NOWPAP MERRAC

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Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

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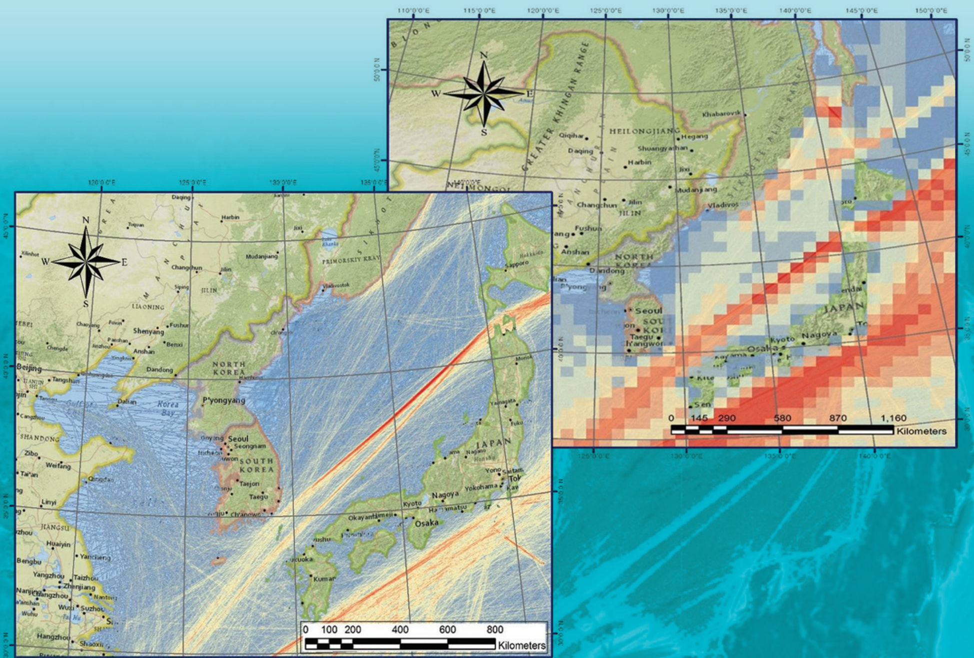
Risk Assessment of Oil Spill Incident:
Focusing on Likelihood Analysis in the NOWPAP Region



Regional Seas

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Foreword

MERRAC, the Marine Environmental Emergency Preparedness and Response Regional Activity Centre, is one of four Regional Activity Centres of the Northwest Pacific Action Plan (NOWPAP) which was adopted in 1994 as a Regional Seas Programme of the United Nations Environment Programme (UNEP) by the People's Republic of China, Japan, Republic of Korea, and Russian Federation. MERRAC is responsible for regional co-operation on marine pollution preparedness and response in the NOWPAP region.

With technical support from the International Maritime Organization (IMO), MERRAC is currently functioning as secretariat for the NOWPAP MERRAC Focal Points Meeting (FPM) and Expert Meeting, and Competent National Authorities (CNA) Meeting for the NOWPAP Regional Oil and HNS Spill Contingency Plan. The Centre is also carrying out other activities including the management of regional information system, organization of training courses and exercises, and co-ordination of research and development on the technical aspects of oil and HNS spill preparedness and response.

As one of major outcomes of MERRAC activities, the NOWPAP Regional Oil and HNS Spill Contingency Plan (RCP) and its relevant Memorandum of Understanding (MoU) were developed and officially came into effect after being signed by all NOWPAP member states. The purpose of the NOWPAP RCP is to provide an operational mechanism for mutual assistance through which the member states can co-operate during major marine oil and HNS pollution incidents in the region.

In order to provide practical and technical guidelines to promptly and effectively respond to major oil and HNS spill accidents within the framework of the NOWPAP RCP, it was agreed to carry out the series of MERRAC Specific Projects. As one of the Specific Projects, the 17th NOWPAP MERRAC Focal Points Meeting and 9th Competent National Authorities Meeting (2014) agreed the project on Risk Assessment of Oil Spill Incident: Likelihood Analysis.

The purpose of this project is to identify hot spot of oil spill incidents in risk in the NOWPAP region by collecting the information on historic spill records, vessel traffic and sources of oil pollution, and conducting statistical analysis using the collected information.

Through this MERRAC Specific Project, the technical report was developed by NOWPAP MERRAC with an external expert Dr. Choong-Ki KIM (Korea Environment Institute, KEI) who was contracted by MERRAC. MERRAC staff (Dr. Seong-Gil KANG, Dr. Jeong-Hwan OH, Ms. Siyeon LEE) finalized and edited the report with technical support of MERRAC Focal Points, NOWPAP Regional Co-coordinating Unit (RCU), and International Maritime Organization (IMO).

As a Director of MERRAC, I would like to thank MERRAC Focal Points and the expert for their support and contribution to finalizing this MERRAC Technical Report.

Seong-Gil KANG

Director of MERRAC

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Chapter 1. Introduction

Risk assessment is the first component of the four-stage contingency plan for oil spill preparedness and response (ITOPF, 2012), which can be used to develop and implement risk-based planning for oil spill incidents.

Northwest Pacific Action Plan (NOWPAP) Maritime Environmental Emergency Preparedness and Response Regional Activity Centre (MERRAC) has conducted several projects related to risk assessment, which includes:

- Vessel traffic conditions (e.g., vessel routes, age, size, etc.) analyzed in 1997 (NOWPAP MERRAC 2016a).
- Sensitivity mapping to collect information on existing and planned ESI maps (NOWPAP MERRAC 2005).
- Regional mapping of vulnerable resources (IMO, 2010).
- Information on oil and HNS spill incidents (NOWPAP MERRAC 2016b, 2016c).

The information on vessel traffic, ESI maps, and spill incident are the essential components of oil spill risk assessment. The information, however, is mostly outdated and not yet combined together to produce damage map in the NOWPAP region.

For a better preparation and responses to spill incident in the NOWPAP region, the 17th MERRAC Focal Points Meeting (FPM) agreed on conducting a specific project, Risk Assessment of Oil Spill Incident. The main objectives of this project includes

- Identifying hot spots of oil spill incidents in risk
- Producing oil spill probability map to help determine the response strategy
- Implementing risk-based planning

This is preliminarily results of the risk assessment of oil spill incidents focusing on likelihood analysis of oil spill incidents in the NOWPAP region.

