Figure 4.2. Pollution enters the Baltic Sea from a mix of sources, including direct point sources, freshwater discharges, rivers and the atmosphere.

BOX 4.1.

The HELCOM thematic assessments of eutrophication, hazardous substances and other pollution

The HELCOM thematic assessment of eutrophication in 2016-2021 (HELCOM 2023b) addresses eutrophication in the Baltic Sea. It provides status assessment results for eutrophication indicators and their trends, as well as integrated assessment results using the HELCOM eutrophication assessment tool, HEAT. The results of the assessments are presented in summary in the current report and are given in full detail in the thematic assessment and its associated indicator fact sheets, which also describe the methods used.

The HELCOM thematic assessment of hazardous substances, marine litter, underwater noise and non-indigenous species in 2016-2021 (HELCOM 2023c) addresses other pollution-related pressures, and provides detailed assessment results and method descriptions for these topics. In addition to results based on the integrated HELCOM assessment tool CHASE (for hazardous substances), the report gives summaries of available indicator evaluations and descriptive knowledge of relevance. It also suggests various ways in which HELCOM assessments could be further improved in the future for the covered topics. For hazardous substances, the current assessments do not address all relevant policy requirements or cover all relevant ecological aspects. While a strong evaluation can be made based on the relatively few well-studied and well-monitored hazardous substances currently included in the assessment, there is a vast array of hazardous or potentially hazardous substances for which we have little information about their presence in the marine environment or their impacts.

The topics addressed in both reports are directly and primarily linked to human activities and have the potential to exert significant pressures on the Baltic Sea marine environment. They share the characteristic that the most effective way to address them is to prevent or limit their initial inputs. Once these pressures are in the marine environment, alleviating or remediating them is often very complex, difficult and costly compared with acting earlier. Different pressures have different scales of impact, but all cause or could cause significant negative effects on the ecosystem, and addressing all of them is of high importance for achieving our aim of a healthy Baltic Sea environment.

4.2.1 Eutrophication

The integrated assessment of eutrophication status shows that eutrophication is still a major problem in the Baltic Sea (Figure 4.3). There were no clear signs of recovery during 2016-2021 compared to the previous assessment period. Excess nutrient inputs to the marine environment increases phytoplankton development, which reduces light levels in the water, contributes to depleting oxygen reserves at the bottom, and triggers a series of other ecosystem changes (Box 4.2).

Inputs of nutrients to the Baltic Sea have decreased significantly but the target for maximum allowable inputs has not yet been achieved in all basins (Figures 4.4-4.5). For the whole Baltic Sea, the normalized total input of nitrogen was reduced by 12% and phosphorus by 28% between the reference period (1997-2003) and 2020 (HELCOM 2023f). The maximum allowable input (MAI) target for nitrogen was fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat. For the Baltic Proper and the Gulf of Finland, the MAI was exceeded, and results for the Gulf of Riga were statistically uncertain. The target for phosphorus was fulfilled in the Bothnian Bay, Bothnian Sea, Danish Straits and Kattegat. In the remaining sub-basins, the MAI was exceeded also for phosphorus.

