



**Perfluorooctane sulphonate (PFOS)**

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



## Perfluorooctane sulphonate (PFOS)

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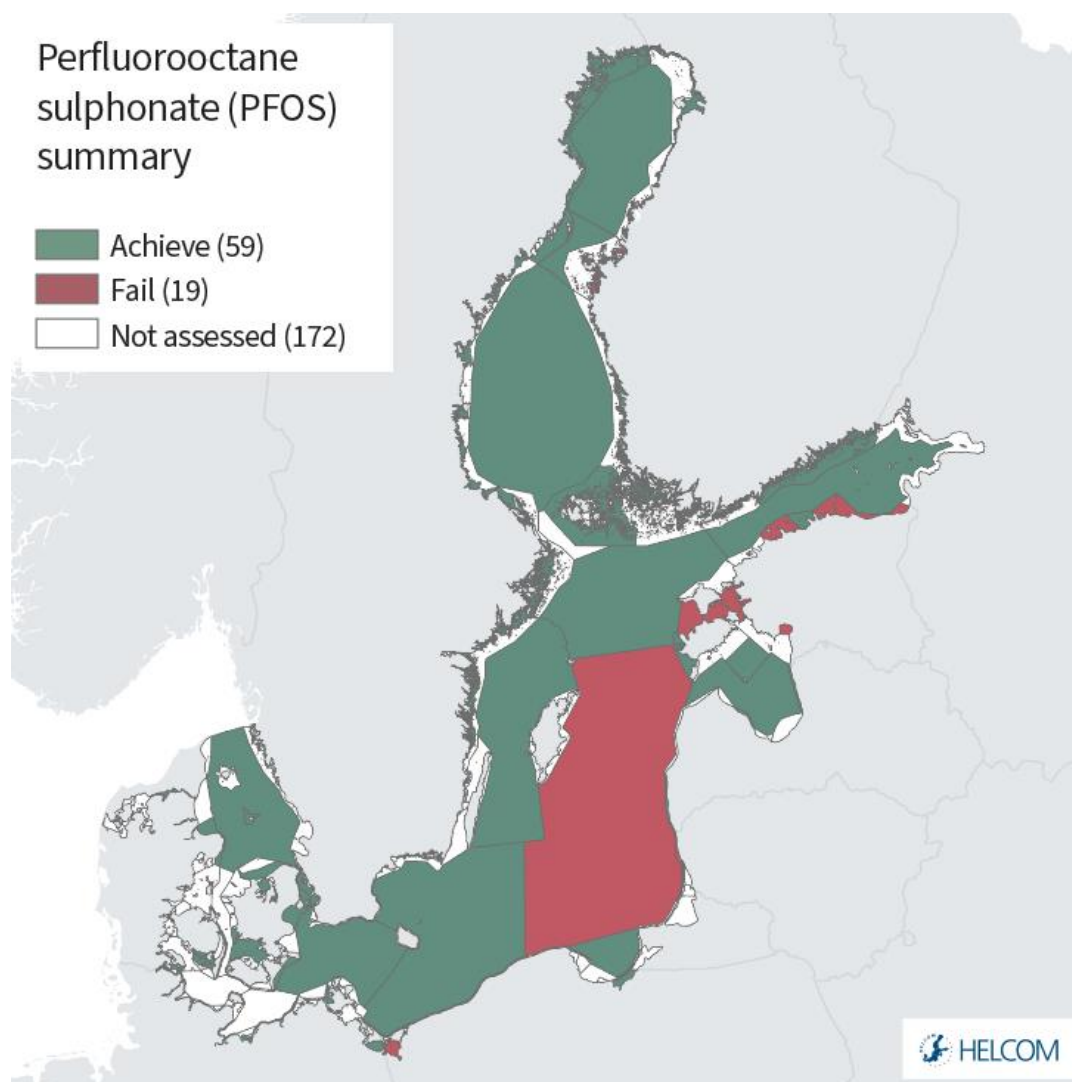
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## 1 Key message

This core indicator evaluates the status of the marine environment based on concentrations of perfluorooctane sulphonate (PFOS) in Baltic Sea fish and, in a number of assessment units, the secondary matrix seawater. Good status is achieved when the concentrations of PFOS are below the regionally agreed threshold values. The current evaluation considers the assessment period 2016-2021 (Figure 1).



**Figure 1.** Status results based on evaluation of the indicator 'perfluorooctane sulphonate (PFOS)'. One-Out-All-Out (OOAO) method, in biota and in seawater. 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.

Figure 1 show the status result for PFOS based on the combined results for biota and water with the lowest status in an area of the two matrixes outranking the better one. Concentrations of PFOS are below the threshold value in biota in almost all the monitored areas, with 68 assessment units evaluated (13 of which are open sea) and only one failing

to achieve the threshold value (failing to achieve good environmental status (GES)). However, the concentrations in seawater exceed the threshold value (EQS for water) for all but two of the twenty (only one open sea) assessment units evaluated. The reason for the failure to achieve GES (red areas in the summary key message indicator map; Figure 1) is therefore mostly linked to the failure of the threshold value for water. Using the primary threshold set for muscle concentration in biota, GES is achieved for all evaluated areas, except for the assessment unit FIN-006 in The Quark sub-basin during the assessment period 2016-2021. Data is available from Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden but there are still smaller areas where data are absent (both open sea and coastal assessment units at HELCOM Level 4) and several areas are evaluated based on only one or few years of monitoring data (especially for water). Therefore, increased monitoring frequency is needed to enable a more complete evaluation throughout the entire Baltic Sea.

Time series of PFOS levels in biota show increasing concentrations since the 1970s and 1980s in the Baltic Proper and the Bothnian Sea. However, in the most recent ten-year period stable or decreasing concentrations of PFOS are observed across the Baltic Sea. Where distinct trends could be assigned in the current analysis this is also what is observed in biota at individual stations.

The confidence of the indicator evaluation results is considered to be moderate with some specific assessment units being of low or high confidence.

The indicator is applicable in all Baltic Sea waters.

### 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) Perfluorooctane sulphonate (PFOS). HELCOM Core Indicator Report. Online. [Date Viewed], [Web link].

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## 2 Relevance of the indicator

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PFOS is a persistent, bioaccumulative and toxic compound with possible effects on the immune, reproductive and developmental systems as well as lipid metabolism in organisms. It is considered a global environmental contaminant. PFOS has been produced since the 1950s and has been used for production of fluoropolymers and to provide grease, oil and water resistance to materials such as textiles, carpets, paper and coatings in general. PFOS has also been used widely in firefighting foams.

Measurements of PFOS concentrations provide information on the contaminant load of the Baltic Sea, the presence of PFOS in biological samples also reflects the bioavailable part of the contaminant. Predators (particularly top predators) and humans are exposed to the contaminant through consumption of the species assessed in this indicator.

### 2.1 Ecological relevance

Perfluorooctane sulphonate (PFOS), perfluoro octanoic acid (PFOA) and other perfluorinated compounds are considered global environmental contaminants. PFOS and PFOA are chemically and biologically inert and very stable (Poulsen *et al.* 2005). PFOS meets the P (Persistent) and vP (very Persistent) criteria due to slow degradation. PFOS is also bioaccumulative (B) and toxic (T) (OSPAR 2005). PFOA is considered very persistent (vP) and toxic (T), but not bioaccumulative (Van der Putte *et al.* 2010). It has a capacity to undergo long-range transportation.

PFOS related substances and PFOA are members of the larger family of perfluoroalkylated substances (PFAS). Perfluorooctanesulfonyl fluoride (POSF) is used to make PFOS and PFOS-based compounds. The POSF-derived substances (PFOS-related compounds) ultimately degrade to form PFOS. Some 100–200 PFOS-related compounds have been identified (KEMI 2006). PFOS binds to blood proteins and bioaccumulates in the liver, egg yolks, serum, and gall bladder unlike most persistent organic pollutants that typically accumulate into fat (Renner 2001; Nordén *et al.* 2013; Goeritz *et al.* 2013; Shi *et al.* 2012).

PFOS has been shown to disturb the immune system, development and reproduction (endocrine disruption) of organisms and influence lipid metabolism. It is also suspected to induce liver necrosis. Falandysz *et al.* (2006) have suggested that the consumption of contaminated fish from the Baltic Sea contributes significantly to human blood levels of perfluoroalkyl compounds.

Due to PFOSs bioaccumulative properties, marine mammals have considerably higher concentrations than marine and freshwater fish, and were found to have the highest PFOS concentrations amongst all Nordic biota (HELCOM 2010). Several hundreds to one thousand  $\mu\text{g kg}^{-1}$  ww of PFOS have been found in the livers of grey seals (in the southern Baltic Proper and Bothnian Sea; Nordic Council of Ministers 2004), harbour seals (Great Belt and the Sound; Nordic Council of Ministers 2004) as well as ringed seals (Bothnian Bay; Kannan *et al.* 2002). In the eggs of common guillemots (Western Gotland Basin), observed PFOS concentrations have mostly been 500-1000  $\mu\text{g kg}^{-1}$  ww for the past two decades (Soerensen and Faxneld 2022). An OSPAR risk assessment (OSPAR 2005) on the

marine environment concluded that the major area of concern for PFOS is the secondary poisoning of top predators, such as seals and predatory birds.

