteria for methods of analysis used in the Water Framework Directive set by the European Commission (2009). In fact, typically results are below detection limits, which in some cases was above the AA-EQS. Thus, the outcome is indicated as failing the threshold (red) due to the detection limits being above the AA-EQS in some of the results (see Figure 5).

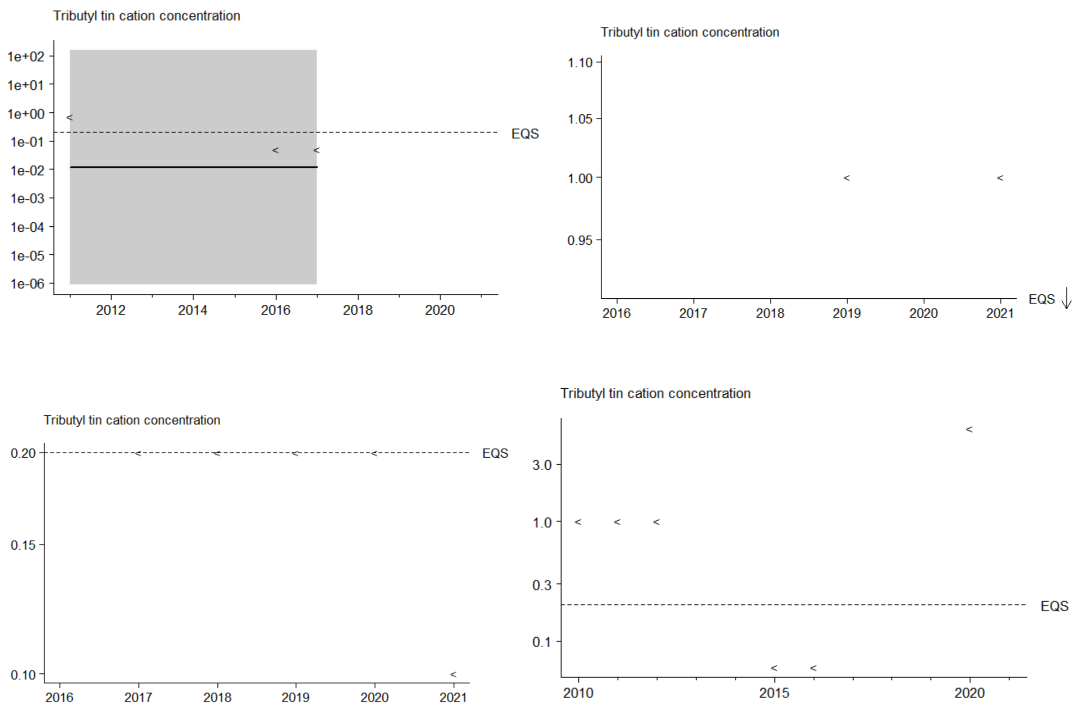


Figure 5. Selected stations: Poland (in unit POL-002, top left - grey colour- confidence level 95% range), Estonia (in unit EST-005, top right), Germany (in unit GER-002, bottom left), and Lithuania (in unit POL-006, bottom right). Typically results are below detection limits, which in some cases was above the AA-EQS. The < symbol indicates data are below the threshold value but due to analytical limits of quantification a defined sample value is not given, so called 'less-than' values.

Marine Gastropods (biota)

The biological effect on the reproductive organs of marine gastropods, known as imposex, has been classified after the Vas deference Sequence (VDS). Overall 14 coastal assessment units (HELCOM Level 4) and 3 open sea assessment units were evaluated. These included the following species *Peringia ulvae, Neptunea antiqua, Littorina littorea, Tritia nitida / reticulata,* and *Buccinum undatum*. In all evaluated assessment units the relevant threshold values were not achieved and thus all are evaluated to be sub-GES (Figure 6).

