



Dissolved inorganic phosphorus (DIP)

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1 Key message

This core indicator evaluates the average dissolved inorganic phosphorus (DIP) concentration in surface waters (0 – 10 m) during winter (December – February) for the assessment period 2016-2021.

Of the 19 open-sea sub-basins, good status (DIP concentration below defined threshold value, which reflects good conditions) was not achieved in any of the sub basins (Figure 1). The winter-time DIP was still at elevated levels in all 19 sub-basins. Kattegat, Great Belt, Kiel Bay and Bothnian Bay achieved moderate status and Kattegat and Great Belt showed only a very minor exceedance of the threshold values. Bay of Mecklenburg, Arkona Basin, Pomeranian Bay and the Gulf of Finland Eastern were in poor status and all other basins were in bad status, with the Gulf of Riga, Northern Baltic Proper and The Quark exceeding the DIP thresholds more than twofold.

None of the basins showed an improving trend, i.e. decreasing winter DIP concentrations, since the 1990s despite a reduction in phosphorus inputs. On the contrary, eight assessment units, Bornholm Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland Eastern and Western, Åland Sea, Bothnian Sea and The Quark showed a significantly deteriorating trend with increasing DIP concentrations and it is possible that this could be attributed to phosphorus leaking from the sediments and phosphate transport by currents between basins.

When comparing the latest two assessments of HOLAS II and HOLAS 3 The Sound was the only assessment unit that showed an improvement in the DIP status, while eight basins showed no change and 10 basins showed a deterioration in the DIP status. Of these, a change from good to not good status was observed in the open Bothnian Bay. The basins with the deteriorating status were mainly situated in the central and Northern Baltic Sea, including the Gulf of Riga and Gulf of Finland.

Concerning the coastal waters DIP was assessed only in 19 Polish and 13 Swedish water bodies. In the Swedish coastal waters only two water bodies achieved good status, while in Polish coastal waters 14 water bodies achieved good status. There were a number of cases where a good status of coastal water bodies was assessed adjacent to open sea basins that had a moderate or worse status. This could be due to a lack of alignment of threshold values between coastal waters and open sea basins (Table 1 and Annex - Table 1) and internal load of phosphorus in the open sea areas

Dissolved Inorganic Phosphorus

Status

- Achieve (17)
- Fail (35)
- Not Assessed (200)

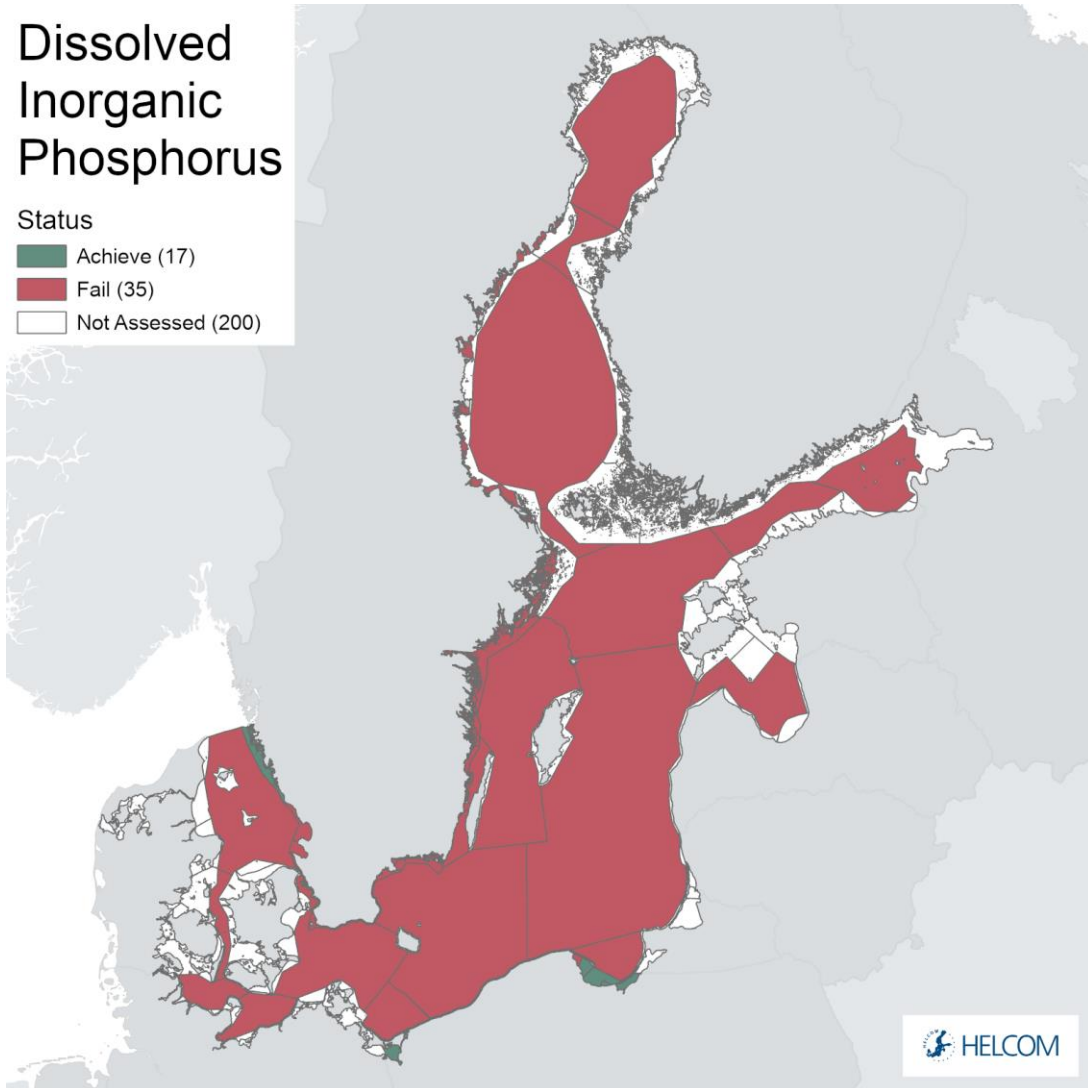


Figure 1. Status evaluation of the indicator 'DIP'. The evaluation is carried out using Scale 4 HELCOM assessment units (defined in the [HELCOM Monitoring and Assessment Strategy Annex 4](#)). See Results section below for details. **See 'data chapter' for interactive maps and data at the HELCOM Map and Data Service.**

The confidence of the presented DIP status estimate was high in eight basins, moderate in seven basins and low in four basins (see Figure 4). Low confidence was mainly caused by insufficient spatial sampling, sometimes also by insufficient temporal sampling.

The indicator is applicable in the waters of all countries bordering the Baltic Sea. In coastal waters, many Contracting Parties assessed total phosphorus instead of DIP (see Total Phosphorus indicator report) in line with the national assessments under the Water Framework Directive.

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). Dissolved inorganic phosphorus (DIP). HELCOM core indicator report. Online. [Date Viewed], [Web link].

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2 Relevance of the indicator

Eutrophication is caused by excessive inputs of nutrients (nitrogen and phosphorus) resulting from various human activities. High concentrations of nutrients and the ratios of these nutrients (e.g. N:P stoichiometric ratios) form the preconditions for algal blooms, reduced water clarity and increased oxygen consumption. Long-term nutrient data are key parameters for quantifying the effects of anthropogenic activities and evaluating the success of measures undertaken.

Eutrophication assessment

The status of eutrophication 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 dissolved inorganic phosphorus, this indicator will also contribute to the overall eutrophication assessment along with the other eutrophication core indicators.

2.1 Ecological relevance

Role of dissolved inorganic phosphorus (DIP) in the ecosystem

Marine eutrophication is mainly caused by nutrient enrichment leading to increased production of organic matter supplied to the Baltic Sea with subsequent effects on water transparency, phytoplankton communities, benthic fauna and vegetation as well as oxygen conditions. Phytoplankton as well as benthic vegetation need nutrients, mainly nitrogen and phosphorus, for growth. Phosphorus is the important limiting nutrient since nitrogen could be replenished by nitrogen fixation. The phosphorus surplus left in surface water after spring bloom may foster primary production, especially by diazotrophic cyanobacterial blooms.

In a simplified conceptual model for nitrogen and phosphorus nutrients (Relevance figure 1), flows between the different components are illustrated. To get a good understanding of the trend in nutrient concentrations in the marine environment the assessment of both, total and dissolved nutrients, is important. Dissolved inorganic phosphorus (DIP) is the phosphorus form that supports primary production. Usually it is subjected to a strong seasonality in surface water (0-10 m) with highest concentration during winter months and a decline during spring and summer, with a relative short term of depletion in midsummer. During autumnal remineralisation activity and storm induced deeper mixing, subsequently DIP is brought back to surface waters. The winter concentration together with inorganic nitrogen supports the amount of algae development during the spring bloom and subsequently controls the growth of diazotrophic cyanobacteria during summer. So the threshold values are elaborated to allow a normal spring bloom without excess phosphorus left for algae growth and cyanobacterial blooms during summer.