The evaluations in this core indicator are made based on concentrations mainly measured in fish, usually from reference areas with no point source pollution. The case studies and measurements from marine mammals in the Baltic Sea, highlight that PFOS may pose more severe contamination risks to the Baltic Sea than the current indicator evaluation would suggest.

In recent years, a few studies has been published that together capture the spatial variability of PFAS across most of the Baltic Sea (excluding the Gulf of Finland and the Gulf of Riga) (Ngyuen *et al.* 2017; Joers *et al.* 2019). Short chain ( $C \leq 9$ ) PFCAs dominated in the surface water with only 10-20% coming from PFOS. PFOS offshore surface water concentrations were found to increase from the Bothnian Bay (0.1-0.9 ng/L) to the Southern Baltic and Belt Sea (0.5-2.5 ng/L; Ngyuen *et al.* 2017). Both  $\Sigma$ PFAS and PFOA were also found to increase from the Bothnian Bay (1.2-4.7 ng/L and 0.2-0.5 ng/L) to the Southern Baltic and Belt Sea (3.5-14.0 ng/L and 0.6-1.3 ng/L; Ngyuen *et al.* 2017). PFAS concentrations from along the German coastline (2-9 ng/L) supported the presence of higher concentrations in the South (Joers *et al.* 2019).

Joseffson *et al.* (2022) presents PFAS concentrations in Baltic Sea sediments that extent from the Bothnian Bay to the Belt Sea (excluding the Gulf of Finland and the Gulf of Riga). The report presents two full surveys from 2014 and 2020/21. The results show  $\Sigma$ PFAS and PFOS of 0.4-2.5  $\mu\text{g}/\text{kg dw}$  and 0.2-1.1  $\mu\text{g}/\text{kg dw}$ , respectively, in the Baltic Proper, southern Baltic Sea and North Sea but significantly higher concentrations in the Bothnian Sea and Bay (7-26  $\mu\text{g}/\text{kg dw}$  and 3.3-6.6  $\mu\text{g}/\text{kg dw}$ , respectively). In the southern Baltic and Kattegat, Joers *et al.* (2019) found  $\Sigma$ PFAS and PFOS concentrations comparable to the findings by Joseffson *et al.* (2022) for the same areas. PFOS levels of up to 0.9  $\mu\text{g kg}^{-1} \text{ ww}$  have been reported from the Gulf of Finland close to Helsinki (Nodic Council of Ministers, 2004) and of 0.03-0.9  $\mu\text{g kg}^{-1} \text{ dw}$  in surface sediments from the Gulf of Gdansk (Falandysz *et al.* 2012). Along the German Baltic Sea coast, concentrations of PFOS in sediments were in the order of 0.02-0.67  $\mu\text{g kg}^{-1} \text{ dw}$  (Theobald *et al.* 2007). The 8-17 times higher PFAS values in the Bothnian Bay and Sea were dominated by PFOS, PFOA and PFNA, while PFOS and PFUnDA were highest at more southerly stations (Joseffson *et al.* 2022). The reason for the high concentrations is unknown and the spatial pattern is not mimicked by  $\Sigma$ PFAS or PFOS in water (Ngyuen *et al.* 2017) or herring (Soerensen and Faxneld 2020)

The most important route of exposure of PFOS for humans is uptake from food (especially fish), drinking water and exposure to indoor dust (FOI 2013).

## 2.2 Policy relevance

The core indicator on PFOS concentrations addresses the Baltic Sea Action Plan's (BSAP) hazardous substances segment's goal of the 'Baltic Sea unaffected by hazardous substances and litter' and the underlying ecological objectives 'Concentrations of hazardous substances close to natural levels' and 'All fish safe to eat'. There also relevance to the Biodiversity segment goal of 'Baltic Sea ecosystem is healthy and resilient'.

The core indicator is relevant to the following specific BSAP commitment:

- 'Agree to start by 2008 to work for strict restrictions on the use in the whole Baltic Sea catchment area of the Contracting States.'

PFOS is included in the HELCOM list of substances or substance groups of specific concern to the Baltic Sea which was adopted as part of the BSAP.

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.

PFOS is included on the revised list of the EU Priority Substances (European Commission 2013) and in the Stockholm Convention list of persistent organic pollutants (POPs), Annex B, which requires the parties to the convention to restrict the production and use of the substance.

The production and use of PFOS has been regulated in some countries (e.g. US, Canada, and the EU), but large-scale PFOS production continues in other parts of the world, e.g. China. PFOS has been produced and used since the 1950s, but due to findings of detectable concentrations in human blood in the general population and negative health effects on living organisms, PFOS was phased out in 2002 by its main producer 3M.

**Table 1.** Overview of key policy relevance elements.

	<b>Baltic Sea Action Plan (BSAP)</b>	<b>Marine Strategy Framework Directive (MSFD)</b>
<b>Fundamental link</b>	Segment: Hazardous substances and litter goal Goal: "Baltic Sea unaffected by hazardous substances and litter" <ul style="list-style-type: none"> <li>• Ecological objective: "Marine life is healthy", "Concentrations of hazardous substances are close to natural levels" and "All sea food is safe to eat".</li> <li>• Management objective: "Minimize input and impact of hazardous</li> </ul>	Descriptor 8 Concentrations of contaminants are at levels not giving rise to pollution effects. <ul style="list-style-type: none"> <li>• 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.</li> <li>• Feature – Contaminants list.</li> <li>• Element of the feature assessed – Contaminants list.</li> </ul>

	substances from human activities”.	
<b>Complementary link</b>	<p>Segment: Biodiversity Goal: “Baltic Sea ecosystem is healthy and resilient”</p> <ul style="list-style-type: none"> <li>• 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”.</li> <li>• Management objective: “Reduce or prevent human pressures that lead to imbalance in the food web”.</li> </ul>	<p>Descriptor 9 Contaminants in fish and other seafood for human consumption do not exceed levels established by Union legislation or other relevant standards.</p> <ul style="list-style-type: none"> <li>• 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: <ul style="list-style-type: none"> <li>(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;</li> <li>(b) for additional contaminants, not listed in Regulation (EC) No 1881/2006, threshold values, which Member States shall establish through</li> </ul> </li> <li>• Feature – Contaminants in seafood.</li> <li>• Element of the feature assessed – Contaminants in Foodstuffs Regulation.</li> </ul>
<b>Other relevant legislation:</b>	<ul style="list-style-type: none"> <li>• The Water Framework Directive and Regulation (EU) 2019/1021 on persistent organic pollutants and the Stockholm Convention on Persistent Organic Pollutants.</li> <li>• 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.</li> </ul>	

### 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 PFOS in the marine environment, this indicator along with the other hazardous substances core indicators are used to achieve an overall assessment of hazardous substances.

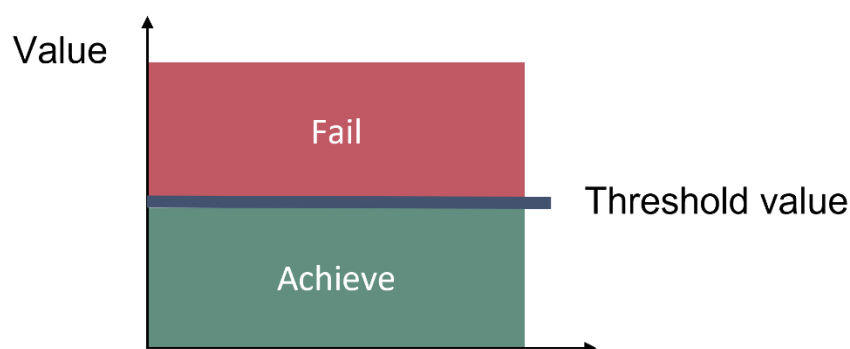


### 3 Threshold values

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Good status is achieved when the concentration of perfluorooctane sulphonate (PFOS) in fish is below 9.1  $\mu\text{g}/\text{kg}$  muscle wet weight (PFOS EQS dossier, 2011). An alternative, secondary threshold value at 0.00013  $\mu\text{g}/\text{l}$  is set for marine water (PFOS EQS dossier, 2011). While biota is the primary threshold matrix, the environmental status is set based on the lowest status for either matrixes if both biota and water (secondary threshold) is evaluated (Table 2).

The threshold value is an environmental quality standard (EQS), derived at EU level as a substance included on the list of priority substances under the Water Framework Directive (European Commission 2000, 2013). Good environmental status within the MSFD is defined as 'concentrations of contaminants at levels not giving rise to pollution effects'. A conceptual visualisation is provided in Figure 2.



**Figure 2.** Good environmental status (GES) is achieved if the concentration of PFOS in fish is below the threshold value of 9.1  $\mu\text{g}/\text{kg}$  muscle wet weight. The threshold value is an environmental quality standard (EQS) derived at EU level as a substance included on the list of priority substances under the Water Framework Directive.

