Baltic Sea Case Study

A Practical Demonstration on the Use of the OpenRisk Guideline

Baltic Marine Environment Protection Commission

Response to spills

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Introduction

Pollution Preparedness and Response in the Baltic Sea

Only few of the around 300 maritime accidents which take place yearly in the Baltic Sea result in an oil spill, and mostly these are small releases with only local impacts. Nevertheless, from time to time larger spills occur, requiring international response actions to avoid significant damages to the environment. With the current traffic intensity and the size of modern ships, including tankers, it is also possible that a major spill could happen in the Baltic Sea area [1].

In order to prepare for major pollution accidents, the coastal countries around the Baltic Sea maintain and develop a high level of preparedness and response capacity (Figure A). Collaboration between states is implemented through a regional agreement on Pollution Preparedness and Response, operationalized by the Baltic Marine Environment Protection Commission (HELCOM) [2]. Further support is provided by the European Union (EU) through the European Maritime Safety Agency (EMSA). Preparedness is manifested by acquiring and maintaining necessary equipment, including specialized spill response vessels and surveillance aircraft. Collaboration also concerns commonly agreed regional procedures, which are trained in, e.g., joint annual BALEX DELTA exercises.

Due to the sensitivity of the Baltic Sea ecosystem, dispersants (chemical products which dissolve oil slicks to minuscule droplets) are not considered as a primary response measure for oil spills. Instead, the focus is on ensuring sufficient mechanical recovery capacity at sea (sweeping arms, skimmers and brushes), as well as booms, to be able to jointly collect the oil at sea, and stop large spills from reaching shorelines.

In addition to such capacity at sea, the countries of the Baltic Sea have recently developed joint response co-operation on the shore. This is necessary as in some cases it may not be possible to stop a larger spill from reaching shorelines. In such cases, international response from the shore may be necessary, involving beach booms, trucks, smaller vessels and volunteers. It may also include preparedness in handling large amounts of oiled wildlife, which might include threatened species.

OpenRisk project

Effective risk management for Pollution Preparedness and Response (hereafter, PPR) is an essential aspect for ensuring a clean marine environment, and for safeguarding other interests of coastal states, such as functioning power plants, tourism, and fishery. In the European Union (EU), national authorities are responsible for managing the risks in their jurisdictions. In addition, regional cooperation initiatives have been established between EU member states and neighbouring states to improve PPR over larger sea areas. In the context of these cooperation agreements, several regional risk assessment initiatives have been implemented, representing important milestones for establishing risk-informed PPR decision making processes [3, 4, 5, 6, 7].

Despite the progress made to date, several shortcomings have been identified in the existing practices in risk-informed decision making, including i) lack of transparency in the methodological basis of the tools used in the risk assessments, ii) lack of comparability of risk assessment results across geographical areas and over time, iii) high costs of implementing regional risk assessments and iv) challenges in implementing the risk assessment results, both in the member states and at regional cooperation level, especially when different authorities are involved.

The OpenRisk project addresses the above shortcomings by focusing on two aspects of effective risk management: i) providing guidelines for implementing regional risk management for PPR authorities, and ii) providing a set of open-access tools to facilitate transparency and comparability of risk assessments. These aspects of effective risk management are included in the OpenRisk Guideline for Regional Risk Management to Improve European Preparedness and Response at Sea [8], which is based on the ISO 31000:2018 standard [9] (here after, OpenRisk Guideline).