Chapter 2. Review of Oil Spill Risk Assessment

Oil spill risk assessment is comprised of three components, including likelihood analysis, vulnerability analysis, and consequence assessment (Figure 12). A full spectrum of risk assessment has been conducted in EU, the United States, etc. In particular, the oil spill risk assessments of the Baltic Sea (BRISK, 2013), North Sea, Gulf of Mexico (French McCay, 2004), and Alaska (NOAA, 2014) have played a major role in establishing and implementing strategies for oil spill preparedness and response (BRISK, 2012; COWI, 2012).

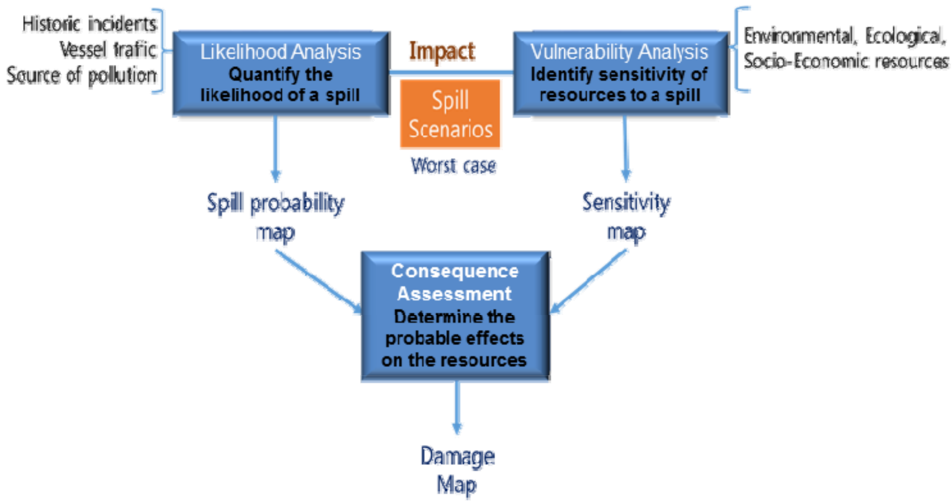

Figure 1. Flow chart of risk assessment.

2.1. Likelihood Analysis

The first step of the risk assessment is to quantify the likelihood of a spill incident based on the information on historic spill records, vessel traffic, and sources of oil pollution. In general, there is a high risk where there are a lot of vessel traffic, where traffic routes intersect intensively and where coastal terrain is complex due to the high incidence of pollution accidents (BRISK, 2012; COWI, 2012). Route of vessel and traffic volume can vary depending on socio-economic and political circumstances, which the risk of marine pollution by region can also be changed. To predict those changes, we need to predict the rate and scale of accidents considering the future route of vessel and traffic volume, and to evaluate the potential oil pollution risk by region. In particular, it is necessary to predict the risk by constructing a future shipping scenario in a region where a significant change in vessel operation in expected, such as opening of the Arctic route by global warming.

2.2. Vulnerability Analysis

Vulnerability analysis is an indicator of the potential impacts of pollutants on the environment, ecology, and socioeconomic resources, and it is evaluated by considering the importance of the sensitive resources, location, and seasonality as well as exposure, sensitivity and recovery from spilled oil. The vulnerability is evaluated to be higher as exposure to spilled oil is longer, sensitivity of resource is higher, and resource’s rate of recovery from the impact of spilled oil is slower. In the case of the Baltic Sea and the Arctic Ocean, vulnerability was highly evaluated in low water level areas, archipelago and coastal areas rather than routes with high density of vessel traffic. This indicates that coastal areas with more sensitive environmental, ecological and socioeconomic resources are more vulnerable to oil pollution. In addition, the seasonal changes in vulnerability need to be monitored because the vulnerability is relatively high in spring and summer compared to winter and fall (BRISK, 2012).

2.3. Consequence Assessment

The final step of risk assessment is to determine the probable impacts of spill incidents by combining both spill probability (the outcome of likelihood analysis) and vulnerability (the outcome of vulnerability analysis), and to produce damage map (Figure 1). As these risk assessment results can provide intuitive and objective information for priority management and in-depth study of hazard area, they are useful for the preparedness and response of marine pollution accidents. In particular, they can be utilized to develop strategies of oil pollution preparedness and response through scenarios based on oil pollution possibility, oil discharge and prevention method.

2.4. Oil Spill Preparedness and Response based on Risk Assessment

In Europe and the United States, oil pollution preparedness and response systems are well-prepared. The risk of the Baltic Sea was evaluated to be high in highly vulnerable coastal regions rather than in vessel routes with high risk of oil spill. The risk was also high in the case of medium-scale pollution accidents below 5,000 tons rather than large-scale ones. This suggests that the preparedness and response of medium-scale pollution accidents are as important as large disaster pollution accidents.

In the case of the Gulf of Mexico in US, a risk assessment was performed according to a control scenario of using mechanical recovery and oil treatment agents (French McCay, 2004). While using oil treatment agents were effective in reducing the impact on coastal and marine pollutions, they tended to worsen the level of pollution in seawater. The rate and scale of accidents in Alaska, US, between the present and 2025 was analyzed by taking into account the amount of vessel traffic, changes in type of oil being transported, and mitigation measures (NOAA, 2014). Maximum Most Probable Discharge and Worst Case Discharge were calculated for each region, and were connected to vulnerability to derive the risk assessment results for the current and future Maximum Most Probable Discharge and Worst Case Discharge by region. At present, the highest hazard area was in the southeastern part of Alaska, and in 2025, the risk of the Beaufort Sea area will be the highest. This information provides very useful information for developing Alaska's future control strategies.

The NOWPAP region is one of the areas with the highest risk of marine pollution in the world. However, it will be difficult to effectively counter large-scale pollution accidents of Tier-3 level because exposure and vulnerability combined risk assessment has never been performed. Recently, as the socioeconomic conditions of China, Korea and Russia have changed rapidly, the risk of marine pollution has changed in time and space. Risk assessment that reflects these changes should be carried out periodically, and a countermeasure system based on risk should be established. The longstanding cultural, political and historical trade-offs among the NOWPAP member states can be a major obstacle to close cooperation. However, risk assessment based on regional seas through MERRAC may help overcome these limitations and serve as a stepping stone for future-oriented cooperation.

Chapter 3. Likelihood Analysis of Oil Spill in the NOWPAP region

It requires lots of resources and data to conduct full spectrum of the risk assessment composed with likelihood, vulnerability, and impact analysis (Figure 1). Considering the limited timeline and resources, this research focuses on the first step, likelihood analysis, to identify the probable risk of oil spill incidents based on vessel traffic and historic spill incidents in the NOWPAP region.

