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Review

The Baltic Sea under Anthropopressure—The Sea of Paradoxes

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Abstract: The Baltic Sea is a unique ecosystem that is especially sensitive to anthropogenic pressure. We analysed human pressure in this sea, which may be considered as paradoxes. One of these, is paradox of "marine" pollution. The Baltic Sea is almost totally surrounded by land and therefore sources of marine pollution are located mainly on the land. Another paradox is connected with shipping traffic intensity and maritime accidents. The Baltic Sea is characterised by the large shipping traffic, but the last decades' data show only more than 100, usually insignificant and minor, accidents and incidents at the Baltic Sea every year. Although the Baltic Sea is characterised by a relatively low native species number compared to most marine systems, it is home to alien species. Moreover, despite the common opinion that a sea is a source of living marine resources, available riches in the Baltic Sea under anthropopressure are limited and the sea does not give expected benefits—it is the next paradox. The fact that the Baltic Sea is warming rapidly due to climate change and more suitable for bathing when the weather is favourable, massive algae growth often prevents it. Therefore, strong human impact on the Baltic Sea should be limited and sustainable use of this sea should be prioritised.

Keywords: marine pollution; maritime accident; marine species; marine resource; sea bathing

Citation: Dobrzycka-Krahel, A.; Bogalecka, M. The Baltic Sea under Anthropopressure—The Sea of Paradoxes. *Water* **2022**, *14*, 3772. https://doi.org/10.3390/w14223772

Academic Editor: Laura Bulgariu

Received: 2 November 2022
Accepted: 18 November 2022
Published: 20 November 2022

1. Introduction

The Baltic Sea is the largest brackish sea in the world, where salinity is lower than seawater in other typical seas, but too high to be a typical freshwater ecosystem, having the highest salinity off the coasts of Germany, Denmark, and Sweden, from where salinity then decreases moving east and north. In the inner reaches of the Bay of Bothnia, the water has almost no salt whatsoever [1]. It is a unique ecosystem. The sea is isolated, inland, semi-enclosed, shallow, and requires 25–40 years to exchange its whole water [1,2]. The enclosed location of the Baltic Sea and its brackish water conditions create a unique ecosystem that make it especially sensitive to the intensification of human uses and it is regarded as one of the most polluted seas in the world [3,4]. This sea, under human pressure, has become the sea of paradoxes.

The goal of this study is to show new insight into the problems of anthropopressure of the Baltic Sea and to analyse the data in order to discuss the relationships between anthropopressure of this sea and different controversial phenomena occurring here, known as paradoxes—logically self-contradictory statements or statements that run contrary to one's expectation.

2. Approach

Based on the previous literature, we point out the anthropopressure of the Baltic Sea. We focus on different aspects of anthropopressure in the Baltic Sea, specially its south, to find different phenomena occurring in this sea known as paradoxes—logically self-contradictory statements or statements that run contrary to one's expectation. Maps illustrating problems are prepared using freely accessible sources: the HELCOM Map and Data Service [5] and the Marine Traffic [6].

The information concerning alien species, and verification of their records in the Baltic Sea, is also obtained from the AquaNIS database [7].

3. The Paradox of Marine Pollution

The current and historical human activity in the Baltic Sea caused sea pollution. However, marine pollutions are not mainly concerned with shipping, fisheries, exploitation of sea resources, offshore installations, and other activity within the sea area, but have sources located mainly on the land. More than 80% of marine pollution comes from land-based activities. In this context, it is important to ensure the human right to safe, sufficient, and physically available environmental resources, including benefits derived from marine sources. Acquiring the right habits is key to proper behaviour in this regard. Some evidence pointed out that habit is an important predictor of intention and behaviour, and showed that habits are becoming more and more important for the intention of frequent repeated behaviour [8].

The Baltic Sea is almost totally surrounded by land. Therefore, it is more endangered by pollution from the land than from marine sources. Moreover, the southern part of the Baltic Sea Region is more densely populated, with predominant agriculture areas [1,2], which is a cause of this region's greater pollution.

The sources of marine pollution are industrial, agricultural, and municipal waste inputs directly into the sea or through rivers. The increase of nutrients (phosphorus and nitrogen compounds) caused eutrophication and consequently, oxygen depletion in the bottom of coastal waters as well as in the depths of the open sea [9]. Nutrients present in the wastewater behave like fertilisers. Their excessive amount in the marine environment disturbs the ecological balance. The ecosystem is being damaged by eutrophication, making it difficult to use marine resources and impacting recreational activities. The solution of this problem is closely related to the connection of sustainable development [10]. Although the objective of wastewater plants is to minimise the concentration of biogenic compounds in wastewater [11], commonly, the municipal wastewater treatment plant commonly receives orthophosphate from sewage in the concentration range 2–14 g/m^3 and ammonium in the concentration of 20–40 g/m^3 [12]. However, the greatest amount of nutrients in the Baltic Sea come from agriculture and main rivers run-off. There are seven big rivers in the Baltic Sea catchment area: Neva, Vistula, Oder, Nemunas, Dauguva, Kemijoki, Gota, which contribute approximately 90% of the total input of phosphorus and 80% of nitrogen [13]. Most of these rivers flow into the southern part of the Baltic Sea, therefore the concentration of nutrients is also higher in the south (Figure 1).

Hazardous substances and micro litter are also part of municipal and industrial releases that are probably the predominant anthropogenic sources in riverine load and land runoff [13]. Despite plastics removal efficiency in wastewater treatment plants being high, they are the most common type of marine debris, constituting 60–80% of marine debris and more than 90% of all floating particles [14]. They are the most common type of marine debris because they are small enough to pass through the wastewater treatment processes and get into the marine environment [15,16].

Ecotoxicological studies of Baltic fish provided in 1987–2015 pointed to the fact that the stability of plastic concentrations in their digestive tracts was observed despite increasing microplastic contamination of the Baltic Sea [17]. It is due to lack of standardised tests methods, resulting in variability in bioassay results [18]. The microplastics are transferred through the food chain and the marine trophic web has a mechanism similar to other hazardous chemicals causing seafood contamination [19].