For harmonization purposes the EC Guidance Document No. 32 on biota monitoring (the implementation of EQS<sub>biota</sub>) under the WFD was developed (European Commission 2014). This guidance document recommends that the results from the monitoring should be standardized to represent fish at a trophic level of 4, which is an estimate of the general trophic level in commercial fish in Europe. The recommendation to obtain PFOS data in fish at a trophic level of 4 is to adjust the values from monitoring in accordance with trophic magnification factors and trophic level. No such harmonization was done for this evaluation.

Article 3 of the EU Directive on environmental quality standards (EQSD) states that also long-term temporal trends should be assessed for substances that accumulate in sediment and/or biota, such as PFOS (European Commission 2008a). A trend indicates if the status of the environment is improving and approaching the threshold value or if the status is deteriorating.

**Table 2.** Threshold value for the core indicator addressing PFOS. Underlined supporting parameters represent parameters without which the indicator evaluation cannot be applied. MU = muscle, MU&EP = muscle and skin, LI = liver.

Indicator	Threshold value	Parameters (PARAM) / Parameter groups (PARGROUP) (see also <a href="http://vocab.ices.dk/">http://vocab.ices.dk/</a> )	Matrix	Species	Matrix	Basis	Supporting parameters and information
PFOS	Primary threshold EQS biota human health 9.1 µg/kg ww	PARAM = PFOS	Biota	Herring & cod (open sea) Flounder, sole, eelpout & Perch (coastal)	MU, MU&EP, ('fillet'), LI or whole fish	W	(lipid content)
	Secondary threshold EQS water EQS AA – 0.00013 µg/l		Water		WT (All – unfiltered is preference)		Surface water layer (≤ 5.5 m)

### 3.1 Setting the threshold value(s)

The EQS for PFOS is based on the QS set for biota to protect human health (9.1 µg/ kg fish ww), defined for edible parts in fish (the fillet consisting of muscle tissue). Qs are derived from ecotoxicological studies to protect freshwater and marine ecosystems from potential adverse effects of chemicals, as well as adverse effects on human health via drinking water and food from aquatic environments. Qs are derived for different protection goals, i.e.: pelagic and benthic communities, top-predators in these ecosystems, and human health. The most stringent of these Qs (in this case QS set for biota to protect human health) is the basis for the EQS (PFOS EQS dossier, 2011).

The alternative secondary threshold value set at 0.00013 µg/l for marine water is derived within the EQS process by using a bioconcentration factor (BCF) and biomagnification factor (BMF) for PFOS and represents the corresponding water concentration to the selected QS biota, secondary poisoning (PFOS EQS dossier, 2011).

To set the PFOS Qs and finally determine the EQS, studies on acute and chronic toxicity effects of PFOS to aquatic life was reviewed. The key studies are presented in the PFOS EQS dossier (2011). These include studies on marine and freshwater algae and aquatic plants, invertebrates, fish, mammals and birds. The human health QS, which was found to be the most stringent of the Qs, was derived based on the mammalian oral toxicity studies with a main focus on results from a subchronic study on the Cynomolgus monkey (Seacat et al, 2002). A tolerable daily intake (TDI) of 0.15 µg/kg bw/day was determined using an uncertainty factor of 200 to the NOAEL of 0.03mg/kg bw/d. The TDI was used as the threshold level (TL) when estimating the  $QS_{biota, hh}$  (µg/ kg fish ww) using the equation from European Commission (2011):

$$QS_{biota,hh} = \frac{0.1 \times TL \times 70 \text{ kg bw}}{0.115 \frac{\text{kg}}{\text{d}}}$$

where the fishery products do not exceed 10% of the TL for a 70 kg human consuming 0.115 kg/d of fishery products.

This EQS only considers PFOS, which has historically been the most widespread PFAS. However, a new indicator focussed on the sum of PFAS is currently being drafted. This indicator will focus on the sum of PFAS present in the environment and include information on the toxicity of the individual PFAS substances (EU, 2021).

## 4 Results and discussion

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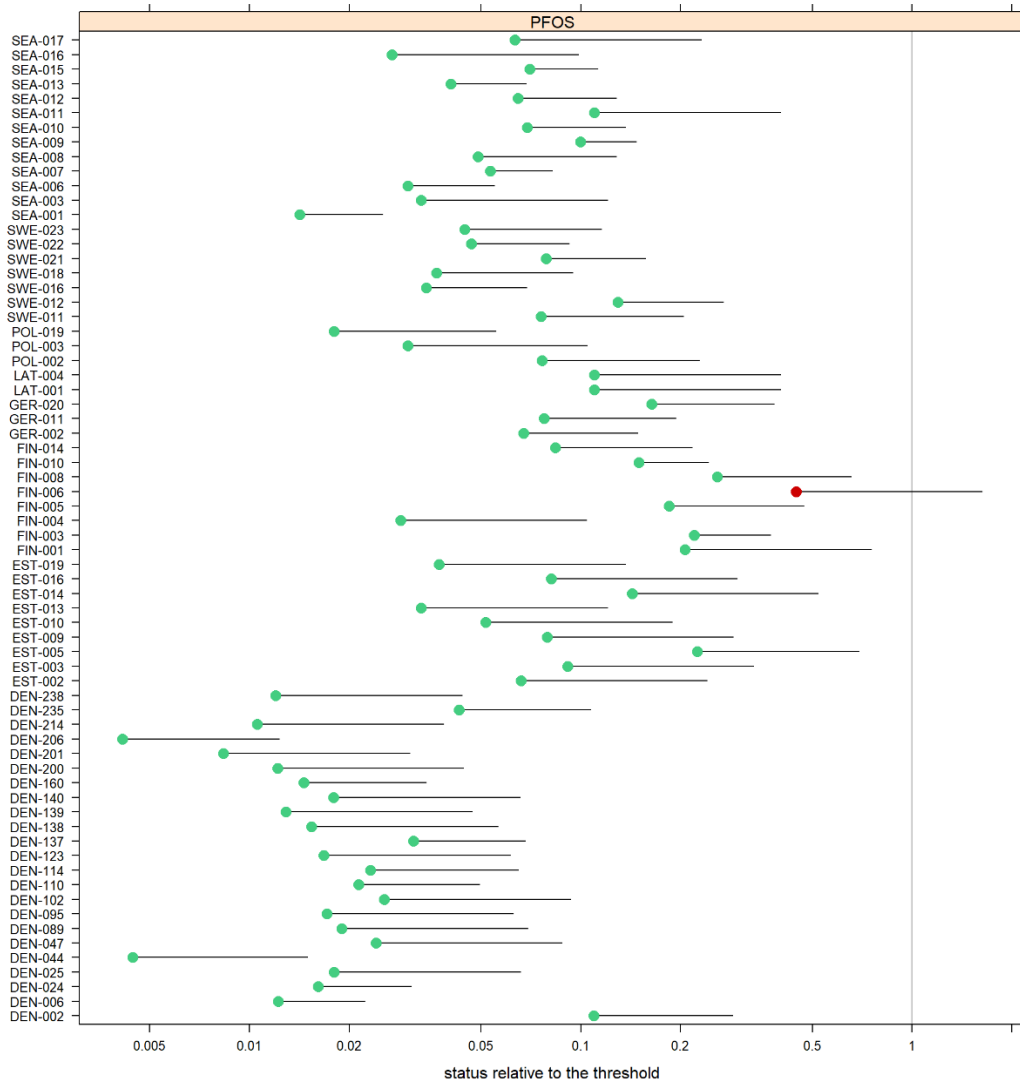
The results of the indicator evaluation that underlie the key message map and information are provided below.

### 4.1 Status evaluation

The data presented in this core indicator report were extracted from 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 PFOS in biota (fish) and water. Overall, the status of PFOS fail the EQS threshold value (sub-GES) in circa 25% of evaluated assessment units (Figure 1), though failure to achieve GES is generally associated with evaluation of the secondary threshold value for water.

#### *PFOS in biota*

All scale 4 assessment units evaluated (including 76% of open sea sub-basins) for the primary matrix, biota, achieved good status during the period 2016-2021, except for coastal assessment unit FIN-006 in The Quark sub-basin. It should be noted that the assessment unit failing the threshold only had one short data series (i.e. 'initial' data, see Methodology). The primary threshold value is set to 9.1 µg/kg wet weight in fish muscle (or 9.1 ng/g ww) with the protection goal of human health generally not exceeded (Figure 3).