3.1 Vessel traffic information

Several databases on vessel traffic information are available in the NOWPAP region, which includes World Meteorological Organization (WMO), Marine Traffic, and AIS data. Because each of these materials is different in characteristics and availability, there are certain advantages and disadvantages in using them in risk analysis.

<u>Voluntary Observing Ship Scheme</u>

WMO-Voluntary observing ship (VOS) is an international scheme, first developed 150 years ago, by which ships plying the various oceans and seas of the world are recruited for taking and transmitting meteorological observations. VOS metadata provides the location of ships, which are daily updated through the interface of the application by authorized users. Figure 2 and 3 are vessel density maps based on the 2005 VOS data, which shows shipping density in the NOWPAP region. The amount of vessel traffic was the highest along the route connecting the East China Sea, the Korea Str. and the Tsugaru Str., and the vessel density was also high along the seas of the southern part of Japan and Vladivostok, Russia.

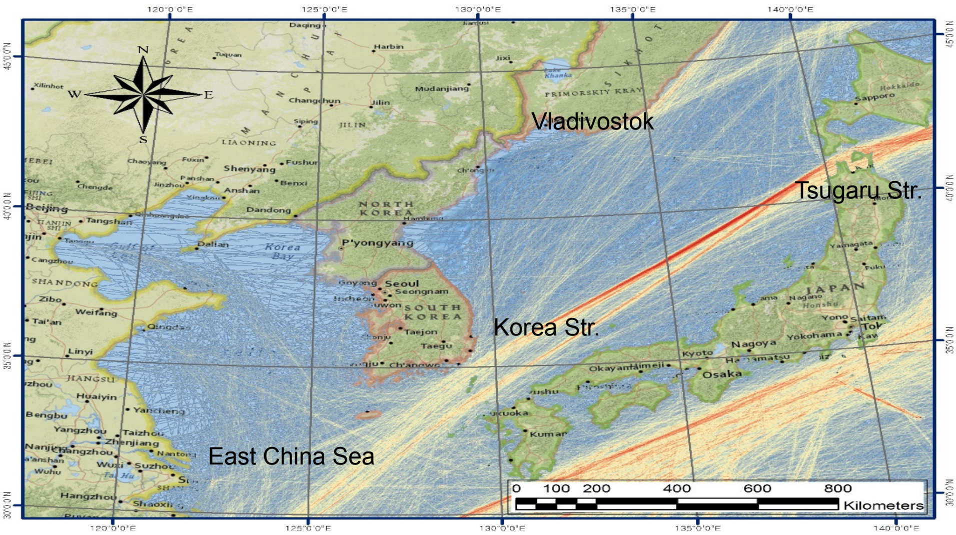

Figure 2. Shipping density map based upon 2005 VOS data (reanalyzed from Halpern et. al, 2008)

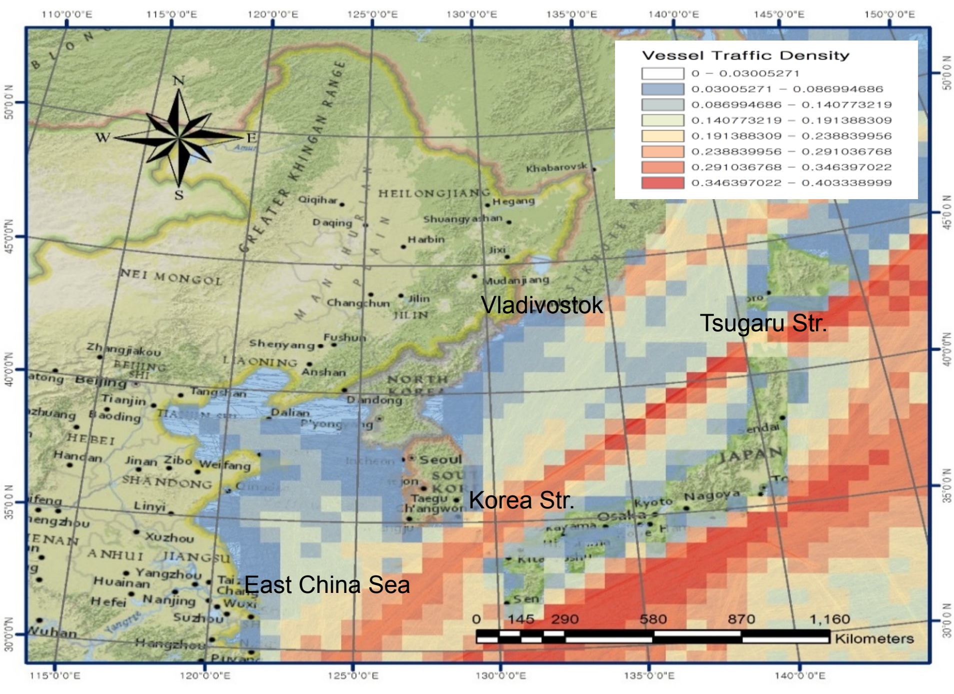

Figure 3. Relative vessel traffic density, ranging from 0.0 ~ 1.0, based upon 2005 VOS data (cell size: 0.5°x0.5°) (reanalyzed from Halpern et. al, 2008)

Analysis of VOS META data coming into NOWPAP region from 2006 to 2014 shows difference by year and the amount of vessel was the highest in 2014 (Figure 4). Most of these vessels were registered in Panama, Hong Kong, and Singapore (Figure 5). While VOS data are available free of charge, it does not provide enough information for risk assessment. For instance, statistically significant analysis could not be performed because the number of vessels passing through the NOWPAP region during 2006-2014 was very low (between 50 and 500). It is necessary to obtain more VOS data and analyze navigation information according to vessel type.

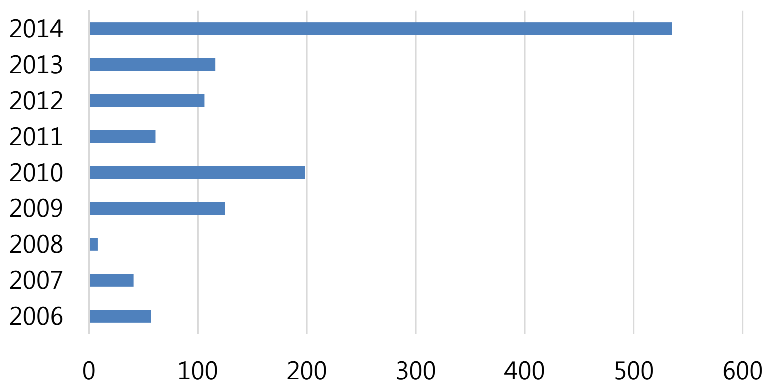

Figure 4. The number of vessels passing through the NOWPAP region.