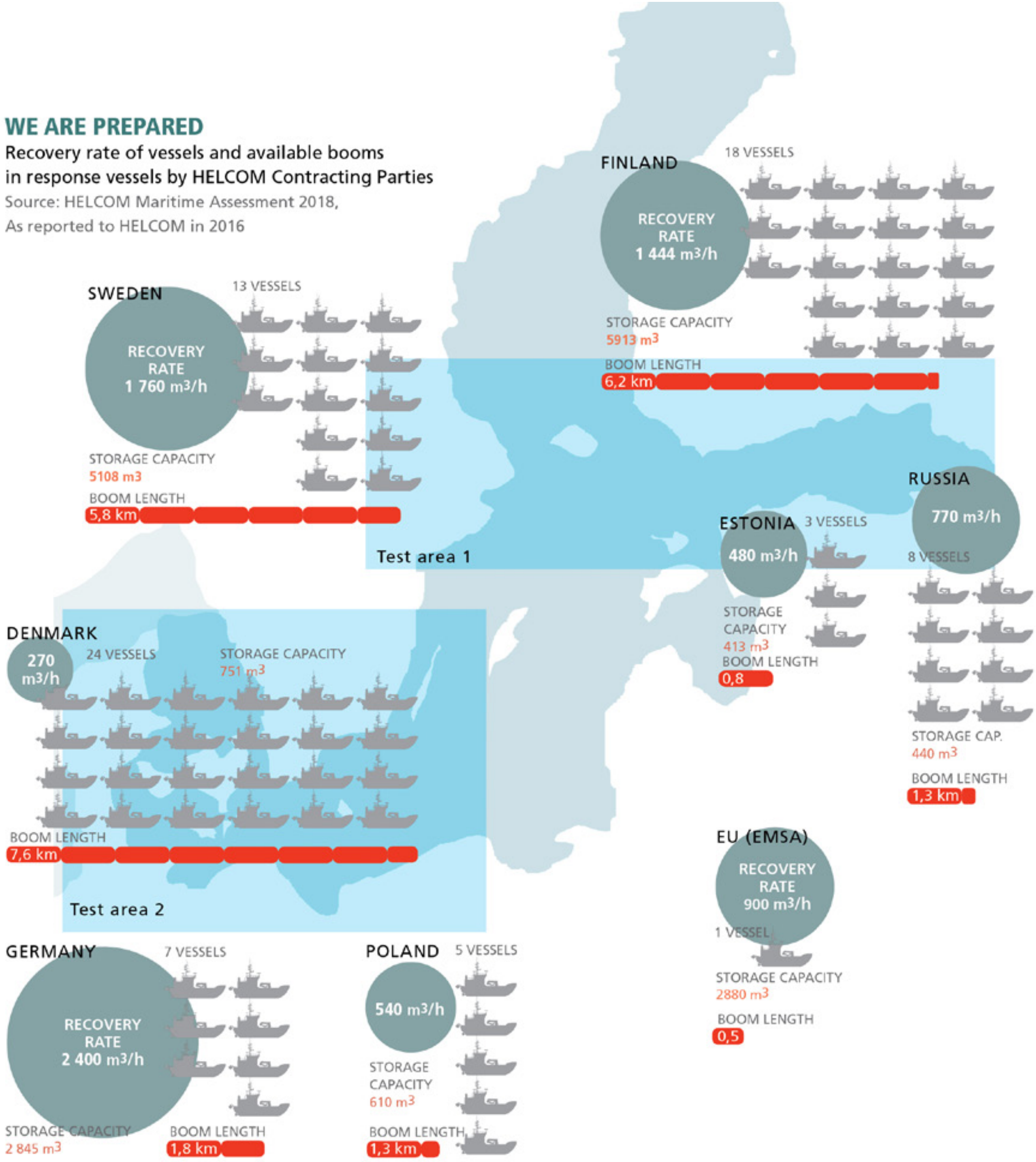

Figure A. Overview of the HELCOM countries' response capacity in the Baltic Sea and equipment of EMSA

The Baltic Sea case study

Overview of the contents

The aim of this Baltic Sea case study is to increase understanding of how the risk management process works in the context of Pollution Preparedness and Response. In this case study, it is demonstrated how to utilize the OpenRisk Guideline in practice for the HELCOM Response risk management. As such, this case study should not be considered as a complete risk assessment of the Baltic Sea area.

From the spatial point of view, this Baltic Sea case study focuses on two test areas, shown in Figure 1. Test area 1 includes the Gulf of Finland and the Archipelago Sea. Test area 2 covers part of the sea area south of Sweden, and the sea areas east of mainland Denmark: Øresund, Fehmarn Belt, Great Belt, and the Little Belt. These sub-areas of the Baltic Sea are selected as illustrative sites for the study, as there was sufficient information available.

This Baltic Sea case study is organized as follows. The next two sections in this chapter present the data sources and the limitations of this study. Thereafter, the different stages of the risk management process described in the OpenRisk Guideline, are handled sequentially. In Stage 1, the context of this study is established. The Stages from 2 to 4 present the results of the risk assessment part. Risk treatment is briefly discussed in Stage 5, and parallel activities are discussed in Section 6and conclusions in Section 7.

Data sources

The data used in this Baltic Sea case study consists of both quantitative and qualitative data sources.