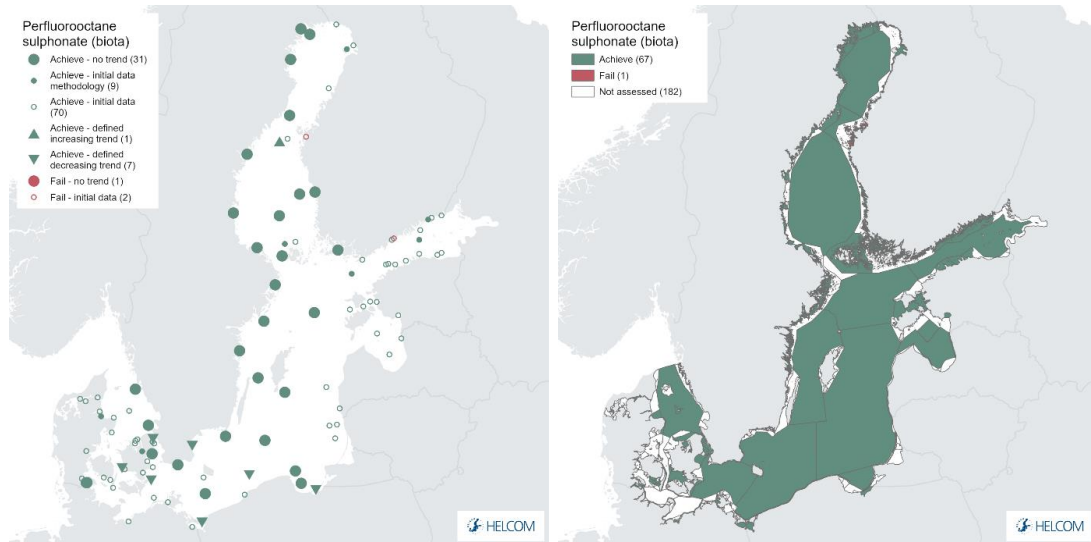


**Figure 3:** Concentrations of PFOS in fish relative to the threshold value. Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.

There are currently smaller areas in the Baltic Sea (including open sea sub-basins) that are not covered by any PFOS monitoring (Figure 4). There are also areas where the results are only based on measurements of 1-2 years ('initial' data: open circles in Figure 4). Thus, increased monitoring frequency is needed to enable a stronger and higher confidence status evaluation for the entire Baltic Sea.

The assessment unit level evaluation is built on monitoring at 121 stations, of which 40 represent 'full' data series (i.e. more than 3 years of data for the period; see methodology) to which distinct trends could be assigned statistically. Seven of these stations showed downward trends (e.g. decreasing concentrations of PFOS). These stations were located in the following sub-basins, the Bornholm Basin (3), Arkona Basin, Gdansk Basin, Great Belt and The Sound, and all achieved the threshold value (were in GES). The other 32 stations with 'full' data series showed no distinct trends and only one of these stations

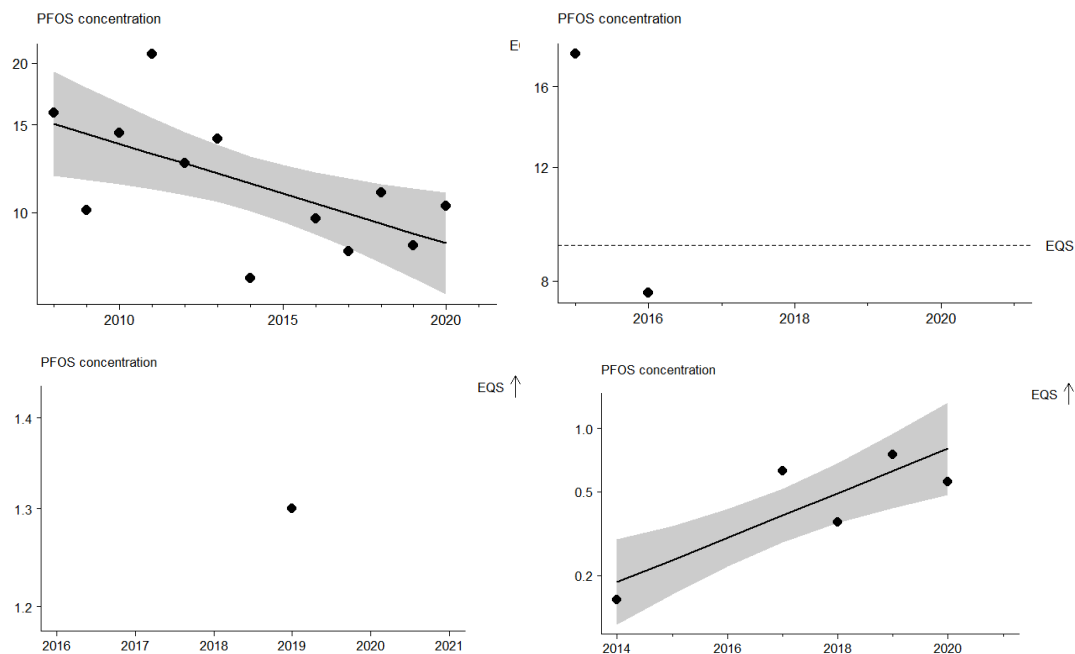
failed to achieve the threshold value (was sub-GES). A single station located in the Bothnian Sea (west Norrskär) was recorded to show an increasing trend in concentrations, but still achieved the threshold value (was in GES). The remaining stations represented ‘initial’ data sets, The only other stations to fail the threshold value were ‘initial’ stations located in coastal areas of the Gulf of Finland (Vanhankaupunginlahti) and The Quark (Vaskiluoto) sub-basins (Figure 4).



**Figure 4:** Spatial distribution of PFOS monitoring stations for biota (herring, cod, perch, eelpout and European flounder are represented) (left) and status evaluation by assessment unit in biota (right). Green colour indicates that the upper 95 % confidence interval for PFOS concentration is below the threshold value (i.e. good status). Small open circles indicate a status evaluation based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. **See ‘data chapter’ for interactive maps and data at the HELCOM Map and Data Service.**

It is important to be aware that the results used for this core indicator are mainly (but not completely) based on fish from stations considered as reference stations with no local pollution. There are most likely local areas within the Baltic Sea where the pollution load of PFOS is higher than presented in the evaluation outcome of this indicator.

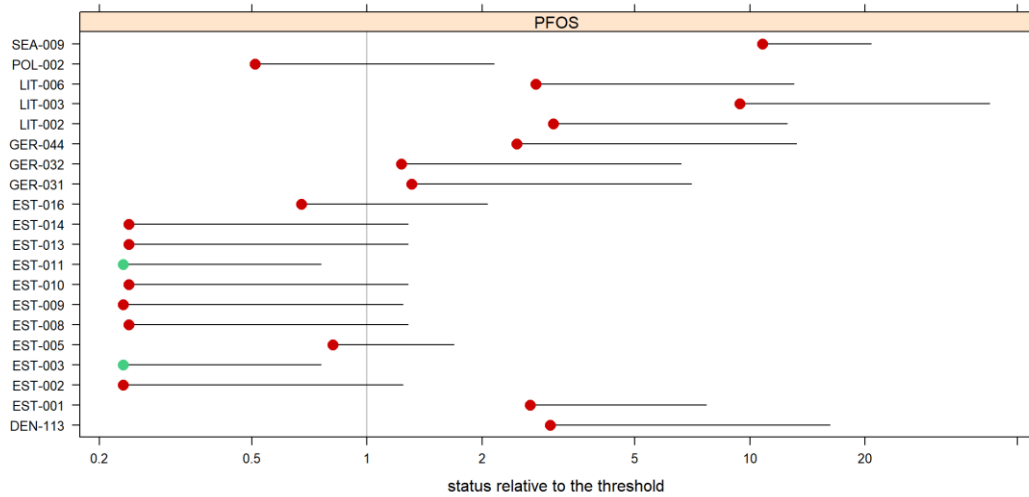
Areas such as the Gulf of Finland, Gulf of Riga, Belt Sea and Kattegat are dominated by stations evaluated as ‘initial’ data series (Figure 4). Examples of different trend patterns at the station level (station time series) are presented in Figure 5 to show the difference between ‘full’ and ‘initial’ data series.



**Figure 5.** Examples of PFOS concentration trends ( $\mu\text{g}/\text{kg ww}$ ) in biota from: the Bornholm Basin, Västra Hanöbukten station (top left – distinct decreasing trend – in GES, ‘full data’), the gulf of Finland, Vanhankaupunginlahti station (top right – sub-GES, ‘initial data’), the gulf of Riga, SJA8835000 station (bottom left – in GES, ‘initial data’), and the Bothnian Sea, west Norrskär station (bottom right – distinct increasing trend – in GES, ‘full data’).

### *PFOS in water*

Concentrations of PFOS have also been monitored in surface water by some countries (Estonia, Germany, Lithuania and Poland). When these results are assessed for the  $QS_{\text{(secondary poisoning)}}$  set in water, all but two of the evaluated assessment units fail to achieve the threshold value (Figure 6). The water QS is derived from biota QS and the difference in PFOS status between biota and water are most likely due to uncertainties in translation of biota QS into water QS. The translation involves assumptions of bioconcentration factors and biomagnification factors with a precautionary approach and may lead to a stricter QS value in water than in biota.