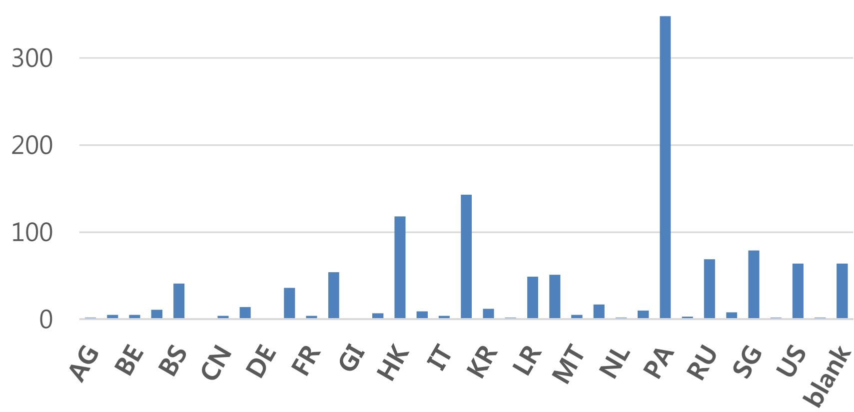

Figure 5. The number of vessels passing through the NOWPAP region by registration country. ***(AG=AFGHANISTAN, BE=BELGIUM, BS=BAHAMAS, CN=CHINA, DE=GERMANY, FR=FRANCE, GI=GIBRALTAR, HK=HONG KONG, IT=ITALY, KR= REPUBLIC OF KOREA, LR=LIBERIA, MT=MALTA, NL=NETHERLANDS, PA=PANAMA, RU=RUSSIAN FEDERATION, SG=SINGAPORE, US=UNITED STATES)***

Maritime Traffic Data

Maritime Traffic is part of an open, community-based project, and provides real-time and historic information to the public, about ship movements and ports, mainly across the coast-lines of many countries around the world (Figure 6). The data collection is based on satellite and terrestrial Automatic Identification System (AIS).

It shows the vessel traffic density in 2014 based on the Marine Traffic Data (Figure 6). The vessel traffic density is very high in the main routes connecting the continents and the coastal areas with lots of industrial activities.

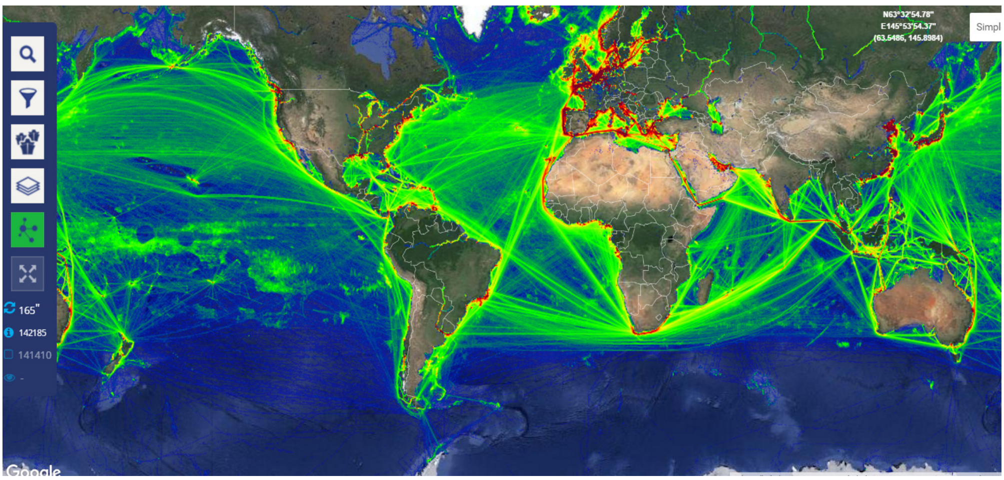

Figure 6. Global vessel traffic density map based on 2014 Maritime Traffic data (http://www.marinetraffic.com).

The NOWPAP region is one of the areas with the highest vessel traffic in the world (Figure 6). In particular, the density of vessel traffic is the highest in the east coast of China, the south coast of Korea, near Vladivostok in Russia, and the coast of Japan (Figure 7).

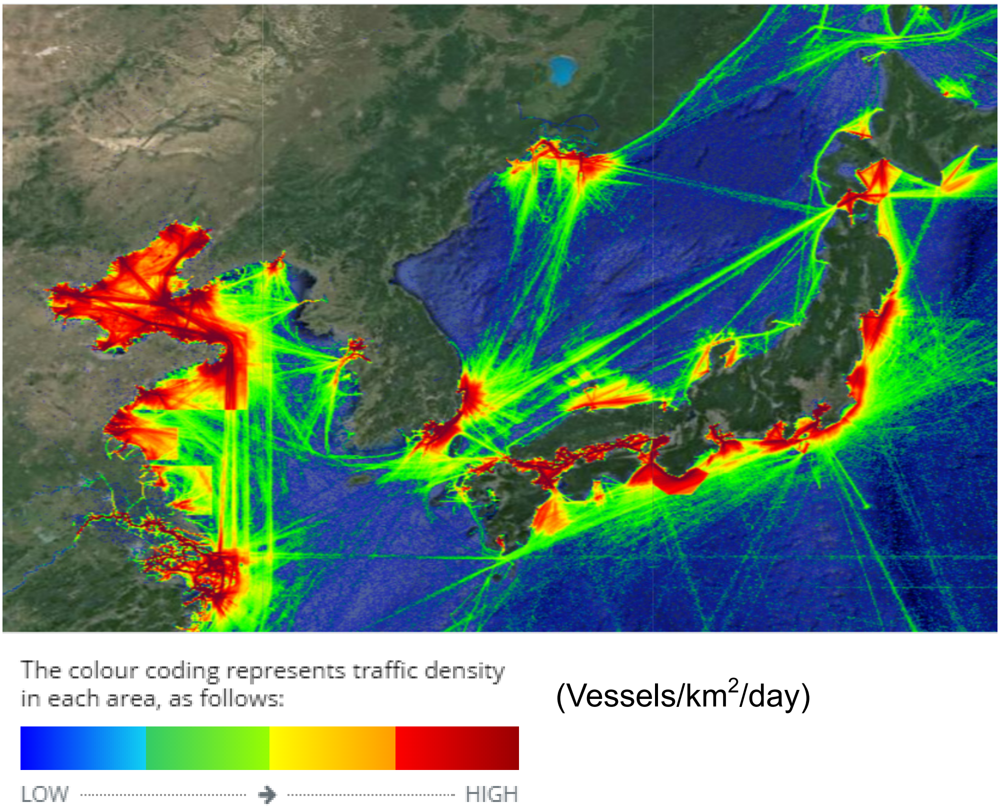

Figure 7. Vessel traffic density map in the NOWPAP region based on 2014 Maritime Traffic data (modified from http://www.marinetraffic.com)

