Use of GIS for assessing the changing risk of oil spills from tankers.

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Abstract

Assessing the risk of oil spills from ships has long been of interest to the maritime industry. Many factors affect the frequency of accidental oil spills, including the amount of oil transported and the combined effect of local conditions. These local factors include weather and sea conditions, visibility, water depth, navigational hazards and nature of the sea bed, which vary both spatially and temporally, and are often unpredictable. It is therefore not possible to quantify the individual effect of each. The approach of this study is to use a GIS platform to model the amount of oil transported on a regional scale, thus facilitating the analysis of spatial/temporal variations and enabling the integration of site-specific data.

An initial study was carried out to provide a general overview of risk in the Regional Seas as defined by the United Nations Environment Programme (UNEP). The approach taken was to deduce the relative risk of spills in different locations by comparing the historical occurrence of spills with the amount of oil transported. Data on historical tanker spills over 100 tonnes was extracted from the ITOPF database of oil spills, and data on laden oil tanker shipments for the years 2001 and 2005 was obtained from Lloyds Marine Intelligence Unit (LMIU). The oil tanker shipments data was digitised using a GIS in order to display the information geographically; the result is a schematic showing the cumulative voyages in any specific region which illustrates traffic density and total volume of cargo. In addition, interpretation and comparison of data from 2001 and 2005 has enabled an assessment of the changing patterns in transportation of oil by sea and consequently, the changing risk. The GIS platform has proved a powerful tool for visualising the tanker voyages, and integrating datasets such as location of historical spills and environmentally sensitive areas.

Background

As interest in the subject of marine oil spills has developed in recent decades; many studies have been carried out to assess the risk of oil spills from ships. These have predominantly operated on a regional level with an aim to understand specific response requirements for a particular area and to implement changes which may decrease or address the risk.

ITOPF regularly participates in activities to promote preparedness and planning in the event of an oil spill, mainly through sharing its experience and accumulated first-hand knowledge of over 550 oil spills worldwide and assisting in studies and activities relating to risk assessment and contingency planning. Assistance is often provided in the form of information from ITOPF's in-house datasets, such as the database of accidental oil spills from tankers started in 1974, or information on oil spill response arrangements in a particular country through the 'Country Profile Series'. GIS, accessible on the Internet, was considered to be an effective and meaningful way to disseminate this information; subsequent datasets depicting tanker traffic flow were also developed to add value to the system and its use in risk assessment. The purpose of this paper is to demonstrate the strengths and limitations of applying this method.

Methodology

It has often been stated that:

Risk = Consequence x Probability

The consequence, or impact, of an oil spill is a function of a number of factors such as volume and type of cargo carried by a vessel at the time of an incident, effectiveness of the incident response and proximity to environmentally and economically sensitive areas.

The probability of an oil spill relates to factors such as vessel traffic density, weather and sea conditions, navigational hazards, visibility, water depth and nature of the sea bed.

Many of these factors are unpredictable and vary both spatially and temporally, making them very difficult to model. In this study the method used to assess probability of an oil spill involved an evaluation of the occurrence of historical accidental oil spills from tankers in relation to traffic density. A GIS was utilised to model this data spatially on a global scale, allowing volume and type of cargo as well as proximity of sensitive areas to be considered on a regional scale.

Due to the complexity of such a risk assessment it was decided that a visual representation (maps) of the individual factors contributing to risk would be more valuable than assigning a value to depict level of risk, with the intention being that the relevant information could later be extracted and applied to any study on a regional level. This could then be integrated with risk related data held locally that may impact the assessment.

Data on historical tanker spills over 100 tonnes was extracted from the ITOPF database of tanker spills, which lists information on size, type and cause of spill from oil tankers since 1974. Datasets on laden oil tanker shipments were purchased from LMIU, these datasets contained voyage information on oil tankers of handy-size and above ($\geq$ 10,000 DWT) carrying Crude oil, Dirty Product (Condensates and Fuel Oil) and Clean Product (Diesel Oil, Gas Oil, Jet Fuel, Residues and Naphtha) for the years 2001 and 2005, therefore enabling a comparison of change in marine oil transportation over a period of 4 years.

