TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 17
Number 4
December 2023
DOI: 10.12716/1001.17.04.24

Shipping Related Activities and Their Environmental Impact – Lessons Learnt from the Estonian Case Study

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ABSTRACT: Baltic Sea maritime transport makes up about 15% of all cargo globally transported via sea, which makes it one of the busiest maritime areas all over the world [1]. At the same time shipping operations create environmental pressures to the air, discharges of oil, sewage from passenger ships as well as invasion of alien organisms from ships' ballast water or hulls [2]. In order to move from assessment of discharges from one ship to a certain area, it is necessary to combine the discharge factors to the activity patterns [3]. In this study the shipping activities that have environmental impact in the Estonian sea area will be analysed. In addition, the activities will be related with their source of pollution (e.g., manoeuvring, anchoring, loading/unloading cargo) and the impact or consequences are analysed (e.g., emission to air (CO2, SOx, NOx) discharge to water (antifouling paints, scrubber water, ballast water, bilge water, black water), physical discharge (underwater noise) etc). Finally, we assess the relative importance of the environmental effect of shipping in Estonian waters.

1 INTRODUCTION

The waterborne transport of cargo and passengers is one human activity that has a global increasing environmental impact [4]. Over 80% of the volume and 70% of the total value of international trade in goods is carried by the sea [5]. In the EU, maritime transport is responsible for 77% of external trade and 35% of intra-EU trade [6]. Baltic Sea maritime transport makes up about 15% of all cargo globally transported via sea, which makes it one of the busiest maritime areas all over the world [1]. The total length of shipping lanes in Estonian sea areas is 1700 km, while shipping lanes of international importance (HELCOM shipping lanes) make up more than half of it (950 km) [7]. At the same time shipping operations create environmental pressures to the air, discharges of oil, sewage from passenger ships as well as invasion of alien organisms from ships' ballast water or hulls [2].

International maritime shipping accounts for less than 3% of annual global CO_2 emissions, hence shipping is considered one of the lowest carbon dioxide (CO_2) emitting modes of transport per distance and weight carried [6], [8]. For instance, in EU, ships generate 13,5% of all GHG emissions caused by transport, whereas road transport is responsible for 71% and aviation 14,4%, nevertheless, pollution from shipping activities has been found to have significant impact on the air and water quality and marine and estuarine biodiversity [8]. The total greenhouse gas (GHG) emissions of the world shipping that include carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N_2O) increased from 977 million tonnes in 2012 to 1076 million tonnes in 2018 (9,6% growth) [9].

According to the UNCTAD 2022 report, the vessel types with the highest emissions increase between 2020 and 2021 were container ships, dry bulk carriers and general cargo vessels, but also from vehicle, ro-ro and passenger vessels. [5] Ships that are registered under the flag of an EU Member State make up to 17.6% of the total world fleet when measured in dead weight tonnage (DWT) [8] and are divided into ship types (not including fishing vessels) as other work vessels (including tugs, barges etc vessels that usually work in ports) - 30%, passenger ships - 19% and tankers - 17% of which, respectively, 45% are RoPax and 45% are chemical tankers [10]. In 2019 there were roughly 18000 ships registered under EU flags, accounting for 266 million GT and passenger ships that were registered to EU flags were able to carry 1.3 million passengers, therefore representing 40% of the world's passenger transport capacity [6], [10].

