Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
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doi: 10.3850/978-981-18-8071-1_P678-cd

Enhancing Proactiveness and Mitigation Concerning Marine Oil Spill Accidents Within the Hellenic Seas

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Marine oil spill accidents pose a serious threat to various countries within the wider European region. Extended pollution can harm marine wildlife and destroy vital habitats. Protecting the Hellenic Seas from oil spills is not only a matter of economic and social importance but also an environmental and ecological imperative. The Greek seas compose a vital natural resource and play a crucial role in the country's economy, culture, and overall well-being. The economy of Greece relies significantly on the country's natural resources including, its marine environment. Substantial economic damage can occur due to the loss of revenue from tourism fishing and other related industries. To successfully mitigate the risk of a potential hydrocarbon leakage within the Greek seas, proactive efforts must be placed on two different levels. Investing in preventing measures that minimize the probability of such accidents to occur, and perfecting emergency response plans to control and repair a potential marine oil spill accident. In order for the above to be achieved, meticulous analysis of all the factors that can lead to such an accident combined with its potential consequences is necessary. In the current study, focus is placed on the different locations where shipping accidents of collision and grounding have occurred throughout the Greek seas. The two types of accidents have been selected, as they have been linked to severe oil spill pollution. The ship's age, type and flag are studied alongside the location of the accident as contributing factors.

Keywords: Oil spill, shipping accident, environmental shipping, oil spill prevention, proactive analysis.

1. Introduction

The majority of global trade, including oil, is transported via sea routes, with tanker ships being increasingly used to meet the ongoing energy demands. While oil spills from tanker accidents make up less than 20% of ocean pollutants, they can have severe and long-lasting effects on the environment and surrounding communities when they occur. However, the number of oil spill accidents has decreased significantly in recent decades due to adoption of regulations and protocols, technological advancements, and improved crew training. Despite this progress, there is still a need for proactive measures to prevent accidents and minimize their consequences in case they happen. Several countries, within or adjacent to the wider European region indicate a significant risk for marine spills. A studied carried during 2016 revealed that the top two countries that seem to hold the highest risk are the United Kingdom and Greece.

1.1. *Significance of studying shipping accidents and their environmental impact in the Greek seas*

Greece's history, culture, and economy have been heavily influenced by the Greek seas, owing to the country's distinct geography featuring an extensive coastline and numerous islands. The sea environment is a crucial component of Greek life, particularly in the fishing and tourism sectors, upon which many Greeks depend for their livelihoods. Additionally, the tourism industry has a significant impact on Greece's economy. A considerable number of visitors are drawn to the country's coastal areas and islands, lured by the stunning beaches, clear waters, and diverse marine life. Meanwhile, fishing has been an integral part of Greece's history, with many coastal communities relying on it as a primary source of income. A big-scale accident with significant impact, can have a noticeable effect on all the above sectors in its surrounding area.

1.2. *Purpose and objectives of the paper*

This research article analyses previous shipping accidents of collision and grounding within the Greek seas. The study focuses on the locations of past accidents and the ships' age, type, and flag. The research aims to highlight the importance of such studies to minimize the negative impacts of oil pollution and prevent future accidents. Various databases and reports were reviewed to collect relevant data, and statistical analysis was used to identify notable patterns and trends.

2. Literature Review

According to the current research, some European countries are at a greater risk of experiencing large-scale oil spill accidents that can cause significant environmental damage (Javier F., 2016). To mitigate this risk, a detailed examination is conducted on the primary legal framework, agreements, codes, and conventions related to this issue. Additionally, an extensive analysis is undertaken based on the existing literature to identify the key factors contributing to collision and grounding accidents and determine the most effective measures to prevent such incidents and their environmental impact. (Zenetos A., 2004, Ventikos N., et al. 2004, Burgherr, P. 2007, Balmat, J.F., et al. 2011, Thanopoulou H., et al. 2014, Nivolianitou N., et al., 2016, Iliopoulou, C et al. 2017).