The rate of accidental spills from bulk transportation of oil varies widely between different locations, and does not solely depend on the amount of oil transported but also on the combined affect of local factors, some of which can be presented on a map, e.g.

narrow channels. For many regions of the world there is little understanding of traffic density or the volume of oil being transported along particular coastlines, therefore the tanker voyage data was developed in a geographical context, enabling it to be viewed and integrated with other geo-referenced datasets, such as location of sensitive areas.

In order to display the tanker voyage data geographically, it had to be transformed from its raw format (see below) to a geographically digitised route, whilst maintaining the relevant data such as cargo type and quantity and vessel type.

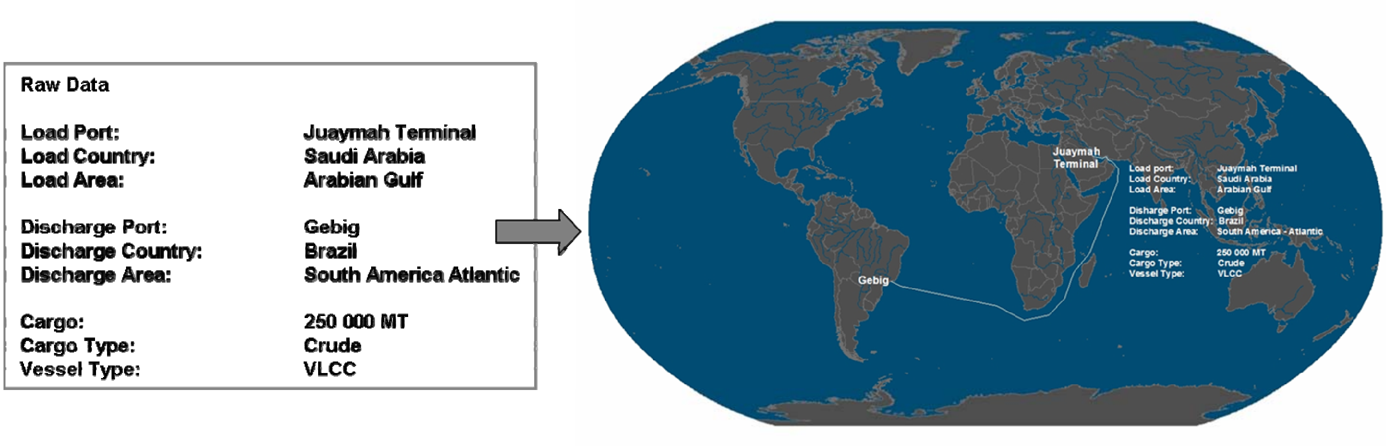

Fig. 1 Raw data digitised and displayed geographically.

Each route was digitised manually through a set of predetermined waypoints using a variety of information sources to deduce the most likely route taken by each vessel. The tanker voyage dataset for 2001 for example comprised of approximately 10,000 individual routes, which once digitised, became the complex tanker route network shown below.

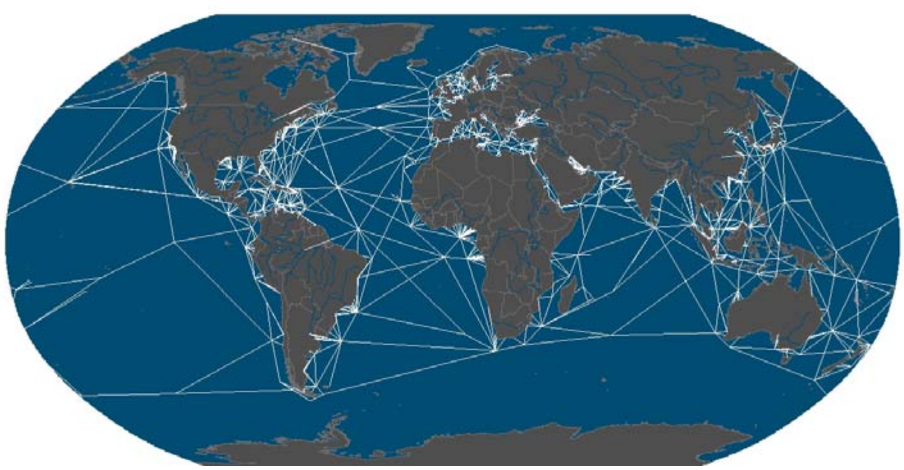

Fig. 2 The network of digitised tanker routes.