The assessment of microplastics pollution and possibility of their degradation are the subject of many studies [20–27]. It is important to understand the kinetics of degradation, disintegration, and biodegradation of polymers in order to be able to assess the probability of their transformation into microplastics. These tests are performed in laboratory conditions as well as in the natural environment. The waters of the Baltic Sea are often used as a natural laboratory to test the biodegradability of newly obtained polymeric materials.

However, as shown by numerous research results, this process is slower than in the case of degradation of these materials under other conditions, e.g., in composting plants [28] or in fluids simulating body fluids [29]. Composites containing natural fibres are susceptible to degradation in natural environments, and as mentioned, the degradation in compost occurs more rapidly than in seawater environments because of the presence of fungi in the compost, which contribute to the biodegradation of the tested material [30]. On the other hand, biodegradation of polycaprolactone takes place faster in a natural seawater environment (6 weeks) than in a pond (98 weeks) due to the different biotic and abiotic conditions [31].

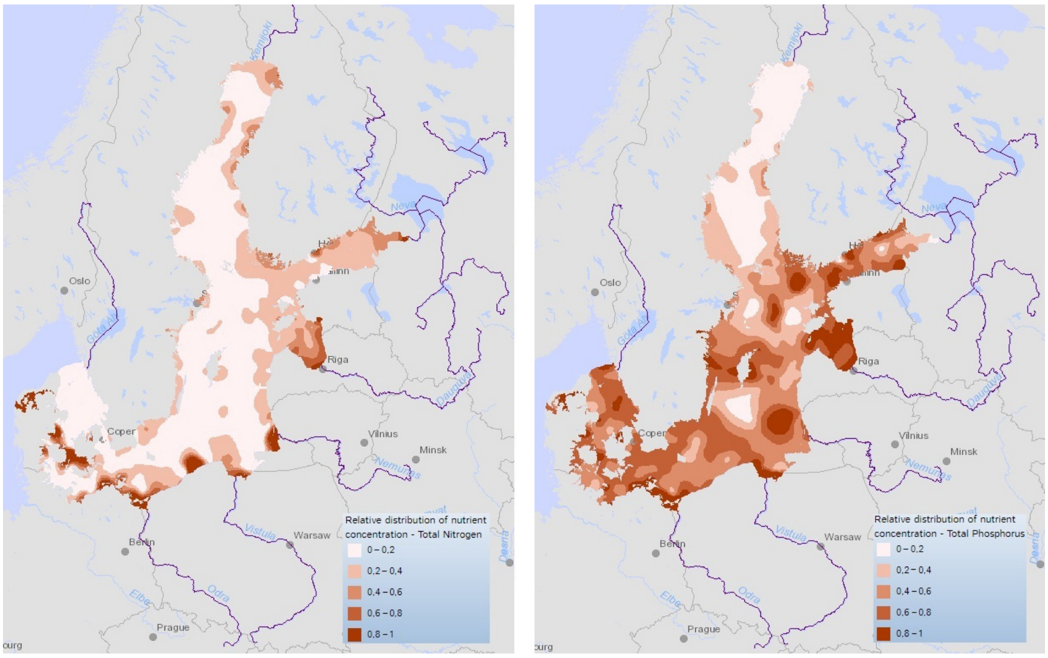

Figure 1. Distribution of nutrient concentration (μg/dm^3) in the surface water of the Baltic Sea, based on HELCOM Map and Data Service [5].

Sheltered port waters favour the accumulation of bottom sediment fractions in which pollutants accumulate [32]. The contaminants can also travel through the air for long distances from cities and industries, contribute to the Baltic Sea contamination, and affect seawater quality [33]. These substances do not occur naturally in the ecosystem or occur at the concentration levels exceeding natural ones. Chemicals and synthetic materials, including heavy metals, pesticides, pharmaceuticals, and radionuclides, are also very important pollutants of the Baltic Sea waters [34]. These kinds of pollutants depend on the industrial sector specific to each country of the Baltic Sea Region. In general, the forestry industry and paper, pulp, or board production is specific to the northern part of the region. Thus, the chemicals used for bleaching or preservation of timber comes from the north. In the southern part of the Baltic Sea Region, many industrial sectors (e.g., petrochemical, chemical, energy, metallurgic, textile, food) are specific with a long list of chemicals as pollutants. Additionally, the agriculture sector is important in this area, therefore, it is responsible for nutrients flow [1,34].

The chlorinated organic compounds comprise a large group of pollutants in the Baltic Sea. They are usually toxic, lipophilic, persistent, and also teratogenic or mutagenic as a result of long exposure. As they are insoluble in the water, they sediment and accumulate on the seabed. The chlorinated organic compounds include chemicals such as pesticides, dioxins, and polychlorinated biphenyls (PCBs).

Pesticides are toxic substances used in agriculture and horticulture to fight weeds and pests [35]. Unfortunately, they are also toxic to human health and biota. All countries of the Baltic Sea Region are responsible for introducing pesticides into the environment [36].

The most known pesticide—dichlorodiphenyltrichloroethane—DDT was commonly used during World War II and years after [37]. On the one hand, DDT was used to stop the spread of the insect-borne diseases such as typhus and malaria. On the other hand, in the 1960s [38], DDT was recognised as a substance that easy accumulates in the fatty tissues of organism, causing serious problems in neural systems functions and disturbing bird reproduction by thinning of eggshells [39]. The derivative emission of pesticide residues in soil and water is currently being observed. Furthermore, the concentration level of these substances is expected to increase with climate change [40,41].

Dioxins are not the deliberate products of industry, but they are by-products of some industrial processes and most combustion processes: iron and sinter plants, pulp bleaching where chlorine is used (still in Russia), and further from recycled paper, incinerators of municipal and clinical waste or nonindustrial sources: domestic heating (wood combustion) [42]. They are subjected to long-range emission through the atmosphere and accumulate in the fatty tissue of organisms and consequently in food chains [36,43].

PCBs have been commonly used on a large scale since the 1930s, for example, in sealants in houses and transformers before they were banned in Sweden in 1970 and subsequently in other countries of the Baltic Sea Region [36]. They enter the Baltic Sea mainly through the air and their concentrations are uniform across the Baltic Sea sediment [44].