The Baltic Sea is a 392 978 km2 semi-enclosed second largest brackish water body in the world, after the Black Sea [11], [12]. It is 54m deep on average and due to the shallowness of the Danish Straits, ships with depth up to 15m can cross to the Baltic Sea, whereas bigger ships can only enter if empty or partially loaded [11], [12]. The sea is surrounded by eight EU member states - Denmark, Germany, Poland, Lithuania, Latvia, Estonia, Finland and Sweden and Russia, but five more countries are in the catchment area - the Czech Republic, the Slovak Republic, the Ukraine, Belarus and Norway [11], [12]. The Baltic Sea area has been designated as a special area in accordance with the International Convention for the Prevention of Pollution from Ships (MARPOL) Annexes I (oil), IV (sewage), V (garbage), and VI (for Sulphur) [2]. As a result, there are strict IMO restrictions on discharge into the Baltic Sea of oil or oily mixtures, sewage from passenger ships and garbage [2]. Furthermore, there are other measures to reduce the pollution, for example The Baltic Marine Environment Protection Commission (HELCOM), that seeks to protect the Baltic Sea from all sources of pollution from land, air and sea [2].

Impact of shipping related activities to the environment cannot be underestimated. First of all due to the consequences that those may have on the surrounding in the long term and secondly due to the tightening regulations of EU and IMO in the area. In April 2018 the IMO adopted its initial strategy to reduce GHG emissions from ships at least 50% by 2050 compared to 2008 level and 40% by the year 2030 compared to 2008 [13]. In July 2021, the European Commission set the target to reduce GHG emissions at least 55% by 2030 compared to 1990 level (Fit for 55 package) [8]. Shipping operations at sea and also at berth are everyday significant sources of different pollution [14], for example discharges to water, air emission and physical impacts, such as noise and artificial light [4].

There are three levels of waterborne traffic in the Estonian sea area [7]:
1. International shipping traffic that takes place in the Gulf of Finland between ports of other European ports and ports that are in the Gulf of Finland north-eastern part of the Baltic Sea, including large-scale transportation of oil and oil products, as well offshore fishing with trawlers.
2. Local shipping traffic (e.g., ferry traffic between mainland and islands).
3. Small vessel traffic (smaller fishing vessels, yachts, fishing boats), the intensity of which is seasonally different, as well as seasonal sea tourism and water sports (kayaking, surfing, etc.).

About pollution of the marine environment from small ships throughout the Baltic Sea scope, a detailed overview is provided in the Johansson et al. article [15].

The main question of this study is to find out what kind of shipping related environmental impacts are relevant in the Estonia sea area? In order to answer that question, we first need to answer:
1. What shipping activities have an impact on the environment?
2. What kind of impact do those activities have?

2 METHOD

Literature search was carried out using online databases (e.g., Science Direct), and maritime related organisations (e.g., HELCOM, EMSA, IMO, UNCTAD) webpages. Mainly shipping-related and environmental impact related articles, reports or other documents were used. Shipping related activities are divided into three categories which are based on a study of Jägerbrand [4]. In this study the shipping activities that have environmental impact will be analysed. In addition, the activities will be related with their source of pollution (e.g., manoeuvring, anchoring, loading/unloading cargo) and the impact or consequences are analysed (e.g., emission to air (CO_2, SOx, NOx) discharge to water (antifouling paints, scrubber water, ballast water, bilge water, black water), physical discharge (underwater noise) etc).

3 RESULTS

As a result of this study, an overview of shipping related activities is gathered and presented in table form. The tables will give answers to questions of what are the shipping activities that have an impact on the environment and what kind of impact it is. Based on a recent study [16], an extra table is presented to give an overview of which shipping activities with environmental impact are relevant in the Estonian sea area. Furthermore, considering if the assumed impact is high (red), medium (yellow) or low (green), first evaluation is given (Table 1).

Table 1. Colour coding of assumed environmental impact of shipping activities.

Assumed impact	Colour
High	(red)
Medium	(yellow)
Low	(green)

According to the Estonian Maritime Document Exchange [17] there has been 11 000 - 12 000 port calls annually in Estonian ports in 2017-2021 (Figure 2) and statistically the vessel type with the highest number of calls was predictably ferry vessels due to the intense passenger transport between Tallinn-Helsinki (Figure 3). As Figure 3 is demonstrating, ferries are followed by general purpose cargo vessels, chemical tankers, roll on-roll off vessels and container vessels.