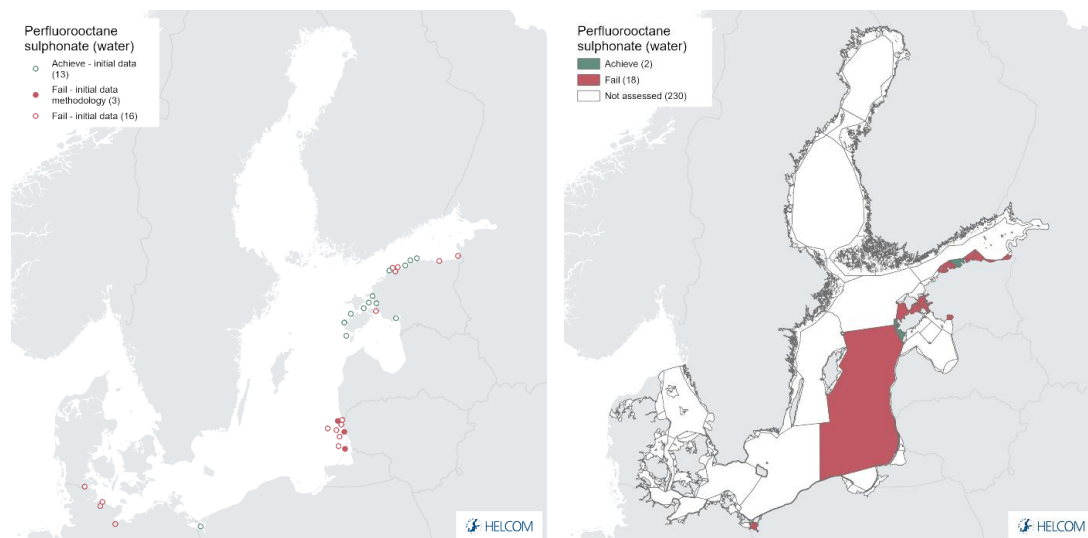


**Figure 6:** Concentrations of PFOS in water relative to the threshold value. Filled circles represent a mean value for each assessment unit and the bar represents the upper 95% confidence limit. Green colour indicates that the assessed area achieves the threshold value and red colour that the assessed area fails the threshold.

There are large areas of the Baltic Sea that are not evaluated for the secondary monitoring matrix of water and in places where water is monitored the stations are currently exclusively evaluated as ‘initial’ data due to the type of available data (Figure 7).

The assessment unit level evaluation is built on monitoring at 33 stations, all of which represent ‘initial’ data series (i.e. 2 or less years of data for the period; see methodology). Six of these stations were located in a single open sea assessment unit (sub-basin) and all others were located in coastal assessment units. Thirteen of the 33 stations achieved the threshold value (were in GES) while the remainder were sub-GES (Figure 7).





**Figure 7:** Spatial distribution of PFOS monitoring stations for the secondary threshold evaluation in seawater (left) and status evaluation by assessment unit in seawater (right). Green colour indicates that the upper 95 % confidence interval for PFOS concentration is below the threshold value (i.e. good status). Small open circles indicate a status evaluation based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. 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](#).

## 4.2 Trends

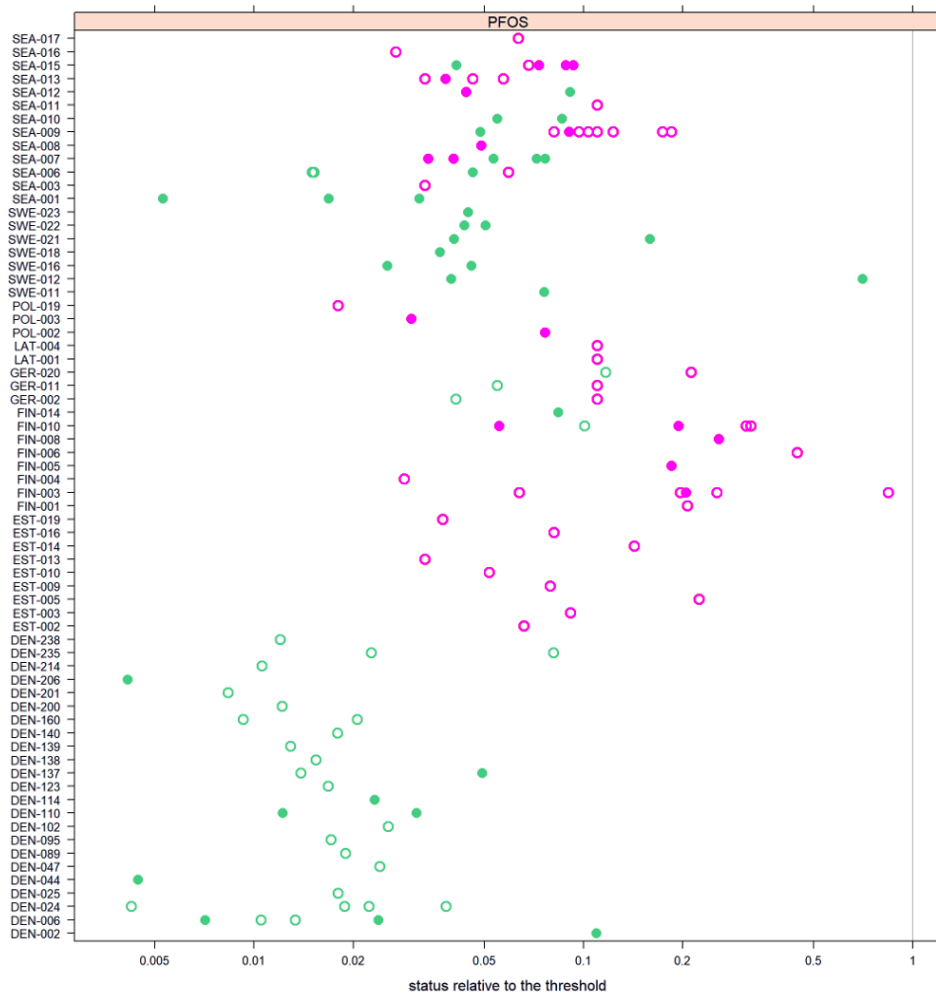
Increasing PFOS concentrations have been shown in biota time series starting in the 1970s and 1980s (Soerensen and Faxneld 2022). However, constant or downward trends are seen in herring from the Bothnian Sea, the offshore station in the Northern Baltic Proper and in Kattegat in the more recent time period (Figure 4) in the current evaluation. Examples of key trends at selected stations are provided above (Figure 5). A number of stations are evaluated as ‘initial’ data series due to limitations in the length or quality of the time series available (small symbols on maps). Increased temporal monitoring of these would provide stronger analytical potential in future evaluations. However, identification of statistical trends is viable and a small number of decreasing trends (i.e. concentrations becoming lower) have been identified. Trends were only possible to evaluate for monitoring carried out in biota, the primary threshold value, and where distinct trends were identified the large majority (7) showed decreasing concentrations, a single station showing a trend for increasing concentrations.

## 4.3 Discussion

PFOS is known to have toxic effects, accumulate in biota and persist in the marine environment. Although regulation and bans have been implemented it remains a group of substances of priority and potential concern due to the vast array of closely related compounds and the large pool of PFOS/PFAS substances already present in items and

materials which may have the potential to spread PFAS to the marine environment. All but one assessment units evaluated for biota, applying the primary threshold value, achieve the threshold value and are in GES. On the other hand the large majority of evaluations against the secondary threshold value in water fail to achieve the threshold value. The secondary threshold value is designed to be applied in areas where an evaluation in biota is not possible to achieve and it is possible that it is more precautionary (i.e. results in a greater likelihood to fail the threshold value) due to uncertainties in its derivation from the biota EQS. However, there is good reasons for continuing the evaluations of water since PFOS often enters the marine environment through discharges into the water column and only subsequently enter biota.

As the tissue utilized for biota monitoring may differ, a conversion factor is applied to ensure the measured concentrations are correctly evaluated against the threshold value (Figure 8). In the case of PFOS a conversion factor<sub>liver/muscle</sub> of 17.9 is applied to reflect higher accumulation in liver as compared to muscle (Faxneld et al., 2014).



**Figure 8.** 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 do not appear to occur (though there are limited stations assessing both): Purple = fish liver (converted to a muscle concentration using a conversion factor of 17.9), and green = fish muscle.

An overview of the outcomes for the open sea sub-basins is provided below (Table 3).

