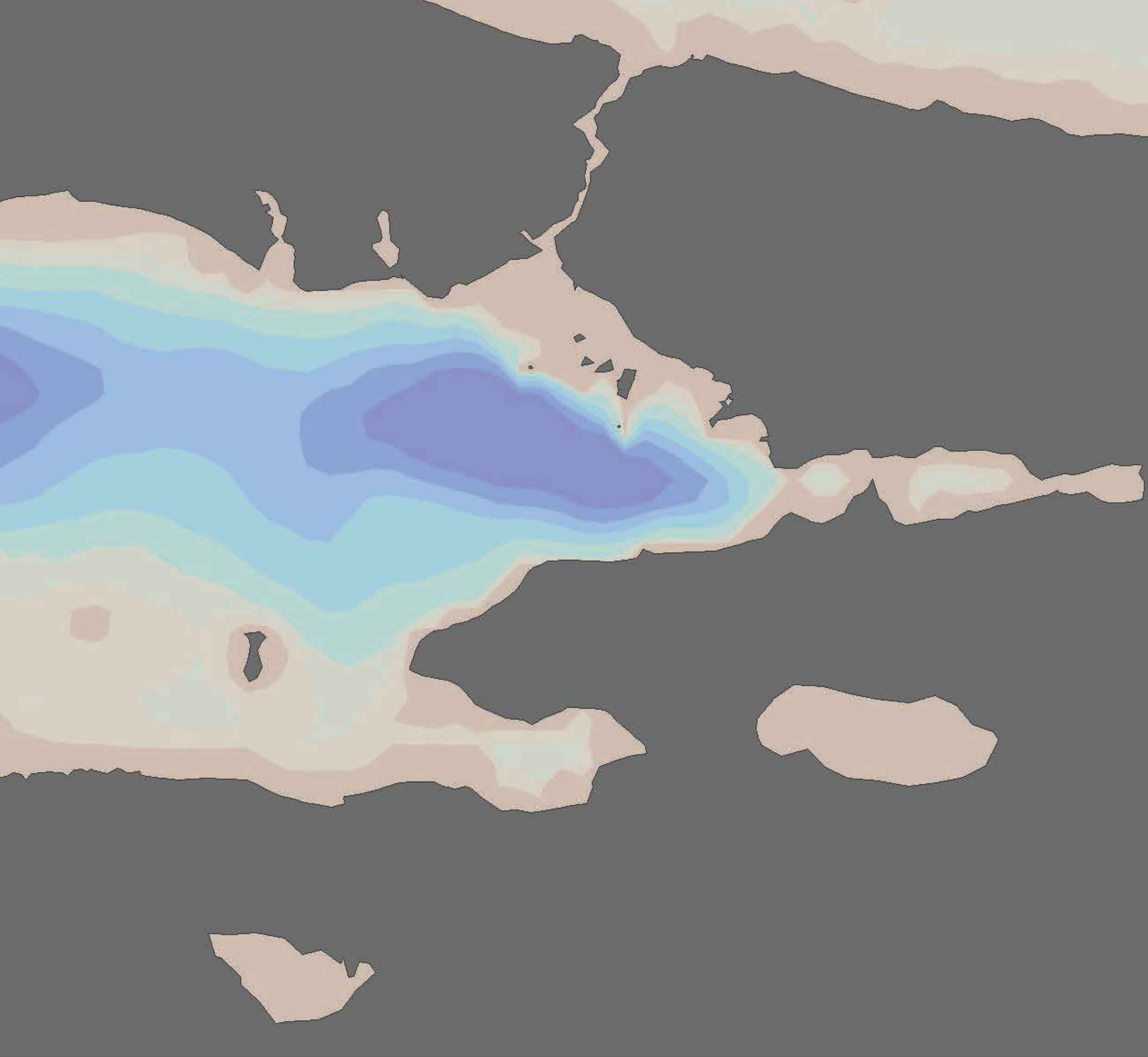

THE SEA OF MARMARA

MARINE BIODIVERSITY, FISHERIES, CONSERVATION AND GOVERNANCE

EDITORS: Emin ÖZSOY, M. Namık ÇAĞATAY,
Neslihan BALKIS, Nuray BALKIS, Bayram ÖZTÜRK

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MARINE POLLUTION FROM SHIPS IN THE TURKISH STRAITS SYSTEM

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1. Introduction

Marine pollution is one of the most important environmental pollution problems for the last 50 years and shipping is the most important factor causing marine pollution. The main environmental impacts of shipping operations include air pollution, oil discharges or other hazardous substances/wastes and transferring invasive alien organisms in global scale.