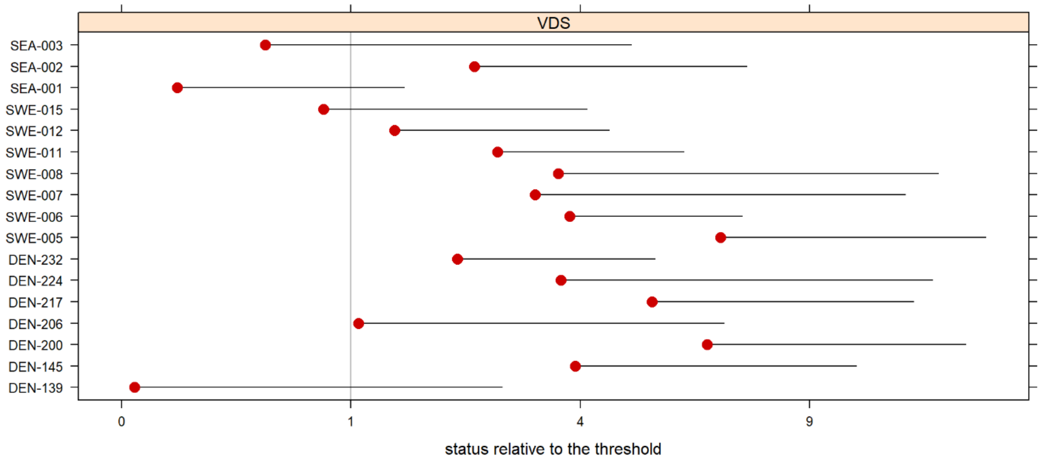


Figure 6. Overview of HELCOM Level 4 assessment units evaluated for Imposex (Biota). Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.

VDS is measured at 37 monitoring stations of which 4 of these individual stations achieved the threshold value. The majority of stations showed no distinct trends (large, filled circles), however there were 4 stations at which decreasing trends were recorded (downward pointing triangles) and one station where an increasing trend was recorded (upward pointing triangle) (Figure 7).

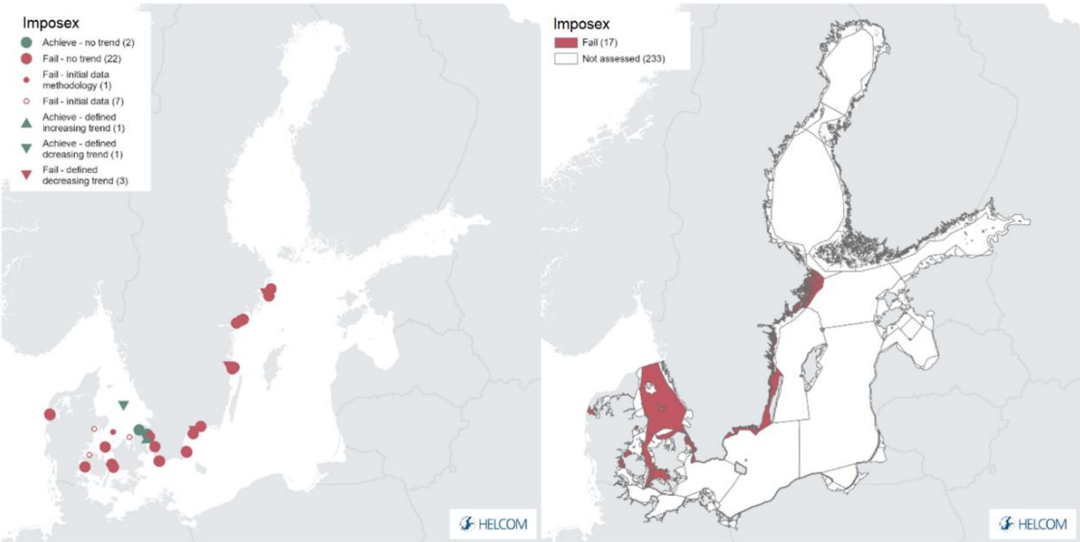


Figure 7. Map presenting status based on imposex effect in (biota) marine gastropods at each sampling station (left). Green colour represents achieving the threshold value (i.e. GES) and red colour represents failing the threshold value (sub-GES). Filled large circles represent results based on five or more years of data, full evaluation (see Methodology), small filled circles represent results based on three-four years and empty circles represent results based on <3 years, initial status evaluation. Triangles indicate trends: downward (decreasing concentrations) or upwards (increasing concentrations). The evaluation is carried out using Level 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.**

The decreasing levels of TBT occur in areas with heavy ship traffic, The Sound and the Kattegat, as also seen in the previous evaluation. This is in agreement with earlier findings in the North Sea area, where 48% of the imposex stations showed decreasing trends (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/imposex-gastropods/).

