

# **The Effect of Dense Maritime Traffic On The Bosphorus Strait and Marmara Sea Pollution**

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## **Abstract**

*The Bosphorus Strait is a geological strait separating the European and the Asian parts of Istanbul and it lies between the Black Sea and the Sea of Marmara. Historically, the Bosphorus has a strategic importance since it is the only maritime route for the five neighboring Black Sea states and the Central Asian Turkish Republics.*

*Although the Bosphorus strait is a difficult body of water to navigate due to its treacherous currents, great twists and turns, it is one of the heaviest sea-traffic regions in the World. The volume of traffic in Bosphorus is five times heavier than the traffic in the Panama Canal. In 1936, when the Treaty of Montreaux had been signed, the number of ships passing through Bosphorus was only 4500 per year. Today, about 55000 ships pass through the Bosphorus per year.*

*The Strait has very special ecological conditions in terms of both marine environment and terrestrial environment since it connects two different seas, Mediterranean Sea and Black Sea, which have different salinity, temperature etc. In addition, the Turkish Straits (Bosphorus and Canakkale) form an "acclimatization zone" for transiting species, allowing those from the Mediterranean to adjust to the different environmental conditions in the Black Sea, and vice versa.*

*International importance of the Sea of Marmara stands in the forefront even though it is an inland sea of Turkey and it deals with increasing ecological problems for the last 50 years. The Pollution in the Sea of Marmara which threatens all living species cause dramatic falling in fishing potential.*

*Increase in the volume of maritime traffic on the Strait and the Sea of Marmara have increased the risk of the maritime accidents over the years and since 1948 the number of ship accidents have been recorded as around 700. Furthermore, being on the transportation way of hazardous and dangerous materials pose environmental and safety hazards for the Bosphorus Strait and the Marmara Sea with the surrounding residential areas.*

*In this paper, adverse effects and environmental impacts of dense maritime traffic in Istanbul and measures to take to prevent and lessen maritime accidents are discussed.*

*Keywords: The Bosphorus Strait, the Sea of Marmara, the Black Sea, sea traffic, sea pollution, maritime accidents.*

## **Background**

The Bosphorus is a geological strait separating the European and the Asian parts of Istanbul and it lies between the Black Sea and the Sea of Marmara. Historically, the Bosphorus Strait has a strategic importance since it is the only sea route of the Black Sea states (Ukraine, Romania, Georgia, Bulgaria and Russia) and the Central Asian Turkish Republics.

Although the Bosphorus Strait is a difficult body of water to navigate due to its treacherous currents, twists and turns, it is one of the heaviest sea traffic regions in the World. The volume of traffic in Bosphorus is five times heavier than the traffic in the Panama Canal.

### **The Bosphorus Strait**

The Bosphorus Strait is about 31.7 km long. The width of strait is 4.7 km (the maximum width) at the northern entrance and 2.5 km at the southern entrance. It is known as the narrowest strait in the world and the narrowest part is only 698 meters at Kandilli-Rumelihisarı-Bebek. Strait depth varies from 30 to 60 m and it reaches a maximum of 110 m at Kandilli.

The Bosphorus Strait has 12 sharp turns including 45° turn near Kandilli (Figure 1) and 80° turn around Yenikoy. The current speed may reach up to 7-8 km per hour. Its narrow and twisted nature makes the Strait geomorphologically and geologically important. Undersea topography of the Bosphorus Strait reveals many holes and banks in the submarine. 50 m isobath which covers Strait from North to South forms a conduit.



Figure 1. A View from the Bosphorus

The Bosphorus Strait has very special ecological conditions in terms of both marine environment (weather conditions, plant and animal diversity) and terrestrial environment since it connects two different seas, the Mediterranean Sea and the Black Sea, which have different salinity, temperature etc.

The most important oceanographic factor affecting the Bosphorus Strait is current. Other oceanographic factors like wave and tides do not affect the sea traffic on the Strait as much as current. The narrow and twisted nature of the Bosphorus increases the importance of currents on the Strait. Current develops under hydrological conditions such as precipitation, evaporation and stream input etc. in the Bosphorus similar to other straits. The strength of the current is affected by precipitation to the Black Sea and stream inputs.