More than 90% of the foreign trade of Turkey, in terms of volume, have been realized with maritime transport (İncaz 2007). The Turkish Straits System (TSS), called Strait (Bosphorus; 17 nm) and Çanakkale Strait (Dardanelles; 37 nm) and the Sea of Marmara (110 nm), is the most important ship route in Turkish Seas (Figure 1). It is opened to international maritime vessel traffic under the Turkish governmental control. The narrow straits at Istanbul and Çanakkale with blind turns and dangerous currents (up to 8 knots) have always been potential threats to the passing ships.

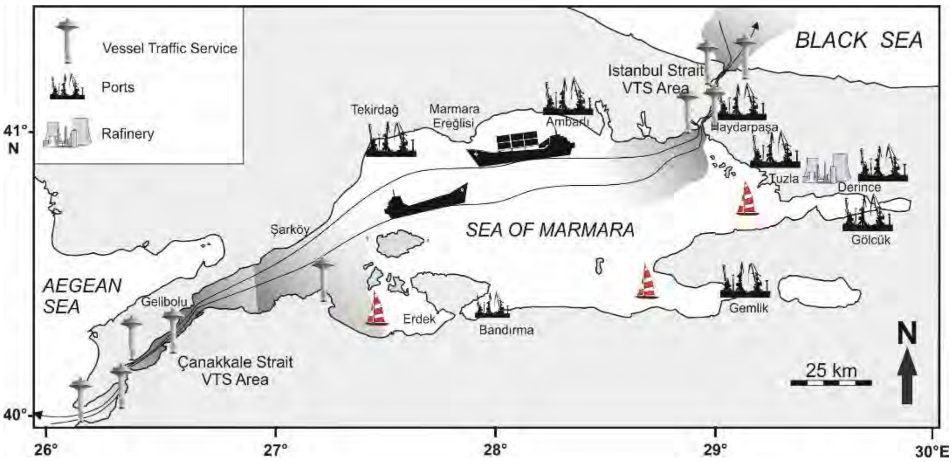

Figure 1. The Turkish Straits System (TSS), including the Istanbul Strait, the Sea of Marmara and the Çanakkale Strait, has many obstacles that may result in a negative effect on environmental management (www.turkishstraits.com/).

The economic growth with increasing oil production and maritime transportation make this threat more devastating on the marine environment especially for small and narrow water passages such as the TSS (Alpar *et al*. 2007). Every year more than 40,000 ships cross the Sea of Marmara, and the constricted waterways of the Istanbul and Çanakkale Straits. Oil tankers are most prone vessels to possible accidents during transit passage in narrow straits, along coastlines with heavy maritime traffic, and especially during storms. The marine transportation intensity in the TSS increased significantly until 2012, under the control of economic growth and oil production. There is however a decrement in recent years. According to 2014 data, for example, the transit passages via the Istanbul and Çanakkale Straits are slightly more than 45,000 and 43,000 (Table 1).

Table 1. Ships crossing the Turkish Straits (after Maritime Sector Reports, 2014).

	ÇANAKKALE STRAIT			**ISTANBUL STRAIT**		
	Vessel	**Tonnage (gross million)**	**Cargo (million tons)**	**Vessel**	**Tonnage (gross million)**	**Cargo (million tons)**
2012	44.613	>735	>454	48.329	>550	>377
2013	43.889	>745	>461	46.532	>551	>380
2014	43.582	>761	>473	45.529	>582	>394

The role of this chapter is to give a short overview of maritime transport activities in the TSS, marine pollution from ships, their types and environmental impacts. In addition, the most important physical impacts of the ships on marine ecosystem will be highlighted.