Shipping related activities are divided into three categories which are based on a study of Jägerbrand [4] - discharges to water, air emissions and physical pollution. This division is used to gather knowledge on what are the main pollution sources and mainly negative impacts.

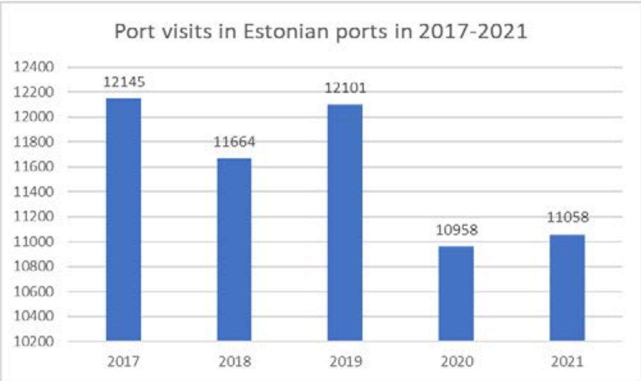

Figure 2. Port visits in Estonian ports in 2017-2021 [17].

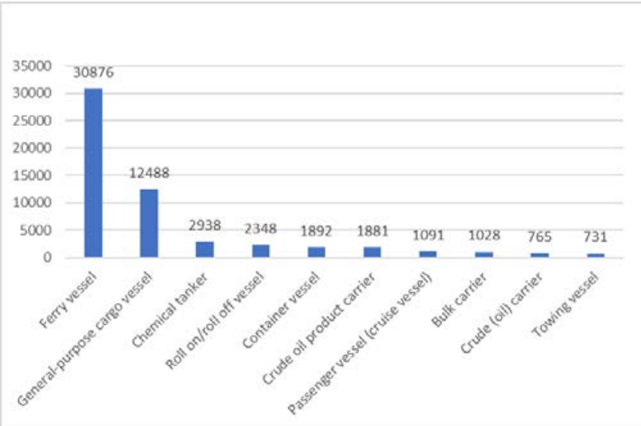

Figure 3. Most common vessel types based on number of port calls in Estonian ports between 2017-2021 [17].

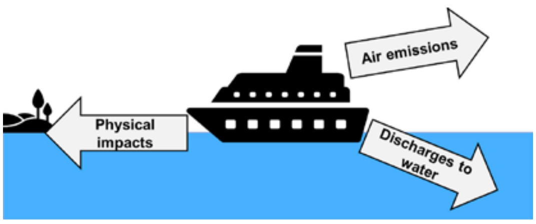

Figure 4. Classification of the environmental impacts of shipping on the aquatic environment into three main categories of discharges to water, physical impact, and air emissions [4].

3.1 *Discharges to water*

The main shipping related wastes that have direct impact to the water are ballast water, oily bilge water, propeller shaft lubricants, tank cleaning water, scrubber discharge, liquid and dry bulk, marine litter, food waste, black and grey water, cooling water and antifouling paints (Table 2). Danish straits, the southwestern part of the Baltic Sea and the Gulf of Finland are under the greatest pressure from pollutants spread by ships in the Baltic Sea [14]. In order to avoid invasion of NIS the International Maritime Organization (IMO) adopted in 2004 the International Convention on the Control and Management of Ships' Ballast Water and Sediments, i.e., the Ballast Water Management Convention that entered into force in Estonia in 2018 [18]. According to the convention, when a ship enters a new body of water, ballast water taken from elsewhere must be replaced with local seawater at a distance at least 200 nautical miles from the nearest land and in water at least 200 metres in depth [18], [19]. Since there is no sea area in the Baltic Sea that meets such conditions (the width of the open part is about 300 km), a gradual exchange of ballast water in the open sea and deballasting of ballast water in ports is a realistic measure here [19].