Dioxins and PCBs are fat-soluble, therefore are found in fatty foods such as fatty fish: herring and wild-caught salmon from polluted areas. The concentration of these substances in Baltic fish decreased over the last several years in relation to the newly established tolerable weekly intake dose, and this decrease is not enough to make Baltic fish safe for frequent consumers [45].

Despite a general decreasing trend of radionuclides concentrations, the Baltic Sea still is one of the most polluted sea areas in regard to anthropogenic radioactive contamination. The source of radioactive fallout is not only the Chernobyl accident (April 1986) but radionuclides transportation towards the upper atmosphere from nuclear weapons tests in 1950–1980, routine operations of nuclear facilities, and discharges from reprocessing plants in the Baltic Sea Region [46–48]. Cesium-137 is the greatest contributor of artificial radionuclides to the Baltic Sea that sediment on the seabed. According to the last published HELCOM report on radionuclides, it was expected that radionuclides concentrations below the threshold value in water and biota may be achieved in the entire Baltic Sea by 2020 [49].

Heavy metals and their compounds are toxic elements released by effluents from metallurgic, chemical, and petrochemical industries [50]. Some metals form the stable complexes with biomolecules deposit into sea water and then their presence, even in small amounts, can be harmful to animals and plants as well as affect human health as they may travel up the food chain. Lead, mercury, and cadmium are indicators on metal pollution in the Baltic Sea [48]. The anthropogenic loads of these metals to the Baltic Sea were approximately 5–7 times higher than the background loads before 1990s [51]. The Gulf of Finland is the area most affected by metals [52,53]. Currently, almost all heavy metal species have declined to the safe levels for human health and the environment [52,54]. Reduction of heavy metals inputs is a result of abatement measures and industrial restructuring, especially in the eastern Baltic Sea Region [52,55,56]. For example, lead concentration has significantly decreased due to cessation of the use of lead tetraethyl in gasoline and the reduction in air emissions from car traffic in the region. On the other hand, the significantly lower reduction rate in mercury deposition is probably caused by much larger long-distance transport, making it considered a global contaminant [34].

Despite the global Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its Protocol thereto (Damping Convention) [57], as well as the International Convention for the Prevention of Pollution from Ships (MARPOL) [58] and its Annex V established by IMO, in force in the Baltic Sea, whose purpose is a prohibition on the dumping of any waste or other matter at sea, the Baltic Sea is contaminated with different garbage [59]. Thanks to these conventions, the amount of waste has been reduced quite well, while their main stream comes from the mainland.

Marine litter consists mainly of plastics as well as metals, glass, ceramics, paper and cardboard, rubber, or textile. These items may affect human health and activities, contaminate marine fauna and flora, and cause aesthetic nuisance or decrease a navigational safety as well. Litter along beaches and other tourist regions is attributed to drinking and eating (Figure 2). Litter that enters the seawater can be transported long distances within the water column and finally often sediment on the bottom [60]. Plastics debris usually contain additives (e.g., phthalates bisphenols and brominated compounds) to improve plastic properties, but they can adversely affect humans and animals, causing cancer or damaging genetic material. Moreover, plastics can absorb pesticides and other toxins that are released into the seawater. The percentage of samples containing microplastics contain up to 67% for blue mussels and up to 34% for different fish species [61].

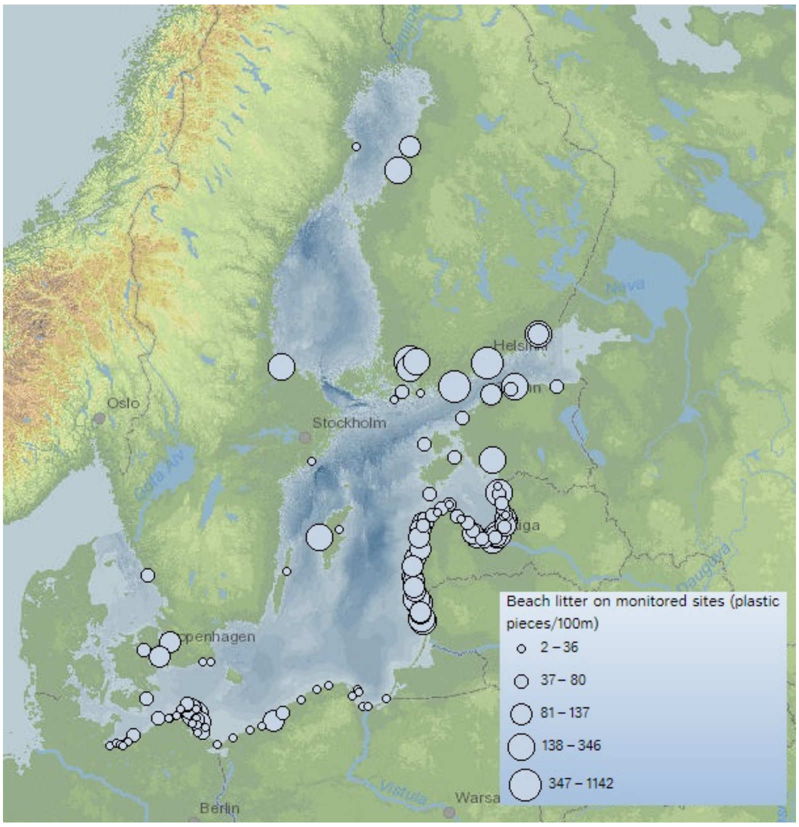

Figure 2. Marine litter monitored on beaches of the Baltic Sea, based on HELCOM Map and Data Service, 2022 [5].

Marine litter on beaches of the Baltic Sea is more frequent in places characterised by higher human pressure (Figure 2), mainly on attractive, sandy beaches of the southern Baltic coasts.

Recent research on Baltic Sea pollution has focused on the inflows of pharmaceutical residues. The problem is not new but has not been investigated before. The main sources of pharmaceuticals in the Baltic Sea are active substances consumed by humans and animals and their excretion in urine and faeces [62]. Thus, the main pathway of pharmaceuticals into the marine environment is through the discharges of effluents from the municipal wastewater treatment plants [63]. The agents of the metabolic, gastrointestinal, and central nervous system are the most frequently detected pharmaceuticals detected in the Baltic Sea waters [64]. A pain killer, diclofenac (usually used in the form of a gel) very often exceeds the safe concentrations in the surface waters [63,65,66]. The largest number of various pharmaceuticals and their highest concentrations are found in blue mussels [64,67].