2. Maritime transportation activities and environmental impacts

2.1. Ship-generated oil discharges and emissions

Accidental spillages (tanker and non-tanker accidents): Oil pollution at sea is of great importance since the major marine environment pollutant is oil, in terms of their volumes. It is a viscous liquid, including crude and refined oils, such as kerosene, gasoline and other heavier petroleum products (diesel and lubricating oils). As it has a density less than that of water, oil spill is rather difficult to clean up. The toxicity and partly smothering effect of oil, especially when it is deposited, cause harm to marine life (Smith 1971). In the intricate and narrow water passages, similar to the Turkish straits, and especially during the times of spawning and migration, the effect of oil pollution on ecosystem and fishing becomes more important (Öztürk 2005). On the basis of the location and sensitivity of the spill area, time, weather and other environmental conditions, the effects of oil spill may last for short or long term. Oil pollution in bottom sediment may continue for years (Ünlü *et al*. 2004; Ünlü and Alpar 2004, 2006).

Regular shipping operations (oil load/discharge operations, oil and cargo transfer etc.) and accidental spillages (e.g. collision, grounding, hull failures, fire and explosion) amounts to around 50 per cent of global marine oil pollution (Table 2). Other half of this share comes from industrial and municipal effluents.

Table 2. Type and percentage of disasters of global marine oil pollution.

	Oil tanker	**Regular shipping operations**	**Municipal/ Industrial**	**Others**
Percent	7-10	35-40	45-50	5-10

The amount of leak entering the sea due to shipping activities has fallen during last 4 decades, which was 2.1, 1.57 and 0.57 million tons in 1973, 1981 and 1990, respectively (IMO 1998). If we look at this decreasing trend from another point of view, large amount of spills (55%) recorded in the 1970s decreased about 7% each decade till the 2000s.

Similarly, numerous accidents and collisions, resulting in oil spills, affected substantially the marine ecosystem and human life in the TSS. Almost all of these accidents occurred in harbours or rather close to the shores. The cargo vessels are most notorious ships involving in these accidents, and they are followed by tankers and passenger ships.

More than 120 transit vessels use the Istanbul Strait per day (Table 1). This is almost 10 times of the ships passing the strait in 1936, when the Montreux Convention was signed for navigation regulations. In addition to transit vessels, the number of passenger ships and small boats crossing between the piers in Istanbul are more than 2000, in other words, two and a half million people per day. These figures increase every year as the city population reached 15 million in 2016. That is, a hundred floating bodies use the water passages of Istanbul in both directions at any time of the day (Oral 2001). More than 450 marine accidents occurred in the Istanbul Strait and at its approaches since 1950, mostly collision due to poor visibility, strong currents and engine failure. The most important sea accidents, which caused severe environmental damage and pollution, are summarized in Table 3 (Marine Ministry Database).

Table 3. The most important marine accidents occurred in the Turkish Straits System

