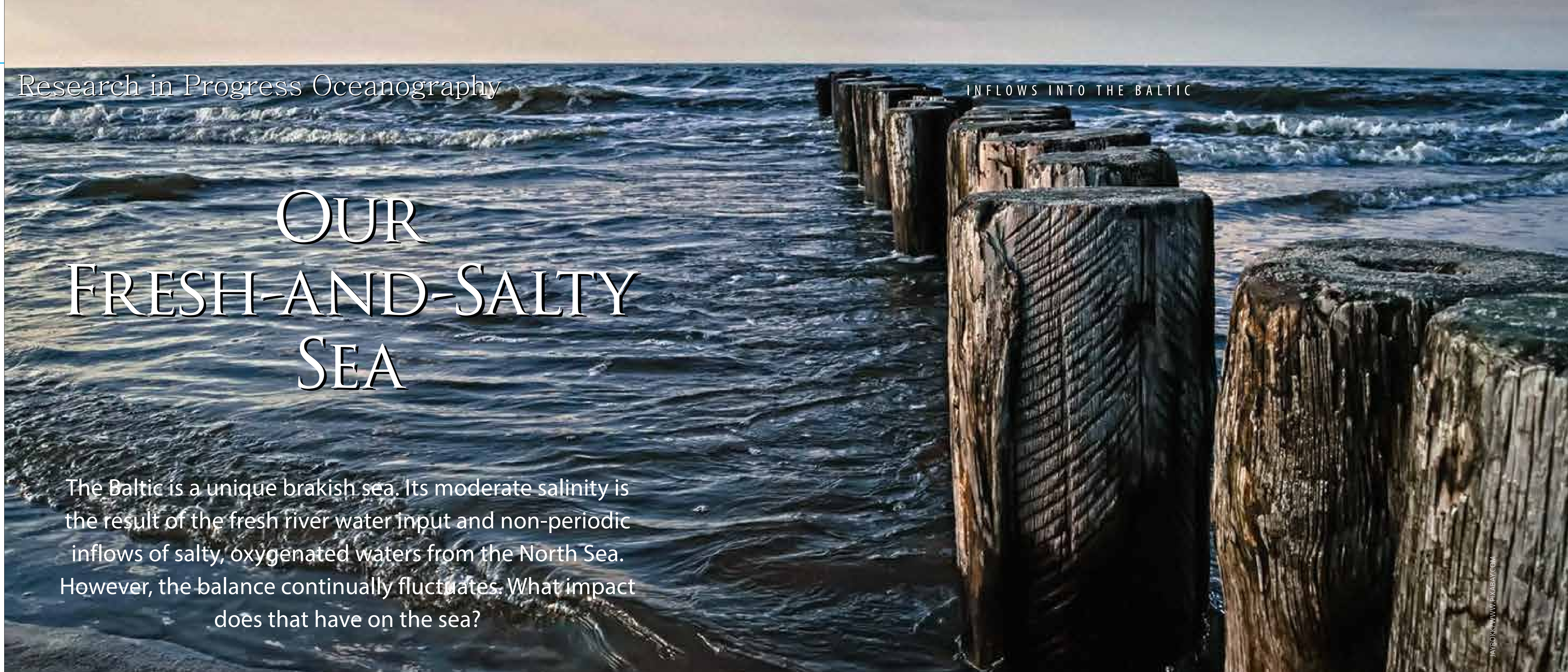

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Our Fresh-and-Salty Sea

The Baltic is a unique brakish sea. Its moderate salinity is the result of the fresh river water input and non-periodic inflows of salty, oxygenated waters from the North Sea. However, the balance continually fluctuates. What impact does that have on the sea?

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The average salinity of the surface waters in the Baltic is five times lower than in the ocean, at 7.5 (previously salinity was measured in PSUs, whereas currently it is standardly stated as a dimensionless value). However, the bottom layer is saltier, and its salt content varies significantly depending on the distance from the Danish Straits. Spatial variations in the physical properties of water in the Baltic Sea increase with depth. While the surface salinity in the Southern Baltic is relatively constant, the difference in practical salinity of the bottom layer in the Bornholm Basin and the Gdańsk Deep is as much as 5. Such large differences result from the complicated structure of the seabed, which significantly limit the exchange of water between individual basins.