The species available in the North Sea area are generally more sensitive to TBT (due to salinity restriction for the sensitive species) than most of the species found in the Baltic Sea area, and many of the time trends include data dating back to before the international ban on TBT in antifouling paints. The majority of the stations however did not show distinct trends. An overview of trends from different stations is presented in Figure 8, utilising selected example stations.

The biological effects therefore support the observations of TBT in mussels and water, generally indicating a reduction in contamination levels. But even so, most stations are still not at GES. As most stations are time trend stations, the biological effects measurements generally have a high confidence rating.

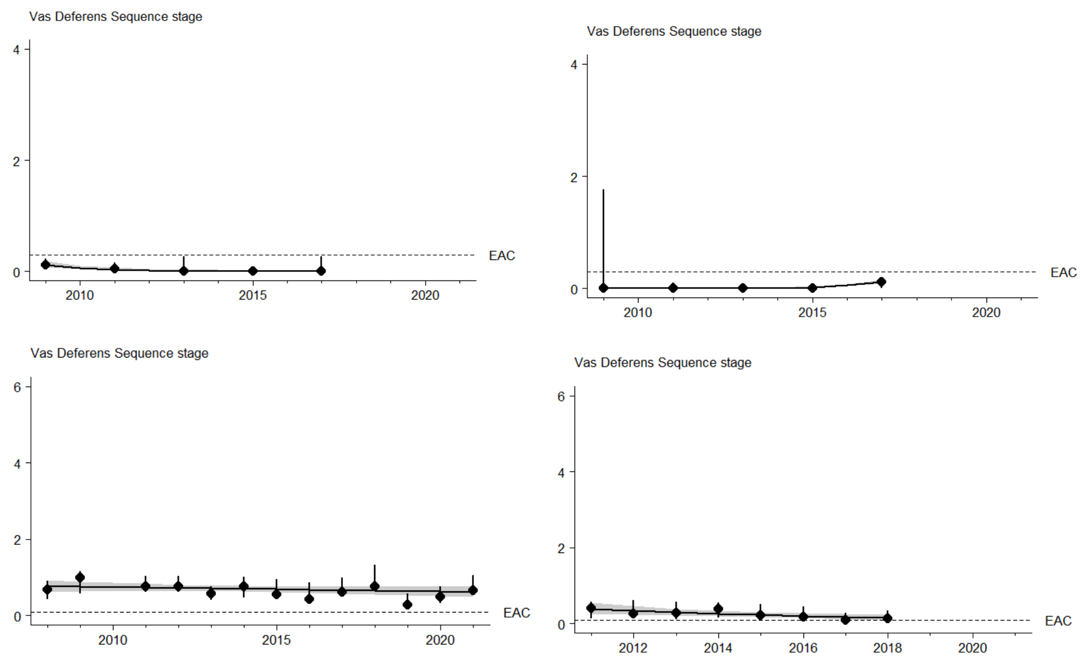


Figure 8. Long-term trends of VDS stage in gastropods at selected stations to illustrate key trend types (grey colour- confidence level 95% range (see Methodology)). Denmark (Top left, DMU D9 – Kattegat, downward trend 'green'), Denmark (Top right, DMU D14 – The Sound, increasing trend 'green'), Sweden (Bottom left, Oxelösunds marina – Western Gotland basin, no distinct trend 'red'), and Trelleborg referens – Arkona Basin, no distinct trend 'red').

Sediment

Samples were available from Denmark, Estonia, Finland, Germany, Poland and Sweden. All data are analysed using the 'initial' approach, in part due to the nature of the monitoring applied for sediments (less frequent sampling since sediments are commonly considered to be a more stable sink for contaminants as compared to changes in water for example). 34 assessment units were evaluated (Level 4 assessment units), including 13 open sea assessment units. Of the evaluated assessment units only one, SEA-015, was deemed to achieve its threshold value and thus be in GES (Figure 9 and figure 10).