Accident (date)	Vessel name	Accident Area	Spilt /environmental impact
1960, Dec. 14	*M/T Petar Zoranić M/TWorld Harmony*	Kanlıca	18,000 tons of petroleum spilled causing severe marine pollution.
1966, Mar. 1	*M/TKransky OktiabrM/T Lutsk*	Kız kulesi	The amount of oil spilled was about 1,850 tons, causing fire at a ferry boat terminal at Karaköy.
1979, Nov. 15	*M/T Independenţa M/V Evriali*	Haydarpaşa	95,000 tons of crude oil was spilt and then burnt for days (Baykut *et al.* 1987; Etkin 1997).
1988, Oct. 29	*M/T Blue Star M/T Gaziantep*	Ahırkapı	1000 tons of ammonia spilled and caused severe water and air pollution.
1990, Mar. 25	*M/T Jampur M/V Da Tung Shang*	Sarıyer	2,600 tons oil spilled into the sea.
1991, Nov. 14	*M/V Madonna Lily M/S Rab Union-18*	Istanbul Strait	The drowned sheep, more than 21,000, in the sunk vessel caused severe pollution (Yurdun *et al.* 1995).
1994, Mar. 13	*M/T Nassia M/V Shipbroker*	Sarıyer	20,000 tons of oil burnt for more than 4 days, so ceasing marine traffic. 9,000 tons of oil spilled into the sea, affecting many places severely in the Black Sea, Istanbul Strait and Sea of Marmara (Oguzülgen 1995; Güven *et al.* 1995, 1996).
1997, Dec. 13	*M/T TPAO*	Tuzla	1500 tons of oil spilled into the sea. Extreme mortality of fish eggs and larvae was reported due to oil pollution, as well as metal pollution on biota. (Okuş *et al.* 1997; Doğan *et al.* 1998; Ünlü *et al.* 2000).
1999, Nov. 7	*M/V Semele M/V Şipka*	Yenikapı	Semele damaged severely and sunk, spreading 10 ton fuel oil into the sea.
1999, Dec. 29	*M/T Volganeft-248*	Florya	1,578 tons of oil spilled to the sea (ITOPF 2000; Otay and Yenigün 2000; Oğuztimur and Parlak 2002). Oil contamination remained in sediment and caused successive pollutions at the shores due to persistent southerly waves for years (Alpar and Ünlü 2007). Plankton and small organisms were affected Taş *et al.* 2011).
2002, Sept. 5	*M/V Şahin-3*	Istanbul Strait	More than 26 tons of diesel fuel has leaked into the sea.
2002, Oct. 6	*M/V Gotia*	Emirgan Dock	18 tons of fuel oil spilled into the sea. The marina and coastal infrastructures were affected even the majority of oil in the sea was transported into the Sea of Marmara (Otay *et al.* 2003; Güven *et al.* 2004).
2003, Nov. 10	*M/VSvyatoy Panteleymon*	Anadolu feneri	500 tons of fuel-oil spilled into the sea.
2004, Feb. 12	*M/V Strontsy*	Kilyos	In order to reduce the impact on marine life, floating fences were used for 6 days to block oil slick's attempts to expand.
2010, Jan. 19	*M/V Orcun-C*	Kilyos	96 tons of fuel oil and 25 tons of diesel oil spread into the area's bays and out to sea.

Shipping emissions: Ships have high powered engines using heavy fuels and the world shipping fleet is powered almost exclusively by diesel engines (Deniz *et al.* 2010). Even though cargo transport by ships is the most efficient transportation method considering its weight and distance crossed, the fuel used by ships is high in sulphur content. The emissions and pollutants from ships (e.g. nitrogen oxide NO_x, sulphur dioxide SO_2, carbon dioxide CO_2, hydrocarbons HC, and particulate matter PM) can be transferred in atmosphere even between the continents. The shipping activities account for almost 3/10 of the NO_x and 1/10 of the sulphur oxides of total global air emissions. Starting from 1990, NO_x, SO_2, PM, and greenhouse gases were increased from 585 to 1096 million tons in 17 years (Buhaug *et al.* 2009). The CO_2 emissions in 2007 were estimated at 943.5 million tons (Psaraftis and Kontovas 2009). This is responsible for 3% of global CO_2 emissions (Buhaug *et al.* 2009). In addition, on the basis of fuel consumption, annual CO_2, NO_x and SO_x emissions from ship corresponds to 2, 11, and 4% of the global anthropogenic emissions, respectively (Endresen *et al.* 2003). As they cannot be controlled tightly, shipping activities and maritime transportation contributes to air pollution, to ozone creating pollution and therefore to climate change. The impacts of shipping emissions on air quality may increase over domestic and inland seas, gulfs, highly-populated straits, and port areas.