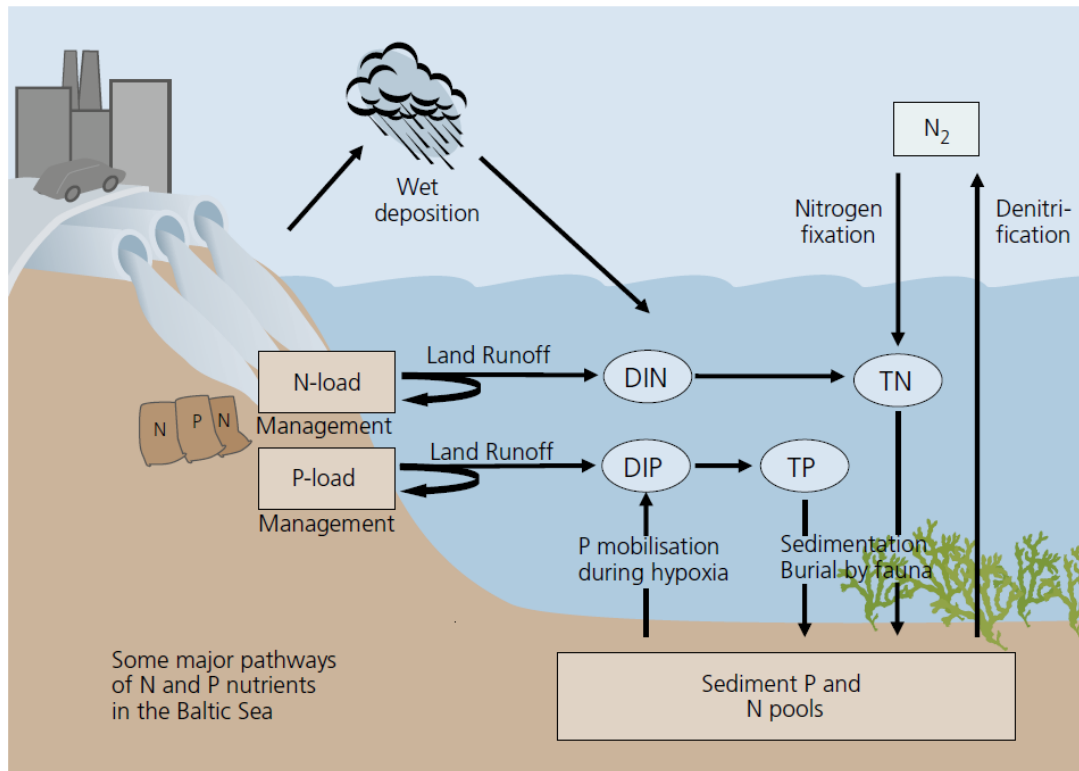


Figure 2. Simplified conceptual model for N and P nutrients in the Baltic Sea, where DIN = Dissolved inorganic nitrogen, TN = Total nitrogen, DIP = Dissolved inorganic phosphorus and TP = Total phosphorus. Flows along arrows into the blue sea area tend to increase concentrations, and flows along arrows out from the sea act in the opposite direction. Management refers to nutrient load reductions.

2.2 Policy relevance

Eutrophication is one of the four thematic segments of the HELCOM Baltic Sea Action Plan (BSAP). The BSAP has the strategic goal of a Baltic Sea unaffected by eutrophication (HELCOM 2021). Eutrophication is defined in the BSAP as a condition in an aquatic ecosystem where excessive nutrient availability stimulates the growth of algae, which leads to imbalanced functioning of the system. Elevated nutrient concentrations in the water column are caused by increased anthropogenic nutrients supply from land and air. The goal for eutrophication abatement is broken down into five ecological objectives, one of which is “concentrations of nutrients close to natural levels” (Table 1). The BSAP management objective is to “minimize inputs of nutrients from human activities”.

The EU Marine Strategy Framework Directive (2008/56/EC) requires that “human-induced eutrophication is minimized, especially to abate adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters” (Descriptor 5). ‘Nutrients in the watercolumn’ (incl DIP) are the criteria elements in MSFD GES Decision ((EU) 2017/848) for assessing eutrophication under the criterion ‘D5C1 – Nutrient concentrations are not at levels that indicate adverse eutrophication effects’.

The EU Water Framework Directive (2000/60/EC) requires good ecological status in the European coastal waters. Good ecological status is defined in Annex V of the Water

Framework Directive, by the quality of the biological community, the hydromorphological characteristics and the chemical characteristics, including phosphorus concentration.’

Table 1. Eutrophication links to policy.

	Baltic Sea Action Plan (BSAP)	Marine Strategy Framework Directive (MSFD)
Fundamental link	<p>Segment: Eutrophication Goal: “Baltic Sea unaffected by eutrophication”</p> <ul style="list-style-type: none"> • Ecological objective: “Concentrations of nutrients close to natural levels”, “Clear waters”, “Natural level of algal blooms”, “Natural distribution and occurrence of plants and animals”, and “Natural oxygen levels”. • Management objective: “Minimize inputs of nutrients from human activities” • The achievement of regional nutrient input targets – Maximum Allowable Inputs (MAI) and Nutrient Input Ceilings (NIC) – for all sub-basins, as identified in this BSAP, is the key prerequisite for achieving the ecological objectives. 	<p>Descriptor 5 Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters - Macrofaunal communities of benthic habitats.</p> <ul style="list-style-type: none"> • Criteria D5C1 Nutrient concentrations are not at levels that indicate adverse eutrophication effects. The threshold values are as follows: (a) in coastal waters, the values set in accordance with Directive 2000/60/EC; (b) beyond coastal waters, values consistent with those for coastal waters under Directive 2000/60/EC. Member States shall establish those values through regional or subregional cooperation. • Feature – Eutrophication. • Element of the feature assessed – DIN, DIP, TN and TP.
Complementary link	<p>Segment: Sea-based activities Goal: “Environmentally sustainable sea-based activities”</p> <ul style="list-style-type: none"> • 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”, “Minimize 	<p>Descriptor 6 Benthic habitats - Benthic broad habitat types.</p> <ul style="list-style-type: none"> • Criteria D6C5 The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), does not exceed a specified proportion of the natural extent of

	<p>harmful air emissions”, and “Zero discharges from offshore platforms”.</p> <p>Segment: Biodiversity Goal: “Baltic Sea ecosystem is healthy and resilient”</p> <ul style="list-style-type: none"> • Ecological objective: “Natural distribution, occurrence and quality of habitats and associated communities”. • Management objective: “Minimize disturbance of species, their habitats and migration routes from human activities”. 	<p>the habitat type in the assessment area.</p> <ul style="list-style-type: none"> • Feature – Benthic habitats. • Element of the feature assessed – Benthic broad habitat types. <p>Descriptor 1 Species groups of birds, mammals, reptiles, fish and cephalopods</p> <ul style="list-style-type: none"> • Criteria D1C6 The condition of the habitat type, including its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), is not adversely affected due to anthropogenic pressures. • Feature – Pelagic broad habitats. • Element of the feature assessed – Trophic guilds.
<p>Other relevant legislation:</p>	<ul style="list-style-type: none"> • EU Water Framework Directive • 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 	

2.3 Relevance for other assessments

This indicator is utilised in the integrated assessment of eutrophication (HEAT tool).

3 Threshold values

Status evaluation is measured in relation to scientifically based and commonly agreed sub-basin specific threshold value, which defines the concentration that should not be exceeded (Figure 3).

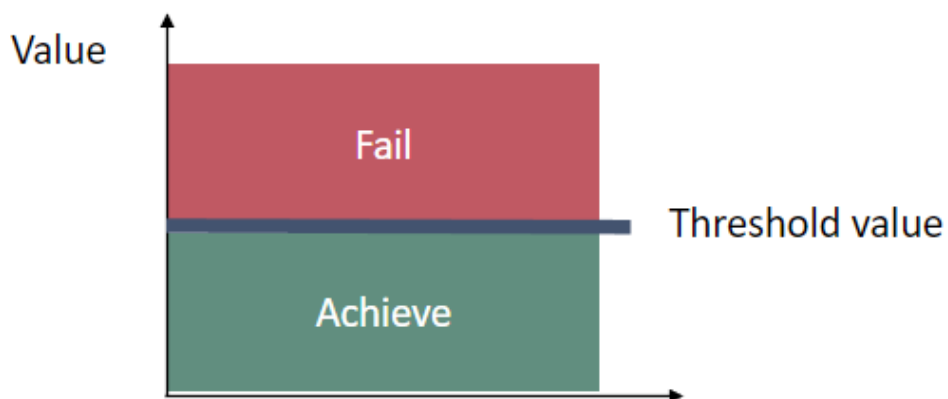


Figure 3. Schematic representation of the threshold values applied in the DIP core indicator, the threshold values are assessment unit specific (see Table 2).

3.1 Setting the threshold value(s)

These indicator threshold values were based on the results obtained in the TARGREV project (HELCOM 2013), also taking advantage of the work carried out during the EUTRO PRO process (HELCOM 2009) and national work for EU WFD. The final threshold values were set through an expert evaluation process done via intersessional activity for the development of core eutrophication indicators (HELCOM CORE EUTRO), and the targets were adopted by the HELCOM Heads of Delegations 39/2012. The threshold values were principally not changed since HOLAS II, but for new assessment units Pomeranian Bay and the split of the Gulf of Finland into an eastern and western assessment unit new thresholds were derived using the HOLAS II thresholds as a basis and adopted by HELCOM HOD 61-2021.

Table 2. Assessment unit specific threshold values for the DIP core indicator.