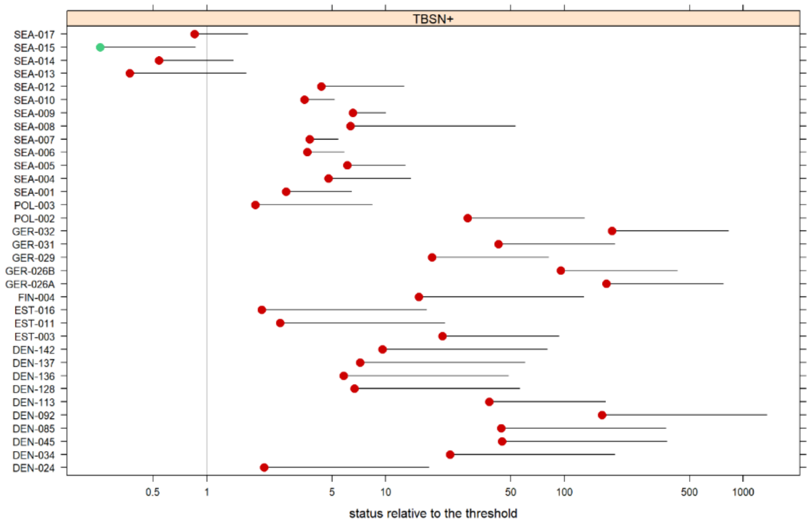
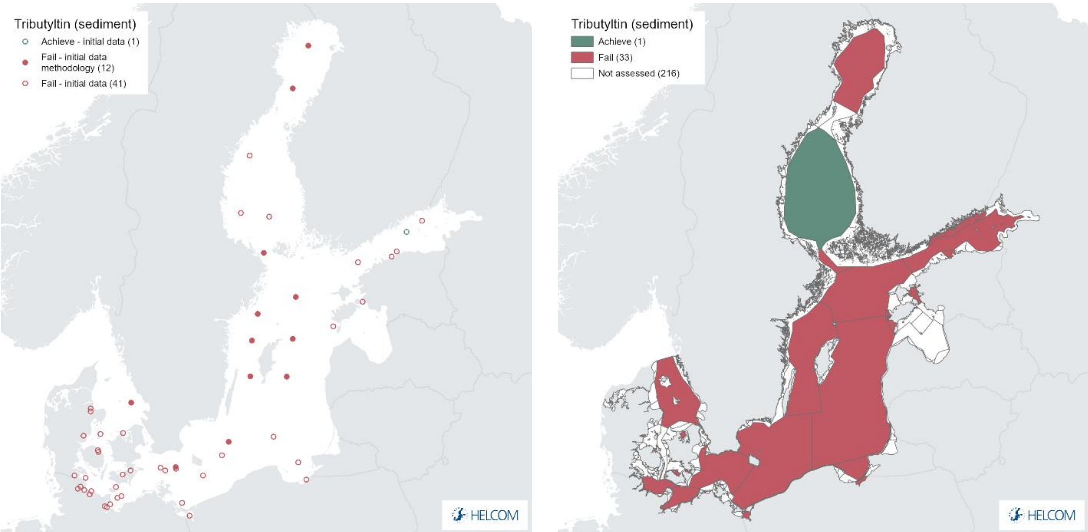


Figure 9. Overview of HELCOM Level 4 assessment units evaluated for TBT in sediments. Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.



Results figure 10. Map presenting station-based evaluation of TBT in sediment (left) and assessment unit evaluation (right). Green colour represents achieved threshold value (GES) and red colour represents failed threshold value (sub-GES). Small filled circles represent results based on three-four years and empty circles represent results based on <3 years, initial status evaluation (see Methodology). The evaluation is carried out using Level 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.**

Of the 54 stations evaluated, only one station LL3A in SEA-013 (Gulf of Finland) achieved the threshold value and was identified as in GES. This station however is, when combined with other stations within the assessment unit, not sufficient to retain the mean value above GES (i.e. the assessment unit level is sub-GES). On the other hand, stations within assessment unit SEA-015 (Bothnian Sea) generally fail their individual threshold values but when aggregated to an assessment unit level mean value, inclusive of the regional uncertainties, the assessment unit itself is in GES. This evaluation should be treated with some caution as there is likely some underlying uncertainties at the level where evaluations are close to the threshold value.

4.2 Trends

Examples of key trends at selected stations are provided above. For certain parameters, such as sediment analyses, assignment of statistical trends is not easy to achieve due to the nature and frequency of the monitoring applied. For other monitoring matrices the identification of statistical trends is viable and a small number of decreasing trends (i.e. concentrations becoming lower) have been identified.