The factors effecting current are geographical structure, the level and salinity differences between the Black Sea and the Sea of Marmara, evaporation and wind.

The normal current which is from the Black Sea towards the Sea of Marmara may change direction under strong southwest wind and makes maneuvering and cruising capabilities of the ships difficult. This upper layer current becomes whirlpool in the coves it enters. There is a lower layer current from the Sea of Marmara to the Black Sea in the regions close to coast. The depth of this current may take the value of 10

miles from the surface depending on the location and the conditions and it has adverse effects on maneuvering and cruising of the heavy ships.

### **The Sea of Marmara**

Although the Sea of Marmara is an inland sea of Turkey, its international importance stands in the forefront and it deals with increasing ecological problems for the last 50 years.

The Sea of Marmara, which has the surface area of 11500 km<sup>2</sup> and the volume of 3378 km<sup>3</sup>, is connected to the Black Sea on the North by the Bosphorus Strait (32 km length, average of 1.6 km width and 35 m depth) and to the Aegean Sea on the South by Canakkale Strait (62 km length, average of 4 km width and 55 m depth). It contains living species from both the Black Sea and the Mediterranean Sea and it is the feeding and breeding ground for the Atlantic originated pelagic fishes during the migrations from the Black Sea to the Sea of Marmara or vice versa. Additionally, the Turkish Straits form an "acclimatization zone" for transiting species, allowing those from the Mediterranean to adjust to the different environmental conditions in the Black Sea, and vice versa.

### **Interaction of the Bosphorus Strait, the Sea of Marmara and the Black Sea**

The Black Sea contains the largest anoxic marine environment in the world. Because of the great depth of the Black Sea and the relatively low salinity (and therefore density), water inflow from rivers (Danube, the Dnieper and the Dniester) and the Mediterranean Sea, freshwater and seawater mixing is limited to the uppermost 100 to 150 m and the water below this interface (called the pycnocline) exchanges only once every thousand years. Therefore, there is no significant gas exchange with the surface, and as a result decaying organic matter in the sediment consumes any available oxygen. In these anoxic conditions some extremophile microorganisms are able to use sulfate (SO<sub>4</sub><sup>2-</sup>) for oxidation of organic material, producing hydrogen sulfide (H<sub>2</sub>S) and carbon dioxide (CO<sub>2</sub>). Since this mix is extremely toxic (a lungful would be fatal to human), almost all of the Black Sea ecology live in that top layer down to a depth of approximately 180 m (600 ft).

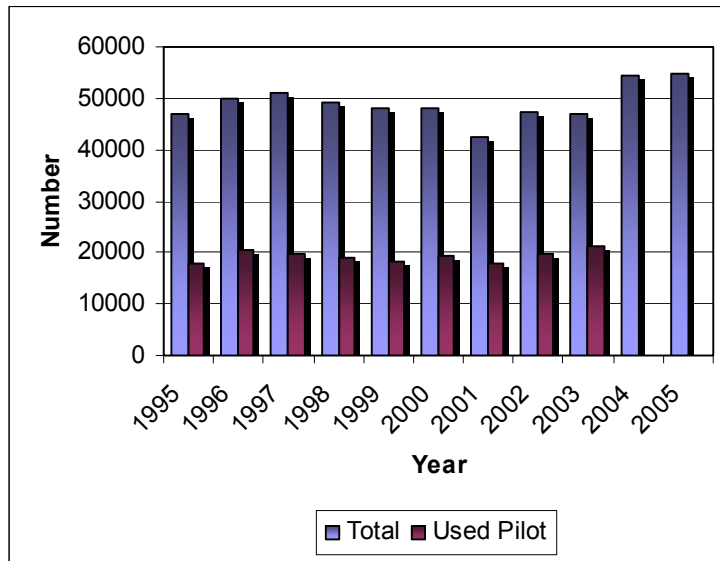
The Black Sea is a closed sea and its only water exchange occurs via the Bosphorus Strait. The Bosphorus Strait and Canakkale Strait (The Turkish Straits) are important biologic corridors between the Mediterranean Sea and the Black Sea. There are especially fish and fishery product migration from the Sea of Marmara to the Black Sea or vice versa depending on the season.