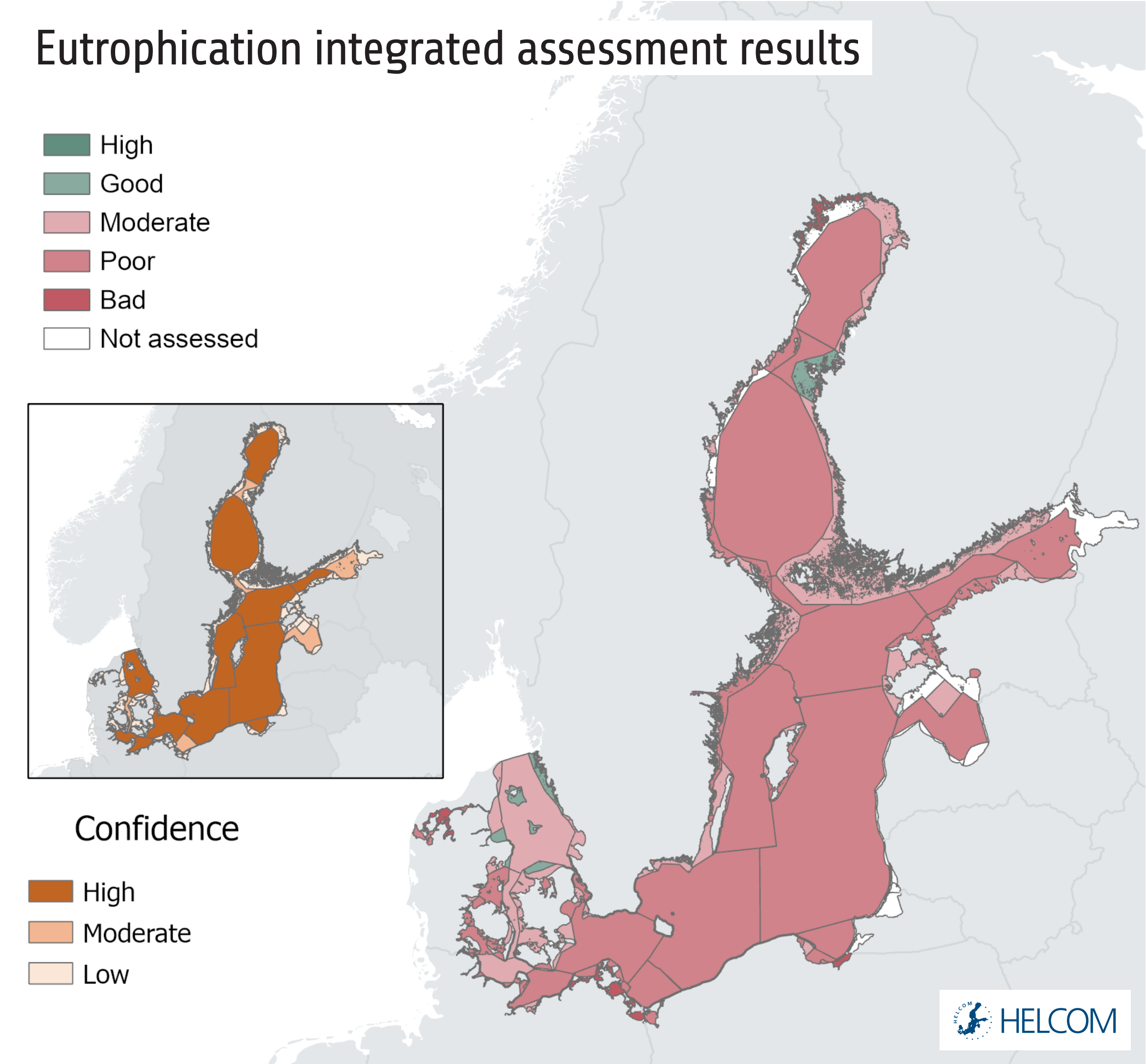

Figure 4.3. Summary of assessment results from the assessment of eutrophication. Source: HELCOM 2023b.

BOX 4.2.

What is eutrophication?

Eutrophication comes from the excessive input of nutrients into the marine system, leading to an increased supply of organic matter. Primary production by algae, plants and cyanobacteria is a key process at the base of the food web, providing energy for organisms higher in the food web. This primary production depends on the availability of nutrients, in particular nitrogen and phosphorus, but too high nutrient levels enhance primary production beyond what grazers in the food web can consume. Early symptoms of eutrophication are increased concentrations of chlorophyll in the water column and the growth of opportunistic algae. These lead to reduced water clarity and increased deposition of organic material to the seabed, which in turn increases oxygen consumption and may cause oxygen depletion. Long-lasting eutrophication can cause changes in species composition, when species that benefit from eutrophic conditions are favoured directly or through food web interactions, and vice versa.

The Baltic Sea Action Plan states the following ecological objective concerning eutrophication:

— A Baltic Sea unaffected by eutrophication

Countries around the Baltic Sea have a long-term commitment to reduce eutrophication in the Baltic Sea. A central tool is the Maximum Allowable Input, which gives the maximal inputs of waterborne and airborne nitrogen and phosphorus that can be allowed to Baltic Sea sub-basins while still achieving good status in terms of eutrophication.