The Baltic's open border at the Danish Straits creates a path for the life-giving waters from the North Sea. These waters flow through Skagerrak, Kattegat, then through the Little Belt and Great Belt, and in some cases even through the Sund. They are very saline and oxygenated. Oxygen and salt are essential for the proper development of marine ecosystems. In addition, oxygen is essential for refreshing the anaerobic zones of the Baltic Sea, where hydrogen sulphide can be released. The route through which these incoming salty waters flow also includes the Polish zone of the Baltic. The transit route of these waters passes from the Danish Straits through the Arkona Basin and Bornholm Gate to the Bornholm Basin. Thus, after crossing the Słupsk Sill, the heavily salted waters flow through the Słupsk Furrow and reach the Gdańsk Deep or the Gotland Deep. The mixing of waters brings the salt from the deepest areas into the surface layer, from where it reaches the furthest corners of the Baltic.

The codfish provides a good example of the impact of salinity on sea ecology. The female cod spawn in the bottom waters where anaerobic conditions prevail, adversely affecting the further development of the eggs. Only periodically, due to an inflow of dense and well oxygenated waters from the Atlantic, do these conditions change. Colloquially speaking, such an inflow is to the Baltic Sea what a powerful gulp of air is to a suffocating man.

Water dynamics

The PAS Institute of Oceanology has been researching the dynamics of the Southern Baltic waters for years. The main research platform is the *RV Oceania*, from which the dynamic processes such as sea currents, eddies and internal waves are measured. Four times a year research voyages are carried out along the main route, along which the inflow waters spread. In addition, anchored measuring systems are set up, in which autonomous devices collect a series of hydrographic data. In 2017, a measuring buoy was placed in the area of the Słupsk Sill, which collects meteorological and oceanographic data and transmits them via satellite. Thanks to the systematic, comprehensive hydrographic measurements conducted by the PAS Institute of Oceanology, it was possible to observe and measure the last three barotropic inflows. They were observed in 1993, 2003 and 2014. Previously (1960–1980) such inflows took place every three or four years, but since

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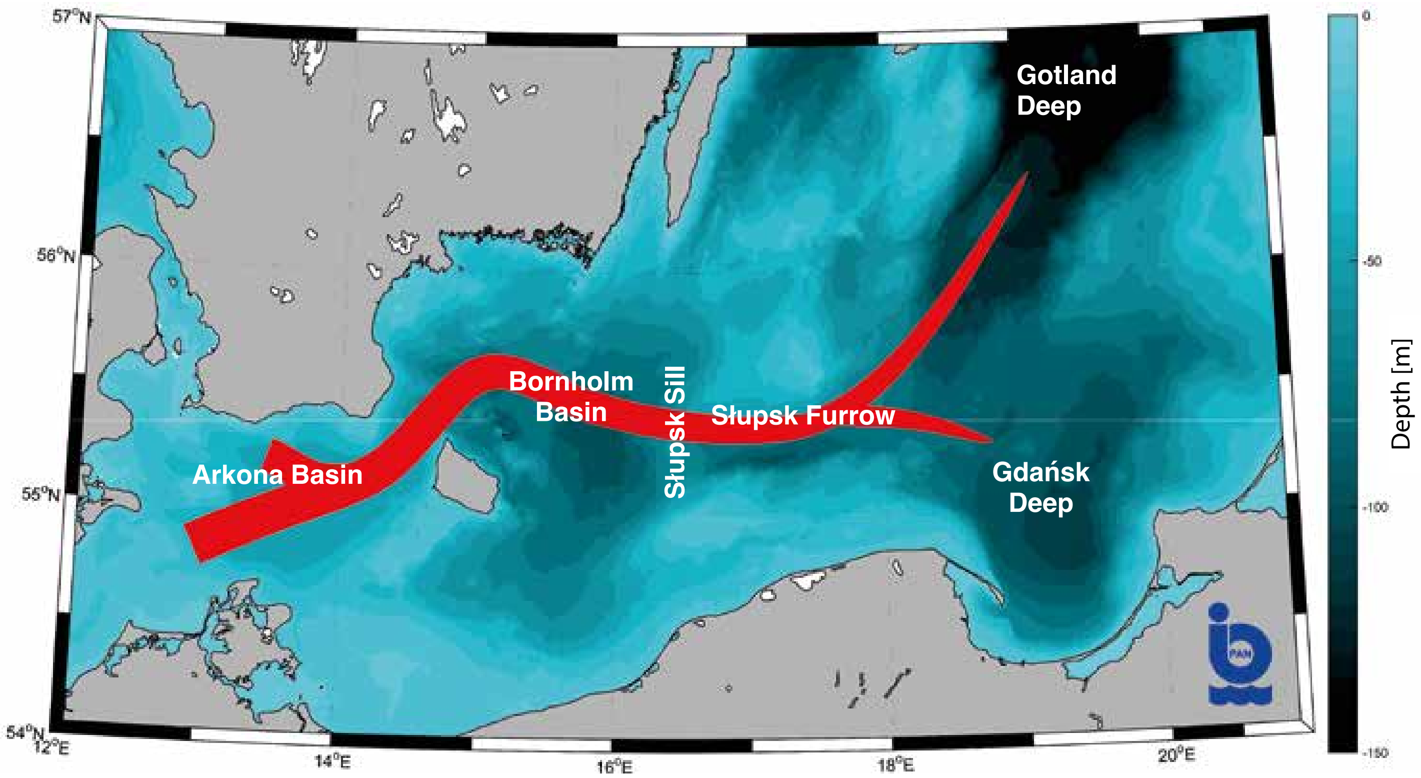
The problem of WWII weaponry

