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Policy Brief

Baltic Sea Centre
Stockholm University

Further land-based measures are needed to reach eutrophication targets

In recent decades, the nutrient loads to the Baltic Sea have decreased sharply. Eventually, this is expected to lead to improvements in the sea, but because large amounts of nutrients are stored in the water and on land, it will take time to see the effects. In order to comply with the commitments in the Baltic Sea Action Plan (BSAP), and simultaneously improve the environment in lakes and watercourses, the countries around the Baltic Sea need to continue to take measures to further reduce nutrient loads from land.

Since eutrophication was first acknowledged as one of the most serious environmental problems in the Baltic Sea, the supply of nutrients to the sea, commonly called the nutrient loads, have decreased drastically. Since the 1980s, the total load of nitrogen has decreased by about one third and the phosphorus load by just over half. The decrease is mainly due to improved wastewater treatment and measures to prevent nutrient leakage from the agricultural sector through, for example, improved fertilisation techniques.

However, substantial efforts remain if the Baltic Sea countries are to achieve the ambitious goals and targets agreed upon through the HELCOM cooperation. At the same time, the EU member states have committed to take measures to improve the water in rivers and lakes through the Water Framework Directive. As improvements in freshwater bodies could contribute to improvements in the sea, it is co-beneficial to implement measures upstream and as close as possible to the nutrient sources.

The Baltic Proper is the biggest challenge

The eutrophication situation varies significantly across the Baltic Sea. The biggest challenge in achieving the goals of HELCOM BSAP lies with the Baltic Proper, which is generally the worst affected by eutrophication compared to other areas. The last two decades, the phosphorus load to the Baltic Proper has decreased by 23 percent and it continues to decrease. To reach the maximum available inputs agreed upon in BSAP, however, the phosphorus load needs to be further reduced by 50 percent relative to 2018.

The nitrogen load to the Baltic Proper has decreased by 10 percent the last two decades. To achieve the BSAP goals, an addition 20 percent reduction is needed, but for about the past ten years the nitrogen load has been fairly constant.

Through the BSAP, the Baltic Sea countries also agreed to reduce

POLICY RECOMMENDATIONS

Focus measures against eutrophication on reducing nutrient loads from land, nearest the source of emissions as possible.

Support the expansion of efficient wastewater treatment plants in the Baltic Sea catchment area, where such are lacking.

Improve nutrient use efficiency of chemical fertilisers and livestock and reduce the import of feed and fertilisers, to slow the build-up of legacy phosphorus on land.