The Black Sea is connected to the Sea of Marmara, the Aegean Sea and the Mediterranean Sea via the Turkish Straits. Because of extensive rainfall, limited evaporation and terrestrial fresh water inputs, surface water is always in excess in water balance in the Black Sea and for this reason, surface waters flows to the Sea of Marmara through the Bosphorus Strait. Inverse current system in the Bosphorus Strait carries salty waters of the Mediterranean Sea to the Black Sea. Overall current system shows large scale cyclonic cycle (counter-clockwise) surrounding the Black Sea along the coast line.

Since adjacent seas are under the hydrologic influence of each other through the meteorological conditions, upper and lower layer currents, any physical or chemical change that occurs in one of the seas affects the others. Annually, about 548 km<sup>3</sup> water flows from the Black Sea to the Sea of Marmara while 249 km<sup>3</sup> water passes from the Sea of Marmara to the Black Sea via lower layer current. This indicates that any pollution occurs in the Black Sea affects the Sea of Marmara two times more than the Sea of Marmara does the Black Sea.

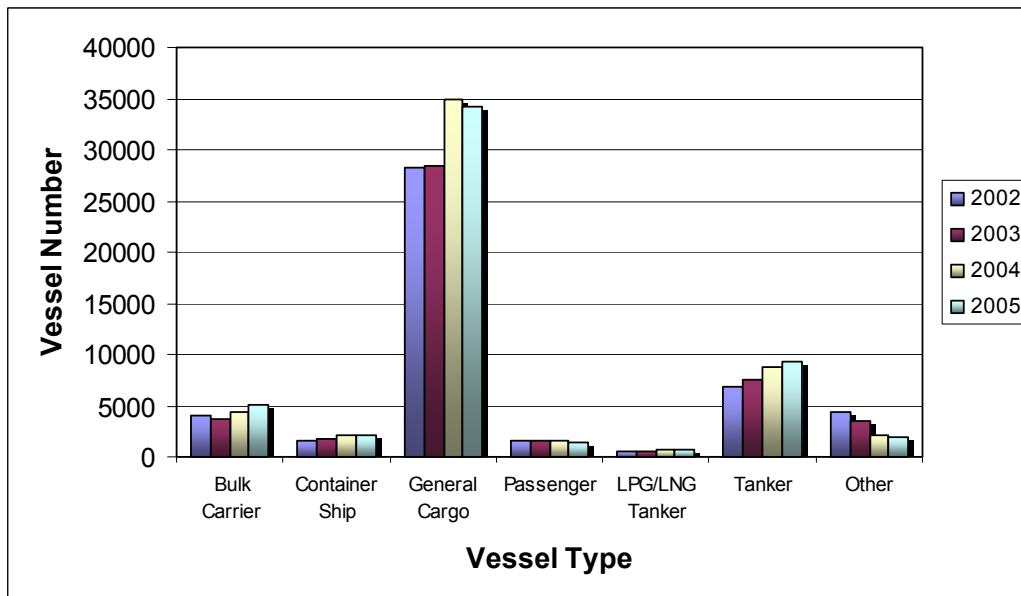
### **The Sea Traffic in the Bosphorus Strait**

Under the Montreux Treaty signed in 1936, navigation through the Turkish Straits is unrestricted for commercial vessels without any restriction on flag and cargo type. Since then, traffic density on Turkish Straits has increased significantly. In 1936 the number of ships passing through Bosphorus was only 4500. Today, about 55000 ships pass through the Bosphorus annually and 23000 of them are transit passing ships. In addition, around 2500 vessel per day (over 700000 per year) sails randomly and approximately 2 million daily commuters cross the strait in ferries and private boats. As seen in Figure 2 more than half of the ships passing the Bosphorus do not use pilot during navigation.