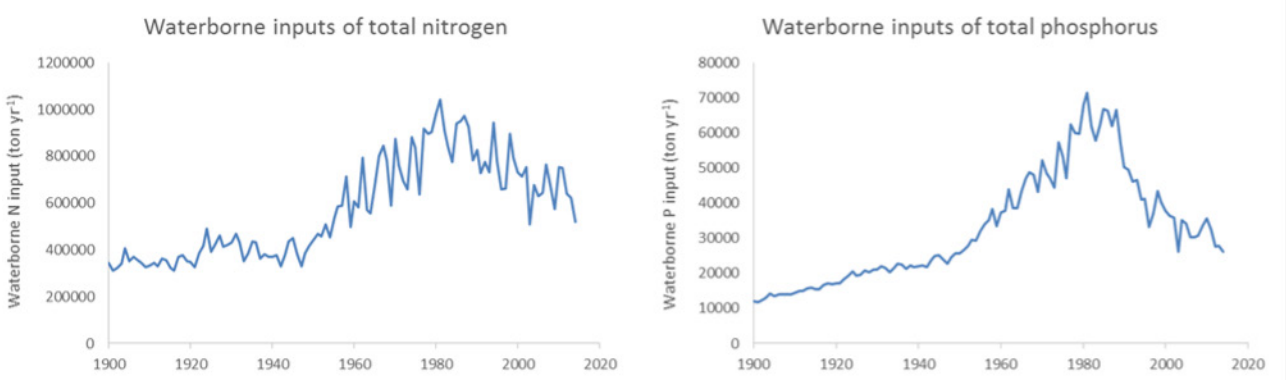

Figure 4.4. Temporal development of waterborne inputs of total nitrogen (left) and total phosphorus (right) to the Baltic Sea Source: HELCOM 2023b.

Figure 4.5. Inputs of nitrogen (left) and phosphorus (right) to the Baltic Sea sub-basins, as these are defined in the HELCOM pollution load compilation. BAS=whole Baltic Sea. The columns show trend-based estimates of total nitrogen and phosphorus inputs in 2020, in tons per year and including statistical uncertainty. The short blue lines show the maximum allowable inputs (MAI). Green indicates that the estimated inputs, including uncertainty, were lower than MAI, while red indicates that they exceeded MAI. Yellow indicates that the statistical uncertainty of the input data makes it not possible to determine whether MAI was fulfilled. Note that the scale of the y-axis differs between charts. Source: HELCOM 2023f.

Impacts of eutrophication in the Baltic Sea ecosystem

Eutrophication initially affects primary producers, and processes in the pelagic system are of key importance for how eutrophication symptoms develop. Widespread and lasting eutrophication can impair ecosystem functions through a combination of direct and indirect impacts on aspects such as species composition, food web dynamics and oxygen conditions (Carstensen *et al.* 2014). These impacts can have widespread effects across a broad range of habitats and species. In the Baltic Sea, eutrophication has been associated with changes in species composition in several key trophic groups, including primary producers, benthic fauna, coastal fish and sea birds. Over time, eutrophication has become a key driver of changes in the trophic state of the Baltic Sea ecosystem. The Baltic Sea has transformed from being a typical low productivity system in the 1920s to a high productivity system today, with the presence of insufficient oxygen conditions becoming a key mechanism and cause for concern (Tomczak *et al.* 2022, Rolff *et al.* 2022).

Eutrophication causes multiple adverse economic and societal effects. Factors such as decreased water clarity, more frequent cyanobacterial blooms, oxygen deficiency in bottom waters, changes in fish stocks and loss of marine biodiversity all decrease the environmental benefits from the Baltic Sea in terms of both use-related values and non-use values (Ahtiainen *et al.* 2016). Examples include increased costs of cleaning, reduced income from tourism, damage to fishing gear and lost fishing possibilities, increased travel costs to reach unaffected areas, and reduced cultural and historical values. Reaching good eutrophication status for the Baltic Sea is foreseen to increase human well-being significantly and bring economic benefits to society.

Sources of nutrient inputs

The majority of nutrient inputs to the Baltic Sea originate from human activities on land and at sea. Waterborne inputs enter via rivers and direct discharge from coastal areas. The main point sources of waterborne inputs are wastewater treatment plants (Figure 4.6), industries and aquaculture. The main diffuse sources are agriculture, managed forestry, scattered dwellings and storm water overflows. In addition, natural background sources contribute to the input.

The main sectors contributing to atmospheric inputs are energy production (combustion) and industry, as well as the transportation of oxidized nitrogen, and agriculture is also a source of reduced nitrogen. A large portion of the atmospheric inputs originate from sources outside the Baltic Sea region. Emissions from shipping in the Baltic and North Seas contribute significantly to atmospheric inputs of nitrogen.

Excess nutrients stored in bottom sediments can re-enter the water column and again enhance primary production. In oxygen-depleted areas, phosphorus can leak out and be used by cyanobacteria that can make use of inert nitrogen. Other habitats have a strong capacity to store and sequester nutrients, such as coastal habitats with rooted plants and long-lived macroalgae (HELCOM 2023d).

Regulations and needs

Minimizing the input of nutrients from human activities is a central management objective of the Baltic Sea Action Plan.

Regional targets for nutrient inputs are defined by the Maximum Allowable Inputs (MAI) and Nutrient Input Ceilings (NIC) in the Baltic Sea Action Plan. Fulfilling these targets for all sub-basins is a key prerequisite for achieving a Baltic Sea unaffected by eutrophication.