For water (of 42 stations) no distinct trends were recorded.

For biota (of 37 stations) 4 downward trends (decreasing concentrations) were identified and a single upward trend.

For sediment (of 54 stations) no distinct trends were recorded.

TBT is highly persistent thus the few identified decreasing trends and the increasing trend from a single station are considered a positive sign that implemented measures have had an impact and controlled further inputs to a valuable level.

4.3 Discussion

TBT is slowly degraded to DBT, MBT and finally tin. The process is however very slow, especially in anoxic sediments, so the sediment concentration is expected to be above the QS many years ahead, but to eventually follow the decreasing pattern as initial signs seen from the imposex and biota results. An overview of the current evaluation results and a comparison to the prior test evaluation are provided in Table 3.

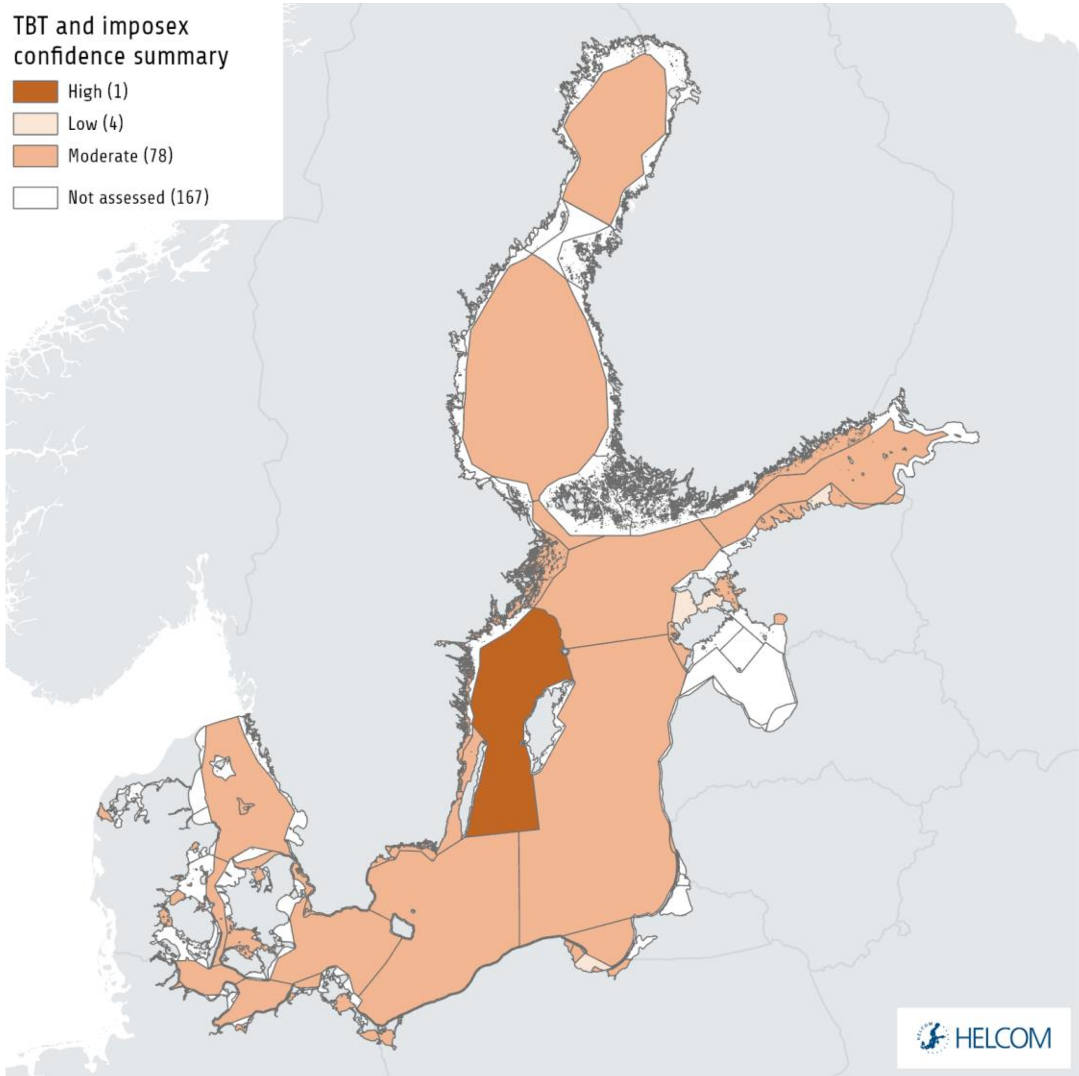
Table 3. Overview of evaluation outcomes and comparison with previous evaluation (using the OOAO evaluation outcomes per assessment unit). Currently this approach is only applied for open sea assessment units.