In order to produce meaningful and usable maps, it was necessary to route voyages through defined waypoints, rather than the widespread and actual distribution that would be expected along the world's shipping channels. This facilitated the accumulation of the individual voyages and subsequent calculations of traffic density and total oil transported along specific coastlines. The amount of oil transported between two waypoints was then summed to provide a schematic of the total amount of oil transported geographically by sea in one year as shown in fig. 3. The main benefit of processing the data in this format is that it can be then viewed and interrogated on any scale from global to port level.

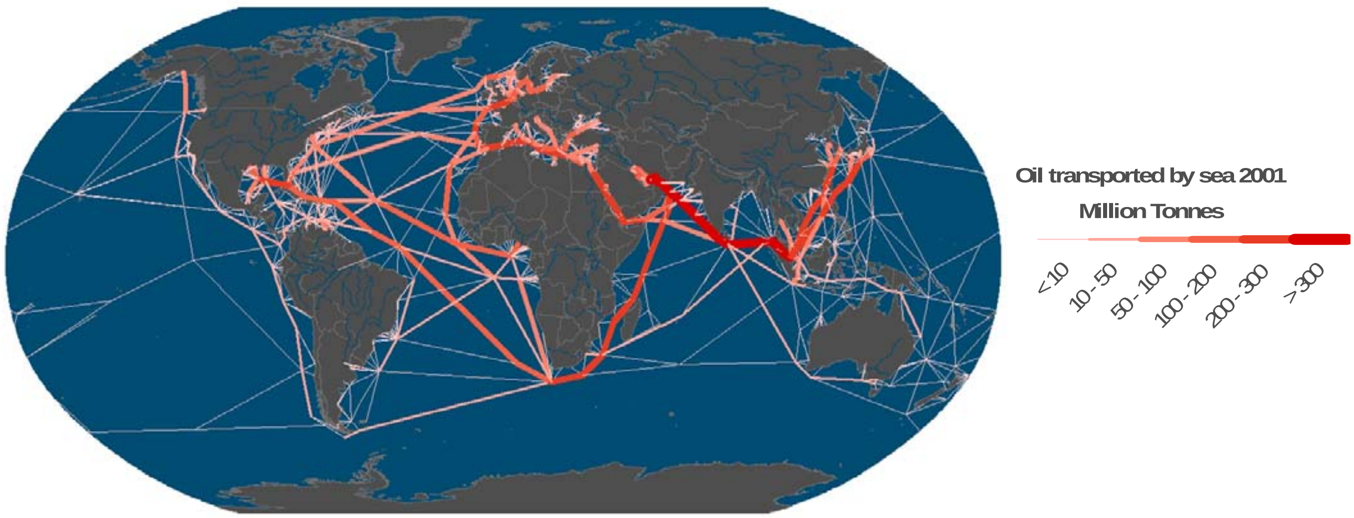

Fig. 3: Total amount of Oil Transported by Sea 2001

The process of digitising tanker voyage data was then repeated for the 2005 tanker voyage dataset. This enabled comparison and analysis of change in oil transported by sea over a 4 year period which in turn enabled an assessment of changing risk.

Analysis

By comparing 2001 and 2005 tanker voyage data it was possible to illustrate the sea areas in which there is the largest growth in total amount of oil transported and consequently growth in oil tanker traffic. Given that the Gross Tonnage of the world fleet increased between 2001 and 2005, most significant changes relate to increases in tanker movement as demonstrated in fig.4.

Figure 4 shows the shipping routes that witnessed a significant (> 25 Million Tonnes) increase in amount of oil transported along them between 2001 and 2005. Major changes within Europe are defined by large increases in oil transported in the Baltic mainly from the Port of Primorsk moving toward the English Channel and along the west coast of France and Spain. Further large increases are also visible from the Port of Novorossiysk transiting through the Black Sea and the Bosporus Strait into the eastern Mediterranean and along the south east coast of Italy.