2.1. *Studies related to spill accidents in the Greek seas*

To this day there is a continuously increasing energy demand (Feng Q., et al. 2021). This elevated demand has visible effects as dense traffic, particularly of tanker ships throughout Europe, (Montewka J 2013, Haapasaari P. et al. 2015, Camphuysen C. et al. 2016). Greece is not an exception to the above (Thanopoulou H., et al. 2014, Nivolianitou N., et al., 2016), as its ports serve as a worldwide connecting transport link. Greece and the UK are the top two countries with indicated high risk for spills (Javier F., M., 2016). A higher accident probability of course translates to elevated risk, but it must also be taken into account, that the potential impact related to such accidents is increased, considering their proximity to the shore. (Coppini, G 2010, Iliopoulou, C et al. 2017). The difficulty to manage oil spills can be quite challenging in confined basins like the Mediterranean, as the spill unfolds and reaches the shores in a relatively small timeframe (Alves, T. 2014). Additionally, it has been commented that within the Greek seas, the route planning of oil transport seems to be mainly decided with an emphasis on cost minimization. (Iliopoulou, C 2017). Given this fact, the need to be appropriately prepared to avert and efficiently face the consequences of an accident of this nature becomes even more pressing.

2.2. *Formal Safety Assessment (FSA)*

Before the IMO's suggestion for Formal Safety Assessment (FSA), the focus of safe navigation was mainly on identifying potential hazards arising from accidents in marine waters and taking action if they occurred. (Haapasaari P. et al. 2015, Nivolianitou N. et al., 2016) While this approach led to increased safety in recent years, the global shipping industry turned its attention to preventing maritime accidents. The IMO established FSA guidelines in 1997 and 2002, which is a structured and systematic methodology for enhancing safety at sea proactively. The guidelines are designed to assess risks associated with navigation safety and environmental protection while considering the costs and benefits of various options. FSA can be used to assess potential new regulations and improve existing regulations by striking a balance between technical and operational issues, maritime safety, environmental protection, and cost. The FSA consists of five steps to analyze all aspects of safety and recommend appropriate protection measures. (MSC-MEPC.2-Circ.12-Rev.2, 2023)

(i) Risk identification.
(ii) Risk assessment.
(iii) Implementation of risk reduction measures.
(iv) Cost/benefit analysis for each risk reduction measure.
(v) Proposal for the implementation of the measures

3. Methodology

3.1. *Research design and methodology*

In the current research, the different locations where shipping accidents of collision and grounding have occurred throughout the Greek seas will be studied. As previously mentioned, these two types of accidents are selected for the analysis, as they have been linked to severe environmental pollution. The ship's age, type and flag are studied alongside the location of the accident. The current research methodology is structured based on the following distinctive steps:

- Data collection of collision and grounding shipping accidents, within the Greek territorial waters.
- Data validation and data curation according to official sources.
- Data base creation.
- Statistical analysis.
- Parathesis of high-risk locations and conclusions.

3.2. *Data collection and sources*

The first step of the statistical analysis is to obtain and curate the available data. For this study, data on collision and grounding accidents of ships within the Greek seas are collected from relevant authorities such as the Hellenic Coast Guard, The Hellenic Bureau for Marine Casualties Investigation, the National Technical University of Athens, and the European Maritime Safety Agency. It was necessary to include as many different sources as possible, to ensure the accuracy of the data collected.

3.3. *Data validation and curation*

After cross-checking the validity of the data between the different data pools as provided from the sources above, the set is treated to remove any outliers, missing data, or errors. Any duplicates have been removed to ensure that each accident is only included once in the dataset. Finally, the database that was formed includes 255 accidents.

3.4. *Database creation*

The created dataset includes information on the type of ship involved in the accident (tanker, passenger, ro-ro cargo, container ship or bulk carrier), the ship's age (new, middle old) and flag (low, medium, high, very high), and the location of the accident. The limits for the Age of the Ship variable were selected according to previous research, as it was produced for the AMINESS project (AMINESS, 2023). Therefore, the different values for the Age variable are set as following. New: If the ship at the time of the accident was less than five years old. Middle: If the ship at the time of the accident was older than five years and younger than twenty-five. Old: If the ship at the time of the accident was older than twenty-five years. The following types of ships are included in the current database: Tanker, Bulk Carrier, Container Ship, General Cargo, and Ro-Ro Cargo. Smaller ships like yachts, ferry boats etc. were excluded as their size, and mostly the size of their tank, is considerably smaller and therefore improbable to cause extensive or significant environmental damage. The Paris MoU (Memorandum of Understanding on Port State Control) represents an agreement between European and North Atlantic countries that forward the operation of sub-standard ships through effective port state control. The Paris MoU report in its essence creates a flag state performance table, where flag states get ranked based on the performance of their ships during port state control inspections. The table is updated annually and assigns each flag state to one of three categories: white, grey, or black. These categories reflect the level of risk that the ship poses to safety, the environment, and human health. The white list represents the best performing flag states characterized by Low risk, while the black list represents the worst performing flag states marked between High and Very High risk. The grey list is the in between category, representing states that do not meet the optimum required performance criteria but at the same time cannot be considered among the worst performers. The flag state performance tables by Paris MoU are presented publicly every year (Paris MoU, 2023). These tables are applied in the current research, to define the risk level of the flags that the ships had at the given time of the accident throughout the structured database. Therefore, the Flag variable is characterized as either Low, Medium, High or Very High risk.