The Baltic Marine Environment Protection Commission (Helsinki Commission—HELCOM) established the point sources, so-called hot spots, around the Baltic Sea as the most polluted land sources. The first list of hot spots was established in 1992 and contained 162 locations at the time, mainly located within the Baltic Sea catchment area. Next, the purpose of HELCOM activities was to delete those hot spots and minimise their number. Now, according to the recently published hot spots list [68], only 40 hot spots are active and six of them come from agricultural areas, 14 from municipal facilities, 17 from industrial plants, and three are sensitive coastal areas, such as wetlands and lagoons. The highest numbers of the Baltic Sea hot spots are located in the southern part of the Baltic Sea Region (Figure 3).

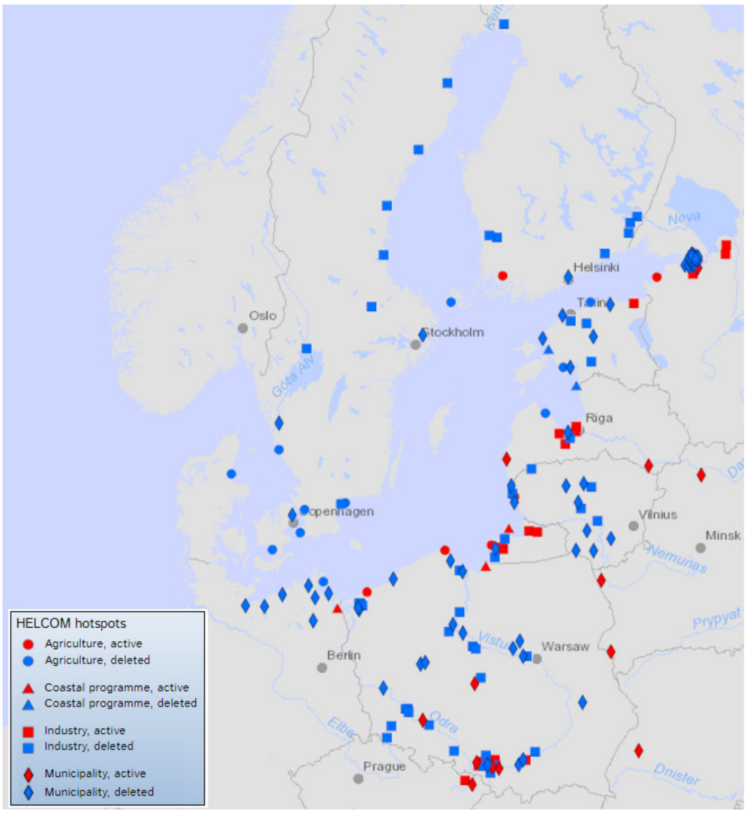

Figure 3. The Baltic Sea hot spots, based on HELCOM Map and Data Service [5].

Although the load of hazardous substances has been reduced or eliminated in the last three to four decades, their concentration in seawater is still significant [34]. The reason for this is the persistent nature of most pollutants that are not easily degraded and can remain in the ecosystem for a long time [34]. Moreover, some pollutants can accumulate up to high levels in marine food, which represents a health risk for organisms of the marine trophic web as well as for land animals and people [69].

Despite the fact that nearly 80 years have passed since the end of World War II, its consequences still affect the Baltic Sea. The most serious problem is the dumped munition as a result of demilitarisation carried out during the last stage of the war. Additionally, Soviet and East Germany armies dumped munition there long after World War II [70]. There are 40 to 60 thousand tonnes of aerial bombs, grenades, artillery ammunition, barrels with chemical warfare agents in the sea floor of the Baltic Sea [71]. The most dangerous are chemical warfare agents, which account for approximately 15% (by mass) of all dumped materials. Their type and effects on human health (blood, chocking, blistering, or nerve agents) depend on their chemical properties. The most common chemical warfare agents, sunk in the Baltic Sea, are yperite (mustard gas), adamsite, phosgene, cyclone B, Clark I, and Clark II [70,71]. The east of Bornholm Depth, the south-east of Gotland Depth, and the Little Belt are the main munition dumpsites (Figure 4) [70–73]. The first cases of appearance and recovery of munition were recorded in the 1950s, mainly on Polish, Danish, German, and Swedish beaches or caught by fishermen [71–73]. Currently, dumped munition poses a threat to people involved in offshore construction activities within the dumping zones [71]. The Baltic Sea waters also contain shipwrecks but not only from World War II. It is estimated that at least 100 of them are dangerous as fuel and cargo still remain in their tanks [74].

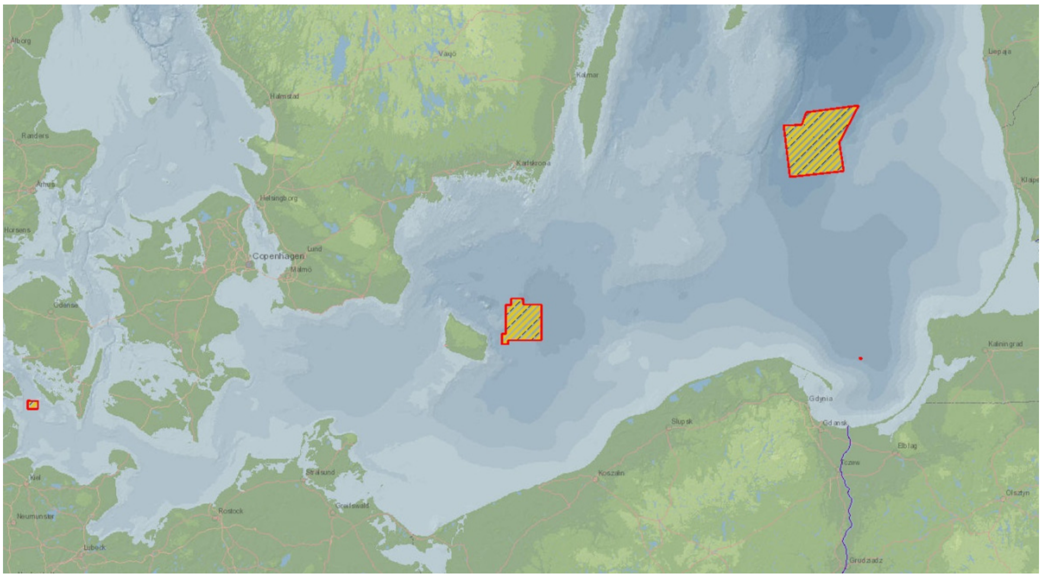

Figure 4. Main munition dumpsites in the Baltic Sea, based on HELCOM Map and Data Service [5].