**Figure 2.** Number of Vessels Navigating through the Bosphorus Strait and Vessels Used Pilot [4]

Figure 3 and Figure 4 show distribution of the vessels passing the Bosphorus by type and length between the years 2001 and 2005 [2]. Because of the technological developments in the shipbuilding industry, transportation of Caspian oils to international markets etc., substantial increase has occurred in the size and tonnage of the ships passing through the Bosphorus Strait and hazardous cargo varieties and amounts they carry. The number of tankers passing through the Bosphorus Strait between 1996 and 2005 [1,2] and the amount of hazardous cargo (especially oil and petroleum products) carried between 2000 and 2004 [3] are given in Figure 5 and 6, respectively. As seen from the figures, the number of tankers passing through the Bosphorus increased about 136% between 1996 and 2005, while the amount of hazardous cargo transferred through the Strait increased approximately 58% from 2000 to 2004.



**Figure 3.** Distribution of Vessels by Vessel Type

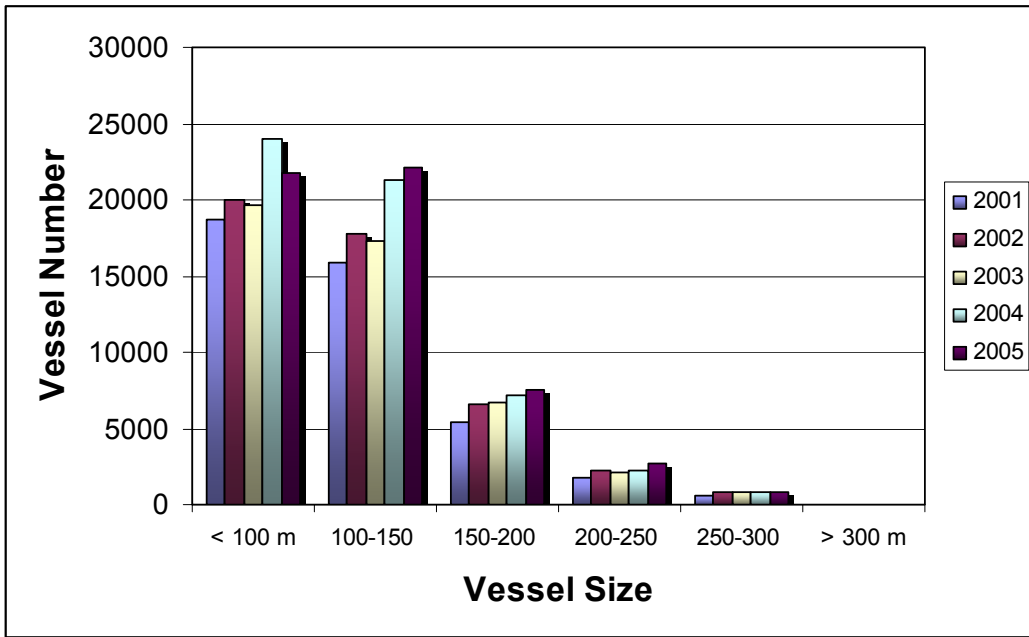