As shown in Figure 6 and Figure 7, Marine Traffic data provide excellent information on vessel traffic to conduct the likelihood analysis, However, its availability varies according to the choices of vessel type and size, data source, number of vessel positions per day (Table 1). A total of 664,095,000 data points were available for vessel traffic information in 2014, which includes all vessel type and size, satellite and terrestrial AIS, and all vessel positions. In this study, we could analyze satellite AIS data (148,924 vessel positions) for all type of vessel bigger than 500 Gton including 8 positions per vessel and day for November 2014 due to limited budget.

Table 1. Vessel traffic data availability from Marine Traffic DB for 2014.

Vessel Type	Vessel Size	Source (Satellite, Terrestrial AIS)	Vessel Positions (#/day/vessel)	Number of Data Points
all	all	Satellite & Terrestrial AIS data	all	664,095,000
all	all	Satellite & Terrestrial AIS data	1	18,310,000
all	> 500 GTon	Satellite AIS data	1	213,889
all	> 500 GTon	Satellite AIS data	6	424,642
all	> 500 GTon	Satellite & Terrestrial AIS data	1	1,316,624
all	> 500 GTon	Satellite & Terrestrial AIS data	6	6,856,018
all	> 500 GTon	Satellite AIS (Nov. 2014)	8	148,924

The distribution of satellite AIS data in the NOWPAP region in November 2014 is shown in Figure 8a and the navigation density is shown in Figure 8b. The areas with intensive crossing of the route along with high vessel traffic tend to have a higher risk of accidents. To analyze it, we investigated the area with intensive crossing of the route based on the satellite AIS data (Figure 8c), and calculated the density (Figure 8d). A hotspot in which there is an intensive crossing of the route has appeared in a more limited area compared to the vessel traffic density. In particular, the hotspot of intensive route crossing is shown in the East Coast of Japan and the La Perouse Strait.

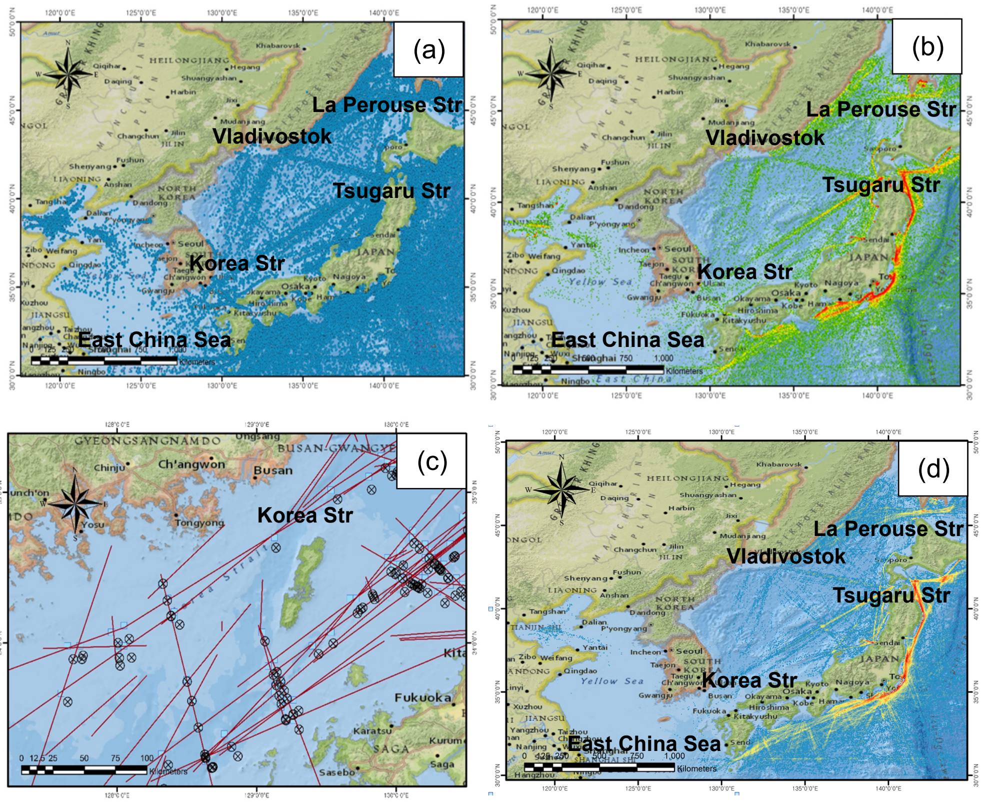

Figure 8. Marine Traffic data in the NOWPAP region, November 2014: (a) Satellite AIS data, (b) Vessel traffic density map (5x5 km^2), (c) Intersection of vessel traffic pathway, (d) Density of intersection of vessel traffic pathway (5x5 km^2).

The vessel traffic density (Figure 8) map for November 2014 does not show a good match with a full year density map (Figure 7). In particular, the November 2014 data could not identify the vessel traffic hot spots in the coasts of China, Republic of Korea and Russia. The dominant hot spots were only observed in east coasts of Japan in the November 2014 data. This result means that the November satellite AIS data consisting of 8 location information per day cannot sufficiently express the traffic information of NOWPAP region. Particularly, it might be very important to acquire terrestrial AIS data in order to understand vessel traffic information in coastal areas where there is a high risk of accidents. However, including the terrestrial AIS data will result in a dramatic increase in the amount of data as well as data acquisition cost, and therefore, it is necessary to build data collection criteria according to analysis objectives. In particular, data collection and analysis should be carried out considering the type and size of vessel, AIS data sources, number of vessel position, and spatial-temporal scope.