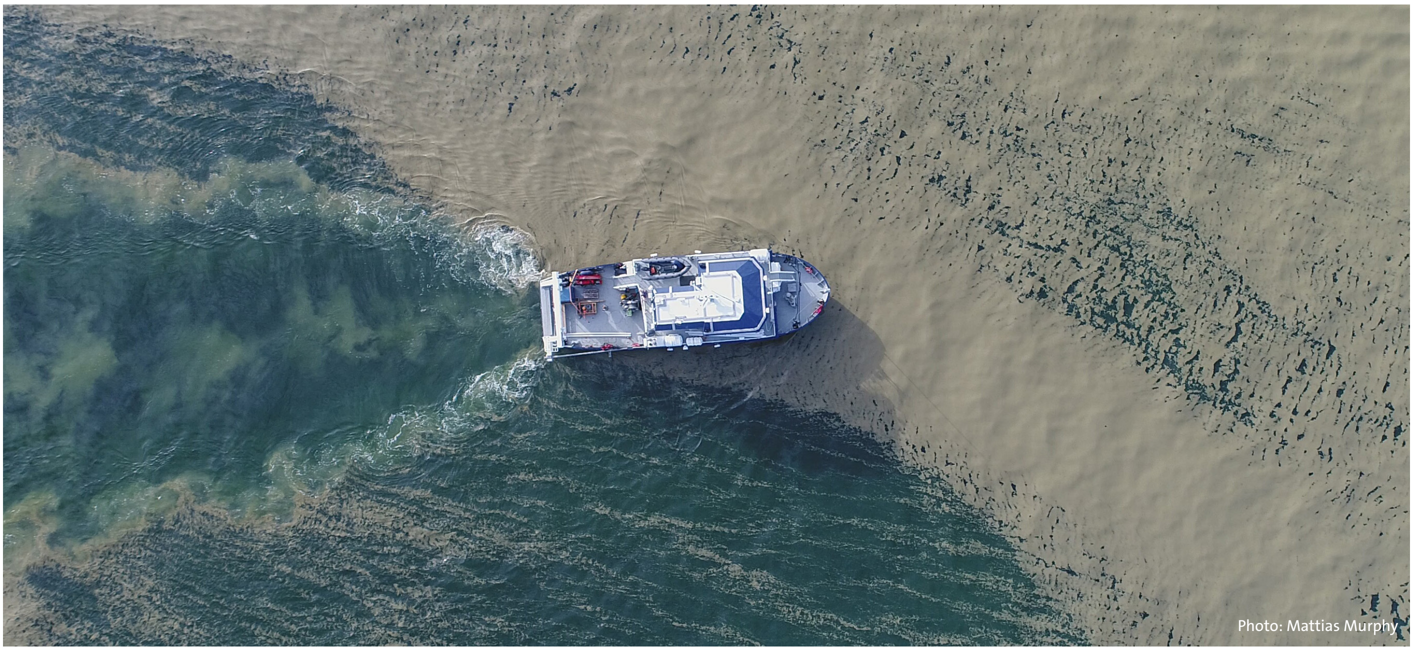


Photo: Mattias Murphy

the load of phosphorus to the Gulf of Finland and the Gulf of Riga. The goal for the Gulf of Finland has almost been reached, but further reductions are required for the Gulf of Riga. The countries also agreed to reduce the nitrogen load to the Gulf of Finland and the Kattegat. The goal for the Kattegat has been reached, but further action is needed to meet the goal for the Gulf of Finland.

A combination of measures can reduce nutrient loads

During the 20th century, large quantities of nitrogen and phosphorus were imported into the Baltic Sea region, primarily in the form of mineral fertilisers. The inefficient use of manure and fertilisers in agriculture and the inadequate treatment of sewage resulted in the accumulation of nutrients in soils and in sediments of lakes and rivers. An estimated 17 million tonnes of phosphorus have accumulated in the catchment area and a significant part of this “legacy” phosphorus continues to leak from land into the Baltic Sea. About 45 percent of the phosphorus load to the Baltic Sea could originate from this pool.

Strong land-based measures are essential for reducing further build-up of phosphorus pool on land that will otherwise contribute to eutrophication in the future. This can be done by regarding the legacy pool as a resource and accounting for soil nutrient status prior to fertilisation. Indeed, soils in many regions contain so much phosphorus that further fertilisation does not increase harvest. Physical measures in the landscape, such as buffer strips and sedimentation ponds, can also help reduce nutrient losses to watercourses. When these measures are implemented upstream, they can also have a major effect locally on lakes and watercourses and could fulfil the aims of the EU Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). At the same time, it is important to have realistic expectations of how quickly the nutrient loads to the Baltic Sea can be reduced. The leakage from land-based legacy phosphorus will continue for decades, but more powerful measures could reduce the magnitude of this leakage.