The quantitative data sources are as follows:
— VTS Incident reports 2014-2016 [10, 11, 12, 13]
— HELCOM accident statistics 2014-2016 [14]
— HELCOM AIS data 2014-2016 [15]
— Finnish Meteorological Institute metocean data 2000

The qualitative information sources include the following:
— HELCOM Manual on Co-operation in Response to Marine Pollution - Volume 1 [16]
— HELCOM Manual on Co-operation in Response to Marine Pollution - Volume 3 [17]
— HELCOM Recommendation 28E/12 [18]
— HELCOM Recommendation 31/1 [19]
— Accident of the oil tanker *Baltic Carrier* off the Danish coastline in 2001 [20]
— Expert judgements of oil by the Finnish Environment Institute

Limitations

This Baltic Sea case study is limited to the HELCOM Response risk management. Maritime accident prevention is thus not in the focus of this study, and any links to prevention are considered exclusively in the communication and consultation activity of the risk management process in Chapter 6.1. In addition, this case study is limited to accidental oil spills of maritime traffic. Hence, hazards such as operational spills, illegal dumping, spills from offshore installations, and security issues are not included.

It should be also highlighted that the VTS Incident reports of the Russian Federation, Germany and the east coast of Sweden were not available for this Baltic Sea case study, which leads to certain limitations of the results for the Test areas, shown in Figure 1.

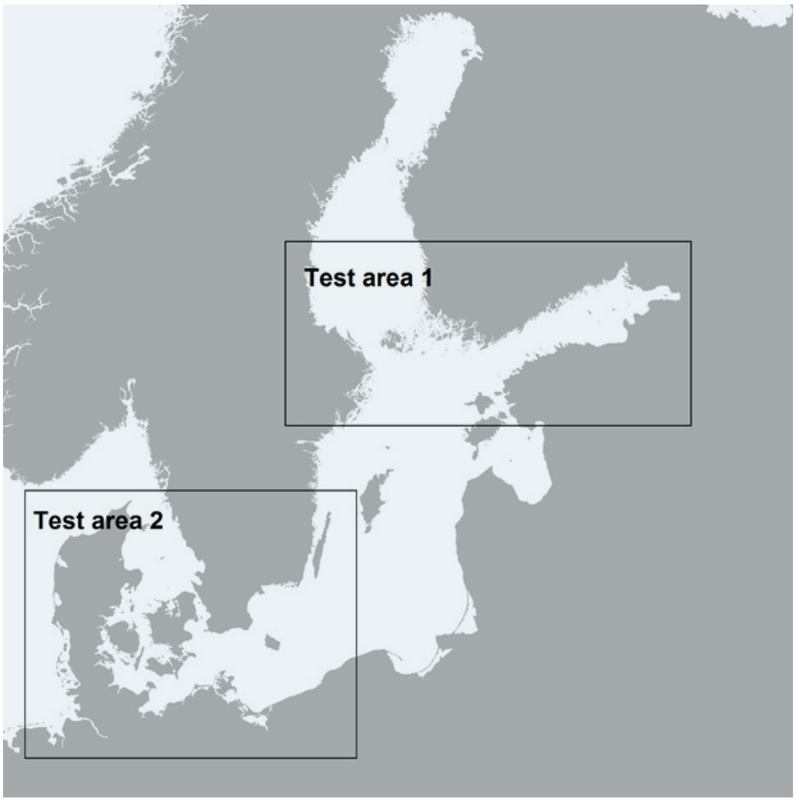

Figure 1. Definition of the geographical scope of the test areas used in the Baltic Sea case study

Stage 1. Establishing the context

In this chapter, the focus is on the first stage of risk management process: establishing the context. The purpose of this stage is to answer why this process is conducted, what are the questions that require answers, what decisions need to be made, and what is hoped to be achieved. This stage is used also to assess the available resources, tools, and competences for executing the risk assessment process.

This chapter provides firstly a brief examination of the external and internal context of the HELCOM Response risk management, including parameters and criteria for evaluating the performance. Secondly, it shows an example of how to set the scope for the PPR risk management process. This includes a set of risk management questions as well as a selection of the tools for answering these questions.

1.1. Defining the external and internal context

The risk management process is embedded in an external and an internal context, which is the environment in which the organization seeks to define and achieve its objectives. The changes in these contexts can have a positive or negative effect on the present risk level. In addition, they influence the decision context, and the data and methods used in risk assessment. Because of this, both of them should be examined and understood when establishing the risk management process.