3.2 *Air emissions*

The main air emissions from vessels that are analysed in this study are nitrogen, sulphur, particulate matter, black carbon, greenhouse gases, volatile organic compounds and gases from using refrigeration systems (Table 3). The nitrogen contribution from shipping activities in the Baltic Sea (both air and water) has been estimated to make up to 1.25 -- 3.3% of the total nitrogen input and about 0,3% of total phosphorus input to the Baltic Sea [4], [28]. NOx in ship exhaust gases worsen the nutrient pollution problem of the Baltic Sea, also called eutrophication [3] SOx is not as important pollutant for the Baltic Sea marine environment compared to inland nature and human health, but it is indirectly very relevant as implementation of SOx regulation ("SECA") is a catalyst for using new greener technologies and alternative fuels such as Liquefied Natural Gas (LNG) that influence also NOx emissions [4]. Black carbon is estimated to be responsible for 6,85% of the global warming contribution from shipping activities in 2018, while CO_2 contributed 91,32% [8]

Table 2. Discharges to water.

Nr	Shipping related waste	Source of the pollutants/pollution to the sea	General environmental impact and/or consequence
1	Ballast Water [2], [3], [8], [20]	Ballast water could be transferred between different marine regions by vessels that take in ballast water upon cargo discharge and empty their ballast tanks when cargo is loaded, since shipping is present in all sea areas non-indigenous species (NIS) are transferred between ports regardless of differences in environmental conditions [3]	Spreading the NIS is ranked as one of the worst threats to the marine environment by the IMO [3]. NIS that have an adverse effect on biological diversity, socio-economic values, human health, or ecosystem functioning are considered invasive alien species [4]. There were 132 NIS in the different basins of the Baltic Sea in 2017 [21]
2	Oily bilge water	The amount might be dependent on the size	Oil and its degradation products might have an

