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Biological invasions into German waters: an evaluation of the importance of different human-mediated vectors for nonindigenous macrozoobenthic species

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Abstract
To date, 35 nonindigenous macrozoobenthic species have been introduced to the inland waterways of Germany, 26 to the German North Sea and 14 to the Baltic Sea coast. For inland waters and the Baltic Sea, the direct introduction of macroinvertebrates by ocean shipping is insignificant, shipping canals built during the last centuries, being the most important gateway. In contrast, on the German North Sea coast about 60% of the nonindigenous species were introduced by ocean shipping. Prior to the introduction of antifouling paints containing the effective biocide tributyltin (TBT) in 1970, and their subsequent common usage, most of these invasive species came from fouled hulls of overseas trade ships. With the introduction of TBT the transfer of potential invaders via ship fouling was reduced considerably. Today, ballast water and hull fouling are of equivalent importance as vectors. On the German North Sea coast most of the introduced macroinvertebrates established permanent populations in estuaries. The combination of brackish water with its unsaturated ecological niches and intense intercontinental shipping traffic creates the highest infection rate for coastal areas. It is likely that climate change will lead to significant modifications of species communities in Northern European coastal waters in the near future.