Figure 4. Distribution of Vessels by Vessel Size

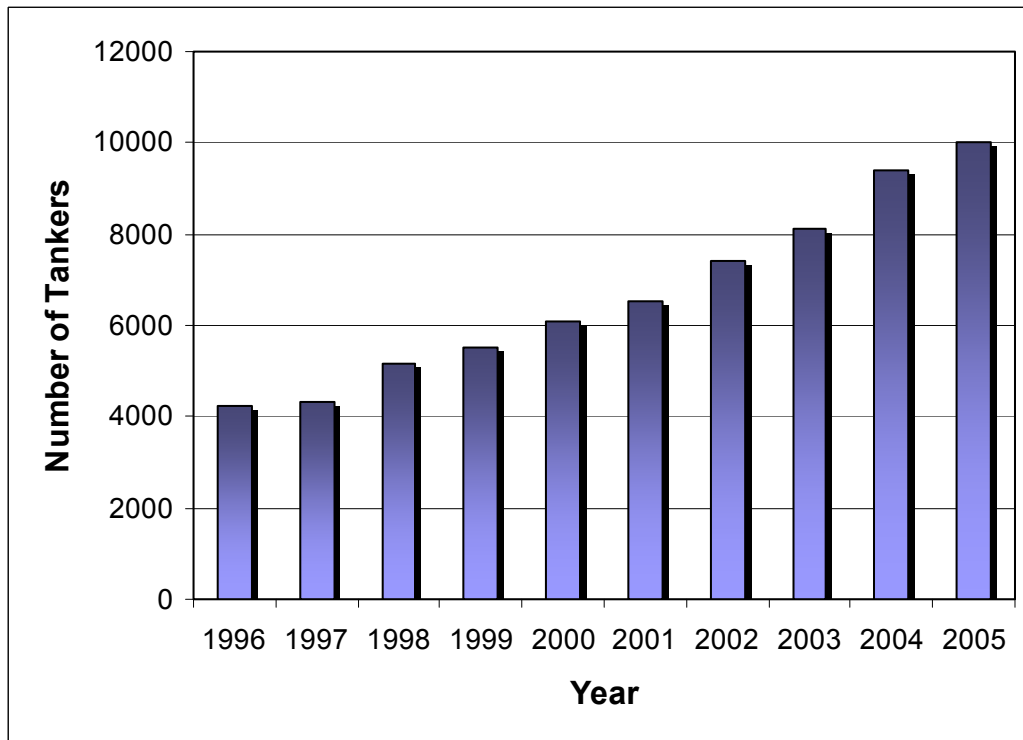
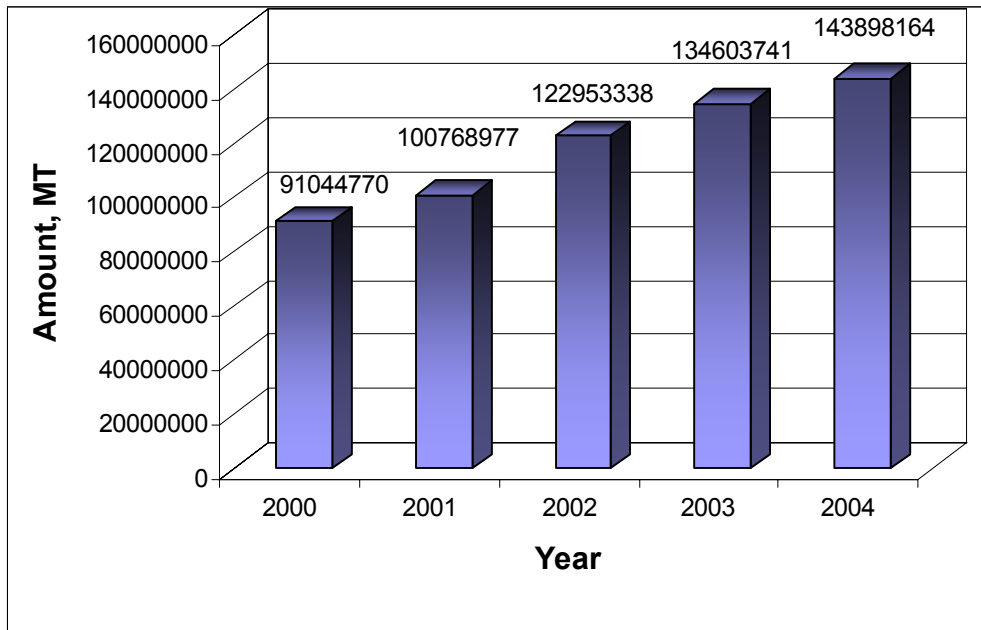


Figure 5. Number of Tankers Navigating through the Bosphorus Strait



**Figure 6.** Dangerous Cargo carried on the Bosphorus between 2000 and 2004

### Effects of Dense Maritime Traffic

The officials say the incredible number of vessels navigating on the Bosphorus and being on the transportation way of hazardous and dangerous materials poses serious environmental and safety hazards for the Bosphorus Strait, Marmara Sea and the surrounding residential areas. The increasing sea traffic also causes considerable congestion on the northern entrance of the Bosphorus Strait. Increase in the volume of maritime traffic on the Bosphorus and Marmara Sea heightens the risk of maritime accidents. According to a mathematical model developed to investigate vessel casualties resulting from tanker traffic through the Bosphorus, number of collisions increases quadratically with the traffic intensity [4].