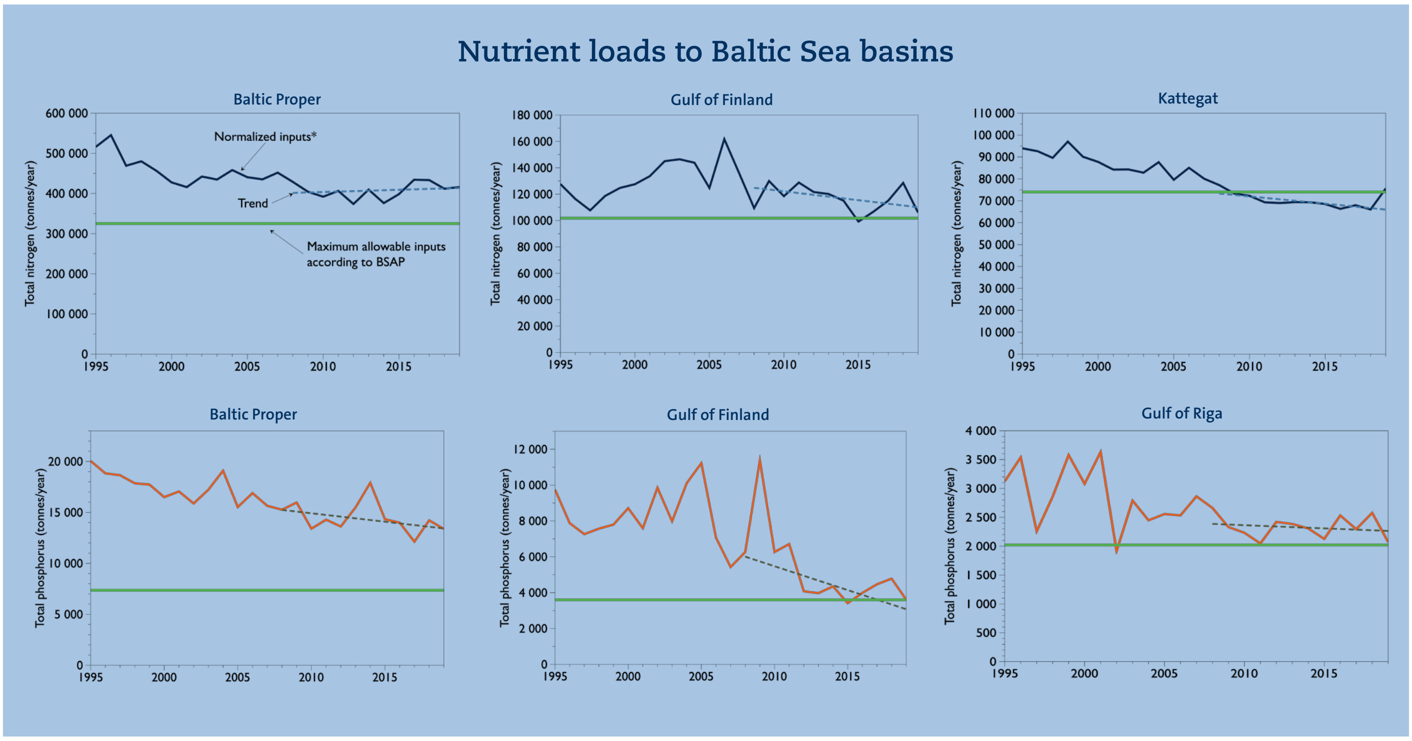
Sewage treatment in the Baltic Sea countries has improved significantly in recent decades, but sewage wastewater still accounts for about 20 percent of the total phosphorus load. HELCOM recommends that major treatment plants remove 90 percent of phosphorus from wastewater. It has been estimated that this, if implemented, would reduce the annual load to the Baltic Sea by 1,000 tonnes. However, the countries upstream of the catchment area, such as Ukraine and Belarus, are not included in that figure, suggesting there is even greater potential for reductions. Building new treatment plants, and improving the capacity and efficiency of existing ones in densely populated areas of the region is probably the fastest way to reduce the loads of both nitrogen and phosphorus to the Baltic Sea.