HELCOM_ID	Assessment unit (open sea)	Threshold value ($\mu\text{mol l}^{-1}$)
SEA-001	Kattegat	0.49
SEA-002	Great Belt	0.59
SEA-003	The Sound	0.42
SEA-004	Kiel Bay	0.57
SEA-005	Bay of Mecklenburg	0.49
SEA-006	Arkona Basin	0.36
SEA-007	Bornholm Basin	0.28
SEA-007B	Pomeranian Bay	0.40
SEA-008	Gdansk Basin	0.36
SEA-009	Eastern Gotland Basin	0.29
SEA-010	Western Gotland Basin	0.33
SEA-011	Gulf of Riga	0.41
SEA-012	Northern Baltic Proper	0.25
SEA-013A	Gulf of Finland Western	0.50
SEA-013B	Gulf of Finland Eastern	0.68
SEA-014	Åland Sea	0.21
SEA-015	Bothnian Sea	0.19
SEA-016	The Quark	0.10
SEA-017	Bothnian Bay	0.07

4 Results and discussion

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

4.1 Status evaluation

Current status of the Baltic Sea DIP concentration

A good status with a concentration of winter DIP concentrations below the threshold was not achieved in any of the assessment units (Figure 1). However, the Great Belt and the Kattegat were close to good status, with the scaled Ecological Quality Ratio (EQRS) being 0.59 and 0.57, respectively. Kiel Bay and Bothnian Bay also achieved moderate status with EQRS values of 0.51 and 0.41. Bay of Mecklenburg, Arkona Basin, Pomeranian Bay and the Gulf of Finland Eastern were in poor status and all other basins in bad status. In Arkona Basin, Pomeranian Bay and Gulf of Finland Eastern the DIP thresholds were exceeded by >50% and in the Bay of Mecklenburg, Bornholm Basin, Gdansk Basin, Eastern Gotland Basin, Gulf of Finland Western, Åland Sea and Bothnian Sea they were exceeded by >100%. In the Gulf of Riga, Northern Baltic Proper and The Quark the DIP thresholds were exceeded by >200%. (Table 3). The large number of basins that substantially exceeded the DIP thresholds indicate the urgency of further lowering the phosphorus inputs to the Baltic Sea.

The variability of the DIP concentrations between the individual assessment years and the large distance from the threshold value for many of the basins is shown in Figure 5. The Bay of Mecklenburg experienced an abrupt reduction of the DIP concentrations from 2019 onwards and concentrations more than halved.

Dissolved Inorganic Phosphorus

EQRS Status

- High (11)
- Good (6)
- Moderate (14)
- Poor (10)
- Bad (11)
- Not assessed (200)

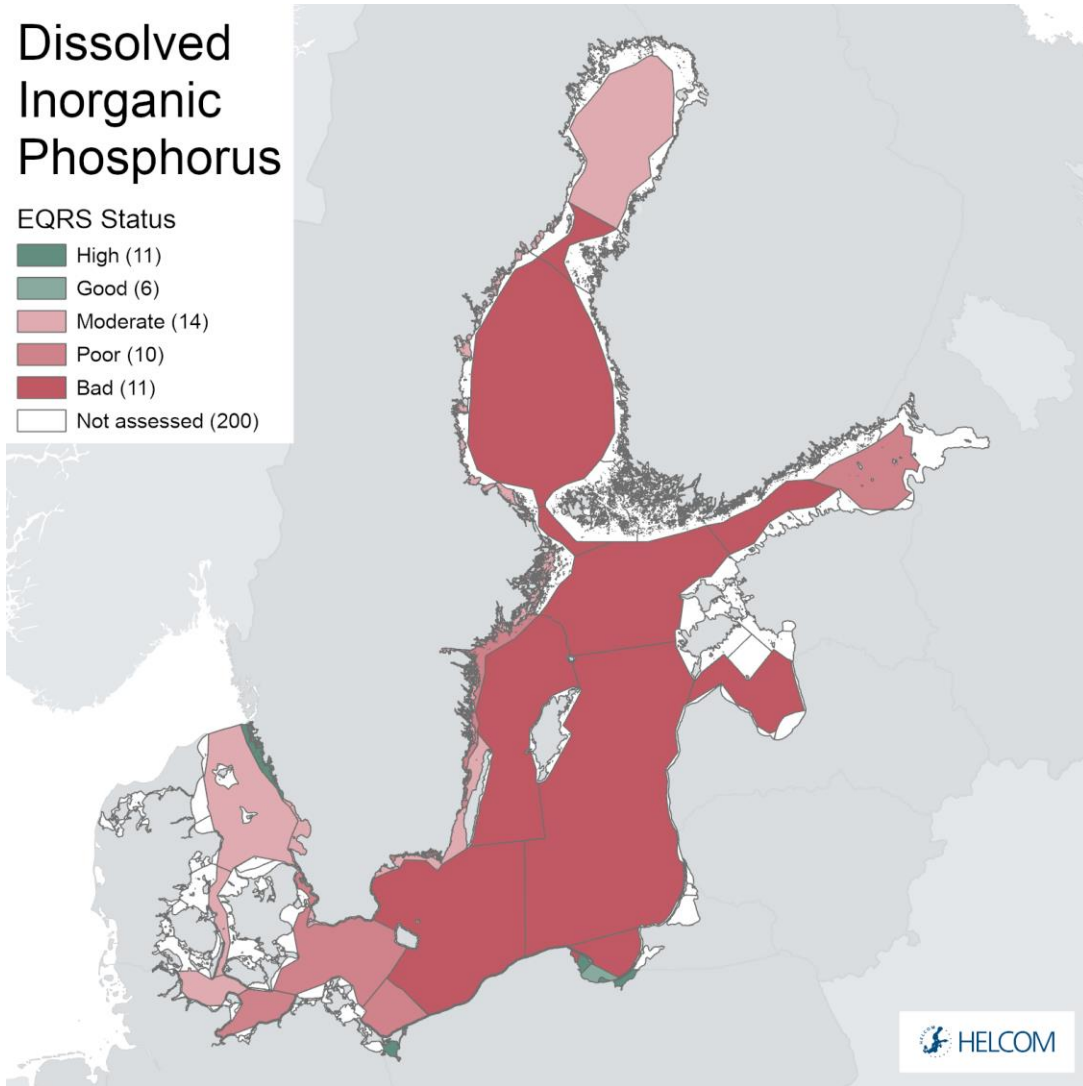


Figure 4. Detailed Dissolved Inorganic Phosphorus (DIP) assessment with the ecological quality ratio scaled (EQRS). EQRS of DIP being split into 5 classes to show a more differentiated picture than the 2-class division used in the key message figures. EQRS is calculated as the ratio of the average concentration during assessment period and the reference value, decreasing along with increasing eutrophication. When $EQRS \geq 0.6$ good status is achieved.

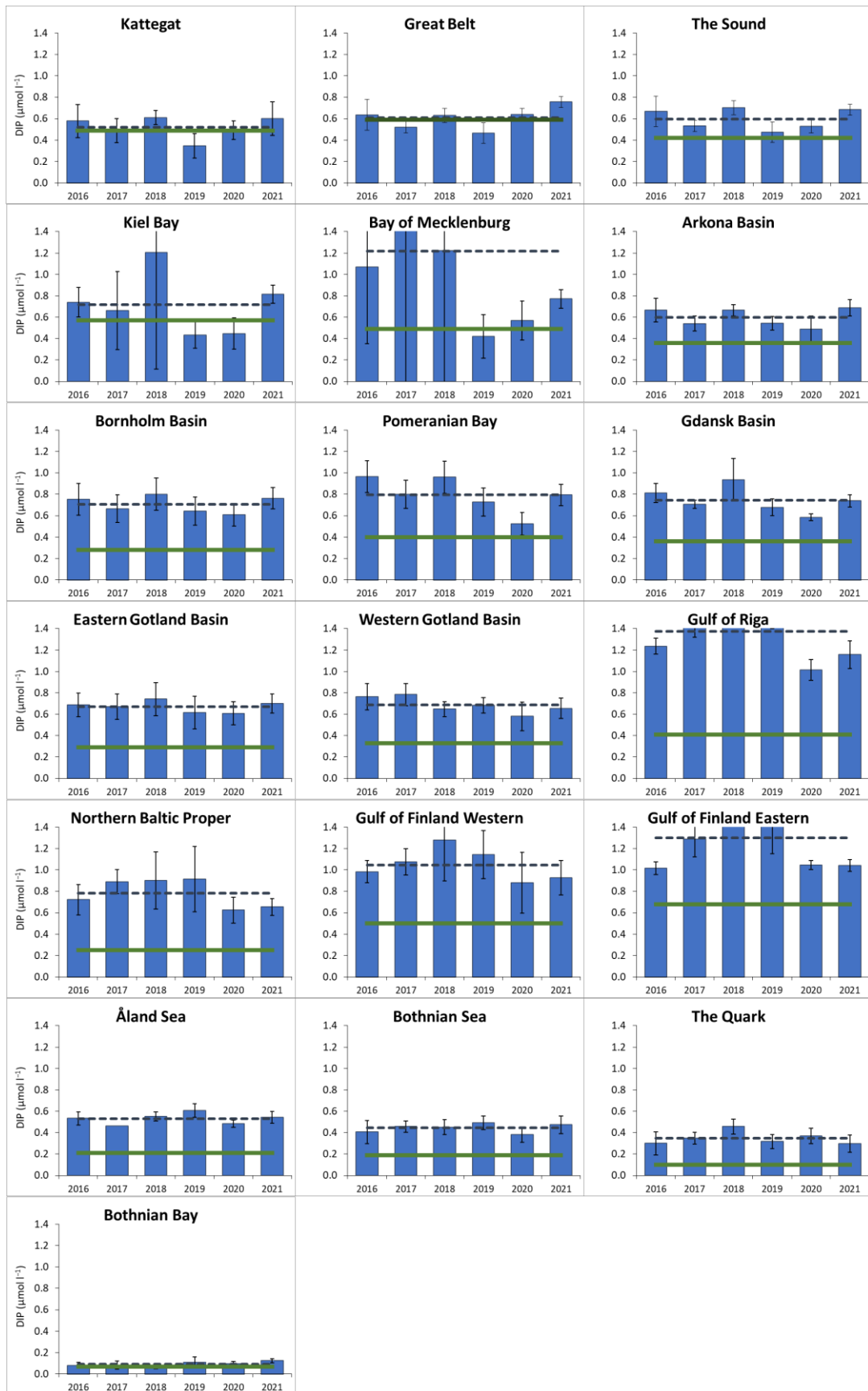


Figure 5. Winter Dissolved Inorganic Phosphorus (DIP) concentrations (dashed dark blue line; average for 2016-2021) in $\mu\text{mol L}^{-1}$ and threshold levels as agreed by HELCOM HOD 39-12 (green line) for assigned Assessment Units (AU).