Comparison among historic vessel traffic information

This study compared three historic vessel traffic maps in the NOWPAP region, based on 1997 vessel traffic data, 2005 VOS data, and 2014 Marine Traffic data (Figure 9). The results of the 1997 analysis have accurately reproduced the hotspot of the vessel traffic in the NOWPAP region, but the spatial resolution is not precise and the traffic information on the east coast of Japan was not analyzed (Figure 9a). The 2005 VOS data has low spatial resolution and is unable to reproduce the hot spots near the coast of China including Bohai Bay (Figure 9b). On the other hand, the Marine Traffic data provides much more detailed information spatially (Figure 9c). In particular, it shows precisely the hotspots of the coastal areas in China, Korea, Japan, and Russia, and it can be used to evaluate the risk of marine pollution in the NOWPAP region. Furthermore, analyzing the point where the vessel route crosses intensively can be useful for risk assessment. Therefore, finer and more recent vessel traffic data should be analyzed for better information on vessel traffic hot spots in the NOWPAP region.

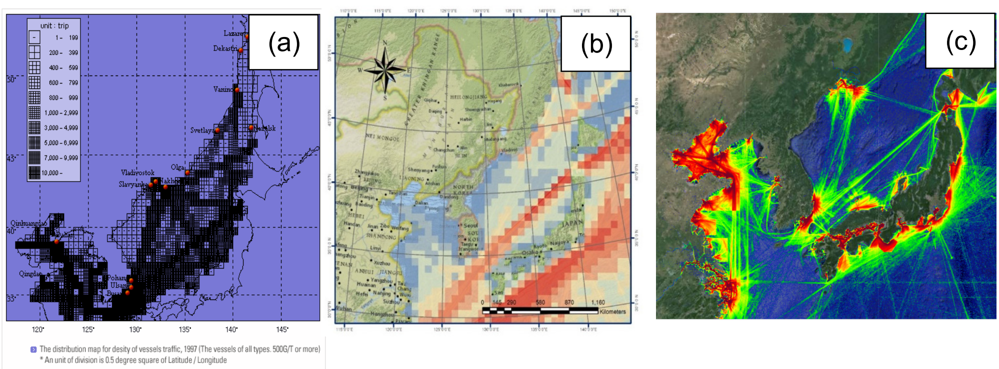

Figure 9. Historic vessel traffic map in the NOWPAP region, based on (a) 1997 vessel traffic data (NOWPAP MERRAC 2016a), (b) 2005 VOS data, (c) 2014 Marine Traffic data (http://www.marinetraffic.com).

In recent years, the number of services that provide vessel type, ports of arrival and departure, navigation speed, and vessel route forecast information in real time has increased (Figure 10, http://www.marinetraffic.com). We can perform real-time risk assessment using this data, and it can be used to establish response against marine pollution accidents more effectively. Vessel traffic information including both real-time and historical data can be used for

- Predicting vessel traffic pathways contributing to cope with critical oil spill incidents
- Statistical analysis of vessel traffic with applications in oil spill response research
- Designing models for the spotting of the origin of a pollution
- Cooperating with institutes dedicated in the protection of the environment

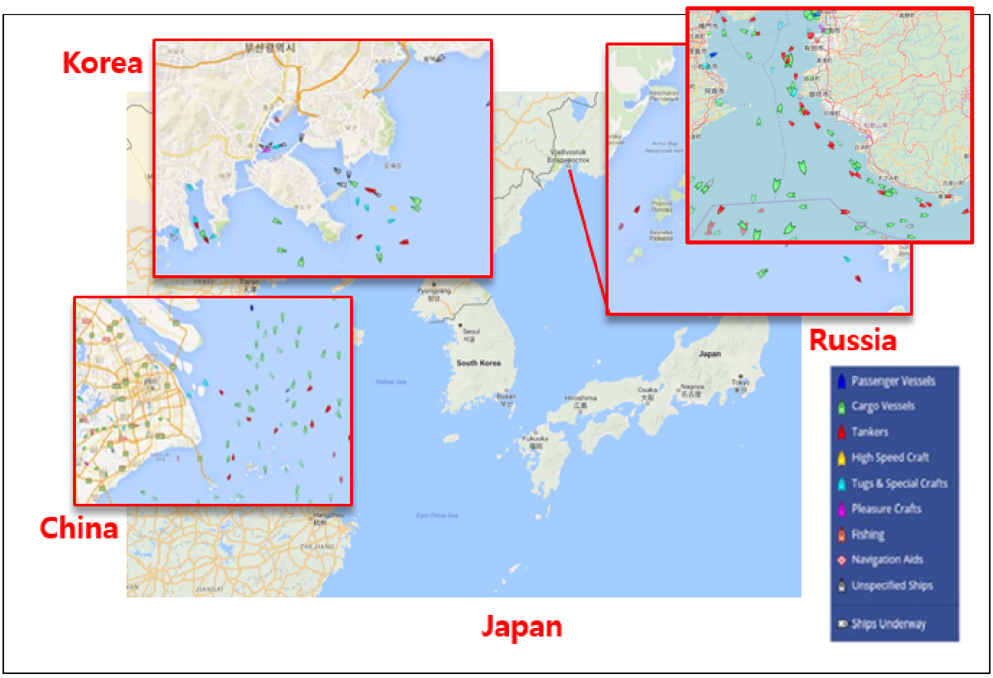

Figure 10. Real-time Maritime Traffic data in the NOWPAP region (modified from http://www.marinetraffic.com).

3.2 Statistics of oil & HNS spill incident between 1990 and 2015

As a routine task, MERRAC has collecting information on Oil and HNS spill incidents over 10 tones, and is maintaining its Data Base (NOWPAP MERRAC 2016b and 2016c). In an average, 11 and 2.4 spill incidents were occurred for oil and HNS in the NOWPAP region, respectively (Figure 11). Tanker, oil tanker and chemical tanker were mostly responsible for the oil and HNS spill incidents in the NOWPAP region (Figure 12). Cargo vessel had the largest number of accidents but the amount of oil spill was not bigger than 5000 tons.