The external context includes, e.g., political, legal, technological, economic and environmental issues. In this Baltic Sea case study, a brief examination of the external context of the HELCOM Response risk management is presented in Annex I, which includes topics such as:

- drivers and trends impacting oil spill hazard;
- governance, roles and accountabilities on oil spill prevention, detection and combat;
- perceptions of external stakeholders regarding the oil hazard.

The internal context concerns issues such as governance, guidelines, models adopted by the organization, capabilities, available resources and the like, which are also briefly examined in Annex I. This includes for instance the following topics:

- goals and objectives of the oil spill risk management, in particular HELCOM Recommendations 28E/12 and 31/1;
- standards, guidelines and models adopted by the organization, e.g. the HELCOM Manual on Co-operation in Response to Marine Pollution;
- national oil spill contingency plans;
- capabilities regarding oil spill preparedness, detection and combat.

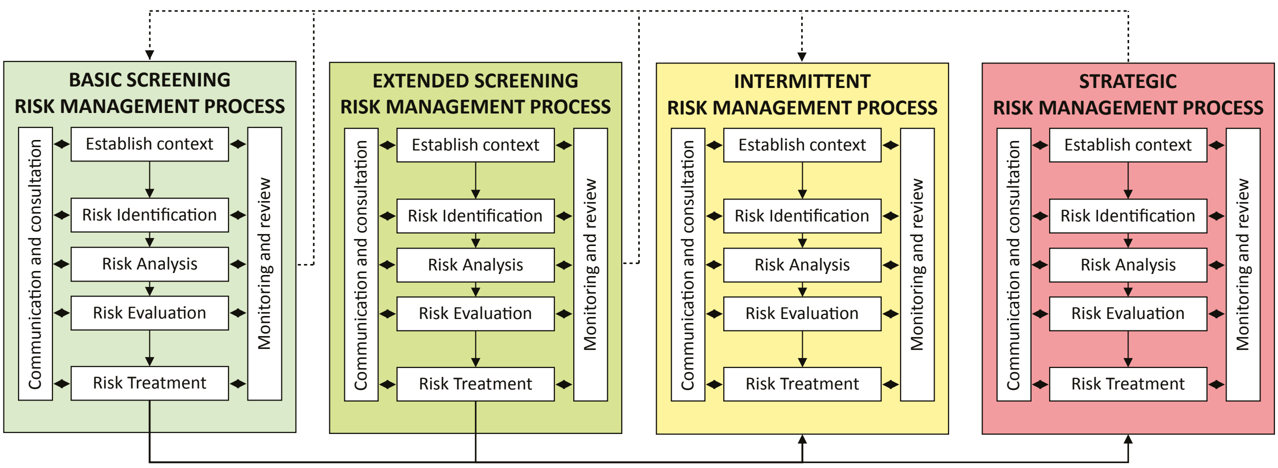

Figure 2. Relations between the Pollution Preparedness and Response risk management processes

1.2. Defining parameters and risk criteria

When designing the framework for managing risk, it is a common practice to define the basic parameters for evaluating the risk management performance, and to set out certain risk-acceptance criteria or decision making principles related to these parameters.

In this Baltic Sea case study, the basic parameters for evaluating the PPR risk management performance are medium-size and large-scale oil pollution incidents in different sea areas, derived from HELCOM Recommendations 28E/12 and 31/1. In addition, the recommendations concerning the response time limits are taken into account, see Recommendation 31/1. The risk-acceptance criteria is based on the risk assessment tool As Low As Reasonably Practicable Principle, see Section 1.4.

1.3. Setting the scope for risk management process

The OpenRisk Guideline includes three different risk management processes for PPR: screening (basic/extended), intermittent, and strategic risk management. In the light of their different decision contexts, these processes have different risk identification, risk analysis, and risk evaluation tools associated with them. Figure 2 presents an overview of these processes and shows how they can be linked to one other. These processes can be used also independently, depending on the actual way the risk management processes are implemented in specific organizations. When designing the scope for the PPR risk management, consideration should include aspects, such as aim and purpose, type of decisions, and required resources.

For the purpose of this Baltic Sea case study, the intermittent risk management process is set as a scope for the rest of work, due to resources available for this study and limited access to data. This risk management process is focused primarily to the internal context in PPR risk management.