IIASA (2007) estimated the shipping emissions for the Black Sea as 3.85, 0.089 and 0.065 Mt for CO_2, NO_x and SO_2. The shipping emissions along the TSS were estimated by taking into account ship engines, fuel types, and operations types, navigation parameters for 2003 (Deniz and Durmuşoğlu 2008). The annual total emissions were estimated as slightly more than 5000, 100, 80, 20, 5 and 4 (x1000) tons for CO_2, NO_x, SO_2, CO, VOC and PM, respectively. So, the NO_x, SO_2 and CO_2 emissions correspond to 1% of the global total shipping emissions, and more than those emissions in the Black Sea. The shipping emissions of NO_x, PM and CO are 46, 25 and 1.5% of road traffic emissions in Turkey. The greatest effect of ship emissions was reported for territorial waters and ports which are the most important gateways for trade in the World. Later, Kılıç and Deniz (2010) estimated shipping emissions for Izmit Gulf and Ambarlı Port. Even though there is no a comprehensive study about the impact of shipping emission on the Sea of Marmara, research from other regions indicated that CO_2, NO_x and SO_2 contribute to ocean acidification. New researches are necessary to estimate the potential impacts of emission-induced acidification on the biochemical and physiological processes of the TSS.

2.2. Operational discharges and environmental impacts

Vessel-related operational pollution includes releases of bilge water from machinery spaces and ballast water of fuel oil tanks, discharge of raw sewage and litter from ships.

Bilge water: It is the water that collects in the lowest compartment of almost every vessel below the waterline. It may contain leaks (solid wastes, urine, detergents, solvents, chemicals) in the hull or stuffing box, or other interior spillage. In case of leakage, untreated bilge water can damage marine life.

Ballast water discharges and transfer of alien species: Ballast water carried in ships' ballast tanks are used to improve ships' stability and balance. It contains all kind of biological materials, including viruses and bacteria. Large numbers of organisms (7-to-10,000 species in different life stages such as eggs, larvae, cysts, spores or resting stages) are transferred throughout the world by the world shipping fleet (GloBallast Partnership Project 2016). The harmful microorganism and bacteria moved by ballast water cause not only destruction of marine ecosystem but also serious economic and ecological damages (Streftaris and Zenetos 2006).

Almost half of the ships in the region have ballast water as much as 24,000 and 20,000 tons for the Istanbul and Çanakkale Straits, respectively (Maritime Sector Report 2014). Their total ballast water capacities are 320 and 312 million tons. Considering all of the seas surrounding Turkey, the total share of ballast waters transported in the Sea of Marmara is the highest with 45% (Olgun *et al.* 2012).The highest rate of ballast water transportation in the Sea of Marmara occurs between the ports located in the Gulf of İzmit, with a share of 43%. These figures are 20, 12, 7, 6 and 5% for the ports of Ambarlı, Istanbul Port, Tuzla, Gemlik and Silivri, respectively (Olgun *et al.* 2012). So, in terms of ballast water transport, the riskiest region in the Sea of Marmara is the Gulf of Izmit with its 39 ports visited by national and international ocean-going vessels.

One of the most important environmental hazards to the Black Sea is the introduction of exotic species. An inventory of alien species at the coasts of Turkey indicated 69 alien species transported by ships (Çınar *et al.* 2011). The authors also reported that 47 of the alien species, 6 of them are suspicious, existed in the Sea of Marmara. In general these species are carried by tanker ballast water and fouling of ships' hulls. An example is *Rapana venosa* which appeared in the Black Sea in the late 1960s, presumably introduced by ships coming from the Sea of Japan. Feeding on mussels, oysters, and clams, their population grew rapidly and expanded southward (Öztürk 1998). In the early 1980, the North American comb jellyfish (*Mnemiopsis leidyi*) were transferred to the Black Sea by ballast water taken up at the Atlantic coast of North America (Vinogradov *et al.* 1989). Affecting pelagic and benthic communities in the Black Sea severely, they caused collapse of fisheries.

Since ballast water is usually taken up at often shallow, turbid and highly-productive port areas, the transporting and spreading risk of invasive alien species in various forms is higher. Introduced pathogens carried by ballast water may even cause death in humans. GloBallast Partnerships Programme, a project Maritime Organization) reported many dangerous species including; a) cholera (*Vibrio cholerae,* known to mutate into new strains and travel widely), b) cladoceran water flea (*Cercopagis pengoi*), c) mitten crab (*Eiocheir sinensis*), d) toxic algae (red, brown, and green tides, may form harmful algal blooms depending on the species), e) round goby (*Neogobius melanostomus*), f) North American comb jelly (*Mnemiopsis leidyi*), g) North Pacific seastar (*Asterias amurensis*), h) zebra mussel (*Dreissena polymorpha*, fouls all available hard surfaces in mass numbers), i) Asian kelp (*Undaria pinnatifida*), and j) European green crab (*Carcinus maenas*) (GloBallast Partnership Project 2016).