Table 3. Shows threshold values, concentration during the assessment period (2016-2021 average), Ecological Quality Ratio Scaled (EQRS) and status of DIP in the open-sea basins. EQRS is a quantitative value for the level of eutrophication, calculated from the ratio between the reference value and the present concentration. When $EQRS \geq 0.6$ good status is achieved.

Assessment unit (open sea)	Threshold value ($\mu\text{mol l}^{-1}$)	Average 2016-2021 ($\mu\text{mol l}^{-1}$)	Ecological quality ratio (scaled) (EQRS)	Status (fail/achieve threshold value)
Kattegat	0.49	0.52	0.57	Fail
Great Belt	0.59	0.61	0.59	Fail
The Sound	0.42	0.60	0.34	Fail
Kiel Bay	0.57	0.72	0.51	Fail
Bay of Mecklenburg	0.49	1.22	0.31	Fail
Arkona Basin	0.36	0.60	0.25	Fail
Bornholm Basin	0.28	0.71	0.14	Fail
Pomeranian Bay	0.4	0.79	0.20	Fail
Gdansk Basin	0.36	0.74	0.18	Fail
Eastern Gotland	0.29	0.67	0.15	Fail
Western Gotland	0.33	0.69	0.17	Fail
Gulf of Riga	0.41	1.37	0.11	Fail
Northern Baltic	0.25	0.78	0.11	Fail
Gulf of Finland	0.5	1.05	0.17	Fail
Gulf of Finland	0.68	1.30	0.22	Fail
Åland Sea	0.21	0.53	0.14	Fail
Bothnian Sea	0.19	0.44	0.15	Fail
The Quark	0.1	0.35	0.10	Fail
Bothnian Bay	0.07	0.09	0.41	Fail

Concerning the coastal waters DIP was assessed only in 19 Polish and 13 Swedish water bodies, since most Contracting Parties assess total phosphorus instead of DIP under the Water Framework Directive. In the Swedish coastal waters only two water bodies situated in the Kattegat and The Sound achieved good status, while in Polish coastal waters 14 water bodies situated in the Gdansk Basin, Bornholm Basin and Eastern Gotland Basin achieved good status. In cases where a good status of coastal water bodies was assessed adjacent to open sea basins that had a moderate or worse status this is most likely due to a lack of alignment of threshold values between coastal waters and open sea basins.

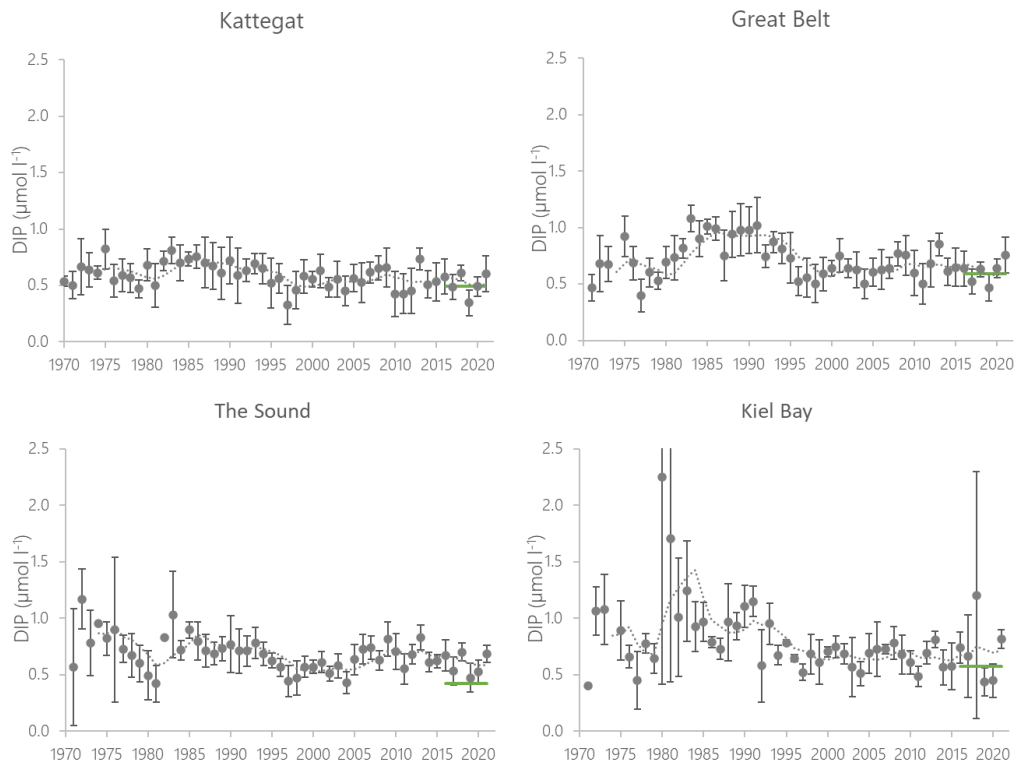
4.2 Trends

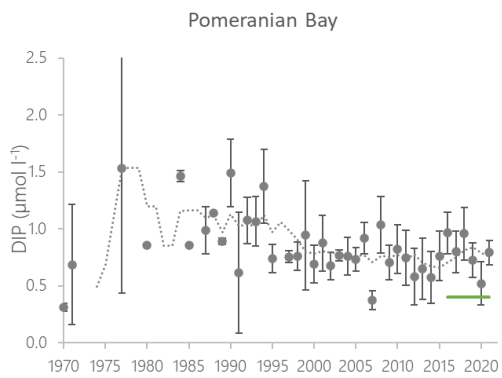
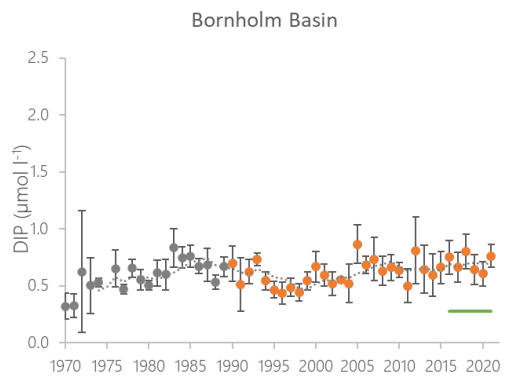
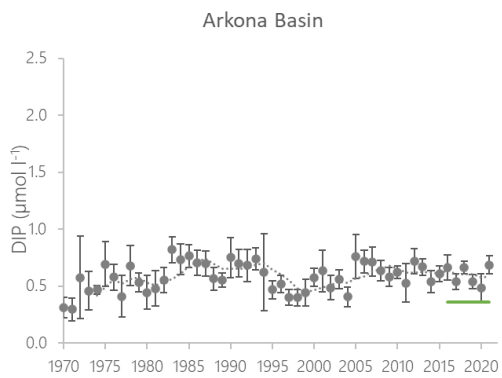
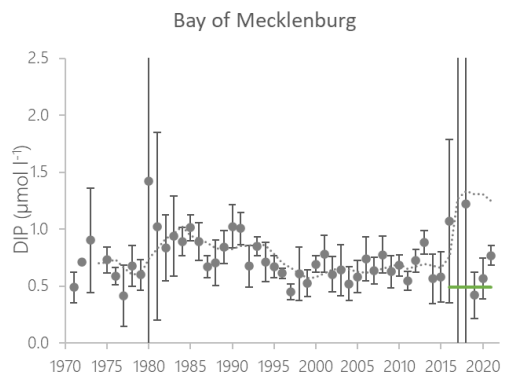
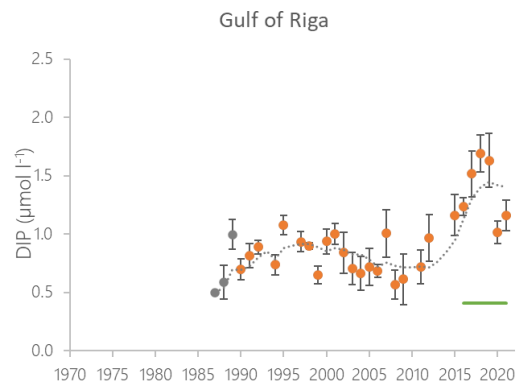
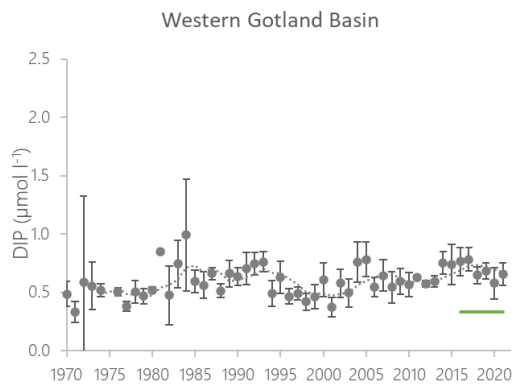
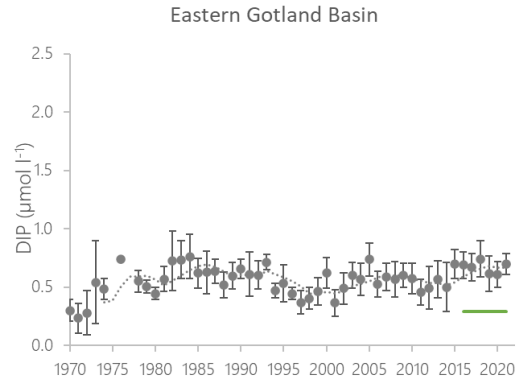
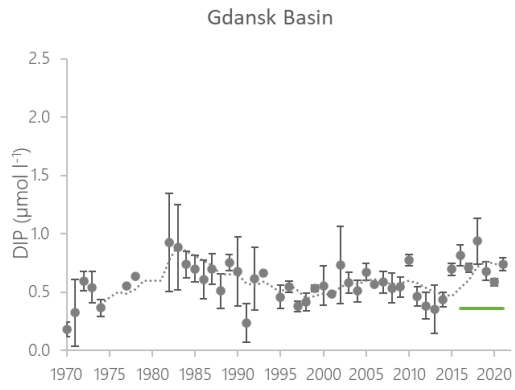
Long-term trends