Little improvement is seen in the sea

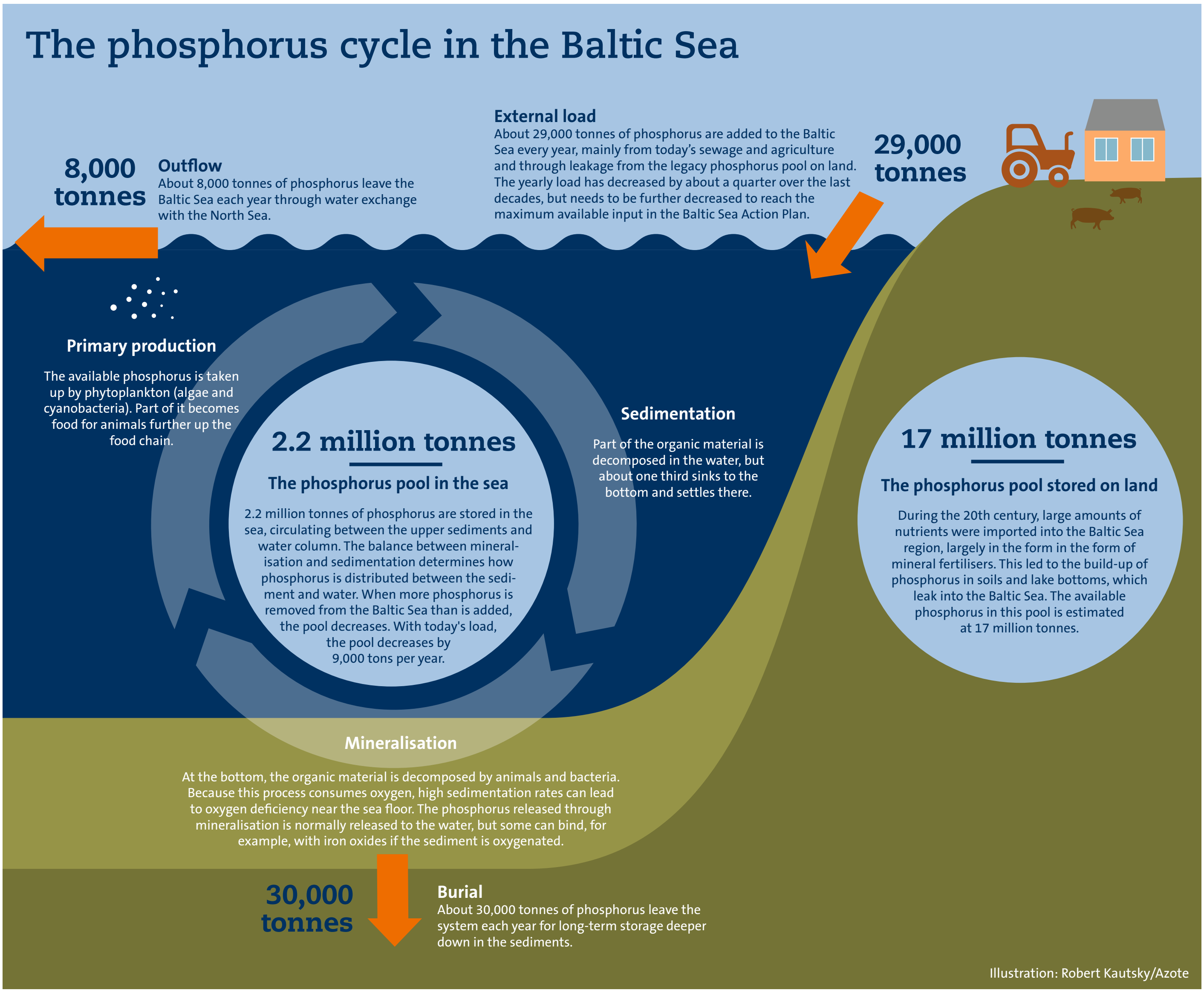
In some coastal areas of the Baltic Sea, improvements in the eutrophication status are now visible, for example, as increased water clarity. In large areas of the open sea, however, the situation is still very worrying and 96 percent of the Baltic Sea remains classified as eutrophic.

In recent decades, areas in the sea with insufficient oxygen to support life have grown to record levels. This situation has likely been exacerbated by higher water temperatures, weather factors, and water inflows from the North Sea. Strong inflows, such as the one in 2014, can, seemingly paradoxically, lead to a greater horizontal spread of oxygen-depleted areas. While the denser, more saline inflow water pushes the oxygen-free water out of deeper areas, it does not provide enough oxygen to counter the severe oxygen-depleted conditions. Many years of eutrophication have led to the accumulation of large amounts of hydrogen sulphide and organic matter along the seabed, which quickly consume any new oxygen.