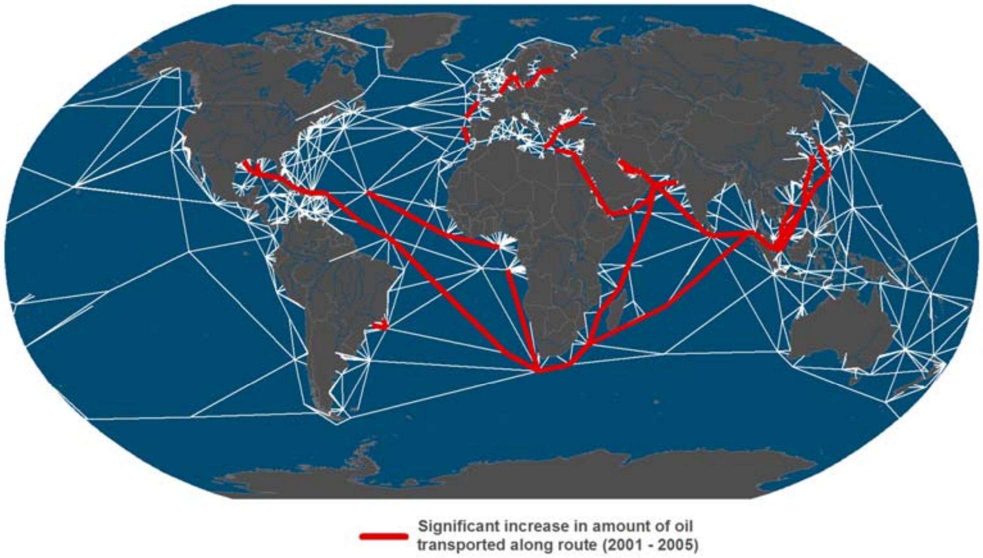

Fig.4 Schematic showing routes along which there is a significant increase in amount of oil transported by sea 2001 – 2005.

The Middle East exports vastly more oil that any other region, between 2001 and 2005 the Straits of Hormuz witnessed the largest increase of oil transported by sea. These exports mainly passed along the coasts of Oman and Yemen toward the Suez Canal via the Red Sea, along the west coast of Africa toward the US Gulf, or along the East coast of India toward the Far East mainly via the Malacca Strait. Fig. 5 shows the change in destination of this increased export capacity.

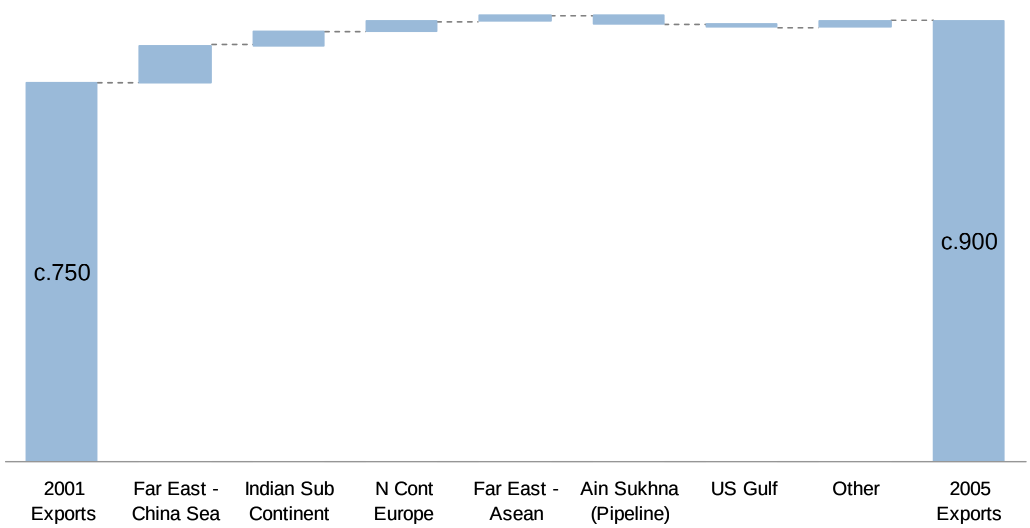

Fig. 5 Change in Exports from Middle Eastern Ports.[1]

1. Oil Export Quantities deduced from LMIU Apex Datasets 2001 & 2005, comprising of voyage details of tank vessels $\geq$ 10,000 DWT (with the omission of Handy-Size product tankers.)

Fig 4 also illustrates the destinations of the increased production in the WACAF (West and Central Africa) region; this has led to large increases in traffic along the coastlines of the WACAF countries toward the Far East, which in turn has added to the increased amounts of oil transported around the coast of South Africa. Exports from the WACAF region have also increased traffic along the Southern United States *en route* to the US Gulf Ports.