Reducing the agreed levels of nutrient inputs is expected to improve eutrophication status at sea, even though the responses at sea may take time (HELCOM ACTION 2021a). Model simulations indicate that significant improvements in eutrophication status can be expected roughly one or two decades after nutrient inputs are reduced to the target levels, and that it could take half a century or more to reach the environmental objectives. In coastal areas, the responses could be faster, if significant direct point sources are removed. This is probably also the case in the eastern part of the Gulf of Finland (HELCOM 2023f).

Measures to restore the natural functioning of Baltic Sea food webs are expected to enhance the natural capacity of the ecosystem to counterbalance eutrophication symptoms. Strengthening trophic control in the food web can curtail the overproduction of fast-growing filamentous algae, for example (see section 3.3).

Measures to strengthen coastal habitats with a strong capacity for nutrient uptake and storage, such as rooted plants and long-lived macroalgae, are expected to strengthen the ecosystem's natural capacity to sequester nutrients at sea.

Climate change is expected to worsen the negative impacts of eutrophication. Climate change effects could enhance algal blooms or oxygen consumption, for example.

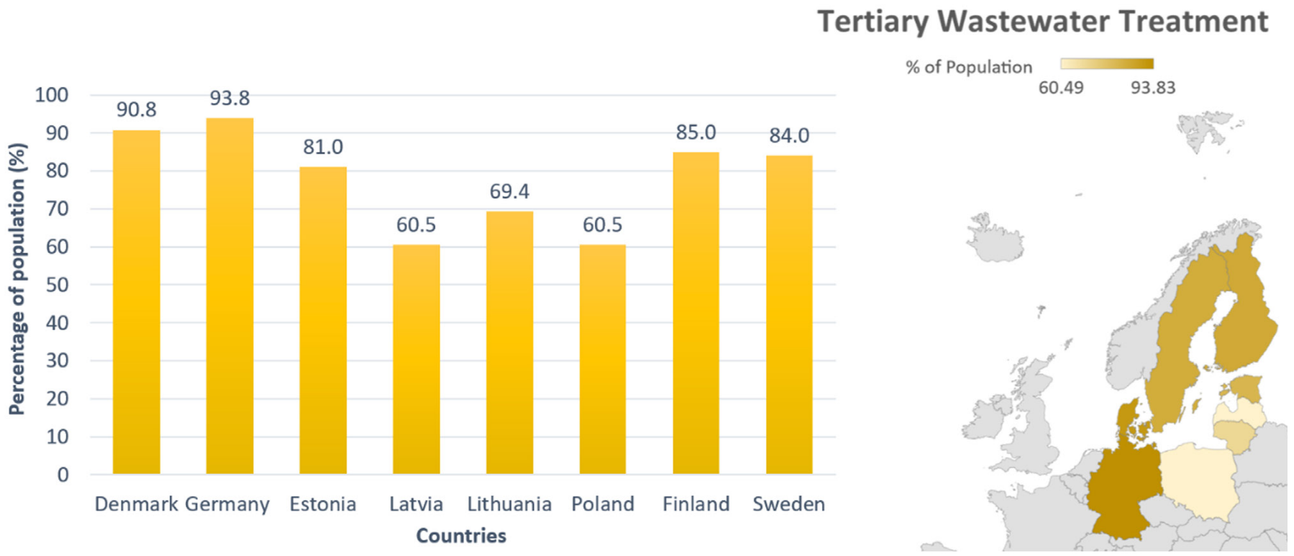

Figure 4.6. Various drivers determine the extent and efficiency of wastewater treatment in the Baltic Sea region, including political will, investment, regulations and the adoption of technology. Overall, 72% of the Baltic Sea catchment area population is connected to tertiary wastewater treatment plants (Eurostat 2022). The bar charts show the percentage of the total population connected to tertiary wastewater treatment plants in Baltic Sea countries in 2020. The chart does not include data from Russia or any non-HELCOM countries. Source: HELCOM 2023d.

4.2.2 Hazardous substances

The status of hazardous substances shows some signs of improvement during the assessment period, however it is still clearly not good (Figure 4.7). The integrated contamination status of the Baltic Sea remained above acceptable minimum levels during 2016-2021. The contamination status was assessed as either bad or poor in roughly 80% of the 57 assessed spatial units, including the majority of the open sea sub-basins. Only one assessment unit in the open sea had good status. The results partly reflect the prevailing monitoring regimes, because units achieving better status tend to be represented by fewer parameters being evaluated or key drivers of the overall status being absent.