Extensive cyanobacterial blooms observed in sea, especially the Baltic Proper, result from the high prevalence of nitrogen-fixing cyanobacteria. These microorganisms benefit from the high concentrations of available phosphorus, phosphate, relative to available nitrogen, essentially nitrate.



Through HELCOM BSAP, the Baltic Sea countries agreed to decrease the nitrogen loads to the Baltic Proper, the Gulf of Finland and the Kattegat, and the phosphorus loads to the Baltic Proper, the Gulf of Finland and the Gulf of Riga. The biggest challenge lies with the Baltic Proper. The phosphorus load to the Baltic Proper decreases continuously, but the nitrogen load has remained fairly constant for the last ten years.



Many years of high nutrient load have resulted in a storage pool of phosphorus in the Baltic Sea, circulating between the water and the upper sediments. The current inflows and outflows are small in relation to that pool, which means that it will take time to see the effects of load reductions.

Nutrients that enter the Baltic Sea remain there for a long time due to limited exchange of water the North Sea. For phosphorus, the residence time in the Baltic Sea is about 50 years. According to model calculations, there is now about 2.2 million tonnes of phosphorus stored in the water and the upper layer of the sediments. About 1.7 percent of the stored phosphorus is removed every year, through transport to the North Sea or burial in deep sediments. Meanwhile, the supply of new nutrients to the sea continues. Today, the pool of stored phosphorus in the Sea is slowly shrinking because more phosphorus is removed from the sea than enters it. However, this process takes a long time. At present, the net reduction in phosphorus is about 9,000 tonnes per year, only 0.4 percent of all phosphorus stored in the sea.

Sediment and water – one storage pool of phosphorus

The Baltic Sea is a shallow sea, which makes processes in the water and on the seabed strongly interconnected. Primary producers, such as algae and cyanobacteria, use inorganic nutrients, especially nitrogen and phosphorus, to fuel their growth and then, as the base of the food chain, supply animals in the sea with energy and nutrients bound to carbon – so-called organic matter. Some of the organic material decomposes in the water column and releases nutrients back to the water, but a significant part (20-30 percent) settles on the seabed.

Most of the organic material that settles on the seabed is decomposed, partly by benthic fauna, but mainly by bacteria. This process consumes oxygen. Extensive primary production – growth of algae and cyanobacteria – and the subsequent sedimentation can result in oxygen-depleted conditions along the sea floor. A small proportion of the organic material is more difficult to decompose or is buried before it can decompose. At present, material containing about 30,000 tonnes of phosphorus is buried every year, which means that it ceases to move between the sediment and water for the foreseeable future. The rate of burial depends on a number of factors, such as the sedimentation rate. During decomposition, some of the nitrogen is converted to nitrogen gas, through a process called denitrification, and escapes to the atmosphere. About half of the nitrogen in the decomposed material leaves the sediments in this way, but because denitrification mainly occurs in oxygen-poor environments, increased oxygen deficiency in the Baltic Proper has reinforced the process. Unlike algae, cyanobacteria can use nitrogen gas, which provides a growth advantage at the expense of other species.

The phosphorus released from sediments largely returns to the water in the form of phosphate. This circulation of nutrients between the water and the sediments takes place in the Baltic Sea all the time. On average, about a third of the available phosphorus is stored in water and about two thirds are stored in sediments, but

IF NOTHING HAD BEEN DONE

The Baltic Sea environment might appear to be a lost cause, but if nothing had been done to reduce the nutrient loads from land, the situation in the sea would be significantly worse than it is today. Studies show that if the external load had remained at the level of the 1980s, phosphorus levels in the Baltic Proper would be 40 percent higher than today, and the amount of phytoplankton would be 50 percent higher. This would have locked the Baltic Sea in a much worse position than today, considering that the balance in the sea is on the threshold of being restored.

there is large natural variability in the relative size of these pools.