The ship ballast waters taken from the ships berthed in the Ambarlı Port has shown that pathogenic bacteria and cultivable bacterial existence and their diversity posed a significant risk (Altuğ *et al.* 2012). Unfortunately, at present, there is no strict restriction for discharging of dirty ballast water in our national ports, the major centres of environmental risks and pollution. As of today, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM), adopted in 2004, has not been yet approved formally by Turkey.

Comprehensive multiple approaches, specific policies and appropriate strategies, at national and international levels, are needed to cut down the introduction risk of invasive alien species through ballast water. In the national level, for example, the ships can freely discharge their ballast water in Turkish seas and ports without any application of risk reduction activity, as long as their ballast water is not dirty. This poses a serious risk on the highly-populated industrial regions which are more sensitive to environmental pollution. Therefore, necessary action plans must be applied in controlling the ballast waters at all of our ports. The most helpful approaches include careful port and shipping operations, well-training, official instruction and examinations.

Sewage: The most important waste water producers (<90%) are the ferries, passenger and cruise ships which dump greywater (from baths, showers, galleys, laundry, sinks and kitchen) and Blackwater (from toilets and medical facilities) into the sea every. Untreated or inadequately treated sewage can contain pollutants at variable strengths and cause bacterial and viral contamination and have adverse effects on the marine environment, producing risks to public health. Faecal coliform bacteria found in untreated wastewater are several times greater than that observed in untreated domestic wastewater.

Solid waste: Solid waste (e.g. glass, paper, cans and plastics) discharged at sea, usually from large cruise ships carrying several thousand passengers, can be hazardous and pose threat to marine ecosystem. Unfortunately, there is no available data representing solid wastes discharged in the TSS.

2.3. Physical effects of marine vessels on marine habitats

Anchoring: Direct physical impact of ships, usually by ship itself, anchors, dragging and swinging of chains and grounding, may be harmful to marine habitat, especially in sensitive areas and benthic species (e.g., sea grasses, shellfish beds and soft corals which take thousands of years to build). Collisions with ship or its propellers may also cause direct physical harm to large marine mammals such as whales. Increasing demand for anchoring/mooring operations cause stresses to the marine environment, such as increased pollution, turbidity and physical damage (Smith 2000). The impacts of such kind of operations are either temporarily by increasing suspended sediments from the disturbance of the bottom or through direct contact with dragging anchors. Damage caused by anchoring may be temporary or permanent depending on type of anchoring/mooring involved, sediment type and sensitivity of benthic species.

Antifouling paints on ships: Growth of organisms, such as molluscs and algae, on hull surface cause a reduction in vessel speed as high as 10%. Hence, hulls have long been coated with anti-fouling paint containing Tributyltin- organotin compounds (TBT) since 1960s. Unfortunately TBTs, which constitute broad spectrum of algaecide, fungicide, insecticide and miticide, and act as biocide, have damaging ecological effects due to their strong eco-toxicity (Ashby and Craig 1990). Their solubility in water is low, with a half-life changing between a few days and a few weeks. In addition, if they are accumulated in bottom sediment, their decompositions may even last for several years depending on the environmental conditions (Ref: TBT in antifouling paints: National Institute for Coastal and Marine Management/RIKZ, Netherlands. MEPC 42/Inf.10). The aquatic environments with heavily silted bottoms, as usually observed at harbours, ports and sometimes in estuaries, are more prone to chronic TBT contamination.