4. The Paradox of Traffic Intensity and Maritime Accidents

Despite the Baltic Sea's relatively small size on a global scale (it is about 1/900 part of world marine ecosystems), 15% of worldwide shipping is concentrated within the Baltic Sea (Figure 5) [75].

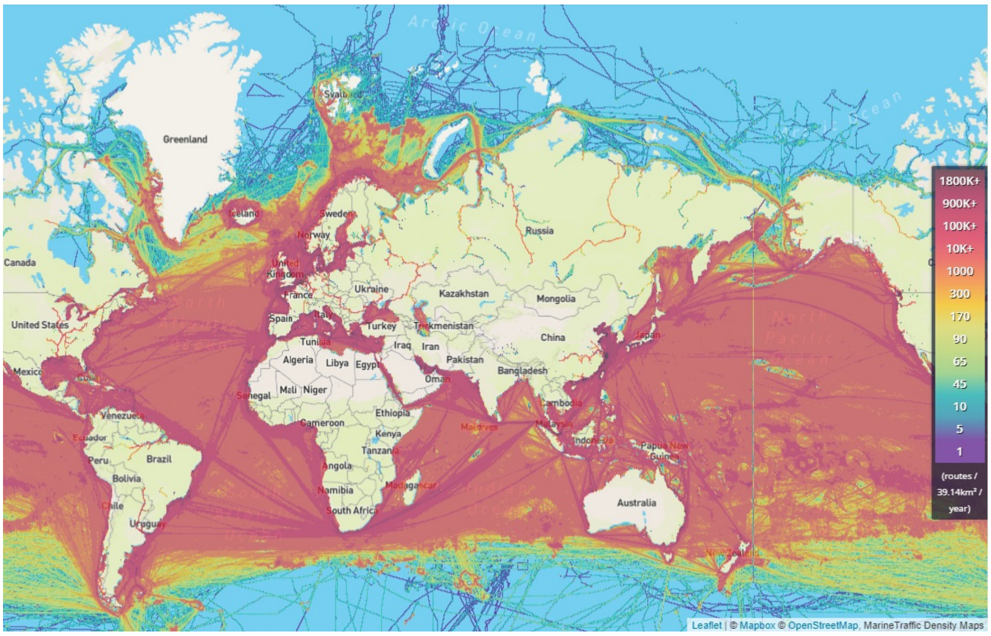

Figure 5. Worldwide marine traffic in 2021, generated from: Marine Traffic [6].

According to the Baltic Port Organization (BPO), there are 87 ports located in the Baltic Sea Region that are included in the Trans-European Transport Network (TEN-T). Out of these, 65 are classified as comprehensive ports and 26 are Member ports of the BPO.

There are usually about 80 thousand ships in the world sea waters whereas there are approximately two thousand ships in the Baltic Sea waters at any given moment (Figure 6). The HELCOM analysis performed in 2020 showed that cargo ships predominated the Baltic Sea and represented 46.6% of the total fleet, while tankers account for 23%, passenger ships 4.4%, and the others were container ships, ro-ro cargo ships, and fishing vessels. In 2020, the ten largest ports in the Baltic Sea handled almost 450 million tons of cargo, which is a 5.6% decrease compared to 2019 [76].