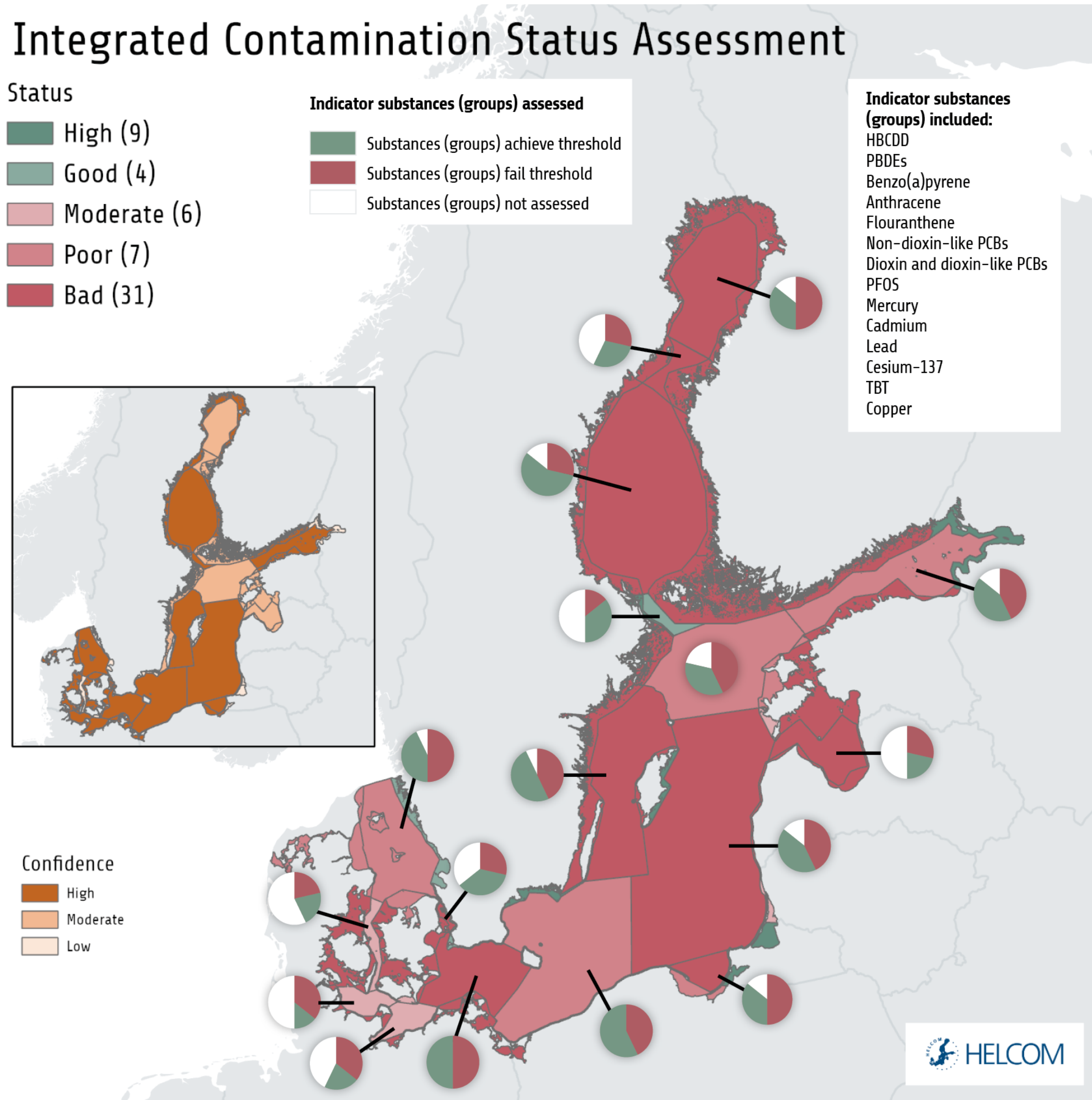

Figure 4.7. The integrated assessment of hazardous substances status in the Baltic Sea, assessed using the CHASE integrated assessment tool. The assessment shows that hazardous substances are a cause for concern in almost all assessed units, and those showing good status generally lack a full and adequate assessment. The integrated assessment is based on 11 core indicators. It integrates concentrations to threshold-derived values (contamination ratios) for fourteen individual hazardous substances or substance groups. The overall assessment is moderated by a parallel assessment of confidence (see inset map on the left) that can be considered an appraisal of the data coverage and assessment quality in any given assessment unit. Source: HELCOM 2023c.