Table 1. Description of the Database's fields.

Variables	Values	% of Completeness
Date	Year, Month and Day of the accident.	**100,00%**
Location of the accident	Location's specific characteristics.	**99,61%**
Type of the accident	Collision, Grounding.	**100,00%**
Ship's Age	New, Middle, Old.	**92,16%**
Ship's Type	Tanker, Passenger, Container ship, Bulk carrier, Ro-Ro Cargo.	**98,43%**
Ship's Flag	Low, Medium, High, Very High.	**90,59%**

During the following chapter, all the main fields of the database as presented by the table above, are inspected further through descriptive statistics and examination. The number of accidents included in the analysis is 255 throughout the years 1999 to 2018, with the set limit of values as described from the table above. The total percentage of completeness of the database is 96,80%.

4. Descriptive Statistics and analysis

4.1. *Type of the accident*

The accident types of collision and grounding are being studied with 64% of them being groundings and 36% collisions as shown from the pie chart below. (Figure 1)

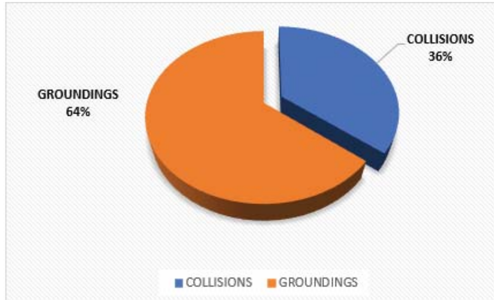

Fig. 1. Total Percentage of Collision and Grounding Accidents within the Hellenic Seas

The two types of accidents are also examined according to the location in which they occurred. The coordinates of the accidents are converted from decimal to DMS (Degrees Minutes and Seconds) and studied according to their location. Interactive maps with one layer for collision and one layer for grounding accidents were created on Google my Maps and Google Earth platforms to present the most interesting findings. The created map on Google my Maps was chosen to present the results in the current research.

Fig. 2. Collision and Grounding accidents within the Hellenic Seas.

The blue mark points represent the grounding accidents, and the orange exclamation points represent the collision accidents, as shown in the figure above (Figure 2). Further analysis will be conducted on certain locations of interest and the different types of accidents that are being observed, during the analysis of the location of the accident.

4.2. *Ship's Type During the Accident*

A necessary part of the analysis includes the examination of the ship's type during the given moment of the accident.

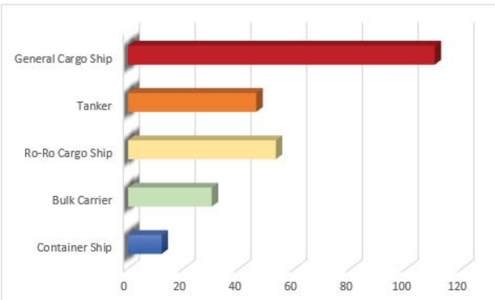

Fig. 3. Ship's Type During the Accident.

The type involved in most accidents is the General Cargo Ship (44%). Following right after are the Ro-Ro Cargo (21%) and Tanker (18%) with the final two being the types of Bulk Carrier and Container Ship with percentages of (12%) and respectively (5%).

4.3. *Ship's Flag*

The hypothesis prior the analysis of the Flag variable was that probably a quite big percentage of ships with Very High and High Risk flags would be responsible for the accidents that occurred. Nevertheless, after more thorough investigation it became evident that ships with Low and Medium Risk flag were responsible for the majority of those accidents. As shown from the pie chart below (Figure 4).