Implications of increasing tanker traffic.

The combination of data on, the increase in amount of oil transported by sea between 2001 and 2005, with global tanker spill data for the same period demonstrates the areas where the risk of oil spills is increasing.

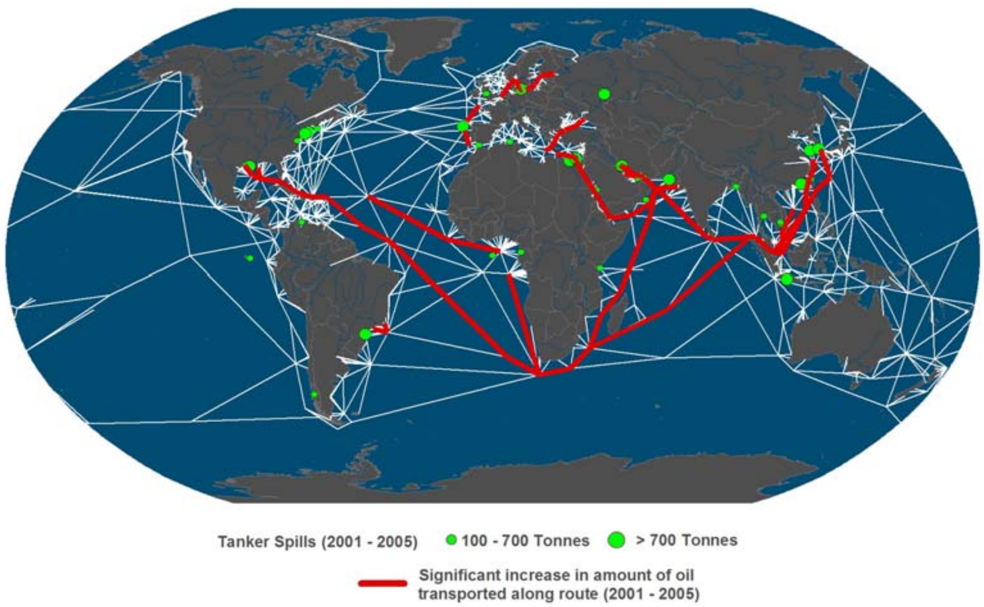

Fig .6 Schematic showing areas of significant increase in oil transported by sea from 2001 to 2005 including location of tanker spills for the same period.

Studies previously carried out by ITOPF found that major spills (defined as greater than 1,000 tonnes) are usually associated with serious casualties such as groundings, collisions, structural failures and fires & explosions and typically occur offshore or outside ports. Therefore many countries at risk are not large oil importers and the threat is therefore often related to traffic in transit to other regions. Fig.6 clearly shows the countries along whose coastline tanker traffic in transit has greatly increased since 2001.

Intermediate spills (defined as between 100 and 1,000 tonnes) usually occur in ports or their approaches, either during routine oil transfer operations such as loading, discharging and bunkering or as a result of less severe casualties such as low-energy collisions, groundings and berthing accidents. The large differences in risk for intermediate spills appear strongly related to the amounts of oil imported and exported by individual countries/ports, rather than to the region as a whole. Some of these high risk areas are summarised in the table below, which lists a number of the world's major oil import and export ports, as well as ports that have experienced major increases in amount of oil loading and discharging between 2001 and 2005, where risk of spills are increasing.

Major Oil Export Ports 2005	Major Oil Import Ports 2005	Large increase in Oil Exports (2001 – 2005)	Large Increase in Oil Imports (2001 – 2005)
Juaymah Terminal (Saudi Arabia)	Rotterdam (Netherlands)	Primorsk (Russia)	Port de Bouc (France)
Ras Tanura (Saudi Arabia)	LOOP Terminal (USA)	Novorossiysk (Russia)	Sao Sebastiao (Brazil)
Kharg Island (Iran)	Singapore	Al Basra Terminal (Iraq)	Port Arthur (USA)
Jebel Dhanna Terminal (UAE)	Ain Sukhna (Eygpt)	Mina al Ahmadi (Kuwait)	Mai-Liao (Taiwan)
Novorossiysk (Russia)	Houston (USA)	Marlin Field (Brazil)	Sikka (India)
Sidi Kerir (Egypt)	Ulsan (South Korea)	Kharg Island (Iran)	Ningbo (China)
Al Basra Terminal (Iraq)	Chiba (Japan)	Arzew (Algeria)	Marcus Hook (USA)

Table 1: Major oil import and export ports in 2005, including the ports that experienced significant increase in oil imports and exports from 2001 to 2005.