Long-term temporal trends allow to evaluate the actual six-year assessment period in its annual changes compared to previous evaluation periods and to previous decades. Moreover, they provide an impression what can be expected for the near future and perhaps when thresholds will be met or concentrations fall below the thresholds in the future. Data of winter DIP concentration are presented for most assessment units for the

extended time period of about 45 to 50 years (Figure 6), with the exception of the Gulf of Riga where DIP data are only available since 1987, and considerable data gaps in the Pomeranian Bay before 1985.

None of the assessment units showed a statistically improving trend (decreasing DIP concentrations) since 1990 and the majority of assessment units showed no trend and either stable or highly variable concentrations. Eight assessment units, Bornholm Basin, Gulf of Riga, Northern Baltic Proper, Gulf of Finland Eastern and Western, Åland Sea, Bothnian Sea and The Quark showed a significantly deteriorating trend (increasing DIP concentrations). The increase in DIP concentrations was particularly steep in the Gulf of Riga since 2010. Since phosphorus inputs to most basins have decreased it is possible that the increases in DIP concentrations can be attributed to phosphorus release from the sediments under oxygen deficiency. In particular Gulf of Riga, Gdansk Basin and Pomeranian Bay showed high interannual variability, most likely caused by larger variations in riverine inputs into these basins.





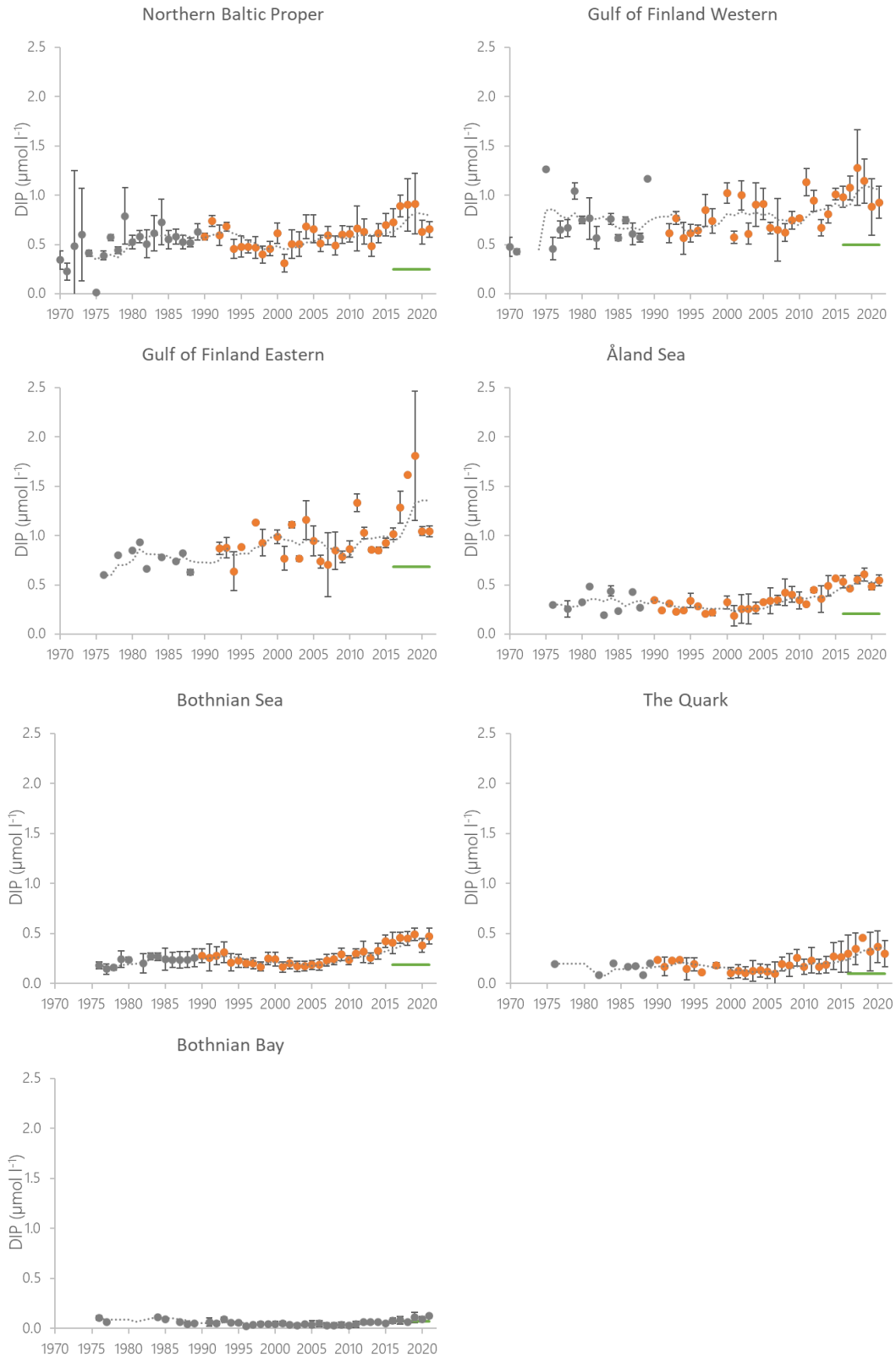


Figure 6. Temporal development of winter dissolved inorganic phosphorus (DIP) concentrations in the open-sea assessment units from 1970-2021. Dashed lines show the five-year moving averages and error bars the standard deviation. Green lines denote the indicator threshold. Significance of trends was assessed with Mann-Kendall non-parametric tests for the period from 1990-2021. Significant ($p < 0.05$) deteriorating trends are indicated with orange data points. No significant improving trends were detected.

4.3 Discussion text

Assessment results for DIP concentrations were compared between the latest two assessments of HOLAS II and HOLAS 3 (Table 4). The Sound was the only assessment unit that showed an improvement in the DIP status with increasing EQRS (i.e. decreasing DIP concentrations), while eight basins showed a stable status (within 15% change between HOLAS II and HOLAS 3). Ten basins showed a clear deterioration in the DIP status, with decreasing EQRS (i.e. increasing DIP concentrations). Of these, a change from good to not good status was observed in the open Bothnian Bay. The basins with the deteriorating status were mainly situated in the central and Northern Baltic Sea, including the Gulf of Riga and Gulf of Finland.

Concerning long-term and short-term trends it can be summarised that the development in DIP concentrations is giving rise to concern since despite decreasing phosphorus inputs the concentrations of winter DIP are increasing in large parts of the Baltic Sea and seem to be decoupled from load reductions. The reasons for this deteriorating state need a careful analysis and might be attributable to the internal phosphorus load, i.e. phosphorus that has accumulated in the sediment and is leaking under anoxic conditions (Gustafsson *et al.* 2012). Moreover, there is notable exchange of phosphorus between basins. The negative change from the previous assessment period in the Northern Baltic Sea is potentially related to earlier salt water intrusions.

Table 4: Comparison of DIP EQRS values between HOLAS II and HOLAS 3 (coloured red or green depending on whether the assessment unit achieves or fails to achieve good status) and a description of the trend observed (distinct change when >15%).

HELCOM Assessment Unit name	HOLAS II 2011-2016 (EQRS)	HOLAS 3 2016-2021 (EQRS)	Distinct trend between current and previous assessment.
Kattegat	0.55	0.57	No distinct change
Great Belt	0.53	0.59	No distinct change
The Sound	0.27	0.34	Distinct improving change
Kiel Bay	0.52	0.51	No distinct change
Bay of Mecklenburg	0.35	0.31	No distinct change
Arkona Basin	0.22	0.25	No distinct change
Bornholm Basin	0.15	0.14	No distinct change
Pomeranian Bay	0.23	0.20	No distinct change
Gdansk Basin	0.39	0.18	Distinct deteriorating change
Eastern Gotland Basin	0.19	0.15	Distinct deteriorating change
Western Gotland Basin	0.17	0.17	No distinct change
Gulf of Riga	0.15	0.11	Distinct deteriorating change
Northern Baltic Proper	0.14	0.11	Distinct deteriorating change
Gulf of Finland Western	0.22	0.17	Distinct deteriorating change
Gulf of Finland Eastern	0.32	0.22	Distinct deteriorating change
Åland Sea	0.18	0.14	Distinct deteriorating change
Bothnian Sea	0.23	0.15	Distinct deteriorating change
The Quark	0.15	0.10	Distinct deteriorating change
Bothnian Bay	0.77	0.41	Distinct deteriorating change from GES to non-GES

5 Confidence

Confidence of the indicator status evaluation

The overall confidence of the indicator is based on the temporal confidence, spatial confidence and accuracy of the monitoring data for the assessment period 2016-2021 carried out in the HEAT tool. In general, the aspect of temporal coverage of monitoring data considers the confidence of the indicator in terms of its year-to-year variation and the continuity of observations during the indicator-specific assessment seasons (winter, growing season). The general temporal confidence (GTC) is assessed based on the number of annual observations during the assessment period, whereas for the specific temporal confidence (STC) the number of missing months in the respective assessment seasons of the different indicators determines the classification. The specific spatial confidence (SSC) evaluates the spatial representability of the monitoring data and is based on a gridded approach. Lastly, the accuracy confidence (ACC) indicates how certain the assessment is in relation to the variability of the data to estimate the probability of correct classification in terms of failing or achieving good status. To combine the different confidence assessments GTC and STC are averaged to an overall result for temporal confidence and this result is then averaged with SSC and subsequently combined with ACC to obtain a result for the indicator.