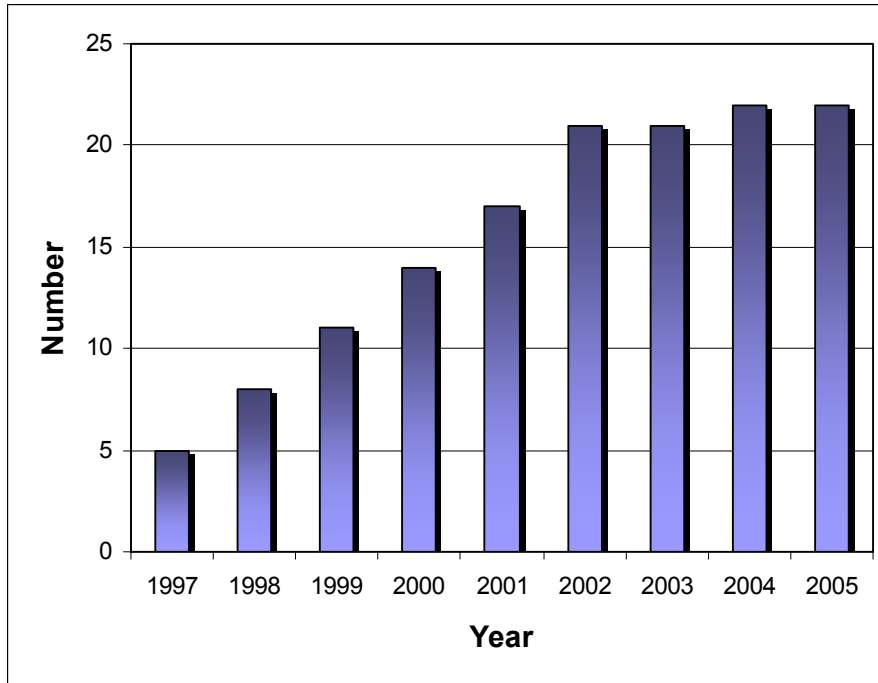
### Maritime Accidents and Oil Spills in the Bosphorus Strait and the Sea of Marmara

Besides dense maritime traffic, hazardous cargo transportation, the geographic and topographic structures of the Bosphorus, increasing ship sizes, complex traffic structure, inconvenient weather and sea conditions, sensitive environmental conditions, navigation without taking pilot and other maritime activities affecting ship traffic are important factors causing maritime accident on the Bosphorus Strait and Marmara Sea. While the number of casualties in the Bosphorus Strait was recorded as 113 between 1948 and 1982 and 208 between 1982 and 1994 [5], this number has rise to 358 between 1997 and 2003 [6]. Salvage operations conducted by the General Directorate of Coastal Safety and Salvage Administration between 1997 and 2005 [7] can also expose the increasing trend of maritime accidents for the last decade (Figure 7). Navigating without the aid of a pilot is one of the important accident initiating factors and 85 % of the ships involving accidents between 1982 and 1994 navigated without pilot [5].

Some of these accidents are severe accidents and caused serious environmental problems with thousands of tons of oil spill. Some of the major maritime accident on the Bosphorus Strait and Marmara Sea are given below:

- On 15 November 1979, Greek tanker M/V Evriali and Romanian tanker M/T Independenta collided in Haydarpaşa and 43 crew members lost their lives. The wreck burned for weeks, about 70 thousand tons of oil spilled to the sea and approximately 50 thousands tons of this oil was burned (Figure 8). The Bosphorus Strait remained closed for weeks. This has been ranked as the 10<sup>th</sup> worst tanker accident in the world due to the amount of oil spill.

- Panama flag ammoniac loaded tanker M/T Blue Star collided with Turkish crude oil carrier M/T Gaziantep on 28 October 1988. Incident occurred in Ahirkapi and about 1000 tons of ammoniac spilled into sea causing severe air and water pollution on the Strait.