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 is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Great Belt (SEA-002)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
The Sound (SEA-003)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Kiel Bay (SEA-004)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Bay of Mecklenburg (SEA-005)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Arkona Basin (SEA-006)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Bornholm Basin (SEA-007)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Gdansk Basin (SEA-008)	Not assessed	Failed	No change in status is	The threshold value is not

			observed. TBT is slow to degrade.	achieved where evaluated for sediment, thus status is sub-GES.
Eastern Gotland Basin (SEA-009)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Western Gotland Basin (SEA-010)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Northern Baltic Proper (SEA-012)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Gulf of Finland (SEA-013)	Not assessed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Åland Sea (SEA-014)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.
Bothnian Sea (SEA-015)	Failed	Achieved		The threshold value is achieved but there are uncertainties to be considered as stations in the assessment unit did not achieve GES.
Bothnian Bay (SEA-017)	Failed	Failed	No change in status is observed. TBT is slow to degrade.	The threshold value is not achieved where evaluated for sediment, thus status is sub-GES.

5 Confidence

The overall confidence of the evaluation is considered to be moderate, with a few assessment units achieving high and some achieving low confidence (see confidence map Figure 11, and table in Annex 1).



Results figure 11. Map presenting the confidence in the overall evaluation based on a OOAO summary of confidence across all monitored matrices (se Annex 1). The evaluation is carried out using Level 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4).

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 4.

After the ban on TBT in antifouling paints, few uses of organotins as pesticides (mainly phenyltins) are still legal. The major source is now its release from impacted sediments in harbour areas and shipping routes (dredging) and illegal use of TBT-containing antifouling paints. Studies in Sweden have also shown that the supply of TBT via contaminated port areas and the management of boats on land are of great importance for continued distribution to the marine environment. High concentrations have been found in stormwater drainage systems (up to 40 000 ng/l in water and up to 285 000 µg/kg TS in the sludge) and in dirt samples (up to 39000 µg/kg TS) sampled close to harbour areas (Bengtsson & Wernersson, 2012).

Table 4. Brief summary of relevant pressures and activities with relevance to the indicator.

	General	**MSFD Annex III, Table 2a**
Strong link	Shipping, leisure boating, maritime activities, dredging and disposal/disturbance of dredged material.	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	Disturbance of material or displacement from marinas and onshore deposits.	

7 Climate change and other factors

Climate change in the Baltic Sea region is expected to have significant impacts on key processes in the marine environment (HELCOM and Baltic Earth 2021). While there are relatively few studies that fully explore the impacts of such changes on hazardous substances direct parameters such as changes in water temperature, atmospheric deposition, precipitation, river run off and sediment transportation could all alter the flow of contaminants to and within the marine environment. Disturbance of historic deposits of TBT, for example in old port areas could conceivably represent a major new source of contamination in such circumstances. In addition, alterations in metabolic aspects as well as food web structure and function may also alter the transfer of contaminants within the ecosystem and food web and thus alter the levels of bioaccumulation (as well as possible effects).

8 Conclusions

Overall, the concentrations of TBT and the respective impacts on biota indicate that the Baltic Sea is not in Good Environmental Status (sub-GES). The indication that there generally are not increasing concentrations occurring is indicative of the fact that the prior bans on the application of TBT in antifouling paints has been successful in controlling further inputs.

8.1 Future work or improvements needed

The indicator is generally fully operational but increased spatial and temporal monitoring as well as improved analytical approaches for certain matrices would benefit the indicator and reduce uncertainties.

9 Methodology

9.1 Scale of assessment

The assessment of the present environmental status in respect of TBT content has been carried out in all assessment units at level 4.