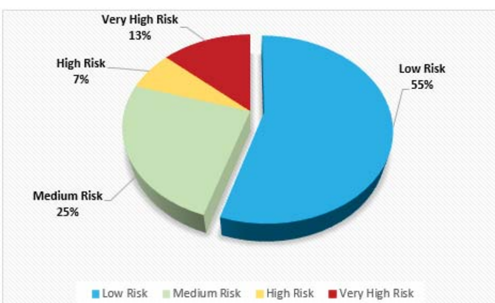

Fig. 4. Pie chart that depicts the Flag Risk of the ships involved in accidents.

However, there are a few different facts that explain the above result. Firstly, as it is evident from the annual reports of the ParisMoU agreement, most countries receive a White or Grey ranking with only a few of them scoring low enough to be placed on the black list. Secondly, most of the accidents happened with ships under a Greek flag (82 accidents, 32,16% of the overall accidents). The majority of the accidents being of Greek flag does not consist an absurd observation, as the analysis is restricted only to Greek territorial waters with Greece being one of the top countries considering its fleet size. Finally, the Greek flag has only received rankings of Medium and Low Risk based on the ParisMoU report system. In the current database created for this research, from the years 1999 until 2000 Greece is considered Medium risk and from 2001 until 2018 Low.

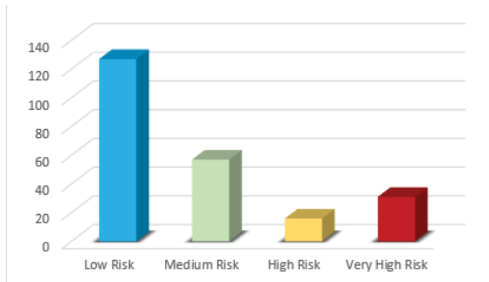

Fig. 5. Bar chart that depicts the Flag Risk of the ships involved in accidents.

As shown from the figure above (Figure 5) The majority of the accidents were caused by Ships carrying a Low-Risk flag. In total 127, with 69 of them waving the Greek flag.

4.4. *Ship's Age*

The hypothesis prior the analysis of the Ship's age variable was that the ships of old age would be involved in accidents at a much higher percentage than the newer ones. Indeed, as shown from Figure 6 the majority of the ships were characterized by old (53%) or middle (39%) age during the moment of the accident.

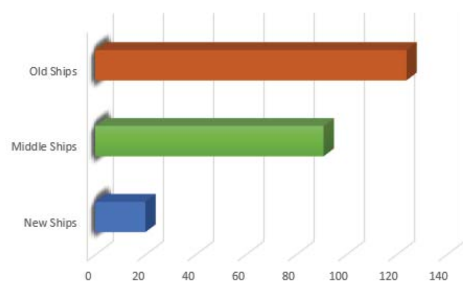

Fig. 6. Ship's Age During the Accident

From the above figure we can observe that ships older than twenty-five years are majorly involved in most of the collision and grounding accidents, regardless of the area in which they occurred.

4.5. *Location of the accidents*

The second aspect of the analysis within the current research, are the different locations that these accidents occurred during the past decades throughout the Greek seas. The above statistical analysis revealed several interesting conclusions. The overall analysis indicates that ships of old or middle age with low or medium flag occur irrespective of their type are distributed evenly in different areas of the Greek seas. However, the variable Type of Accident seems to have a unique correlation between the different locations of the Greek seas. Therefore, a selected number of locations that are ideal to describe these noteworthy observations is being presented in the current chapter. Before the analysis of these locations some worthy general observations made over the locations of the accidents are:

- The majority of the accidents (82 accidents, 19,57%) occurred either near or inside a port. With 15% of these accidents happening inside the Piraeus port.
- 27,45% of the accidents occurred within a Gulf. With 34,29% of them occurring in the Saronic Gulf (where also the Piraeus port is located).
- 14,12% of the accidents occurred at a Strait.
- 10,20% of the accidents happened within the wider area of the Dodecanese islands.
- 7,45% of the accidents occurred within the wider area of the North Aegean Sea.
- 6,27% of the accidents happened within the wider area of the Ionian Sea.
- 5,88% of the accidents happened within the wider area of Cyclades islands (Central Aegean Sea)
- 3.92% occurred within the wider area of the Cretan Sea.

2.3.2. *Locations of Interest*

Throughout the statistical analysis, it became evident that certain locations seem to be more vulnerable against certain types of accidents. The two areas that hold an increased collision risk are the port of Piraeus and the Kafireas Strait. Both of these locations have been inflicted with a considerable number of accidents, with the majority of them being collision accidents. (Figures 7,8)

Fig. 7. Accidents observed at the port of Piraeus

Fig. 8. Accidents observed at the Strait of Kafireas.