Year	HNS	Oil	Total
1990		5	5
1991		5	5
1992	1	7	8
1993	1	7	8
1994	1	6	7
1995	2	13	15
1996	4	9	13
1997	3	10	13
1998	1	7	8
1999	1	5	6
2000	4	8	12
2001	1	13	14
2002	3	25	28
2003	1	17	18
2004	4	18	22
2005	4	24	28
2006	1	14	15
2007	3	20	23
2008		8	8
2009	5	7	12
2010	3	16	19
2011	4	7	11
2012	1	12	13
2013		11	11
2014		11	11
2015		1	1
Total	48	286	334

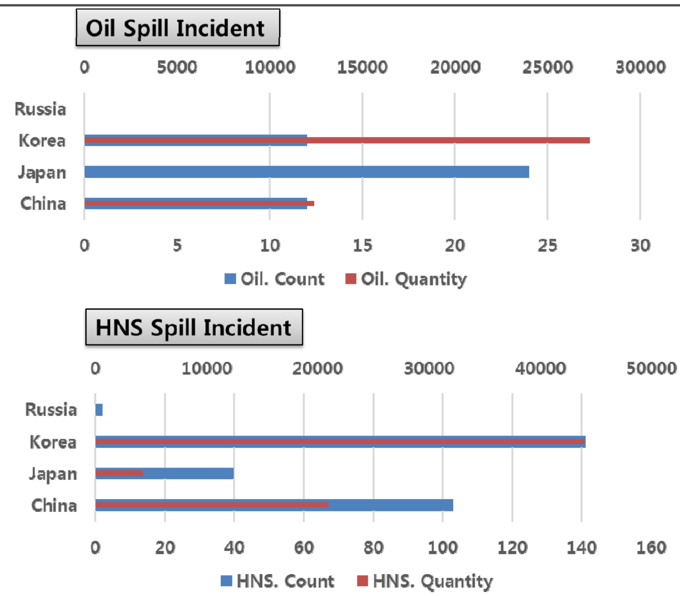

Figure 11. Statistics of oil & HNS spill incidents between 1990 and 2015

Type of ship	Count	Quantity(Tonnes)
Barge	4	245
Barge /Waste Oil Storage	1	68.4
Barge for dredge	1	164.6
Bulk cargo ship	1	20.33
Bulk Carrier	13	1266.18
bulk chemical carrier	8	3765
Cargo vessel	58	6276.574
Chemical carrier	3	89.6
Chemical tanker	35	22786.58
Container vessel	14	2780
Engineering ship	2	75
Fish carrier	1	94
Fisher boat	4	81
Fishing vessel	29	657.7
General Cargo	23	1538
Ground Facility	2	250
LPG tanker	3	50
Non-Tanker	17	4454.8
Oil Barge	4	384.83
Oil Tanker	42	23907.18
Ref. Carrier	1	30.1
Research	1	85
Sand Carrier	1	11.5
Special purpose vessel	2	203.7
Tanker	40	36287.6
Towing vessel	1	15.8
Tug Boat	4	70
Work boat	1	11.5
Unknown	16	3088
Passenger ship	2	314
Total	**334**	**109071.974**

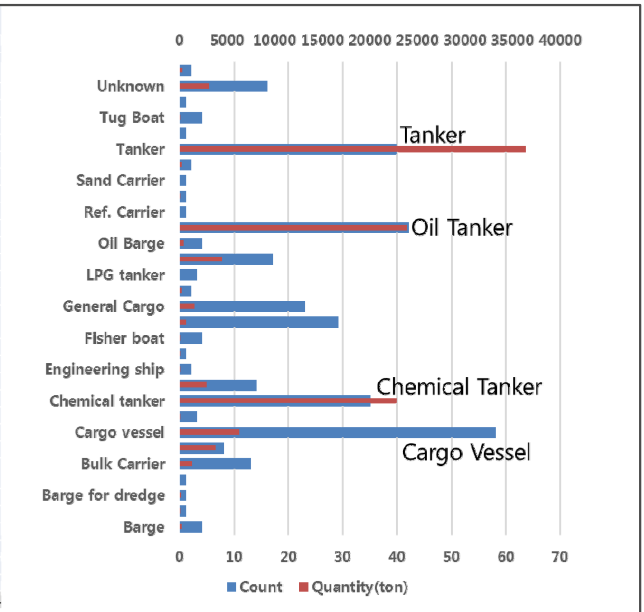

Figure 12. Statistics of oil & HNS spill incidents between 1990 and 2015 based on ship type.

Figure 13 and Figure 14 show the spatial distribution of oil and the HNS spill incidents. In the case of an oil spill, 11-26 accidents occurred in the Busan area on the south coast of Korea and 7-10 accidents occurred each in Yeosu and Gyeonggi Bay (Korea), Tsingtao and Shanghai (China) (Figure 13). Another 1-2 accidents occurred in Bohai Bay, the coast of Japan and Vladivostok. HNS cases occurred in more limited areas than oil spills. 3 HNS incidents occurred in Yokohama (Japan), 4-6 cases each in Kobe (Japan) and Busan (Korea). In addition, 1-2 cases have been recorded in the south and west coasts of Korea, near Shanghai, China, and the coast of Japan. In general, compared with Korea and China, much less amount of oil and HNS was spilled in Japan and Russia.

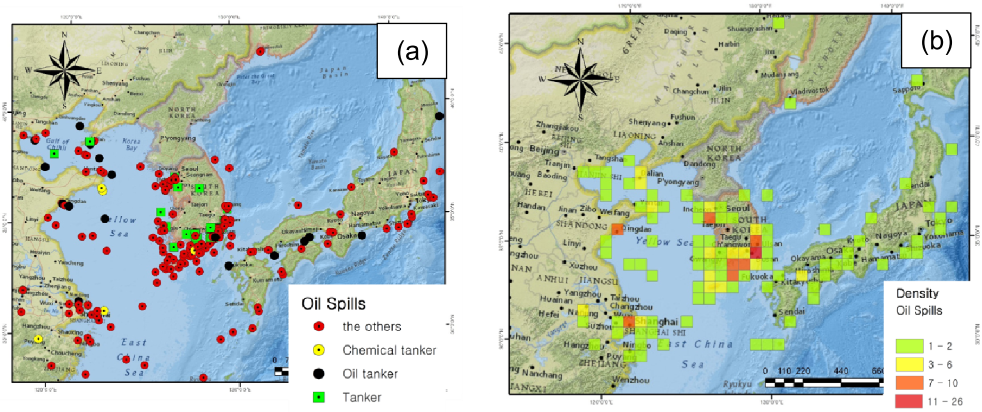

Figure 13. The location of oil spill incidents by ship type (a), and the density map of oil spill incidents (b) in the NOWPAP region.