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

<b>HELCOM Assessment unit name (and ID)</b>	<b>Threshold value achieved/failed – HOLAS II</b>	<b>Threshold value achieved/failed – HOLAS 3</b>	<b>Distinct trend between current and previous evaluation.</b>	<b>Description of outcomes, if pertinent.</b>
Kattegat (SEA-001)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with all 3 stations being ‘full’ data and all achieving the threshold value (no distinct trends) for biota.
Great Belt (SEA-002)	Not evaluated	Not evaluated	NA	NA
The Sound (SEA-003)	Not evaluated	Achieved	Greater data availability allows an evaluation in this assessment period, GES being achieved.	GES is achieved, with a single ‘initial’ data station achieving the threshold value for biota.
Kiel Bay (SEA-004)	Not evaluated	Not evaluated	NA	NA
Bay of Mecklenburg (SEA-005)	Not evaluated	Not evaluated	NA	NA
Arkona Basin (SEA-006)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with one ‘full’ data station and three ‘initial’ and all achieving the threshold value (no distinct trends) for biota.
Bornholm Basin (SEA-007)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with all 5 stations being ‘full’ data and all achieving the threshold value (3 downward trends) for biota.
Gdansk Basin (SEA-008)	Achieved	Achieved	Status (in GES) remains constant in both	GES is achieved, with a single ‘full’ data station and achieving the

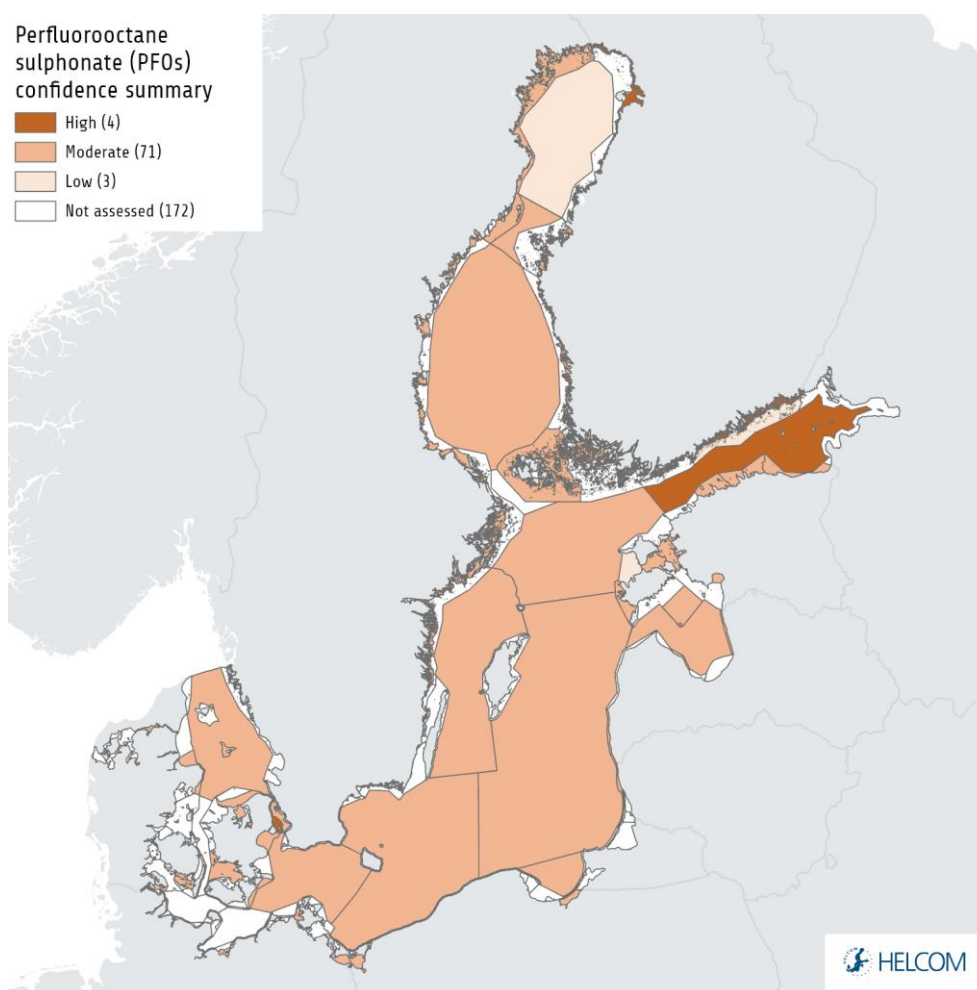
			assessment periods.	threshold value (no distinct trends) for biota.
Eastern Gotland Basin (SEA-009)	Failed	Failed	Status (sub-GES) remains constant in both assessment periods. This is based on a OAO approach where the overall evaluation is driven by monitoring in water.	GES is not achieved (sub-GES, with 2 stations being 'full' data and 8 'initial' and all achieving the threshold value (no distinct trends) for biota. However, 6 'initial' water stations all fail to achieve the threshold value.
Western Gotland Basin (SEA-010)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with 2 stations being 'full' data and both achieving the threshold value (no distinct trends) for biota.
Gulf of Riga (SEA-011)	Not evaluated	Achieved	Greater data availability allows an evaluation in this assessment period, GES being achieved.	GES is achieved, with a single 'initial' data station achieving the threshold value for biota.
Northern Baltic Proper (SEA-012)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with 1 'full' and 1 'initial' data station both achieving the threshold value (no distinct trends) for biota.
Gulf of Finland (SEA-013)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with 5 stations being 'initial' data and all achieving the threshold value (no distinct trends) for biota.
Åland Sea (SEA-013)	Not evaluated	Not evaluated	NA	NA
Bothnian Sea (SEA-015)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with 4 stations being 'full' data and one 'initial' and all achieving the threshold value for

				biota, though one showed an increasing concentration trend.
The Quark (SEA-016)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with a single 'initial' data station achieving the threshold value (no distinct trends) for biota.
Bothnian Bay (SEA-017)	Achieved	Achieved	Status (in GES) remains constant in both assessment periods.	GES is achieved, with a single 'initial' data station achieving the threshold value (no distinct trends) for biota.

## 5 Confidence

The geographical resolution for the coverage of the whole Baltic Sea is relatively good and has improved since the previous evaluation (HOLAS II) but certain areas are characterised by many stations only having short (one to a few years) of observations and no detailed geographical studies to investigate the variability have yet been carried out. The conversion of PFOS concentrations in liver to muscle values introduces uncertainties into the status evaluation (see 9.2 Methodology Applied). In addition, the trophic level of the fish used for monitoring (predominantly herring, which has a trophic level of approximately 3 in the Baltic Sea) is lower than recommended for the threshold, thus leading to possible underestimations in relation to the threshold.

Despite the uncertainties described above, and since most evaluations are well below the threshold value, the confidence in the evaluation of the aggregated assessment units is considered in general to be moderate, with some assessment units having high or low confidence (Figure 9 and further details in Annex 1).



**Figure 9.** Map presenting the confidence in the overall evaluation based on a OAO 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](#)).

## 6 Drivers, Activities, and Pressures

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Drivers are often complex issues that are difficult to quantify, though in certain instances proxies can be utilised to represent them or changes in them. A driver may for example 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 production and the subsequent pressures for that activity. A brief overview of key pressures and activities is provided in Table 4.

PFOS is both intentionally produced as well as formed as an unintended transformation product from related anthropogenic chemicals. PFOS is still produced in several countries, such as China. Some PFAS have been manufactured for more than five decades. They are applied in industrial processes (e.g., production of fluoropolymers) and in commercial products such as water- and stain-proofing agents and fire-fighting foams, electric and electronic parts, photo imaging, hydraulic fluids and textiles (Paul *et al.* 2009).

The American company 3M was the main producer of PFOS and its related substances until 2002. They started the production of perfluorochemicals already in 1949. The production of PFOS increased between 1966 and 1990 and peaked between 1990 and 2000. In 2003, China started a large-scale production of PFOS. Between 2003 and 2008 China was both the main global producer and user of PFOS substances. However, also Japan and Germany produced PFOS during the same period, but after 2007 PFOS has not been produced in Germany (Carloni 2009).

The major transport ways of PFOS to the Baltic Sea has been shown to be rivers (77%) but also atmospheric deposition (20%). Wastewater treatment plants on the other hand were shown to have a negligible contribution (less than 2%) (Filipovic *et al.* 2013). The sources of PFOS to the atmosphere are still not clear, but a major contributor is believed to be transformation of precursor compounds (FOSA (Perfluorooctane sulfonamide) and FOSE (Perfluorooctane sulfonamidoethanol)) that have been emitted from production facilities and fluorochemical products (Armitage *et al.* 2009). Seventy-eight percent of the total PFOS in the Baltic Sea was estimated to be stored in the water column (Filipovic *et al.* 2013).

PFAS can be introduced into the environment both from point sources (e.g. landfills, manufacturing plants, application of firefighting foam containing PFOS) and non-point sources such as atmospheric deposition and degradation of precursors (Ahrens & Bundschuh 2014). High amounts of PFOS have been found in both sludge and groundwater close to military air base sites and airports where firefighting foam has been used to prevent fires (FOI 2013; Arias *et al.* 2015). Furthermore high levels of PFAS, including PFOS, have been found close to industries producing fluortelomers (Wang *et al.* 2014; Shan *et al.* 2014).

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

	<b>General</b>	<b>MSFD Annex III, Table 2a</b>
<b>Strong link</b>	Use of synthetic compounds to increase grease, oil and water resistance of materials Use of firefighting foams	Substances, energy and litter - Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events
<b>Weak link</b>		



## 7 Climate change and other factors

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Precipitation and river discharge are predicted to increase as a result of climate change in especially the northern Baltic, while some decreases in river inflow are expected in the south (HELCOM 2021). While both are sources of PFOS (and precursors) to the Baltic Sea, river inputs are currently deemed to be the more important source currently delivering 77% of the PFOS load (Johansson and Undeman, 2020; Filipovic *et al.* 2013). However, increased precipitation could increase leaching of PFOS from contaminated sites and thus contribute to increases in the PFOS loading to Baltic Sea. The increase in PFOS loads due to increasing precipitation and river discharge could partly counteract the current decline in inputs due to the decrease in emissions.