Finally, the two areas that revealed an increased grounding risk are the Preveza canal and Kos Island including its surrounding islands and islets (Figures 9,10). These results indicate that there might be hazardous shallow waters near these areas with elevated grounding risk.

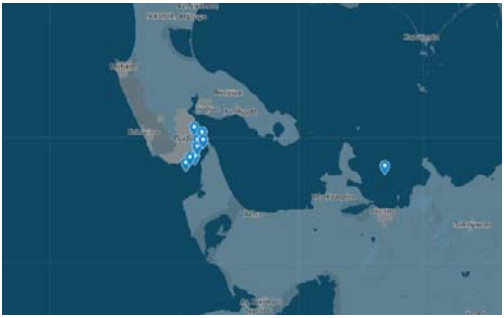

Fig. 9. Accidents observed at the Preveza canal.

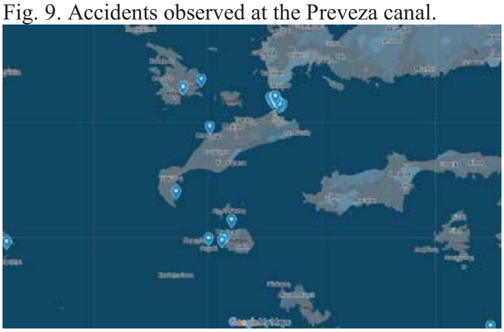

Fig. 10. Accidents observed at Kos and its surrounding area.

5. Conclusions

In the current research an analysis of all the factors that can lead to accidents of collision and grounding within the Hellenic seawaters is being performed. The different factors chosen for the current analysis is the location of the accident, as well as the ship's type, age and flag. Overall, 255 accidents that have occurred within the years 1999 until 2018 at the Greek seas were studied. Finally, the results of the descriptive and statistical analysis were presented. A number of these results had quite a few noteworthy indications as is presented in the following sub chapter.

5.1. *Summary of the key findings*

Perhaps one of the most notable findings that occurred from the analysis, is that there is an increased risk observed for collision and grounding accidents when the ship approaches, or is inside, a port. Also, an increased risk is observed when navigating through straits. Particularly there was a plethora of accidents observed at the Kafireas strait, from which the overwhelming majority were collision accidents. The port of Piraeus was also a location in which multiple collision accidents happened. An elevated number of grounding accidents is observed near the location of Kos Island and the Preveza canal. The most affected area from past accidents is the Saronikos Gulf. Most of the ships getting involved in an accident where General Cargo ships, with Ro-Ro Cargo and Tanker ships following right after. The majority of the ships that got involved in either a collision or grounding accident waved a Low hazard flag and were above 25 years old.

5.2. *Impact on future research*

The importance to produce proactive research to avert or at least minimize severe shipping accidents with substantial impact is paramount. Especially if we consider the risk level that European countries like Greece hold concerning their potential impact. The findings of the current analysis can serve as a valuable resource for subsequent research efforts that aim to safeguard the Hellenic seawaters from major spill accidents.

5.3. *Recommendations for future research*

Undoubtedly substantial additional research is needed in order to properly protect the Greek seas in a proactive way.

Firstly, a thorough examination of the meteorological parameters that may affect the sailing conditions and the visibility should be performed. These meteorological factors should include analysis of the parameter of wind speed and swell. Additionally, if possible, meteorological parameters such as the rain and fog which may affect safe navigation should also be studied alongside the accidents.

Moreover, all the main shipping routes within the Greek seas must be identified as they seem to indicate a higher collision risk. The areas where a higher grounding risk was observed should be studied according to their geomorphological characteristics. For example, an area were many grounding accidents are being observed does not necessarily mean that the risk for a severe pollution incident is high. The specific area could be of shallow waters but with no sharp rocks or formations and mostly sand. Which makes the possibility for a serious crack to the hull of the ship and therefore an extended spill leakage more unlikely. The areas that have shallow waters but with the bottom of the sea different than that of soft sand must be studied and noted for their elevated risk for a grounding accident.

Finally, additional research is needed where the analysis of the impact/cost of a potential spill is needed. The analysis should be performed having in mind the fourth step of the proactive FSA guidelines.

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