**Figure 7.** Salvage Operations Conducted by General Directorate of Coastal Safety and Salvage Administration



**Figure 8.** Romanian Tanker Independenta under Fire after Collision with Greek Tanker Evriali

- On 29 March 1990, Iraqi flag M/T Jambur and Chinese flag bulk carrier M/V Da Tong Shan collided in the location of Buyukliman due to improper navigation. About 2600 tons of gasoline spilled from Jambur and heavily polluted the Strait. Jambur grounded off after the collision. Cleaning of the Bosphorus took several weeks.
- Due to improper navigation the Lebanese flag vessel Rabunion-18 collided with M/T Madonna Lily, Philippines flag vessel, on 14 November 1991 around Anadoluhisari. Three crewmembers died and Rubenion-18 sank with 20000 sheep.
- Greek flag M/T Nassia collided with another Greek flag vessel, M/V Ship Broker, on 13 March 1994 and 27 crew members from both ships lost their lives. Shipbroker burnt totally and fire on Nassia affected the Strait and the environment. Important portion of Nassia's cargo, approximately 20000 tones of crude oil, spilled over the sea and caused fire and severe pollution as seen in Figure 9. The fire lasted for several days and suspended traffic in the Strait.



**Figure 9.** Fire on the M/T Nassia Caused Pollution and Suspended Traffic in the Bosphorus Strait

- On 29 December 1999, Russian tanker Volganef-248, which was carrying about 4000 tons of fuel-oil, grounded and split into two pieces due to severe weather conditions (Figure 10). About 1500 tons of fuel-oil spilled to sea around the coast of Florya and with the strong southwest wind most of the spilled oil was carried ashore causing serious environmental pollution (Figure 11). Two hundred people involve in the clean-up operation and it took about two years to clean the coast, under sea and contaminated land according to national and international criteria.



**Figure 10.** Russian Tanker Volganef-248 Split into Two Pieces on the Coast of Florya





**Figure 11.** Two Hundred People Involved in the Clean-Up Operation for Volganefit-284 Incident

- Malta flag M/V Gotia, carrying 163 metric tons of fuel oil in her fuel tanks, ran into the Emirgan Pier in the Bosphorus and was damaged on her fuel tank. Approximately 18 tons of fuel-oil spill to the Strait. With the strong surface current oil was transported to the south entrance of the Bosphorus, and during this passage sea water, the boats and waterfront structures along the western coast of Bosphorus were contaminated.
- Georgian-flagged cargo ship named Svyatoy Panteleymon ran aground off around Anadolufereni on the Bosphorus Strait and split into two due to severe weather conditions on 10 November 2003. A total of 25 crew members of the ship were rescued. Some of its 220 tons of diesel and 260 tons of fuel-oil spilled to the sea and approximately 600 meters of shore line was polluted with the effects of waves (Figure 12).



**Figure 12.** About 600 meters of Shore Line Were Polluted after Svyatoy Panteleymon Accident

- Russian cargo ship Stronsy dragged the anchor and ran aground off Turkeli-Aslanburnu on 12.02.2004 and seriously damaged on the head. The ship had 20 MT gas-oil and 2 MT lub-oil.

- On 13.02.2004, Cambodia flagged ship Hera sunk with 19 crew members due to severe weather conditions. The incident occurred about 10 miles away from Turkeli Feneri on the Black Sea and ship sunk to the 73 meters depth. There was 175 MT fuel-oil and 62 MT diesel-oil on the ship.
- On 13.02.2004, 3884 GRT North Korean cargo ship named Lujin-1 ran aground off with its scrap iron cargo on Turkeli-Dalyan. The bottom of the ship was damaged. The ship had 30 MT fuel-oil and 20 MT diesel-oil.

### **Environmental Impacts**

There are two types of potential pollution on the Bosphorus and The Sea of Marmara as a result of dense sea traffic. The first one is the increasing accidents and unavoidable pollution they cause and the second one is the domestic wastewater, bilge water, ballast water and solid waste that are formed during normal activities of ships pollute the sea constantly as parallel to the heavy maritime traffic. Ship-source pollution is the most important and the most underscored pollution in UNCLOS (United Nations Convention on Law of the Sea) and in practice [8]. It is emphasized that it is necessary to put efforts to prevent, reduce and control ship-source pollution. Nowadays, besides pollution from daily activities of the ships, discharges and pollution due to accidents are also important factors. That is why, international cooperation exertions on taking effective precautions and determining high standards and applications will continue.