In the same way that we were able to visualise change in amounts of oil transported along various coastlines (fig.4) it is also possible to visualise change in cargo type, vessel size, exports and imports by port, country and region which all have their own risk implications but are beyond the scope of this demonstration and more suitable for region-specific studies.

Analysis of changing risk due to Russian exports by sea.

During the years covered in this study (2001 – 2005) Russia has consistently increased oil production and has become the second largest producer of oil after Saudi Arabia (see fig. 7.) There has also been much change in how Russia exports its oil, most noticeably through the large increase via the Ports of Primorsk and Novorossiysk.

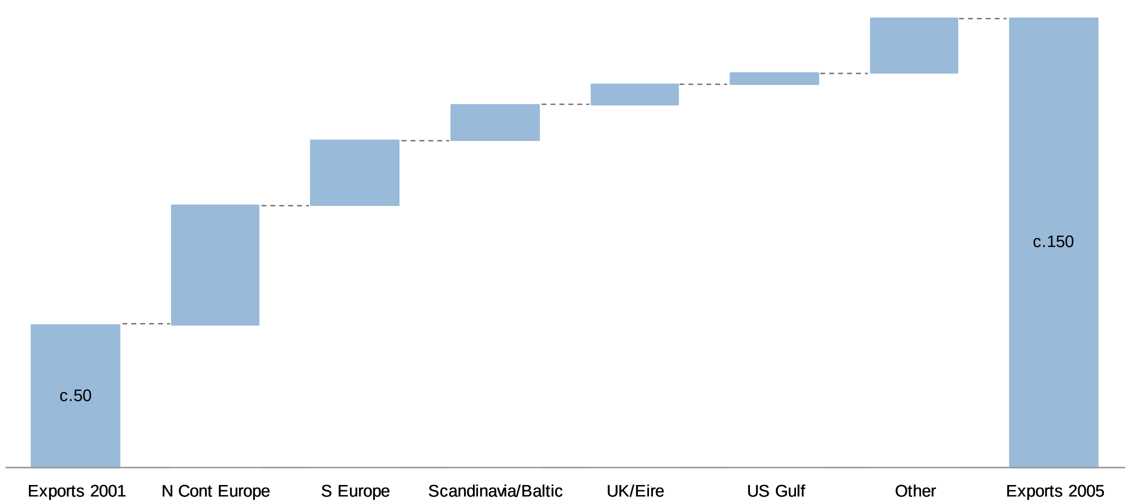

Fig. 7 Change in oil exports from Russian Ports 2001 – 2005.[1]

The Baltic acts as a key transit route for Russian exports to Northern Europe and beyond. The Russian crude oil pipeline system is connected to three ports on the Baltic Sea: Latvia's port of Ventspils, Lithuania's Port of Butinge and the Russian Port of Primorsk, which since its completion in 2002 exports the largest share, increasing quantities transiting through the Gulf of Finland, simultaneously causing a decrease in exports from the Port of Ventspils and Butinge.

The Gulf of Finland is both narrow and rich in environmentally sensitive areas (see fig. 8), increasing volumes of oil in transit in these often ice-infested waters contribute to this being one of the most significant increased risk areas.