The core indicator evaluates the status with regard to concentrations of TBT using HELCOM assessment unit Level 4 (division of the Baltic Sea into 17 sub-basins and further division into coastal and offshore areas). The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

9.2 Methodology applied

To evaluate contamination status of Baltic Sea, the ratio of concentration of TBT in the biotic and abiotic elements of marine environment to the specified concentration (threshold) levels are used. Data are extracted from the HELCOM COMBINE database as specified in the extraction table to ensure that the values are from the appropriate measurement matrices (Table 2).

All available data on TBT concentrations in seawater, molluscs and sediments from 2016 to 2021 (longer historic data used in trend assessment where available), reported by HELCOM Contracting Parties to the HELCOM COMBINE database, were used to assess the state of the Baltic Sea environment for this assessment period (2016-2021). Also imposex in marine gastropods, as VDS, was used.

A two-way approach was used to determine the representative concentrations of the individual TBT and imposex 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, the average values were calculated and these values were defined as initial status evaluation station data. The lower confidence of these data was taken into account during assessment process.

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

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 and Biological effects of contaminants (imposex) [still under development]

Quality assurance in the form of international workshops and proficiency testing has been organized annually by QUASIMEME starting from development exercises in 1998, 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 TBT and imposex are monitored regularly in few countries, mainly in the more saline parts of the Baltic Sea. Monitoring is performed in sediment (Denmark, Sweden, Germany, Lithuania), mussels and fish liver (several contracting partners but no threshold for fish livers) and Water (Germany, Lithuania and Poland). Imposex is reported by Denmark and Sweden.

The number of sediment and biota monitoring stations per sub-basin is indicated in Monitoring Figure 1.

Description of optimal monitoring

TBT 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 mussels and marine gastropods. Current levels are close to detection limits in pristine areas away from ship routes and harbours with historic contaminations.

Sediment monitoring can complement the evaluation. Sediment represents longer timespans than biota (typically years vs. months), and is 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.

Water monitoring is generally at levels close to or below the current quantification levels, and can only be recommended with quantification levels around 0.05 ng/l or preferably better.

Monitoring of TBT 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.

[Result: TBT and imposex in biota]

[Result: TBT and imposex in sediment]

[Result: TBT and imposex in water]

[Data: Hazardous substances in biota]

[Data: Hazardous substances in sediment]

[Data: Hazardous substances in water]

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

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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.

Earlier versions of the core indicator report:

Tributyltin TBT and imposex HELCOM core indicator 2018 (pdf)

HOLAS II component - Core indicator report – web-based version July 2017 (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 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) 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 applied 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 water, sediments and biota below (Annex 1 - Tables 1-3).

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 water.

Assessment unit	Spatial component	Temporal component	Methodological component	Evaluation component	Overall category
EST-001	Moderate	Moderate	High	Moderate	Moderate
EST-002	Low	Low	High	Low	Low
EST-003	Moderate	Moderate	High	Moderate	Moderate
EST-005	Moderate	High	High	High	Moderate
EST-008	High	Low	High	Low	Moderate
EST-009	High	Low	High	Low	Moderate
EST-010	Low	Low	High	Low	Low
EST-011	Moderate	Moderate	High	Moderate	Moderate
EST-013	Moderate	Low	High	Low	Moderate
EST-014	Low	Low	High	Low	Low
EST-016	Moderate	Moderate	High	Moderate	Moderate
GER-002	High	Low	High	Moderate	Moderate
GER-005	High	Low	High	Moderate	Moderate
GER-007	High	Low	High	Low	Moderate
GER-010	Moderate	Low	High	Low	Moderate
GER-013	Moderate	Low	High	Moderate	Moderate
GER-020	Moderate	Low	High	Moderate	Moderate
LIT-002	High	Low	High	Moderate	Moderate
LIT-003	High	Low	High	Moderate	Moderate
LIT-006	Moderate	Low	High	Moderate	Moderate
POL-001	High	Low	High	Moderate	Moderate
POL-002	Moderate	Moderate	High	Moderate	Moderate
POL-003	Moderate	Moderate	High	Moderate	Moderate
POL-004	Moderate	Low	High	Low	Moderate
POL-005	Moderate	Low	High	Low	Moderate
POL-006	Low	Low	High	Low	Low
POL-007	High	Low	High	Moderate	Moderate
POL-008	High	Low	High	Low	Moderate
POL-009	High	Low	High	Moderate	Moderate
POL-010	High	Low	High	Low	Moderate
POL-011	High	Low	High	Low	Moderate
POL-012	High	Low	High	Low	Moderate
POL-014	High	Low	High	Low	Moderate
POL-015	High	Low	High	Low	Moderate
POL-016	Moderate	Low	High	Low	Moderate
POL-017	High	Low	High	Low	Moderate
POL-018	High	Low	High	Moderate	Moderate
POL-019	High	Low	High	Moderate	Moderate
SEA-005	High	Low	High	Moderate	Moderate
SEA-006	High	Moderate	High	Moderate	Moderate
SEA-007	Moderate	Moderate	High	High	Moderate