Long chained PFAAs like PFOS have a high water solubility but are still found in the sediments (Josefsson 2022) and burial account for around 10% of the PFOS loss in the Baltic (Filipovic *et al.* 2013). Climate induced increases in sediment transport in coastal areas (HELCOM, 2021) could therefore cause a release of buried PFOS back into the water column. However, an increase in dissolved organic carbon and humic acids in the northern Baltic in combination with an increase in surface-water temperature could also result in a faster sedimentation of PFOS (Jia *et al.* 2010). Maybe more importantly, if an increase in river discharge also result in an increase in water outflow from the Baltic to the North Sea, this is likely to increase the loss of PFOS as outflow through the Danish straits are the largest sink of PFOS from the Baltic (~90% of total loss; Filipovic *et al.* 2013).

Climate models project slight increases in wind speed in the northern Baltic and decreases in the south (HELCOM, 2021) but it could be the increase in extreme situations with wind gusts associated with thunderstorms and an increase of 5% in wave height in the north and east of the Baltic that affect PFOS the most. Recent studies have shown that PFOS concentrations are enriched in sea spray aerosols (Johansson *et al.* 2019) and an increase in wave activity could lead to an increased loss of PFOS from the water to land.

The Baltic Sea average surface-water temperature has increased by around +0.6°C/decade for 1990- 2018 (Siegel and Gerth 2019). A further increase in surface water-temperature is one of the most certain future consequences of climate change in the Baltic Sea (HELCOM 2021). The increase in surface-water temperature is likely to have direct effect on fish body growth, recruitment, and mortality. Increases in growth rate (already a factor today across monitoring data covering a wide range of average temperature from the northern to the southern Baltic Sea; Soerensen and Faxneld 2022) can affect the biomagnification through increased growth dilution. The effects from changes in recruitment and mortality are less straightforward but is part of the indirect climate impact on the overall ecosystem and food web dynamics. The sum of direct climate change parameters (temperature, radiation, salinity, river discharge, precipitation, wind etc.) will affect the oxygen content, microbial communities and food web dynamics (stocks and species; HELCOM 2021). Changes in living conditions and food web structure could change the flow of PFOS through the food web, which will likely affect the overall biomagnification. Further, different species likely has different ability to biotransform PFOS precursors, thus a change in the food web structure could cause a change in the biotransformation. However, more work is needed to understand if climate induced food web changes will lead to an increase or decrease in concentrations in top predators.

## 8 Conclusions

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Overall, the concentrations of PFOS achieve Good Environmental Status (GES) for almost all assessment units evaluated assessment units when the primary threshold value for biota is applied. Where sub-GES status occurs it is heavily influenced by the failure to achieve the threshold value against the secondary threshold value for water.

### 8.1 Future work or improvements needed

A new PFAS EQS focusing on the accumulated effect of PFAS rather than just PFOS is currently under preparation (EU, 2021). It should be considered if this new EQS should be used in future evaluations instead of focusing solely on PFOS. Introducing this new EQS would allow for an evaluation of the combined toxicity risks posed by PFASs in the Baltic Sea. This is especially important as PFOS trends are currently levelling off or decreasing in the Baltic Sea due to the phase out of precursor compounds, while other PFASs follow different temporal and spatial patterns.

Available studies on liver to muscle conversion factors for PFOS indicate that the variability in conversion factor between species is much larger than within species (Soerensen *et al.* 2022; Larsen and Bossi 2019). More data on conversion factors for especially herring, cod, eelpout and European flounder are needed to lower the uncertainty associated with the tissue contaminant conversion.

The recommended trophic level for contaminant evaluation is 4.5 (European Commission, 2014). For this evaluation, no adjustment for trophic level was done. A uniform approach where all observations are normalised to the same trophic level should be considered for future evaluations. As the food web in the Baltic Sea is usually relative short (trophic level: herring ~3-4, cod ~4-5, white tailed sea eagle ~4) a lower trophic level than 4.5 (representing one trophic level below top predators) could be considered for evaluation in the Baltic Sea if the focus is on overall good environmental status.

Exploring the possibility and suitability of adding additional fish species (e.g. roach, bream) could be explored to evaluate if the spatial distribution of these species can support improved coverage and improved confidence of the indicator in the future.

## 9 Methodology

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The overall methodology is set out below.

### 9.1 Scale of assessment

PFOS is considered a global pollutant, widely distributed in biological samples and even present in samples from remote places such as the Arctic region. The PFOS core indicator is therefore relevant for the whole Baltic Sea and can be applied in all regions.

The core indicator evaluates the status with regard to concentration of PFOS using HELCOM assessment unit scale 4 (division of the Baltic Sea into 17 sub-basins and further division into coastal and offshore areas and division of the coastal areas by WFD water types or water bodies). This division is applied in order to take into account the different routes by which PFOS enters the Baltic Sea - via air and via run-off from land, including also potential point sources.

The assessment units are defined in the [HELCOM Monitoring and Assessment Strategy Annex 4](#).

### 9.2 Methodology applied

#### *Data processing*

The threshold value is defined with the protection goal to prevent adverse effects on human health via consumption of fishery products. As human fish consumption is mainly focused on muscle fillet of fish, the status evaluation is calculated based on PFOS concentrations in fish muscle. Some data may therefore require transformation into the relevant matrix and unit given for the threshold value, which is µg/kg wet weight.

Ideally, the data should be analyzed in the same matrix, which for the purposes of the indicator evaluation is muscle fillet concentrations in fish, representing a trophic level of 4 (European Commission 2014). However, the majority of the PFOS data reported are analysed in liver tissue in different fish species at varying trophic levels. PFOS concentration values that are originally measured in fish liver are therefore converted to a muscle concentrations. This has been done using conversion factors generated by Faxneld *et al.* (2014). The conversion was performed with the use of the general conversion factors for 'all species' (liver:muscle ratio: 17.9), see Table 5.

**Table 5.** Mean liver:muscle ratios for PFOS with 95% confidence intervals within parentheses. The column indicated "all species" includes herring, perch (marine and limnic), eelpout, pike, arctic char and cod. Data taken from (Faxneld *et al.* 2014).

	<b>All species</b>	<b>Herring</b>	<b>Perch</b>	<b>Eelpout</b>
PFOS	17.9 (16-20)	19.0 (17-21)	18.2 (16-20)	11.1 (6.0-16)

As seen on the conversion factors (Table 5), liver concentrations are higher than muscle concentrations and several studies have reported that PFOS accumulate in protein rich tissue, with liver being one of the tissues where the highest concentrations are found (Goeritz *et al.* 2013; Shi *et al.* 2012). Comparing liver concentrations directly to the EQS value set for muscle fillet could therefore lead to a false positive. However, it is of great importance to be aware of the uncertainties introduced to the results in the conversion procedure.

No correction for trophic level has been made. The monitored species are at a lower trophic level than the general trophic level estimated for commercial fish and suggested by the EC Guidance Document No. 32 (European Commission 2013), implying a risk of underestimation of the concentrations, since PFOS biomagnifies in the food web. The information on trophic level, is lacking for the reported results and a proper trophic magnification factor (TMF) has not been agreed upon yet. It is therefore presently not possible to translate the results to the recommended trophic level 4 for the status evaluation. The results should therefore be considered tentative at this time.

New studies have been published on conversion factors recently but given the fish species dependence on the conversion factor (Larsen and Bossi 2019; Soerensen *et al.* 2022), more studies on relations between liver, muscle and whole body concentrations of PFOS in relevant Baltic Sea fish species are needed in order to improve the comparisons to the threshold value.

#### *Statistical evaluation*

The evaluation protocol is structured in three main parts, 1) changes in log concentrations over time are modelled, 2) check for compliance against threshold value and evidence for temporal change of contaminant concentration per station and 3) a spatial aggregation of status per assessment unit.

It should be noted that the evaluation protocol makes the assumption that monitoring data stems from the same monitoring stations during consecutive years. The stations used by the protocol are defined in the ICES Station Dictionary. Stations with similar station name are grouped together, but it is also possible to define a group of stations with different names to be defined as the same station in the Station Dictionary. Usually a station is defined in the Station Dictionary with coordinates and a valid box around these coordinates, but coordinates outside of the box will only give a warning when reporting the data, and are not used in the actual data extraction.

## Overview

Time series of contaminant concentrations are assessed in three stages:

1. The concentrations are log transformed and changes in the log concentrations over time are modelled using linear mixed models. The type of temporal change that is considered depends on the number of years of data:
  1. 1-2 years: no model is fitted because there are insufficient data
  2. 3-4 years: concentrations are assumed to be stable over time and the mean log concentration is estimated
  3. 5-6 years: a linear trend in log concentration is fitted
  4. 7+ years: more complex (smooth) patterns of change over time are modelled
2. The fitted models are used to assess status against available threshold value and evidence of temporal change in contaminant levels in the last twenty years
3. The fitted models are also used for spatial aggregation to assess status against available threshold value and evidence of temporal change in contaminant levels on a scale 4 level HELCOM assessment unit.