	[3], [4], [8], [20]	of the ship, oil could end up in the bilge water from condensation and leakages in the engine room [8]	impact on the whole ecosystem, starting from damages on the DNA level up to changes in community structure [4]. For example, oil may change the community composition since species with higher tolerance increase [4]. Coastal wetlands are vulnerable to oil spills as they are low-oxygen environments with slow decomposition, for instance dilutions of 2.5 -- 5% bilge water or low concentrations of diesel may significantly change the marine environment [4]. Bilge water, lubrication of propeller shaft bearings, or the illegal cleaning of tanks could give more than 70% of the total shipping related oil discharge [4]
3	Propeller shaft lubricants and/or stern tube oil [3], [4], [8], [20]	Pollution ends up in the sea due to the waste streams that are related to the operations of propulsion and engine [3]	
4	Tank cleaning and washing water (slop) [3], [4], [8]	The amount of pollution is related to the number of tanks that must be cleaned and the size of loading capacity [8]	
5	Scrubber discharge [3], [4], [20]	Pollution for the environment comes from the low-pH water from exhaust gas scrubber systems [4]	In experiments with scrubber discharge there has been observation of increased mortality and reduced feeding in copepods [4]
6	Liquid bulk (HNS - hazardous and noxious substances)	Dry bulk, packed and liquid fertiliser cargoes that are carried on vessels could end up in the sea during transportation, loading/ unloading, transhipment and cleaning of cargo holds [22]	Release of hazardous substances like hydrocarbons, heavy metals etc into aquatic environments may cause indirect ecological effects like including changes in behaviour, competition, and predator-prey interactions that may have impact on the general marine life [4]
7	Dry bulk [4], [22]		Due to containing nitrogen and phosphorus, large amount of dry bulk may smother vegetation or induce algal blooms [4]
8	Marine Litter/solid waste (most commonly plastic, but also paper, metal scrap) [4], [23]	Waste that is generated on vessels include, for example, glass, tin, plastics, paper and food waste, whereas food waste is also separately categorised as garbage [4]	In addition to being an aesthetic problem, marine litter also causes socioeconomic costs, threatens human health and safety and has impacts on marine organisms [2]. Consumption of tiny micro plastics is also a concern as it may end up in the food chain [2]. Furthermore, marine litter might end up damaging and degrading habitats (e.g., in terms of smothering) and might help the transfer of alien species [2].
9	Garbage and other waste (Food waste/biowaste, food oil) [3], [20]	Food waste might end up in the sea from shops, restaurants etc, but also from transportation of livestock [8]	When discharging food waste to the sea, it may cause an increased biological or chemical oxygen demand as the organic matter is degraded in the marine environment and its nutrient content (Nitrogen discharge from food waste [20]) may also increase eutrophication [3]
10	Black water (sewage from passenger ships) [2]–[4], [20]	Black water (sewage) comes from onboard toilets and the amount is dependent on the number of passengers on board, but also the type of toilets, length of voyage [4], [8]. Sewage from medical facilities on board is also considered black water [24]	An excess input of nutrients may cause eutrophication in marine environments [4]
11	Grey water [3], [4], [20]	Grey water from vessels is non-sewage wastewater that includes drainage from showers, kitchens, laundry facilities and galleys [4], [24]	
12	Cooling water [3]	Seawater is used in the vessels machinery systems as a cooling media for heat exchangers, freshwater is used in a closed circuit to cool down the engine room machinery [25] After the freshwater has cooled the machinery then it is further cooled by the seawater in a sea-water cooler [25]	There is a small potential for transport of non-indigenous species [26]. In addition there is a potential to cause thermal environmental effects once the cooling seawater is discharged and the discharged seawater might contain dissolved materials from the components of the seawater cooling system [26]
13	Non-indigenous species (NIS) [4]	International maritime transport has resulted in the translocation of species attached to the hull [4]	The translocation of NIS might cause changes in the trophic chain (e.g., new predators) or decrease in indigenous species populations due to competition with NIS for space or food [8] Another impact could be the introduction of new pathogens and parasites that are dangerous for marine organisms in the area and also for human health [8].
14	Biofouling and antifouling paints [3], [4], [20]	Different antifouling agents are used on the ship hull to prevent the accumulation of organisms [4]	Antifouling paints could be a major source of copper to the marine environment and tributyltin (TBT) that has been used in ship paints has found to cause imposex, which is an endocrinal disturbance leading to the development of male genitalia in female marine gastropods [4]. Negative impacts by TBT have also been reported for other marine organisms, however, TBT was phased out of use from 1st of January in 2008 by IMO [4], [27]

Table 3. Air emissions.