The overall confidence of the indicator status evaluation in open sea areas, based on the spatial and temporal coverage of data and the accuracy of the classification results was high in the Kattegat, Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Eastern Gotland Basin, Northern Baltic Proper and Bothnian Sea. The overall confidence was moderate in The Sound, Pomeranian Bay, Gdansk Basin, Western Gotland Basin, Gulf of Finland Western, The Quark and Bothnian Bay. The overall confidence was low in the Great Belt, Gulf of Riga, Gulf of Finland Eastern and the Åland Sea (see Figure 7). Looking at the different components of the overall confidence assessment separately, the accuracy of the assessment was high for all assessment units except the Great Belt, that was within the moderate range, indicating correct classifications with a probability >90%. Selected assessment units showed a moderate to low temporal confidence and the spatial confidence was overall assessed to be worst, with a larger number of assessment units showing a moderate or low spatial confidence, necessitating an increase and better spread of monitoring stations (see Figure 8). High spatial confidence was only achieved in the Kattegat, Bay of Mecklenburg, Arkona and Bornholm Basin. Confidence was assessed in all open sea assessment units, but not in coastal waters.

Eutrophication Confidence 2016-2021
Dissolved Inorganic Phosphorus (DIP)
Months: 12-2, Depths: 0-10, Metric: Mean

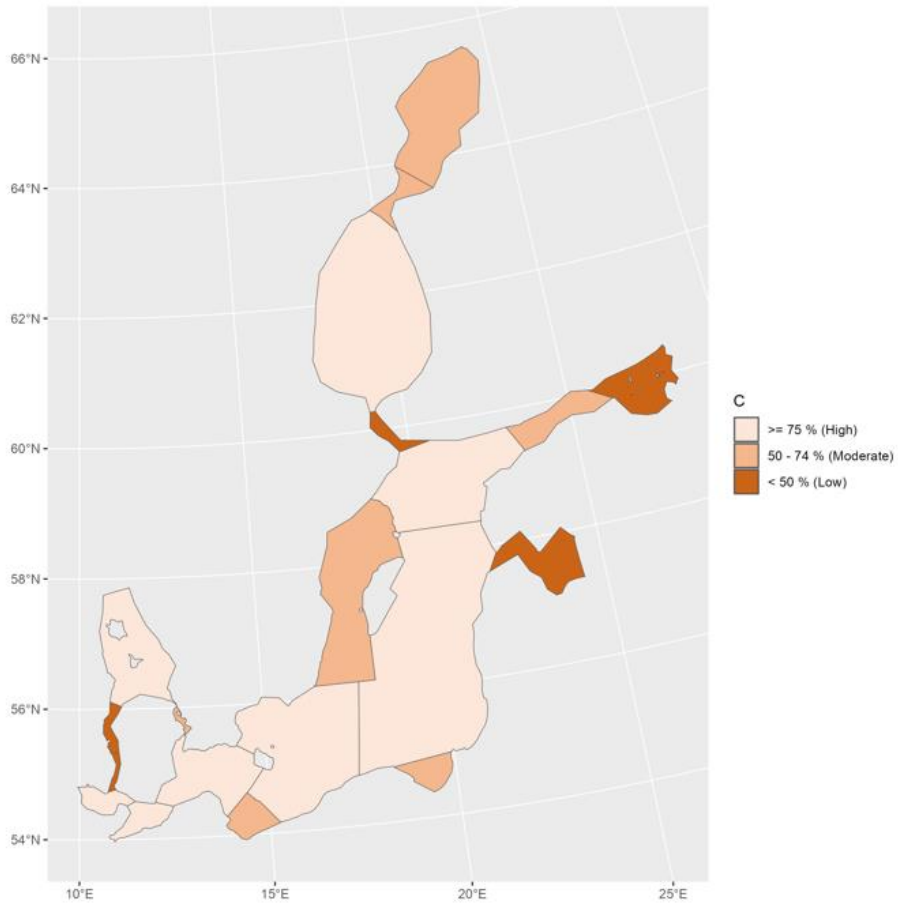


Figure 7. Overall indicator confidence, determined by combining information on data availability and the accuracy of the classification for failing or achieving good status. Low indicator confidence calls for increase in monitoring.

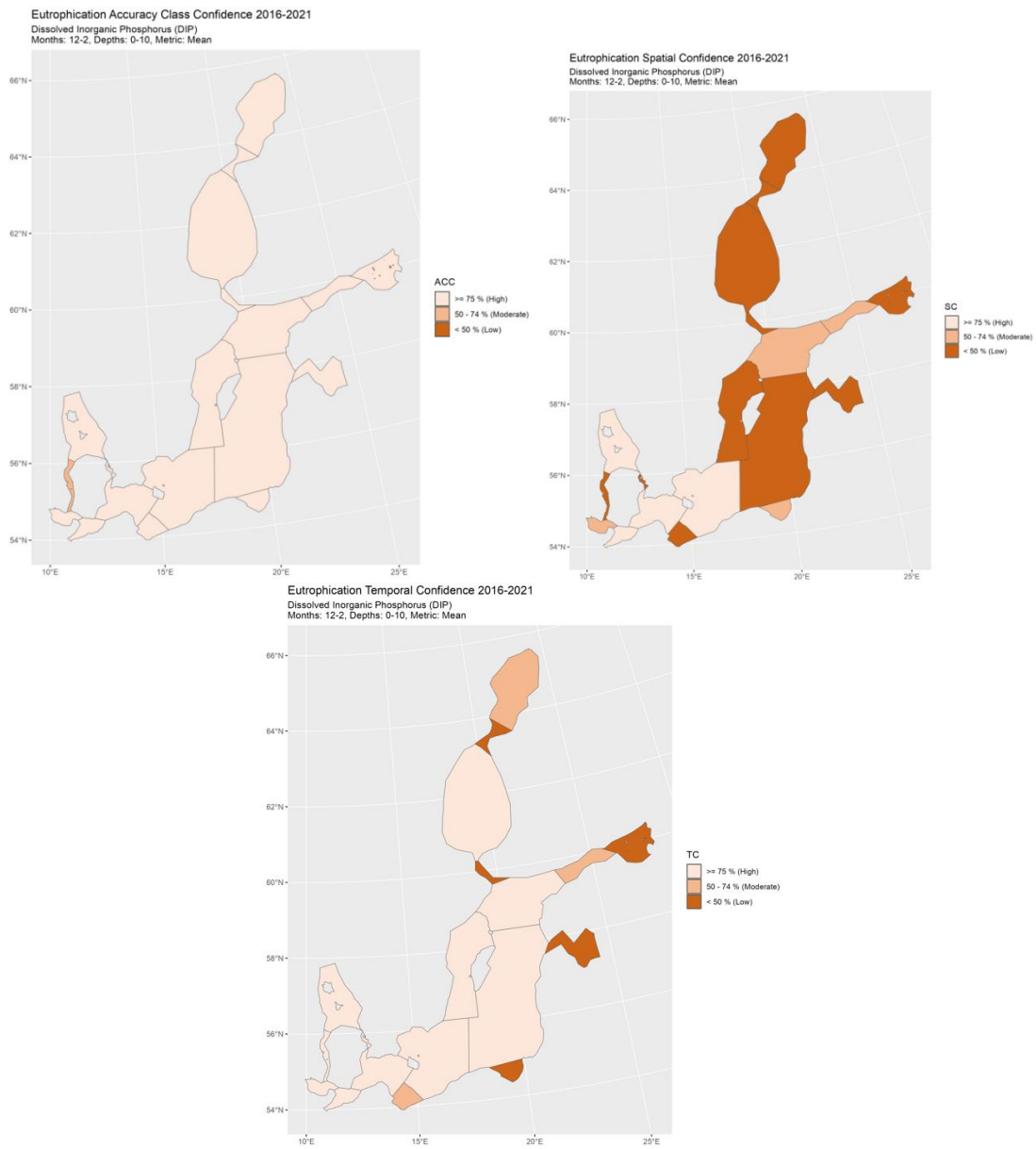


Figure 8. Confidence maps for accuracy class confidence (ACC), spatial confidence (SC) and temporal confidence (TC).

6 Drivers, Activities, and Pressures

For HOLAS 3 initial work has been carried out to explore Drivers (and driver indicators) to evaluate how such information can be utilised within such management frameworks as DAPSIM. Although it is recognised as only addressing a small portion of the drivers (via proxies) of relevance for eutrophication wastewater treatment ([Drivers and driver indicators for Wastewater Treatment](#)) and agriculture ([Drivers and driver indicators for Agricultural Nutrient Balance](#)) have been explored in these pilot studies for HOLAS 3.