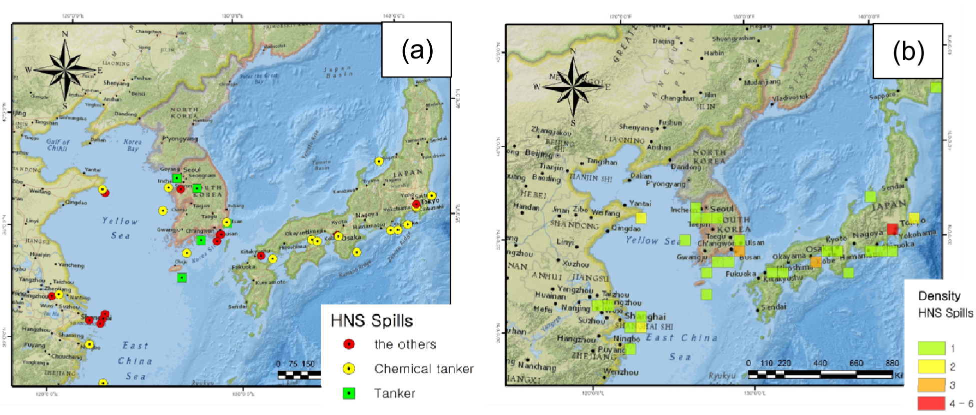

Figure 14. The location of HNS spill incidents by ship type (a), and the density map of HNS spill incidents (b) in the NOWPAP region.

3.3 Overlay analysis combining both vessel traffic and spill incidents

The overlay analysis shows a good link between vessel traffic and spill incidents in the NOWPAP region. Most oil and HNS spill incidents were occurred in the high vessel traffic area in China, the Republic of Korea, Japan, and Russia (Figure 15). Particularly, in the south coast of Korea, Shanghai and Bohai Bay of China, the coast of Japan, and Vladivostok, Russia, vessel traffic density was the highest and oil and HNS spill incidents occurred the most.

To access the probable risk of oil and HNS spill incidents in the NOWPAP region, it is necessary to find a quantitative relationship between vessel traffic and spill incident data. For a statistical analysis, we used a portion of November 2014 data (Figure 8), and these data could not represent the actual traffic density information as shown in Figure 15. Because of this limited information, we could not proceed the quantitative analysis.

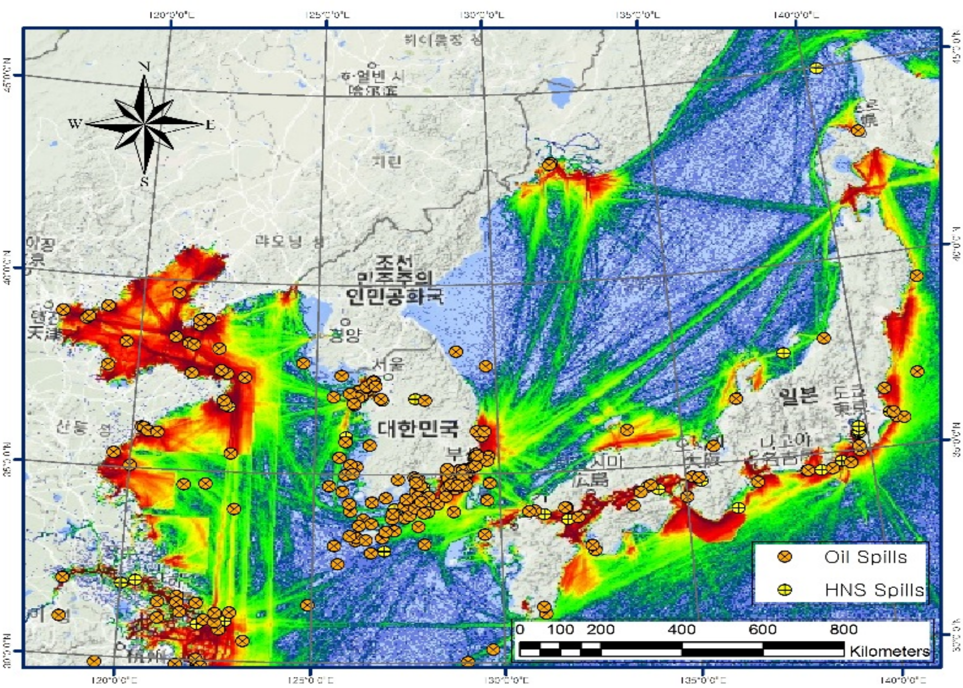

Figure 15. Vessel traffic density (2015) overlaid with oil and HNS spill incidents between 1990 and 2014.

Chapter 4. Summary and discussion

According to the 17th NOWPAP MERRAC FPM, a specific project on risk assessment of oil spill incident was conducted for a better preparation and responses to spill incidents in the NOWPAP region. Among the three components of risk assessment including likelihood analysis, sensitivity analysis, and consequence assessment, this study focuses on the first step, likelihood analysis, to identify the probable risk of oil spill incidents base on vessel traffic and historic spill records.

First, various types of vessel traffic data was analyzed. VOS METADATA for vessel traffic are freely available, but they provide very limited information in the NOWPAP region. The Marine Traffic provides very high resolution vessel traffic data, which has enough information for risk analysis. The data, however, costs a lot and NOWPAP MERRAC needs a strategy to access the data. NOWPAP members are encouraged to share the AIS data of vessel traffic in near-real time, so that the risk analysis is feasible for oil and HNS spill incidents in near-real time.

This study found that most oil and HNS spill incidents were occurred in the high vessel traffic area. In particular, compared with Japan and Russia, much more amount of oil and HNS was spilled in coasts of Korea and China with complex shoreline and high ship traffic. These results indicate a qualitative relationship between vessel traffic density and spill incidents in the NOWPAP region.

For quantitative statistical analysis, the Satellite AIS data over 500 Gton in November 2014 was analyzed. About 664 million vessel traffic information is collected in Marine Traffic per year, among which 0.022% was used for analysis. Due to the limitations in collecting available data, the analysis results of the November 2014 could not accurately reproduce the traffic hotspots shown in the annual traffic density distribution. Because of this, we could not find the quantitative relationship. Therefore, NOWPAP MERRC needs to continue risk assessment in order to develop an algorithm to link quantitatively with the vessel traffic and spill incidents in the NOWPAP region, which is the key component to access the probable risk of oil and HNS spill incidents.

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NOWPAP MERRAC

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