Nr	Shipping related waste	Source of the pollutants/pollution to the sea	General environmental impact and/or consequence
15	Nitrogen (NOx) [2], [4]	The nitrogen is formed during fuel combustion [4]	NOx emissions formed during fuel combustion are known to cause acidification in freshwater systems (also referred as "acid rain") [4] . Furthermore, through an increase in bioavailable nitrogen, NOx also contributes to water eutrophication [4] . In addition, NOx together with volatile organic compounds (VOC) is a precursor for ground-level (or "bad") ozone (together with VOC) and particles that are harmful for human health [4] .
16	Sulphur (SOx) [2], [4]	Sulphur is generated when vessels are using marine fuels, but also by other combustion machinery, for example oil-fired boilers [4] .	SOx emissions might cause acidification in freshwater systems (also known as "acid rain") [4].
17	Particulate matter (organic carbon) [2], [4]	Particular matter is released during fossil fuel burning or could be formed in reactions with SOx [4]	The organic compound accumulation might cause anoxia [4]
18	Black carbon (Artic areas) [4]	If black carbon on snow or ice, it darkens them and decreases their ability to reflect sunlight, eventually leading to higher heat absorption and melting, that is especially relevant in the Arctic since this adds to temperature rise in the Arctic that is already much faster than anywhere else in the world [8]	
19	Greenhouse gas (CO2, CH4 – methane) [2], [4]	Greenhouse gases are generated from vessels when the burning of fuel [4]	Emission of GHG is linked to chemical changes like ocean acidification that affects shell-formation of various calcifying species (e.g., reef-forming corals) and has the fastest changes and largest impacts observed in the polar and tropical regions [4]. In addition, decreases in pH may be larger in the Baltic Sea due to lower concentrations of buffering dissolved inorganic carbon [4]
20	Volatile organic compounds (VOC) [4]	VOC are generated from handling crude oil as cargo [4]	The ingestion or inhalation of petroleum components may have a negative influence on the digestive, respiratory, and circulation systems [4]
21	Ozone-depleting substances (ODS) [4], [23]	The ODS emission from vessels comes from the extensive use of halocarbons as refrigerants [4]	The use of refrigerants on vessels contributes to the anthropogenic impact on the ozone layer and due to the rise in UVB radiation, as a consequence of ozone layer depletion, there is a negative effect on aquatic species and possibility of changes in aquatic communities [4], [23]
22	Fluorinated greenhouse gases (F-gases) [29]	The gases (most common are hydrofluorocarbons - HFCs) are usually found on vessels in air-conditioning, refrigeration and inert gas drying systems, but also in the production of insulation foam and firefighting equipment [29]	The global warming potential of 1kg of R-404A (one of the refrigerant) being released into the atmosphere is equivalent to significant 3922 kg CO2 [29]

3.3 *Physical pollution*

In the Estonian sea area, when it comes to accidents, then attention should be paid to the potential risk of pollution incidents to the Narva River Downstream Conservation Area, which aims in particular to protect fish and their habitats [30]. Regarding groundings and sinkings then on average, more than 10 new wrecks are found in Estonian sea areas every year, and a total of 594 wrecks lying on the seabed of Estonia have been mapped in the database of the Transport Agency - 490 of them have been found during surveying work, the rest have been identified either from aerial photographs or from previous sea charts [31]. In the Gulf of Finland, anthropogenic noise exceeds (5% of the time) the high natural noise level in approximately half of the assessment area, due to shipping lanes located in the middle of the gulf [32]. Man-made underwater continuous sound occurs in a large part of the Estonian sea area, and there is a potential to have a long-term effect on marine animal species whose activities necessary for life are near shipping lines. At the same time, there is also a sufficiently large sea area in which natural sound levels dominate, and marine animals are not significantly disturbed by ship noise [32]. The main shipping related physical pollution is underwater noise, but also artificial light, wildlife collisions, ship groundings and accidents (Table 4).

4 DISCUSSION

4.1 *Shipping related activities and their environmental impact on Estonian sea area*

In relation to the intensifying maritime traffic, including small craft traffic related to leisure and industrial offshore activities in the Baltic Sea and especially in the Finnish Bay area, shipping related activities that have environmental impact, become under discussion of both public and private sector bodies. It is important to develop and improve appropriate decision support tools for assessing the environmental effects of possible pollution caused by shipping to mitigate the increasing environmental risks.

Table 4. Physical pollution.