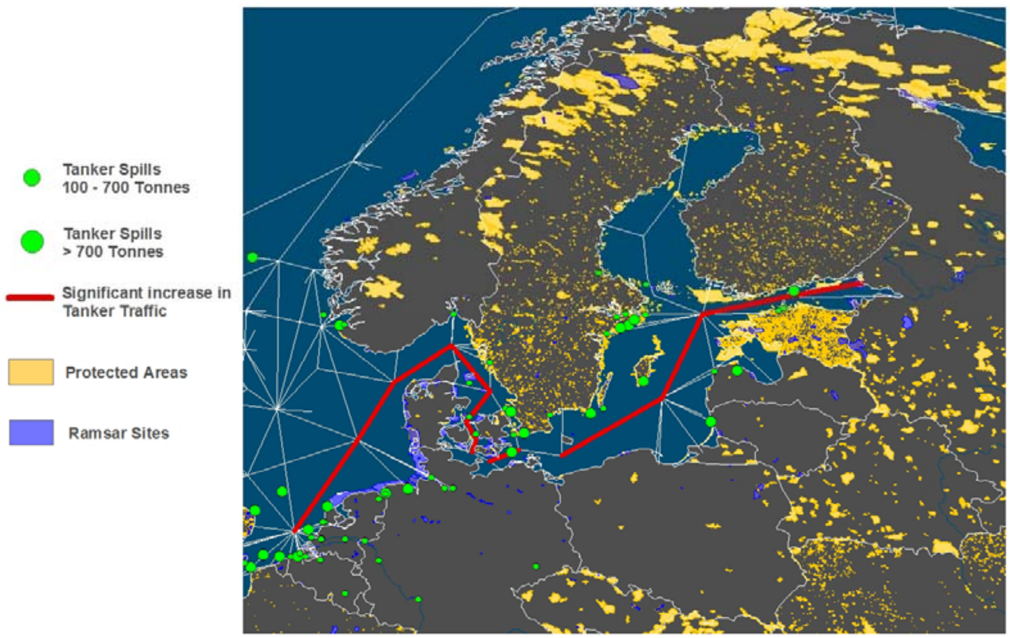

Fig.8. Map showing significant increase in oil transported in North-East Europe, including locations of historical spills (1974-2006) and sensitive areas. (Data on Protected Areas and Ramsar Sites from UNEP-WCMC)

The Russian port of Novorossiysk has also experienced an increased amount of exports from 2001 to 2005 (see fig. 9.) This is in part due to the CPC (Caspian Pipeline Consortium) crude pipeline system coming online late 2001 transporting crude oil from the Caspian region. Volumes of oil and traffic transiting the Black Sea and through the Bosporus and Dardanelles have significantly increased; these areas are both environmentally and economically sensitive. The Bosporus, which at its narrowest point is only 0.5 miles wide, has suffered a number of large tanker spills in the past. Increased traffic in the region will contribute to an increased risk of oil spills.

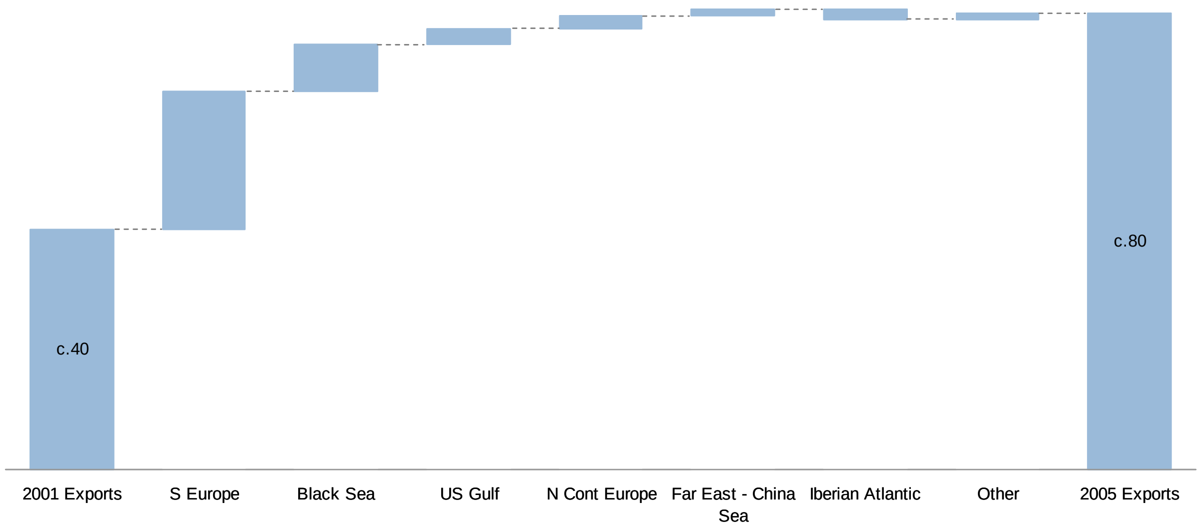

Fig.9 Change in oil exports from Novorossiysk 2001 – 2005.[1]