World-wide increment of organotin concentrations has been detected in marine organisms and food chain since the beginning of 1970s. The organotin compounds with antifouling effects cause larvae mortality, imposex in many marine species, thickening or structural deformations of shells (Santos *et al.* 2002; Strand and Asmund 2003). The most sensitive organisms are gastropods, bivalves and sea snails. Female marine snails, for example, may develop male sexual characteristics. The organotin compounds affect immune systems of contaminated fish, seabirds, and marine mammals and even to human consumers. Because TBTs reduce the resistance to infection in fishes, e.g. flounder and other flatfish especially living in harbours and estuaries with silty sediment (Ref: TBT in antifouling paints: National Institute for Coastal and Marine Management/RIKZ, Netherlands. MEPC 42/Inf.10). Ship movements through water and waves cause organotin compounds in the sea water to diffuse in air as aerosols.

Considering the unwanted effects of harmful TBTs, their usage in antifouling systems was banned all over the world, firstly by the International Maritime

Organization (IMO) in 2003 and then for TBT coatings on all ships by the Marine Environmental Protection Committee (MEPC) in 2008 (Champ 2003). However, this does not mean that the TBT pollution studies were over, especially at the critical areas such as seaports, marinas and fishing areas where organotin compounds and other biocides having antifouling effects.

The seaports, public and private shipyards and rapidly developing marinas along the shores of TSS are the most notable localities for the investigation of organotin compounds and other biocides (Kırlı 2005). Their impacts to the marine organisms and their reflections to the sea products must be studied as well. Although it is well known that the tributyltin and its derivatives are extremely hazardous to marine ecosystem, there are very rare data on their levels and detrimental impacts on marine environment, particularly at the hot spots involving heavy commercial maritime processes along the TSS. In one of the earlier studies, Yemenicioğlu (1997) discussed methyltin distributions and provided a brief evaluation of butyltin results for the Mediterranean and Black Seas, and the TSS, which all have different physical and biochemical properties.

Yozukmaz *et al.* (2011) stated the importance of organic tin contaminated sediment in marine pollution, emphasizing that sediment is not a final stop for organic tin compounds. Instead it is a renewable resource, so sediment is an important factor for continuation of organic tin compounds (OTC's) concentration. Waste and sludge mix removed from sea bottom in harbours could cause additional contaminations (Hoch 2001). As the present prohibition and regulations in use of TBT will not evidently terminate the level of TBT concentrations rapidly, some comprehensive studies are needed on kinetics and durability of OTC's pollution along the TSS, as well as at its hot spots. Surprisingly no improvements reported from many developing countries, implying that they possibly carry on employing effective biocide and producing OTC's. Employment of new antifouling chemicals in paints, instead of OTC, may also create harmful effects in aquatic environment and should be debated together with prohibition of OTC usage.

3. Conclusions and Suggestions

The Sea of Marmara and its connections with neighbouring seas are the most important sea pathways of the World and play a vital role for the fish migration. The environmental rules should be applied strongly due to heavy sea traffic in that region. Action plans and innovative strategies have to be developed for decreasing the sea traffic load as possible. This is important because of for the maritime transportation and safety and also environmental pollution prevention. Although additional information and comprehensive researches are needed to understand the ecological effects on habitats and species, it can be said readily that the impacts of maritime traffic in the Sea of Marmara are high in intensity, repeatability, duration and geographic distribution. Some specific mitigation measures can then be identified. First priority management steps which must be acted upon in the Sea of Marmara in short, medium and long terms were outlined below.

- Short term management steps include a) development of permanent mooring stations at sensitive marine areas, b) preparation of more specific national standards, in addition to international standards, to regulate the ballast waters, which is a must to protect ecosystem and public health.

- Medium term management steps include a) monitoring TBT levels and organic biocides, b) fortify national coastguard surveillance to prevent and reduce oil spills, c) coordinate multilateral efforts in order to enforce MARPOL, d) definition of appropriate methods and technologies in making reduction in ship emissions, and e) implement the recommendations of international conventions developed by IMO.

- Long term management steps include a) enhance public awareness for the effects of maritime transportation on biodiversity, b) encourage the use of cleaner marine fuels, innovative vessels with modern engines, installation of on-board pollution control facilities, c) reduce ship emissions at port operational procedures, d) use very-high frequency radio-based automatic identification systems in order to enable the identification and necessary parameters of ships to prevent accidents and also for estimating ship emissions and monitoring defiant vessels passing through the TSS.

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