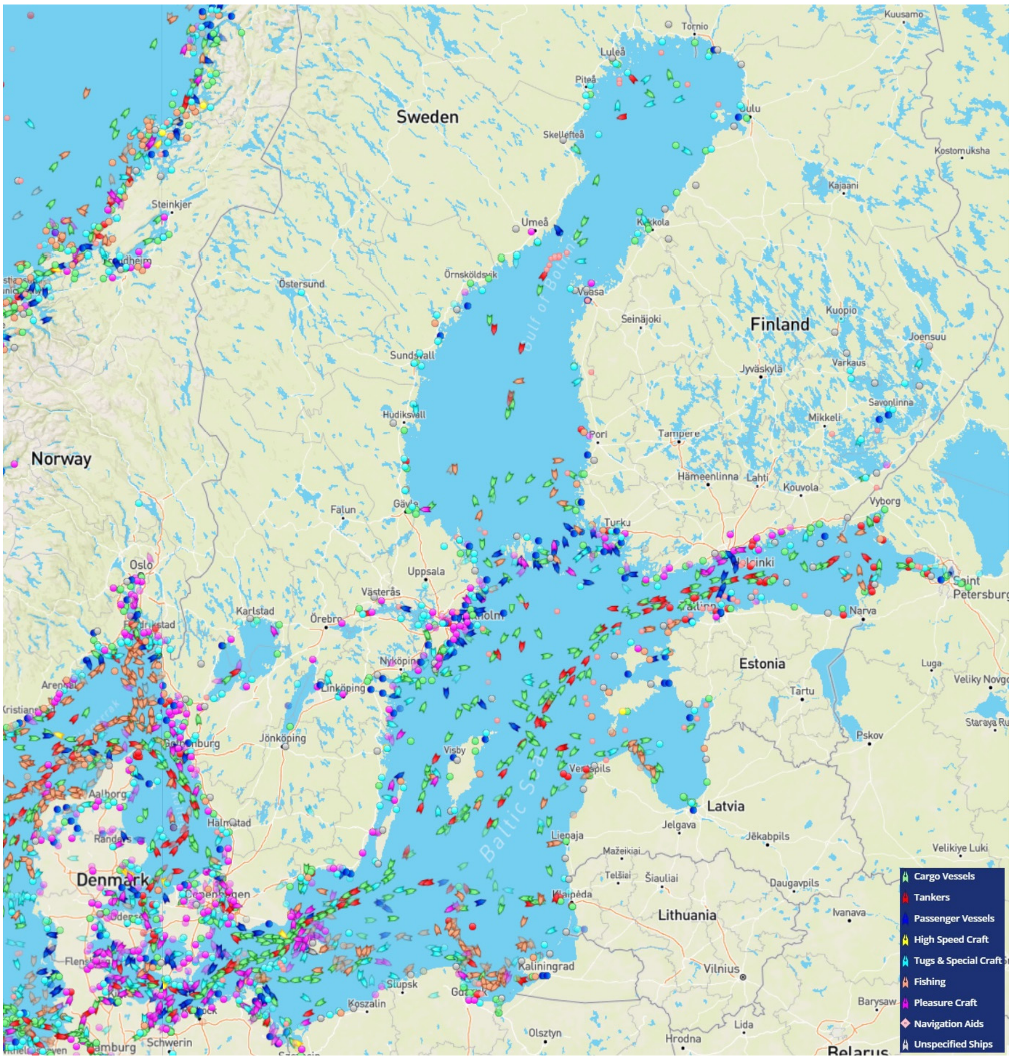

Figure 6. Number of moving ships on the Baltic Sea waters, generated from: Marine Traffic [6] (27 April 2022, 13:16).

Ships carrying various cargoes, if accidentally released, may affect the ecosystem. Oil is a common pollutant as it is transported both as cargo and as a fuel. Taking into account the huge traffic within the Baltic Sea, at least one major accident with the cargo or fuel release is expected per 3–4 years. Fortunately, data from the last decades show more than 100 incidents and accidents in the Baltic Sea every year, and usually no more than 10% of them result in small oil spillage [77–85]. The first time the total number of reported accidents in the Baltic Sea exceeded 200 was in 2018 (Figure 7).

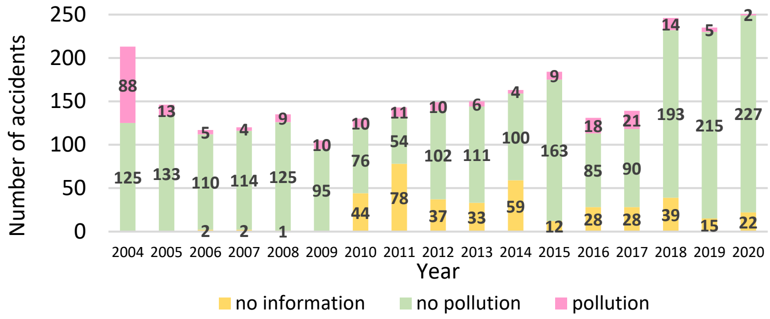

Figure 7. Number of reported accidents in the Baltic Sea in years 2004–2020 [82–85].

The biggest disaster during the last half-century within the Baltic Sea took place in 1994. The passenger ferry m/v Estonia sank 22 nautical miles from the Finnish coast due to the technical failure, severe weather conditions, and finally the ferry listening [86]. The accident claimed 852 lives. On the other hand, the British tanker m/s Globe Asimi accident was the most severe one occurring in the Baltic Sea, causing significant water pollution. On 19 November 1981, under rough weather conditions, the tanker loaded with 20 thousand tons of fuel oil was leaving the port in Klaipėda when it hit the pier. Most of the cargo (16 thousand tons of oil) released into the sea, causing environmental pollution. The spillage was classified as medium compared to the most tragic shipping accident in the world that happened in the Caribbean Sea in 1979. Then, two large tankers, SS Atlantic Empress and m/t Aegean Captain, collided with each other during a rainstorm, causing a spillage of 287 thousand tonnes of crude oil [87].

The HELCOM reported approximately 3190 accidents in the Baltic Sea in 1989–2020. On average, 6.3% of them (in 2004–2020) resulted in marine environment pollution, with 0.1–1 tones of only oil substances [88]. Pollution with chemicals other than oil was last recorded in 1996 with the leakage of 0.5 m^3 of ortho-xylene in Gothenburg on 13 February 1996 [82–85,89].

Offshore critical infrastructures such as wind farms, oil rigs, and pipelines could also be the source of hazardous substance leakages, especially oil. Natural disasters, hazards coming from dumped munitions in the Baltic Sea, and terrorism-related hazards are the main threats to these critical infrastructures [90–92]. The failure of pipelines caused by breakage, corrosion, or anchors passing over the pipe can result in oil spills. Leaks can be also caused by operational spills and blowouts or discharges from oil wells. Furthermore, wind farms and other offshore installations, permanently attached to the sea floor, can interfere with hydrological processes of the sea by transportation of sediments or altering water currents [93]. Fortunately, there are no known successful terrorist attacks on critical infrastructures of the Baltic Sea before 2022 [94]. However, reports from September 2022 and the preliminary investigation say that sabotage is the most likely reason of leaks from two Baltic gas pipelines between Europe and Russia, around the Nord Stream pipelines. One of the leaks occurred in the Danish economic zone and the second in the Swedish economic zone [95]. This accident proves the increasing possibilities of terrorist attacks nowadays, and the dumped munition in the Baltic Sea, also considered in Section 3, may become a serious and real threat.

5. The Paradox of the Number of Species

Despite the Baltic Sea being characterised by a relatively low number of native species compared to most marine systems, mainly due to brackish water and its young (post-glacial) geological age [96–100], it is home to alien species. Human mediated dispersal of organisms is visible in the Baltic Sea. Alien species in the Baltic Sea—those that have spread from their original distribution range (other geographical regions) due to human activity (e.g., shipping, aquaculture, man-made waterways, etc.), are newcomers that can establish in this sea despite problematic conditions.

In the Baltic Sea, as in brackish water bodies in general, the salinity gradient is the main factor that determines the distribution patterns of organisms. The salinity from about 0 PSU in the innermost parts of the large gulfs in the north, through 6–8 PSU in the Baltic proper to 20–24 PSU in the Danish straits, makes the Baltic Sea susceptible to the introduction of freshwater, brackish, and marine species. However, salinities ranging from 5 to 8 PSU, i.e., the so-called 'critical salinity zone', may comprise an ecological [101], physiological, and evolutionary barrier that is practically insurmountable for many species [96–99], but is not a barrier for many alien species, e.g., [102–107]. The ability of numerous introduced species to live and reproduce in the low salinity waters of the Baltic Sea is a key factor which determines their success [108]. As a consequence, native species of the Baltic Sea are exposed to other brackish biota, owing to the breakdown of ecological, physiological, and evolutionary barriers [109,110].