Nutrient concentrations in the water column are affected by increased anthropogenic nutrient loads from land and air. Diffuse sources constitute the highest proportion of total phosphorus (about 56%) inputs to the Baltic Sea (HELCOM 2022). Natural background loads have the second highest share of total phosphorus inputs to the Baltic Sea (20%), followed by point sources (17%) and atmospheric deposition (7%). Point sources include activities such as municipal wastewater treatment plants, industrial plants and aquacultural plants and diffuse sources consists of anthropogenic sources such as agriculture, managed forestry, scattered dwellings, storm water etc.

A significant reduction of nutrient inputs has been achieved for the whole Baltic Sea. The normalized total input of phosphorus was reduced by 28% between the reference period (1997-2003) and 2020 (HELCOM 2023). The maximum allowable input (MAI) of phosphorus in this period was fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat. This has, however, not yet resulted in a good status of winter DIP concentrations in these basins, as demonstrated in this indicator assessment, indicating the delay in recovery processes from eutrophication and possibly the effects of internal phosphorus leake from the sediments (Gustafsson *et al.* 2012).

Further developing an overview of such components and the relevant data to be able to better quantify the linkages within a causal framework provide the opportunity for more informed management decisions, for example targeting of measures, and can thereby support the achievement of Good Environmental Status. This indicator itself addresses the status and a number of other status indicators as well as an indicator for the input of nutrients to the Baltic Sea (i.e. pressures) exist, thus an improved understanding of the relevant components related to drivers and activities (their data sources and how to evaluate them) can significantly improve the overall understanding of eutrophication and appropriate management of the issue.

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

	General	MSFD Annex III, Table 2a
Strong link		Substances, litter and energy - Input of nutrients – diffuse sources, point sources, atmospheric deposition
Weak link		

7 Climate change and other factors

The current knowledge of the effects of climate change to eutrophication is summarized in the HELCOM climate change fact sheet (HELCOM and Baltic Earth 2021). The effect of climate change on the nutrient pools is not yet separable from the other pressures, and the future nutrient pools will dominantly be affected by the development of nutrient loading. The phytoplankton growth season has already prolonged due to changes in cloud cover and stratification. Climate change is, with medium confidence, considered to increase the stratification, further deteriorate near-bottom oxygen conditions, and increase the internal nutrient loading (Gustafsson *et al.* 2012). Climate change also leads to a higher variability in riverine nutrient inputs, with an increase of floods and droughts. Such extreme events might have a direct impact on the nutrient concentrations in the Baltic Sea.

8 Conclusions

The status evaluation fails to achieve good status in all assessed sub-basins.

8.1 Future work or improvements needed

A better harmonisation of the thresholds for winter DIP between coastal waters and the open Baltic Sea basins might be necessary in the future, in particular in areas where coastal waters are already assessed as achieving good status while the open basins still fail to achieve good status. Although high phosphate concentrations are mainly caused by riverine nutrient inputs, sediments are becoming a more and more important source of phosphorus due to the increasing spread of hypoxia. A better understanding needs to be developed on how winter DIP concentrations react to ongoing climate change and how they are influenced by expanding oxygen deficit areas. Sediments are already or could become an important source of phosphorus leakage during oxygen depletion, which could be more and more important during increasing spread of hypoxia. A better understanding needs to be developed on how winter DIP concentrations react to ongoing climate change and how they are influenced by expanding oxygen deficit areas.

9 Methodology

9.1 Scale of assessment

The core indicator is applicable in the 19 open sea assessment units (at least one nautical mile seawards from the baseline). In the coastal units the indicator is assessed using comparable indicators developed nationally for the purposes of assessments under the EU Water Framework Directive, including their respective threshold values.

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

9.2 Methodology applied

For the open sea assessment, this core indicator is updated using data reported by Contracting Parties to the HELCOM COMBINE database hosted by ICES, using the algorithms developed for the eutrophication assessment work flow. The values are achieved using indicators specifications shown in Table 6 (see [HELCOM Eutrophication assessment manual](#)).

Table 6. Specifications for the DIP indicator.

Indicator	DIP
Response to eutrophication	Positive
Parameters	DIP = PO4 concentration (μM)
Data source	Monitoring data provided by the HELCOM Contracting Parties, and kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk)
Assessment period	2016 – 2021
Assessment season	Winter = December + January + February
Depth	Surface = average in the 0 – 10 m layer
Removing outliers	No outliers removed
Removing close observations	No close observations removed
Indicator level	Average of winter average values, in which the months are grouped by winter season (Most recent concentrations included are those of January and February of 2021).
Eutrophication Quality Ratio (EQR)	EQR = BEST/ ES, where BEST= $ET / (1 + ACDEV / 100)$ ET= threshold (table 1) ACDEV= acceptable deviation: 50 % for DIP. The final EQR values are scaled after normalisation to five classes of 0.2 width and a Scaled Eutrophication Quality Ratio is obtained (EQRS).
Indicator confidence	The confidence assessment for eutrophication indicators is included in HEAT, and includes aspects of temporal, spatial and accuracy confidence. The general methodology of the confidence assessment is described in Document 4.2 of IN-Eutrophication 16-

2020 and updates are described in documents 4J-80 of State & Conservation 14-2021 and 4-2 of EG-EUTRO 20-2021. The R-code is available via <https://github.com/ices-tools-prod/HEAT>.

The aspect of temporal coverage of monitoring data considers the confidence of the indicator in terms of its year-to-year variation and the continuity of observations during the indicator-specific assessment season (annual/summer). The general temporal confidence (GTC) is assessed based on the number of annual observations during the assessment period, whereas for the specific temporal confidence (STC) the number of missing months in the respective assessment season (annual/summer) determines the classification. The specific spatial confidence (SSC) evaluates the spatial representability of the monitoring data and is based on a gridded approach. Lastly, the accuracy confidence (ACC) indicates how certain the assessment is in relation to the variability of the data to estimate the probability of correct classification for failing or achieving good status. To combine the different confidence assessments GTC and STC are averaged to an overall result for temporal confidence and this result is then averaged with SSC and subsequently combined with ACC to obtain a result for the indicator.

The evaluation criteria for general and specific temporal confidence are given in the table below.

Confidence class	Evaluation criteria for general temporal confidence	Evaluation criteria for specific temporal confidence
High (100)	The evaluation is based on > 20 annual observations during the given assessment period	0 missing months per year
Medium (50)	The evaluation is based on 7 - 20 annual observations	1 missing month per year
Low (0)	The evaluation is based on < 7 annual observations	≥ 2 missing months per year

If the specific temporal confidence is high (100) for at least half of the assessed years, it is set as high (100) for the assessment period. The total temporal confidence is the average of the general and specific temporal confidence aspects.

The evaluation criteria for spatial confidence are given in the table below.

Confidence class	Evaluation criteria for spatial confidence
High (100)	Sampled grid cells cover > 70 % of the assessment-unit area
Medium (50)	Sampled grid cells cover 50-70 % of the assessment-unit area

	Low (0)	Sampled grid cells cover < 50 % of the assessment-unit area
	The accuracy aspect assesses the probability of correct classification (the classification being below or above the threshold for good status).	
	The evaluation criteria for accuracy aspect are given in table below.	
	Confidence class	Evaluation criteria for spatial confidence
	High (100)	GES has been/ not been achieved by $\geq 90\%$ probability
Medium (50)	GES has been/ not been achieved by $70 < 90\%$ probability	
Low (0)	GES has been/ not been achieved by $< 70\%$ probability	
Indicator value confidence	threshold	MODERATE

9.3 Monitoring and reporting requirements

Monitoring methodology

Monitoring of DIP in the Contracting Parties of HELCOM is described on a general level in the HELCOM Monitoring Manual in the [sub-programme Nutrients](#).

[Monitoring guidelines](#) specifying the sampling strategy for [phosphate](#) are adopted and published.

Current monitoring

The monitoring activities relevant to the indicator that are currently carried out by HELCOM Contracting Parties are described in the HELCOM Monitoring Manual [sub-programme Nutrients](#) monitoring concepts table.

Description of optimal monitoring

Regional monitoring of dissolved inorganic phosphorus is considered sufficient to support the indicator evaluation. Increased temporal and spatial monitoring in certain areas would further improve the confidence in future assessments.

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: Dissolved inorganic phosphorus

Data source: The average for 2016-2021 was estimated using monitoring data provided by the HELCOM Contracting Parties, and kept in the HELCOM COMBINE database, hosted by ICES (www.ices.dk). Nominated members of HELCOM State & Conservation Working Group were given the opportunity to review the data, and to supply any missing monitoring observations, in order to achieve a complete dataset.

Description of data: The data reflect *in situ* phosphate concentrations, determined using colorimetric methods, as explained in the HELCOM monitoring manual. In the assessment, only winter (December – February) surface water measurements at depths of 0-10 m are reported.

Geographical coverage: The observations are distributed in the sub-basins according to the HELCOM monitoring programme, added occasionally with data from research cruises.

Temporal coverage: The raw data includes observations throughout the year, during the assessment period 2016-2021.

Data aggregation: The 2016-2021 averages for each sub-basin were produced as inter-annual winter (December-February) estimates.

11 Contributors

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12 Archive

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

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

Earlier versions of the core indicator report are available:

[Dissolved inorganic phosphorus DIP HELCOM core indicator 2018](#) (pdf)

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

[DIP concentrations 2007-2011](#) (pdf)

[Nutrient concentrations 2003-2007 - HELCOM Core Indicator Report](#) (pdf)

13 References

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HELCOM (2023) “Inputs of Nutrients to the Sub-Basins (2020). HELCOM Core Indicator Report. Online.” 2023.