Ship accidents and heavy marine traffic threatens the biological diversity of the Turkish Straits and hence the ecological balances of adjacent seas since the Straits form an acclimatization zone between Mediterranean and Black Sea basins. Exotic species (bioinvaders), such as *Rapana thomasiana*, *Mnemiopsis leidyi* and *Cunearca cornea*, have become resident, similarly *Phocoena phocoena*, *Tursiops truncatus*, *Delphinus delphis* and *Monachus monachus* populations have disappeared from the Straits as a result of pollution [9]. The bioinvaders that entered to the Straits and Black Sea via ballast water of the ships grew quickly competing with native species for food and habitat space and caused ecological and economical damage. As an example, *Mnemiopsis leidyi* had a catastrophic effect on the entire ecosystem of the Straits and the Black Sea. As a consequence it almost exterminated anchovy fisheries.

Oil pollution on sea that is caused by oil leakage, discharge of bilge water and oil spill from maritime accidents is another threat for sea ecosystem. Oil contains toxic hydrocarbons and heavy metals which can be fatal to marine life even in very small quantities. The extent of this effect related to the amount of spilled oil, dispersion ratio and the size of the polluted area. The effect of oil pollution on ecological balance and fishing potential is more important in narrow passages like Bosphorus Strait especially during spawning and migration periods. It is known that spawns and larva of the sea species are very sensitive against oil pollution. Many of fishes and crustacean species swim on the surface during the early face of their life that is why they are exceedingly affected by oil on the sea [10]. Waterfowls are also considerably affected by oil pollution. The influence of oil pollution on the food chain in the sea is also an important issue to accentuate.

### **Conclusion**

The Bosphorus Strait is the most dangerous waterway in the world and serious maritime accidents occurred in the past causing severe environmental destructions besides the loss of life and property. The nature of the Strait, current, navigation without pilot, dense maritime traffic, inconvenient weather conditions etc. were considered as the major accident initiating factors in the Bosphorus Strait. There is an anomalous increase in tanker traffic and dangerous cargo carried. As tanker traffic will likely increase with the economical developments in the Black Sea countries, so will the probability of occurring a major accident that will damage the Bosphorus and Istanbul City, which is one of the most important economical centers of the World with a population of 15 million. An accident occurs in the Bosphorus or Marmara Sea will affect not only Istanbul but also countries in the Black Sea Region. Independenta, Nassia and Volganef-248 incidents, which caused thousands of oil spills, expose oncoming threats of dense maritime traffic and transportation of hazardous cargo.

Prevention is certainly preferred to clean-up and mitigation. Flag, port and coastal States and ship owners all have responsibilities preventing maritime accidents. Although the flag states responsible from ship

standards, port state control provides a safety net to catch substandard vessels and ensures that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules. Advanced weather prediction, improved engineering designs, improvements in ship operations, stronger inspection procedures by flag and port states, and enhanced training of mariners are some of the precautions to reduce the risk of maritime accidents. Taking the nature of the Bosphorus Strait into consideration, vessels should definitely navigate with the aid of pilot through the Strait in order to prevent accidents.

General Directorate of Coastal Safety and Salvage Administration have started to install Vessel Traffic System (VTS) in 2003 to ensure safety at sea, to fight against environmental pollution, to control maritime traffic, and to maintain coastal and port surveillance. In the first 6 months' period, navigation safety of Turkish Straits were established and average waiting time approximately reduced to 5 hours and number of ships passing through increased about 20 % within the safety framework. It will be one of the longest VTS coverage areas in the World with the 204 miles of monitoring area after the completion of Marmara Sea phase in 2006.

Since prevention efforts cannot eliminate accidents, all risks of transporting hazardous cargo, facilities and vessels are required to have an action plan for accidents and conduct response actions if an accident occurs. Additionally, all vessels should be insured in order to avoid problems during compensation of all sorts of damages including environmental damages after an accident.

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