Approximately 132 alien and cryptogenic species have been reported in the Baltic Sea by Ojaveer et al. [111], but according to databases such as the AquaNIS, there are more [7] and their numbers are growing. It is evident that conditions of this sea do not prevent alien species introductions and proliferation.

The Baltic Sea is a very dynamic water body, strongly affected by not only natural, but also anthropogenic processes. Anthropopressure can be a huge problem for some organisms. Some species may disappear locally, e.g., due to eutrophication, oxygen depletion, pollution, etc., whereas others, e.g., alien species, arrive and may become established here, e.g., [112–114]. In many cases, the richness of native species declines with increasing pollution while alien species numbers significantly increase [115]. There is also a general consensus that climate change will potentially favour alien species, leading to new introductions, e.g., [116]. The effects of climate warming are a cause of physiological stress (which acts more strongly on species already close to their tolerance limit). Anomalous temperature stress can cause mass mortalities in organisms that lead to empty niches, which can be used (and therefore colonised) by new alien species [117]. So, if certain taxa become less abundant, they may create further opportunities, due to their population declines, for newcomers [118]. Changing seasonal patterns of temperature may favour the settlement of alien species in a particular time of the year and have long lasting consequences in preventing the recruitment of native species later [117]. Due to climate change, the survival potential of the newcomers from warm regions will increase in the warmer Baltic Sea, e.g., [116,119].

The continuous increase in the number of alien species in the Baltic Sea (Figure 8) suggests that the number of new alien species will most probably further increase. Moreover, aquatic pollution and climate change may promote and favour invasion and increase the success in establishment of alien species.

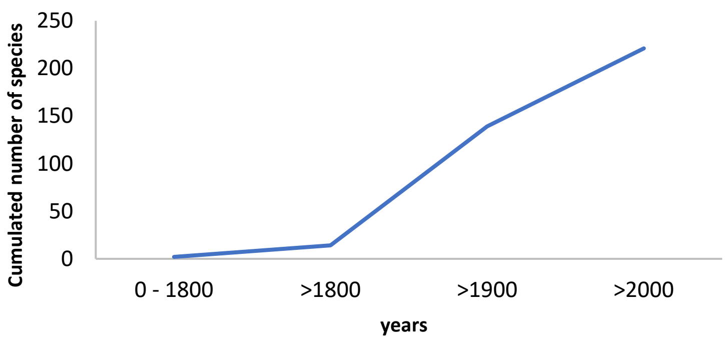

Figure 8. Cumulated number of alien and cryptogenic species in the Baltic Sea recorded over time (with verified records from AquaNIS 2022 [7] based on the first record of alien species).

Shipping is estimated to be responsible for the global transfer of over 10 billion tonnes of ballast water annually, with the result that approximately 10 thousand marine species (fauna and flora, including pathogens) are transported globally in ballast water each day [120]. The number of alien species introduced into the Baltic Sea has increased significantly since 1960 [121]. The ballast water is necessary to reduce the stress on the ship's hull, provides transverse stability, improves propulsion and manoeuvrability, and compensates for weight changes in various cargo load levels and due to fuel and water consumption. The problem of invasive species in the ballast water is largely due to the expansion of trade and traffic volume in recent decades. Thus, the International Maritime Organization established the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004, which entered into force in 2017. The convention is the first international convention to introduce legal and technical instruments to address the risks arising from the movement of organisms in ballast water.

6. The Paradox of Living Marine Resources

Despite the common opinion that a sea is a source of living organisms which may be used by humans, living marine resources in the Baltic Sea under anthropopressure are limited and the sea does not provide expected benefits.

The Baltic Sea contains a species-poor fish community that supports limited fisheries [122], because the production and distribution of fish depend strongly on environmental conditions such as salinity and temperature.

The case of limited living resources in the Baltic Sea countries is Poland. The main aquatic commercial species exploited in Poland are carp, mackerel, salmon, trout, but fishery of basic fish species such as cod, herring, eel, and salmon is presently unsustainable due to over-exploitation and impairment of conditions for reproduction [123]. The structure of basic marine fish catches (including sprat, herring, cod, and flatfish) in the Polish fishery changed over time (Figure 9).

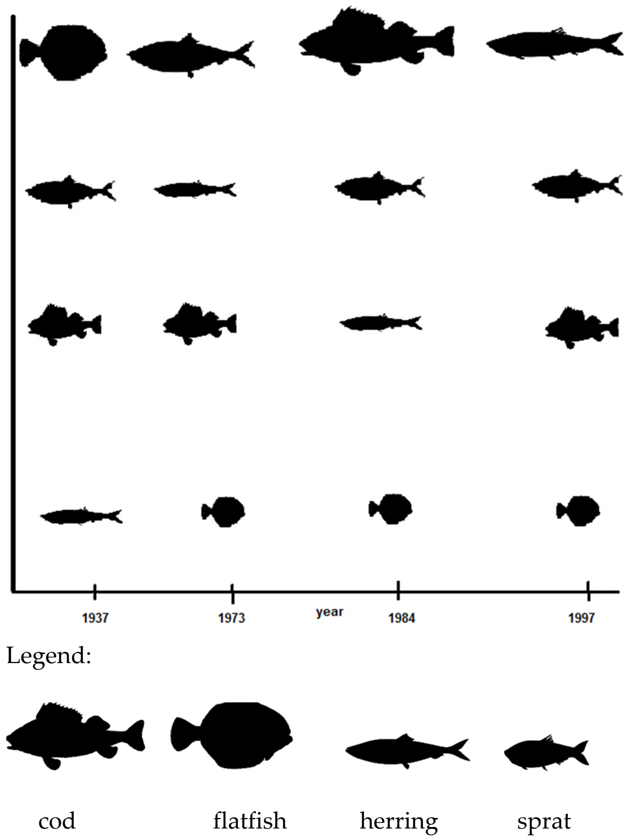

Figure 9. The structure of marine fish catches (including sprat, herring, cod, and flatfish) in the Polish fishery over time (from the top—the most often caught), based on [128–135].