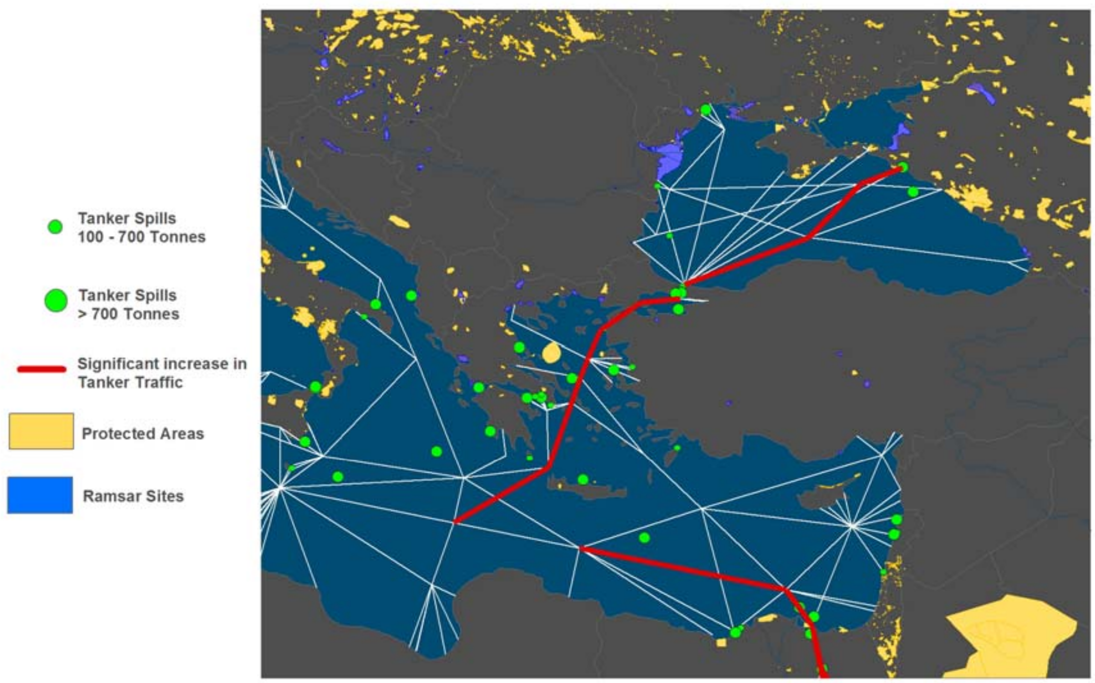

Fig.10. shows the significant increase in oil transported in the Black Sea and East Mediterranean including locations of historical spills (1974-2006) and sensitive areas. (Data on Protected areas and Ramsar sites from UNEP-WCMC)

Other Russian export ports include Murmansk in the Barents Sea, and Sakhalin Island in the Sea of Okhotsk. In the period covered by this study, exports from these areas by sea were minimal and therefore change in risk was not significant. Development plans for Sakhalin include transporting oil by pipeline to the export terminal of De-Kastri on the

Russian mainland, which will then be transported to world markets via the Talat Strait and Sea of Japan, though the Korea or La Perouse Straits. Increased tanker traffic in this relatively harsh environment will lead to a significant rise in risk of marine oil spills. Furthermore proposals are in place for a pipeline to service the Far East of Russia i.e. Nakhodka which again would contribute to increased tanker activity in the Sea of Japan.

Conclusion

Visualising the datasets using a GIS has proved very useful in this study, in particular for displaying the spatial and temporal distribution of risk. It is a valuable tool in that it facilitates the addition of site specific datasets as well as having the ability to interrogate the data on a variety of levels, from a specific port to worldwide.

Limitations exist in the graphic simplification of tanker movements. Because many factors influence the route a particular tanker will travel, assumptions based on background research and industry knowledge have to be made on the most likely path a vessel would travel. The addition of non-tank vessel traffic would also enhance any risk analysis. Nevertheless, the system, as presented, widens the scope, within which these datasets can be utilised, to the extent that it enables the data to be interactively viewed and manipulated.