Nr	Shipping related waste	Source of the pollutants/pollution to the sea	General environmental impact and/or consequence
23	Underwater noise [2]–[4]	Passenger ships, container and tanker propellers are the biggest noise polluters, in addition, the noise may be caused by the construction and operations of offshore facilities, dredging, geological prospecting etc [4]	The intensity of sound could be measured, but the impact of it to most of the animal species is not completely understood[4]. A danger zone is the proximity of a source of noise at which the sound pressure is high enough to cause damage to the tissues of a living organism that causes a temporary increase in hearing threshold, a permanent increase in hearing threshold or more severe damage such as death of a living organism [32]
24	Artificial light [4]	Port operations, trucks, train, vessels that visit the port, increases when a lot of dark time (little daylight)	Since cruise tourism usually concentrates its activities in remote environments then it might influence negatively sensitive nocturnal marine species with the high levels of artificial light [4] Light pollution may potentially cause a reduction of biodiversity or loss of habitats and it may also impact species orientation, reproduction and recruitment, predation, and communication [4]. Furthermore, seabirds attracted to the light from vessels or offshore platforms can become disoriented, collide with structures, starve, become dehydrated, or be taken by predators [4]. Artificial light may also cause stress for nearby inhabitants
25	Wildlife collisions [4], [23]	Vessel speed might be related to the probability of a collision taking place, but also to the severity of impact and besides direct collisions, vessels may also interfere with marine fauna indirectly, by changing their behaviour or habitat [4], [23]	The impacts of wildlife collisions might be injuries and fatal results [4]. But also disturbances that are causing alterations in behavioural traits, whereas prolonged disturbances potentially alter survival rates or population size [23]
26	Waves and currents [4]	Vessels create waves and currents when they are operating [4]	Vessels cause physical impacts in coastal areas and watercourses and that might cause erosion & resuspension [4]. One of the results of erosion is shoreline vegetation that is continuously forced further from the waterline, and the roots of trees and bushes are exposed, which might cause their falling [4]
27	Ship grounding and sinking [4], [33]	Vessels might end up on the seafloor because of severe weather, collisions or war casualties [4]	Vessels that have grounded or sunk can cause a leakage of substances and chemicals in the environment such as, for example, TBT-based antifoulant, oil or fuels, in addition, sinking vessels may also cause physical damage of ecological habitats and are considered unsafe for the environment [4], [33]
28	Accidents [8], [30]	The pollution might come from lost cargo or leakage of fuel, oil or other harmful substances	Accidents might cause oil spill, loss of cargo(containers) [8]. The risk of pollution incidents and the environmental impact are higher in sensitive areas, including protected areas [30]

Current research contributes to the creation of tools by pinpointing on the environmental impact of shipping on the Estonian sea area. Without harmonised and detailed statistics used throughout different fields of research and decision making, there cannot be a unified approach.

International maritime transport has a great influence on Estonian sea areas, as Estonia is located along the largest trade routes, including the trade route to Russia's St Petersburg and other Baltic Sea ports in the Leningrad Oblast area, but also routes serving Estonian needs and including transit through Estonian ports. Therefore, developments in the international shipping sector should be considered.

The table below (Table 5) indicates shipping related activities and their assumed impact that is relevant in the Estonian sea area. Operational emissions and discharges from vessels are regulated through international conventions, primarily the IMO MARPOL, the Ballast Water Management Convention and the Antifouling Systems Convention and in order to move from assessment of discharges from one ship to a certain area, it is necessary to combine the discharge factors to the activity patterns [3]. Amount of pollution might be dependent on several factors like vessel size, speed and hull design, but also seabed sediment grain size, water depths and under-keel clearance [23]. For anchoring and mooring, waiting at the port with the engine running and grounding the amount of pollution might also be dependent on vessel size, speed and hull design, but also seabed sediment grain size, water depths and under-keel clearance [23].

Bunkering of ships in Estonian waters is regulated by Regulation No. 51 "Procedures for handling dangerous and harmful substances at sea, Narva River and Lake Peipsi" [30]. From August 2021, bunkering is allowed in four anchorage areas in Estonia [30]. Performing STS operations outside the STS area may take place in justified exceptional cases by agreement with the Estonian Police and Border Guard Board [7]. The main reasons for accidents caused by bunkering are: a) pipeline breakage, b) lack or non-use of absorbent booms, and c) poor communication [30]. When it comes to defence operations or dumping of unwanted munitions, there are special area requirements (navigation signs and shooting ranges) and with war legacy there might be a risk of hazardous substances [34]

Table 5. Shipping related activities and their environmental impact relevant in Estonia.