The essential impact on the quantity and structure of fish catches has resulted in, among other things, the division of the sea into economic zones and regulations of the In-ternational Fishing Commission of the Baltic Sea [124]. As a result, the amounts of fishing limits for basic species are determined. In the end of the 1980s and in the beginning of the 1990s of the 20th century, the above problem was also affected by the drop in the resources of cod, decrease of sprat, and the herring price on the European Market, as well as protec-tion of some species and general increase of fishing costs and deterioration of economic indexes of fishing industry, e.g., in Poland [125]. The effects on marine fish resources re-lated to habitat degradation are caused by, e.g., tourism, pollution, and the influence of disappearing places for fish reproduction [126]. Additionally, contaminants have caused health and reproduction problems in numerous marine fishes [127]. There is now strong evidence that global climate change has had an anthropogenic component in recent decades [122].

Poland is among the top EU producer countries of freshwater fish, e.g., carp and trout [123], and has huge potential in the production of fish products. In 2017, the Polish fish processing industry was the fourth largest in the European Union supplying EU markets [136]. It has a high position in employment in the EU fisheries industry and fisheries production over time (Table 1). For several years, the fish processing industry has been considered one of the fastest developing sectors of the food industry in Poland [137]. Poland is Europe's top fish processor, although using, to large extent, imported fishes [123].

Table 1. Position of Poland in the EU rankings in different categories regarding aquaculture production, catches by marine areas fish processing, employment in the EU fisheries industry and fisheries production, and per capita household nominal expenditure on fishery and aquaculture products (source: EUMOFA [123,138–140] based on Eurostat [141]).

Year	Position in Aquaculture Production in the EU Countries	Position in Catches by Marine Areas in the EU Countries	Position in Employment in the EU Fisheries Industry and Fisheries Production	Position in Per Capita Household Nominal Expenditure on Fishery and Aquaculture Products
2017	11th	10th	n.a.	27th
2018	7th	10th	6th	27th
2019	8th	8th	6th	27th

Note: Abbreviations: n.a.—not available.

Despite the huge potential and leading position in the fish processing industry, the availability of fresh Baltic fish is small for the average Pole, and at the same time, many of the once popular species are becoming endangered. It is not surprising that in Poland, consumption of fish is low, because fishes are less popular on the menu than meat. This is caused by competition from cheaper pork and poultry meat [136], and at the same time, carp is more traditionally served during Christmas in Poland. In 2019, 62% of Poles ate little fish that year, 37% of Poles declared that they were not eating enough fish, and only 1% of Poles ate too much fish [142]. Poland was ranked 27th per capita in the EU countries (in 2017) in consumption of fish [139]. Actually, advancing an efficient use of renewable aquatic resources should be prioritised.

7. The Paradox of Sea Bathing

Despite the rapid warming of the Baltic Sea ecosystem under climate change and more suitability for bathing, when the weather is favourable for bathing, massive algae growth often prevents it. Also cyanobacterial blooms are suspected to become more prevalent with warming temperatures [143]. In fact, according to HELCOM [144], the summer of 2018 was the warmest on the instrumental record in Europe, and also the warmest summer in the past 30 years in the southern half of the Baltic Sea, with the average surface water temperature increasing by +0.59 °C per decade. The amount of blue-green algae resulting from sea warming has statistically significantly increased in open sea in the Gulf of Finland, Sea of Aland, and the Sea of Bothnia in the last approximately 40 years.

Large algae blooms caused by eutrophication are observed every summer [34]. Generally, the growth of cyanobacteria, like other photoautotrophic organisms, depends on the availability of nutrients and light and is also influenced by other abiotic factors, such as temperature and salinity [143]. On the other hand, anthropogenic nutrients enter the Baltic Sea through rivers and air–sea fluxes [145,146].

Cyanobacterial blooms are unattractive. They hinder recreational use of water, but more importantly, can cause health problems in humans and animals, because these blooms can produce cyanotoxins (Table 2; [147,148]). There is also evidence that the production of cyanobacterial toxins can increase with increasing nitrogen supply [149].

Table 2. Cyanobacterial toxins and primary organ targets, due to [147,148] with modifications).

Toxins	Primary Organ Targets
Hepatotoxins—toxic chemical substances that damage the liver	
microcystins (MC)	liver
nodularins (NOD)	liver
Cytotoxins—toxic chemical substances that damage cells	
cylindrospermopsins (CYN)	liver, kidney, spleen, intestine, heart, thymus
Neurotoxins—toxic chemical substances destructive to nerve tissue	
anatoxins (ANTX-a)	nervous system
anatotoxins (ANTX-as)	nervous system
Dermatoxins—toxic chemical substances that damage skin, mucous membranes, or both	
aplysiatoxins	skin
lungbyatoxins	skin
lipopolisacharids (LPS)	gastro-intestinal system, respiratory system

8. Conclusions

The problems presented in this article are actual and reflect the nature of changes in the Baltic Sea. Human activity in the Baltic Sea Region strongly affects the Baltic Sea [150]. The impact of anthropopressure in this sea is mainly associated with, e.g., inputs of pollutants from the land (nutrients: nitrogen, phosphorus, and hazardous substances loading) [111,151–153].

The Baltic Sea catchment area is currently inhabited by around 85 million people, which has a cumulative impact on the state of the marine environment [154]. Not only high population density of the Baltic Sea Region, but also poor agricultural management and poor management in different areas, including areas of intensive tourism, urban expansion, infrastructure development, etc., cause strong human pressure on this region [155]. Due to increasing consumption and a lack of care for the environment, pollutions are continuously accumulating in this sea.

Strong human impact should be limited in the future and sustainable use of the sea should be prioritised. It is necessary to remember that only sustainability, increasing the awareness of all inhabitants of the Baltic Sea states, will help improve the condition of the Baltic Sea and protect it properly, ensuring access to clean, biodiverse, and safe sea waters for future generations. Improving the environment is crucial, so an increase in scientific knowledge for sea health, reduction of marine pollution, and protection of natural resources are necessary.

Author Contributions: A.D.-K. and M.B.—conceptualisation, methodology, formal analysis, investigation, resources, data duration, writing—original draft preparation, review and editing, visualisation, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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