In oxygenated sediments, phosphate is bound to certain forms of iron and manganese. When the environment becomes oxygen-depleted, however, that bond is broken and the phosphate is returned to the water. The oxygen conditions at the bottom thus affect the balance between how much phosphorus is present in the sediment and in the water. As oxygen-depleted areas in Baltic Proper have grown, a greater proportion of the total phosphorus storage has been transferred to the water. This process has been called a "vicious circle": the spread of oxygen-depleted bottoms leads to a larger proportion of the phosphate being released into the water, which further aggravates eutrophication. Once the oxygen along the seabed has been depleted, however, no further such displacement takes place. Hence, the image sometimes painted of oxygen-depleted bottoms "leaking" phosphorus to the water is not correct.

Internal load – a redistribution of phosphorus

The release of phosphorus from the sediments into the water is sometimes called the "internal load". However, there is disagreement on the use of the term. While some include all phosphorus released from the sediments in the internal load, others include only the net supply to the water, in other words, the difference between the amount released and the amount settled over a year. With the latter definition, there is currently no internal load in the Baltic Sea as a whole, because the sedimentation of phosphorus (260,000 tonnes / year) is greater than the return flow to the water (236,000 tonnes / year). Some people use an even narrower definition and include only phosphorus that reaches the upper water layers. Regardless of the definition used, the concept of internal load can be misleading. The internal load is not a new source of phosphorus to the sea, but a redistribution between the sediment and water of phosphorus accumulated in the system over many years of high nutrient loading from the surrounding land area.

Several different geoengineering ideas have been proposed to make a larger proportion of the phosphorus to remain in the sediments. One such idea is to pump oxygen down to the oxygen-depleted seabed to enable phosphorus to bind to iron and manganese. However, it is very uncertain whether iron and manganese are available in the sediments in such concentrations to have an effect, and what the long-term consequences would be of such an intervention for the nutrient cycle and for the ecosystem.

Another method that has been used with some success in lakes and also in certain coastal areas is the addition of a substance such as aluminium to bind phosphorus to the upper sediments, even in an oxygen-free environment. This method does prevent some phosphorus from being released to the water and contribute to further eutrophication. However, the fact that phosphorus is bound in sediments does not address oxygen-deficiency; new organic matter continues to settle, decompose, and consume oxygen. In order for the treatment to impact primary production and the oxygen conditions on a larger scale, repeated treatments and large amounts of aluminium, which can take a long time to apply to sediments, may be required. As a result, this method is not a "quick fix" for the Baltic Sea. There is also great uncertainty regarding how a large-scale supply would affect marine life and the extraction of aluminium is a resource-intensive process.

What can we expect in the future?

Today, the external nutrient loads to the Baltic Sea are less than the quantities leaving the system through exchange with the North Sea, burial in sediments, and denitrification (nitrogen only). This means that the concentrations of nitrogen and phosphorus in the sea – meaning the sediment and water together – are decreasing. However, the size of these flows in relation to the quantities stored in the sea mean the process takes a long time. Also, there is large natural variation in the location of nutrients in the system (water versus sediment) and the effects on primary production and sedimentation. The concentration of phosphorus in surface waters has not decreased in recent decades. Variations in temperatures, winds, and inflows from the North Sea, among other things, can conceal long-term improvements.

In the long term, however, the marine environment could improve even with the current nutrient loads. With further load reductions, the improvements could be more apparent more quickly. In a couple of decades, the south-western parts of the Baltic Sea may be unaffected by eutrophication if the load continues to decrease. In the Baltic Proper, the process will take longer, but significant improvements could be visible within half a century, according to computer modelling.

Nutrient budgets and future loads and responses in the Baltic Sea were estimated using the modelling tool BALTSEM (Baltic Sea Long-Term Large Scale Eutrophication Model). BALTSEM was developed by researchers at Stockholm University in the 1990s and has been an important tool in quantifying nutrient load reductions in the HELCOM BSAP.

TO BRIDGE THE GAP BETWEEN SCIENCE AND POLICY

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Scientists, policy and communication experts work together to bridge the gap between science and policy.

We compile, analyse and synthesise scientific research on Baltic Sea related issues and communicate it at the right moment to the right actor in society.

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