Another feature of the North Sea inflows into the Baltic is their impact on the spread of toxic compounds released from chemical munitions, which were sunk into the Baltic after World War II. Chemical warfare agents (CWA) were sunk together with conventional ammunition (including unarmed bombs and artillery missiles) in the same areas. Therefore, there is a significant risk of an explosion and the spread of CWA. The main areas where the ammunition was dumped are the Baltic Proper areas: the Bornholm Basin, the Gdańsk Deep and the Gotland Deep, which are the basins lying on the main transit axis of the inflows. Bottom measurements of sea currents during stagnation between inflows indicate that their speed is sufficient for the resuspension of sediments, which can contribute to the transport of contaminated sediments. Therefore, a numerical model was used in order to estimate the size of the area contaminated due to CWA leakage. Assuming the initial concentration of CWA to be 10 µm cm^{-3} and an accepted limit of contamination at 0.1 µm cm^{-3}, the area contaminated within a period of three days is about 4 km^2. However, the speeds at which inflow waters travel are twice as fast as the estimates adopted in the model, reaching 50 cm s^{-1}, and therefore there is a real risk that toxic chemicals will be transported even to the deepest areas of the Baltic Sea.



The main axis of saltwater inflows from the North Sea to the Baltic Sea

1993 their frequency has decreased. Currently, dense waters from the North Sea appear in the Baltic once every ten years. In the 16-years of measurements by the PAS Institute of Oceanology, the 2014 inflow was one of the strongest recorded thus far. The high density of the inflowing waters means that their advection takes place in the bottom layer, and as a result of diffusion the impact of their mixing is observed in the entire water column.

The cause of large-scale barotropic inflows should be sought in a difference in water levels between the Baltic and the North Sea. A significant difference in levels can only arise as a result of a baric system that causes a particular type of atmospheric circulation. The intensity of the favorable wind system and how long it lasts will determine the scale of the inflow, and only large-scale inflows are able to refresh the Baltic ecosystem. During the latest such inflow, the incoming cold and dense waters pushed the oxygen-starved waters in the Bornholm Deep up into the intermediate layer. Thus lifted, these waters were then able to flow over the Słupsk Sill. The inflow waters, filling the basin of the Bornholm Deep, were then able to follow behind the oxygen-poor layer and thereby to penetrate into the deeper areas of the Słupsk Furrow. As a result, just two months after the process began, increased salinity levels were observed in the Gdańsk Deep. Due to the episodic nature of such inflows, the newly-appearing oxygen is very quickly used in the decay of organic matter. It is estimated that waters originating from the North Sea remain in the Baltic for around 30 years until being fully exchanged . However, significantly more quickly than that, their salinity and dissolved oxygen concentrations return to average values for the individual basins of the Baltic Proper. Salinity levels in this area take from 2.5 to 3 years to return to average values, whereas small inflows occurring during this time do not have any significant influence on that duration. The most recent inflow, from 2014, was characterized not only by high salinity but also by high oxygen content. However, anaerobic conditions returned to the Bornholm Deep 9 months after the inflow began, and to the Słupsk Furrow after 10 months.

The inflow of dense waters changes the hydrodynamic conditions in the bottom layer and, as a result of vertical mixing, through the entire water column. This has an impact on the speed by which the signal of seasonal temperature variations is propagated through the water column. The surface layer speed for different basins is similar, with depth differences appearing between individual basins.. The temperature signal, resulting from seasonal changes in the amount of solar energy supplied to the surface of the sea and the conditions for energy exchange between the sea and the atmosphere, is propagated the fastest into the water column in the Gdańsk Deep, where it takes 37 days at a depth of 50 m. In the Bornholm Basin, the speed of this signal is 71 days.

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Further reading:

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