Subcluster	Activity	Activity more specifically	Possible type of environmental impact	Assumed environmental impact
Shipping [35]	Cargo transport, passenger transport, cruise tourism [34]	Propeller wash and vessel wake [23] (basically moving vessels)	Discharges to water	Cu and Zn from antifouling paints, pyrene from scrubber discharge, bilge water, grey water [16]
			Air pollution	Nitrogen (16% of Baltic Sea) [16]
			Physical pollution	Underwater noise [16]
		STS Bunkering	Discharges to water	Cu
			Air pollution	
		Transfer of goods from one ship to another in STS areas [7]	Discharges to water	Cu
			Air pollution	
		Anchoring and mooring [23]	Discharges to water	
			Air pollution	
		Waiting at the port with the engine running	Discharges to water	Cu and Zn from antifouling paints [16]
			Air pollution	
		Grounding [23]	Discharges to water	
			Physical pollution	
	Defence operations. Dumping of unwanted munitions [34]		Discharges to water	
			Physical pollution	

5 CONCLUSION

Currently, the generally accepted methodology for determining the environmental impact of shipping activities in the Estonian sea area is not yet available. In general, there are three different categories of pollution coming from operating vessels - discharges to water (e.g., ballast water, oily bilge water, scrubber discharge, black and grey water, antifouling paint etc), air emissions (e.g., nitrogen, sulphur, black carbon etc) and physical pollution (e.g., underwater noise, wildlife collisions, ship grounding etc). All those activities have impact on the surrounding environment. For example, when discharging food waste to the sea, it may increase eutrophication which is considered one of the main issues in the Baltic Sea region. Furthermore, NOx that is formed during fuel combustion on vessels also contributes to water eutrophication.

Based on previous studies carried out in the Estonian sea area [16], [32], it was assumed in this study that noise, as one of the shipping related physical activities has the highest impact on the environment, followed by Cu and Zn from antifouling paints, which is discharge to water, pyrene from scrubber discharge, bilge water and grey water and nitrogen that occurs when fuel is burned. Nevertheless, the estimations are inconclusive, because the approximate quantities of emissions released into the air or water in the Estonian sea area are not available. It would be valuable to have a well-developed methodology to find out numerical values for water discharges, air emissions and physical discharges for example like the ones that the Maritime Working Group of HELCOM compiles for the whole Baltic Sea. The first step towards that could be to compare methodologies that are used in the nearby countries, like Finland, Sweden and Latvia and see if those would be suitable to use in the Estonian sea area as well.

This overview is a starting point for further, more detailed studies of what are the main shipping activities that have the largest (negative) impact on the (marine) environment in the Estonian sea area. Furthermore, this study lacks the analysis of the environmental impact of shipping related activities that is caused by the fishing vessels and leisure craft vessels that are not registered in AIS. Study also lacks quantitative analysis of the environmental impact of shipping due to the lack of developed methodology on the Estonian sea area. These should be evaluated in further studies.

FUNDING

This research was funded by the Ministry of Environment, Estonian Research Council and Estonian Ministry of Economic Affairs and Communications, RITA2/133. “Preparation of a methodology for the assessment and characterisation of the environmental impact of shipping in the Estonian maritime area and preparation of a preliminary assessment.” https://www.etis.ee/Portal/Projects/Display/96f073dc-7b2c-4af8-a6fc-3a240d48910f and by the European Commission, ER188, “ADRIENNE+”. https://www.etis.ee/Portal/Projects/Display/41a33d7c-cfc1-4700-a207-28dbd3808c3e

ACKNOWLEDGEMENT

The authors would like to thank all the other participants of the project “Preparation of a methodology for the assessment and characterisation of the environmental impact of shipping in the Estonian maritime area and preparation of a preliminary assessment.” – Rivo Uiboupin, Ilja Maljutenko, Urmas Raudsepp, Jonne Kotta, Robert Aps, Urmas Lips, Natalja Kolesova, Madli Kopti and Siim Pärt and participants of the project “Adrienne+”.

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