SEA-009	Moderate	High	High	High	Moderate

Annex 1 – Table 2. Summary table showing categorical confidence per component and overall for biota.

Assessment unit	Spatial	Temporal	Methodological	Evaluation	Overall category
DEN-139	Moderate	Low	High	Moderate	Moderate
DEN-145	High	Moderate	High	Moderate	Moderate
DEN-200	Moderate	Moderate	High	Moderate	Moderate
DEN-206	Low	Moderate	High	Moderate	Moderate
DEN-217	Moderate	Moderate	High	Moderate	Moderate
DEN-224	Moderate	Low	High	Moderate	Moderate
DEN-232	High	High	High	Moderate	Moderate
SWE-005	High	High	High	Moderate	Moderate
SWE-006	Moderate	High	High	High	Moderate
SWE-007	Moderate	Moderate	High	Moderate	Moderate
SWE-008	Low	Moderate	High	Low	Moderate
SWE-011	Moderate	High	High	High	Moderate
SWE-012	Moderate	High	High	Moderate	Moderate
SWE-015	Low	High	High	Moderate	Moderate
SEA-001	Low	High	High	Moderate	Moderate
SEA-002	Moderate	High	High	Moderate	Moderate
SEA-003	High	Moderate	High	Moderate	Moderate

Annex 1 – Table 3. Summary table showing categorical confidence per component and overall for sediment.

Assessment unit	Spatial	Temporal	Methodological	Evaluation	Overall category
DEN-024	Moderate	Low	High	Low	Moderate
DEN-034	Moderate	Low	High	Low	Moderate
DEN-045	Moderate	Low	High	Low	Moderate
DEN-085	High	Low	High	Low	Moderate
DEN-092	High	Low	High	Low	Moderate
DEN-113	High	Low	High	Moderate	Moderate
DEN-128	High	Low	High	Low	Moderate
DEN-136	High	Low	High	Low	Moderate
DEN-137	High	Low	High	Low	Moderate
DEN-142	High	Low	High	Low	Moderate
EST-003	Moderate	Moderate	High	Moderate	Moderate
EST-011	Moderate	Low	High	Low	Moderate
EST-016	Moderate	Low	High	Low	Moderate
FIN-004	Low	Low	High	Low	Moderate
GER-026A	High	Low	High	Moderate	Moderate
GER-026B	High	Low	High	Moderate	Moderate
GER-029	High	Low	High	Moderate	Moderate
GER-031	High	Low	High	Moderate	Moderate

GER-032	High	Low	High	Moderate	Moderate
POL-002	Moderate	Low	High	Moderate	Moderate
POL-003	Moderate	Low	High	Moderate	Moderate
SEA-001	Low	Moderate	High	Moderate	Moderate
SEA-004	Moderate	Moderate	High	Moderate	Moderate
SEA-005	High	High	High	High	High
SEA-006	High	High	High	High	High
SEA-007	High	High	High	High	High
SEA-008	Moderate	Low	High	Low	Moderate
SEA-009	Moderate	High	High	High	Moderate
SEA-010	High	High	High	High	High
SEA-012	Low	Low	High	Moderate	Moderate
SEA-013	Moderate	Moderate	High	Moderate	Moderate
SEA-014	Moderate	Moderate	High	Moderate	Moderate
SEA-015	Moderate	Moderate	High	Moderate	Moderate
SEA-017	Moderate	Moderate	High	High	Moderate