HELCOM and Baltic Earth (2021) Climate Change in the Baltic Sea. 2021 Fact Sheet. Baltic Sea Environment Proceedings N°180. <https://doi.org/ISSN:0357-2994>.

14 Other relevant resources

HELCOM: First version of the 'State of the Baltic Sea' report – June 2017, Baltic Marine Environment Protection Commission – HELCOM, Helsinki, Finland, 197, 2017.

[Eutrophication status of the Baltic Sea 2007-2011 - A concise thematic assessment](#) (2014)

[Approaches and methods for eutrophication target setting in the Baltic Sea region](#) (2013)

[HELCOM core indicators. Final report of the HELCOM CORESET project](#) (2013)

[Eutrophication in the Baltic Sea. An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region](#) (2009)

[Development of tools for assessment of eutrophication in the Baltic Sea](#) (2006)

Tables below provide an overview of the detailed coastal data.

Annex 1. Annex providing an overview of additional coastal evaluations reported by Contracting Parties

Annex table 1. Results for national coastal winter DIP indicators by coastal WFD water type/water body. The table includes information on the assessment unit (CODE, defined in the [HELCOM Monitoring and Assessment Strategy Annex 4](#)) and description, assessment period (start year and/or end year), average concentration during assessment period (ES) in $\mu\text{mol/l}$ for IndicatorID **8003** and mg/L for Indicator ID **7005-7006**, with standard deviation (SD), Ecological Quality Ratio (EQR) and Ecological Quality Ratio Scaled (EQRS). EQRS shows the present concentration in relation to the reference value, decreasing along with increasing eutrophication. EQRS_class estimates the ecological status based on the EQRS value.

IndicatorID	Name	Period	Unit ID	HELCOMID	HELCOM ID description	Assessment Unit	ET	ES	SD	EQR	EQRS	EQRS Class	
7005	Dissolved Inorganic Phosphorus	20162021	7001	POL-001	PL TW I WB 9 very sheltered, fully mixed, substratum: silt/sandy silt/silty sand; ice cover >90 days, water residence time 52 days	Bornholm Basin		0.09	0.05	0.03	0.91	0.89	High
7005	Dissolved Inorganic Phosphorus	20162021	7002	POL-002	PL TW I WB 8 very sheltered, fully mixed, substratum: silt/sandy silt/silty sand; ice cover >90 days, water residence time 52 days	Bornholm Basin		0.09	0.06	0.02	0.92	0.91	High
7005	Dissolved Inorganic Phosphorus	20162021	7003	POL-003	PL TW I WB 1 very sheltered, fully mixed, substratum: silt/sandy silt/silty sand; ice cover >90 days, water residence time 52 days	Gdansk Basin		0.05	0.03	0.01	0.90	0.88	High

7005	Dissolved Inorganic Phosphorus	20162021	7004	POL-004	PL TW II WB 2 very sheltered, fully mixed, substratum: lagoonal fine sand/medium grained sand/silty sand; residence time 138 day, ice cover >90 days	Gdansk Basin	0.00	0.01	0.00	0.22	0.11	Bad
7006	Dissolved Inorganic Phosphorus	20162021	7005	POL-005	PL TW III WB 3 partly protected, partly stratified, substratum: medium grained sand/pebbles/marine silty sand; ice-incident	Gdansk Basin	0.02	0.01	0.00	0.97	0.97	High
7006	Dissolved Inorganic Phosphorus	20162021	7006	POL-006	PL TW IV WB 4 partly stratified, moderately exposed, substratum: sand/silt; ice - incidental	Gdansk Basin	0.02	0.01	0.01	0.77	0.72	Good
7006	Dissolved Inorganic Phosphorus	20162021	7007	POL-007	PL TW V WB 6 river mouth, partly stratified, partly sheltered, substratum: medium grained sand/silty sand	Bornholm Basin	0.04	0.02	0.00	0.96	0.96	High
7006	Dissolved Inorganic Phosphorus	20162021	7008	POL-008	PL TW V WB 5 river mouth, partly stratified, partly sheltered, substratum: medium grained sand/silty sand	Gdansk Basin	0.04	0.02	0.01	0.92	0.91	High

7006	Dissolved Inorganic Phosphorus	20162021	7009	POL-009	PL TW V WB 7 river mouth, partly stratified, partly sheltered, substratum: medium grained sand/silty sand	Bornholm Basin	0.04	0.02	0.01	0.88	0.87	High
7006	Dissolved Inorganic Phosphorus	20162021	7010	POL-010	PL CWI WB2 coastal waters, moderately exposed, fully mixed, substratum:sand/fine sand	Gdansk Basin	0.02	0.02	0.03	0.68	0.64	Good
7006	Dissolved Inorganic Phosphorus	20162021	7011	POL-011	PL CWI WB1 coastal waters, moderately exposed, fully mixed, substratum:sand/fine sand	Gdansk Basin	0.02	0.02	0.02	0.86	0.83	High
7006	Dissolved Inorganic Phosphorus	20162021	7012	POL-012	PL CWI WB3 coastal waters, moderately exposed, fully mixed, substratum:sand/fine sand	Gdansk Basin	0.02	0.04	0.03	0.36	0.25	Poor
7006	Dissolved Inorganic Phosphorus	20162021	7013	POL-013	PL CW II WB 8 central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Bornholm Basin	0.02	0.03	0.00	0.40	0.25	Poor
7006	Dissolved Inorganic Phosphorus	20162021	7014	POL-014	PL CW II WB 6W central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Bornholm Basin	0.02	0.02	0.01	0.68	0.61	Good

7006	Dissolved Inorganic Phosphorus	20162021	7015	POL-015	PL CW II WB 6E central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Bornholm Basin	0.02	0.01	0.01	0.76	0.71	Good
7006	Dissolved Inorganic Phosphorus	20162021	7016	POL-016	PL CWII WB5 central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Eastern Gotland Basin	0.02	0.02	0.01	0.69	0.62	Good
7006	Dissolved Inorganic Phosphorus	20162021	7017	POL-017	PL CWII WB4 central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Gdansk Basin	0.02	0.01	0.00	0.84	0.82	High
7006	Dissolved Inorganic Phosphorus	20162021	7018	POL-018	PL CW III WB 9 central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Bornholm Basin	0.02	0.03	0.01	0.65	0.57	Moderate
7006	Dissolved Inorganic Phosphorus	20162021	7019	POL-019	PL CW III WB 7 central Polish coast, coastal waters, exposed, fully mixed, substratum: sand/pebbles/gravel	Bornholm Basin	0.02	0.03	0.01	0.42	0.28	Poor
8003	Dissolved Inorganic Phosphorus	20182018	8001	SWE-001	1s West Coast inner coastal water	Kattegat	0.60	0.35	NA	1.15	1.00	High

8003	Dissolved Inorganic Phosphorus	20182018	8002	SWE-003	4 West Coast outer coastal water, Kattegat	Kattegat	0.60	0.30	NA	1.35	1.00	High
8003	Dissolved Inorganic Phosphorus	20182018	8003	SWE-004	5 South Halland and north Öresund coastal water	Kattegat	0.60	0.45	NA	0.88	0.41	Moderate
8003	Dissolved Inorganic Phosphorus	20182018	8004	SWE-005	6 Öresund inner coastal water	The Sound	0.60	5.02	6.12	0.79	0.73	Good
8003	Dissolved Inorganic Phosphorus	20172017	8005	SWE-006	7 Skåne coastal water	Arkona Basin	0.38	0.62	NA	0.41	0.47	Moderate
8003	Dissolved Inorganic Phosphorus	20182018	8006	SWE-007	8 Blekinge archipelago and Kalmarsund, inner	Western Gotland Basin	0.37	0.54	NA	0.46	0.37	Poor
8003	Dissolved Inorganic Phosphorus	20182018	8007	SWE-008	9 Blekinge archipelago and Kalmarsund, outer	Western Gotland Basin	0.38	0.63	NA	0.40	0.56	Moderate
8003	Dissolved Inorganic Phosphorus	20172017	8010	SWE-011	12n Östergötland and Stockholm archipelago	Northern Baltic Proper	0.38	0.81	NA	0.32	0.48	Moderate
8003	Dissolved Inorganic Phosphorus	20182018	8011	SWE-012	12s Östergötland and Stockholm archipelago	Western Gotland Basin	0.38	0.79	NA	0.33	0.41	Moderate
8003	Dissolved Inorganic Phosphorus	20172017	8012	SWE-013	13 Östergötland inner coastal water	Western Gotland Basin	0.40	1.32	NA	0.21	0.48	Moderate

8003	Dissolved Inorganic Phosphorus	20172017	8013	SWE-014	14 Östergötland outer coastal water	Western Gotland Basin	0.37	0.86	NA	0.29	0.20	Poor
8003	Dissolved Inorganic Phosphorus	20182018	8015	SWE-016	16 South Bothnian Sea, inner coastal water	Bothnian Sea	0.28	0.27	NA	0.70	0.45	Moderate
8003	Dissolved Inorganic Phosphorus	20182018	8017	SWE-018	18 North Bothnian Sea, Höga kusten, inner	Bothnian Sea	0.26	0.29	NA	0.59	0.57	Moderate
8003	Dissolved Inorganic Phosphorus	20172017	8019	SWE-020	20 North Quark inner coastal water	The Quark	0.20	0.24	NA	0.56	0.41	Moderate