These stages are described in more detail in the link below. There is also information on how the methodology is adapted when there are 'less-than' measurements (treated as 'initial' data), i.e. some concentrations are reported as below the detection limit, and missing uncertainties, i.e. the analytical variability associated with some of the concentration measurements was not reported.

### *Assessment methodology for contaminants in biota and water*

All initial data is handled in a highly precautionary manner to further ensure that the risk of false positives is minimised. 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,  $\Psi$ ) 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:  $\exp(\text{meanLY} + \text{qnorm}(0.95) \cdot \frac{\Psi}{\text{sqrt}(n)})$ , 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 PFAS guidelines describing monitoring methods, reporting, storage and quality control for PFAS biota monitoring within HELCOM was published in 2019 (HELCOM 2019). Additional information about monitoring in the region is documented in the HELCOM Monitoring Manual under the [sub-programme: Contaminants in biota](#).

#### *Current monitoring*

Monitoring activities relevant to the indicator, currently carried out by HELCOM Contracting Parties are described in the HELCOM Monitoring Manual in the relevant [Monitoring Concept Table](#).

Sub-programme: Contaminants in biota

#### [Monitoring Concept Table](#)

Denmark, Sweden, Finland, Poland, and Germany monitor PFOS concentrations in their national monitoring programmes. Germany began monitoring of PFOS in water in 2017 and in biota in 2018. Lithuania monitors PFOS in water, sediments and biota every 3 years since 2015 resulting in one sample per station so far. Estonia has included PFOS analyses in coastal waters (water, sediment and biota) from 2017. PFOS is not included in the monitoring programmes in Latvia and no information is available from Russia.

#### *Description of optimal monitoring*

The core indicator for PFOS has increased its geographical coverage in national monitoring programmes in recent years but better time series data is needed to enable evaluation of temporal trends. It is therefore vital that the stations added in recent years are sampled regularly in the future.

The performance of existing monitoring should be evaluated in relation to the monitoring objectives, but first there is a need to quantify these objectives. These quantitative objectives need to be specified for each kind of monitoring, e.g. temporal trend-, incident-, geographical (spatial)- and compliance monitoring for environmental status and/or human exposure. For example, for temporal trend monitoring: what statistical power is required, during what time period should a certain trend be possible to detect and with what specified power (with certain one- or two-tailed statistical tests at a specified significant level)? With these definitions at hand it is possible to estimate e.g. required sample sizes and sampling frequencies. It can be shown that for a monitoring period of 12 years or shorter, generally the power to detect trends will decrease substantially if the sampling is carried out every second or every third year compared to annual sampling. For geographical studies the required spatial resolution should be determined. For compliance monitoring, it is imperative to know the distance to target levels (and variance) before sample sizes are estimated.

Time series of PFOS concentrations in fish are missing or too short to enable evaluation for several sub-basins in the Baltic Sea region. The geographical resolution is generally too poor to make reliable generalized maps from interpolation of the existing stations using Kriging. No serious attempts to study patterns of variation in fish (coastal- offshore) through variograms have been made that could give guidance to the uncertainty and to the distance between sites needed to achieve required confidence in generalized maps.

## 10 Data

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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: Perflurooctane sulphonate \(PFOS\) in biota](#)

[Result: Perflurooctane sulphonate \(PFOS\) in water](#)

[Data: Hazardous substances in biota](#)

[Data: Hazardous substances in water](#)

The data used in the evaluation is based on data from the HELCOM COMBINE database to which Contracting Parties report regular monitoring data. The data are extracted based on the HELCOM core indicator extraction table.



## 11 Contributors

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## 12 Archive

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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 this indicator are available below:

[Perfluorooctane sulphonate PFOS HELCOM core indicator 2018](#) (pdf)

[HOLAS II component - Core indicator report – web-based version March 2017](#) (pdf)

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## Annex 1 Assessment unit level confidence summary

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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 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 the 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<sup>2</sup>) 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 - Tables 1-2).

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



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

<b>Assessment unit</b>	<b>Spatial</b>	<b>Temporal</b>	<b>Methodological</b>	<b>Evaluation</b>	<b>Overall</b>
DEN-002	High	Low	High	Moderate	Moderate
DEN-006	High	High	High	High	High
DEN-024	High	Moderate	High	High	Moderate
DEN-025	High	Low	High	Low	Moderate
DEN-044	High	Low	High	Low	Moderate
DEN-047	High	Low	High	Low	Moderate
DEN-089	High	Low	High	Low	Moderate
DEN-095	High	Low	High	Low	Moderate
DEN-102	High	Low	High	Low	Moderate
DEN-110	High	High	High	Moderate	Moderate
DEN-114	High	Low	High	Moderate	Moderate
DEN-123	High	Low	High	Low	Moderate
DEN-137	High	High	High	Moderate	Moderate
DEN-138	High	Low	High	Low	Moderate
DEN-139	High	Low	High	Low	Moderate
DEN-140	High	Low	High	Low	Moderate
DEN-160	High	Moderate	High	Moderate	Moderate
DEN-200	High	Low	High	Low	Moderate
DEN-201	High	Low	High	Low	Moderate
DEN-206	Moderate	Low	High	Moderate	Moderate
DEN-214	High	Low	High	Low	Moderate
DEN-235	High	Moderate	High	Moderate	Moderate
DEN-238	High	Low	High	Low	Moderate
EST-002	High	Low	High	Low	Moderate
EST-003	High	Low	High	Low	Moderate
EST-005	High	Low	High	Low	Moderate
EST-009	High	Low	High	Low	Moderate
EST-010	Moderate	Low	High	Low	Moderate
EST-013	High	Low	High	Low	Moderate
EST-014	High	Low	High	Low	Moderate
EST-016	High	Low	High	Low	Moderate
EST-019	Moderate	Low	High	Low	Moderate
FIN-001	Moderate	Low	High	Low	Moderate
FIN-003	High	High	High	High	High
FIN-004	Low	Low	High	Low	Low
FIN-005	Moderate	Low	High	Moderate	Moderate
FIN-006	High	Low	High	Low	Moderate
FIN-008	High	Low	High	Moderate	Moderate
FIN-010	High	High	High	High	High
FIN-014	Low	Low	High	Moderate	Moderate
GER-002	High	Moderate	High	Moderate	Moderate

GER-011	High	Moderate	High	Moderate	Moderate
GER-020	High	Moderate	High	Moderate	Moderate
LAT-001	High	Low	High	Low	Moderate
LAT-004	High	Low	High	Low	Moderate
POL-002	High	Moderate	High	Moderate	Moderate
POL-003	High	Moderate	High	Low	Moderate
POL-019	High	Low	High	Moderate	Moderate
SWE-011	Moderate	Moderate	High	Moderate	Moderate
SWE-012	High	High	High	Moderate	Moderate
SWE-016	High	High	High	Moderate	Moderate
SWE-018	Moderate	Moderate	High	Moderate	Moderate
SWE-021	High	High	High	Moderate	Moderate
SWE-022	High	High	High	Moderate	Moderate
SWE-023	Low	Moderate	High	Moderate	Moderate
SEA-001	Moderate	High	High	High	Moderate
SEA-003	High	Low	High	Low	Moderate
SEA-006	Moderate	High	High	High	Moderate
SEA-007	Moderate	High	High	High	Moderate
SEA-008	Moderate	High	High	Moderate	Moderate
SEA-009	High	High	High	High	High
SEA-010	Low	High	High	Moderate	Moderate
SEA-011	Moderate	Low	High	Low	Moderate
SEA-012	Low	High	High	Moderate	Moderate
SEA-013	High	High	High	High	High
SEA-015	Moderate	High	High	High	Moderate
SEA-016	High	Low	High	Low	Moderate
SEA-017	Low	Low	High	Low	Low

**Annex 1 – Table 2.** Summary table showing categorical confidence per component and overall for PFOS in water.

<b>Assessment unit</b>	<b>Spatial</b>	<b>Temporal</b>	<b>Methodological</b>	<b>Evaluation</b>	<b>Overall</b>
DEN-113	High	Low	High	Low	Moderate
EST-001	High	Moderate	High	Moderate	Moderate
EST-002	Moderate	Low	High	Low	Moderate
EST-003	High	Moderate	High	Low	Moderate
EST-005	High	Moderate	High	Moderate	Moderate
EST-008	High	Low	High	Low	Moderate
EST-009	High	Low	High	Low	Moderate
EST-010	Low	Low	High	Low	Low
EST-011	High	Moderate	High	Low	Moderate
EST-013	High	Low	High	Low	Moderate
EST-014	Moderate	Low	High	Low	Moderate
EST-016	High	Moderate	High	Moderate	Moderate
GER-031	High	Low	High	Low	Moderate
GER-032	High	Low	High	Low	Moderate
GER-044	High	Low	High	Low	Moderate
LIT-002	High	Moderate	High	Low	Moderate
LIT-003	High	Low	High	Low	Moderate
LIT-006	High	Moderate	High	Low	Moderate
POL-002	High	Low	High	Low	Moderate
SEA-009	Moderate	Moderate	High	High	Moderate