As stated in the OpenRisk Guideline, in the intermittent risk management process, decisions concerning the HELCOM Response activities should focus on relatively small adjustments to the organization of the current response system, e.g. reviewing/updating operational or training procedures. Such decisions require relatively limited resources, typically within already available organizational budgets. The process thus focuses on gaining a better understanding of the risks in the maritime transportation system from a PPR point of view. The main characteristics of the intermittent risk management process are presented in Table 1.

Table 1. Characteristics of the intermittent pollution preparedness and response risk management process [21]

INTERMITTENT RISK MANAGEMENT PROCESS	
Aim and purpose	Understanding the pollution risks of shipping activities in sea areas, i.e. where what kinds of accidents are likely to happen, what would be the possible oil spills from those, where spills would drift to, what effects those would have to marine and coastal areas, and how effective the response is to those risks.
Type of decisions	Determining whether adjustments in the preparedness planning and/or response organization is needed, typically limited to relatively small adjustments to the fleet or operational procedures, within already available budgets.
Periodicity	Ad hoc, based on the outcome of the screening risk management process.
Decision makers	Pollution Preparedness and Response authorities
Typical stakeholders	Regional response secretariats, maritime administrations, vessel traffic services, voluntary response organizations
Required resources	Medium: some tools allow a certain level of automation, and while most tools require little resource commitment, the value of the process comes from applying several tools in sequence. Information gathering and processing requires moderate resources commitments (time, funds and personnel). Reporting is more extensive.
Required competences	Medium: experience with the toolbox for the intermittent process is required, in terms of execution and interpretation

Within the scope of the intermittent risk management process, the aim of this Baltic Sea case study is to answer the following risk management questions:

1. Where are accidents likely to happen?
2. When are accidents likely to happen?
3. Which system functions are responsible for the variation in the system performance?
4. What kinds of accidents are likely to happen?
5. What would be the likely oil spills in such accidents?
6. Where would the oil drift to in the sea area?
7. How effective would be the response at sea to those risks?
8. How much can the results of the risk analysis be relied on?
9. How do different scenarios compare to one other in the different dimensions of risk?
10. Are the risks acceptable?

1.4. Selecting the risk assessment tools

To support the risk based decision making processes of PPR authorities, several open source risk assessment tools are available in the toolbox part of the OpenRisk Guideline [22]. This so-called OpenRisk Toolbox is a set of tools and techniques especially for identifying hazards and analyzing risks of maritime activities. It is focused on accidental oil spills from maritime transportation, where regional cooperation would be required.

This Baltic Sea case study includes a demonstration of six different tools of the OpenRisk Toolbox and two additional tools of the Finnish Environment Institute, each providing answers to particular risk management questions introduced in the previous section. Figure 3 shows a general view of

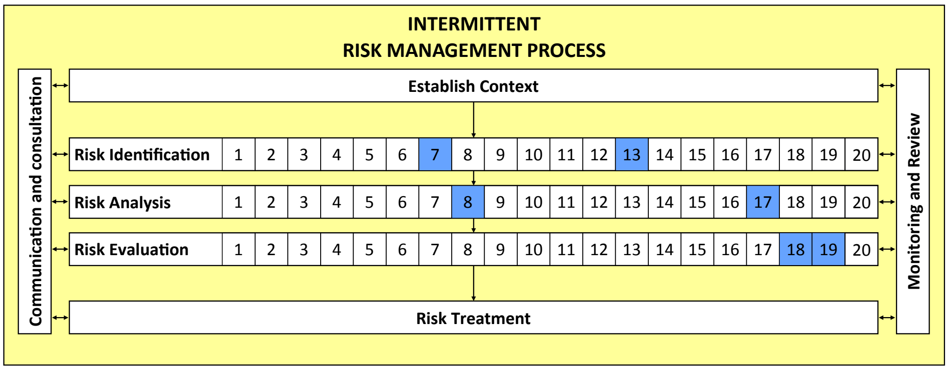

Figure 3. Selected risk assessment tools of the OpenRisk Toolbox applied in this case study for different stages of the risk assessment process.

Table 2. Selected tools of the OpenRisk Toolbox: Attributes of the tools [25]

ID	Tool name	Resources needed	Skill required	Output: Quantitative	Output: Qualitative
7	Maritime Event Risk Classification Method	★★☆	★★☆		✓
8	Accidental Damage and Spill Assessment Model for Collision and Grounding	★☆☆	★★☆	✓	
13	Functional Resonance Analysis Method	★★★	★★★		✓
17	Strength of Evidence Assessment Schemes	★☆☆	★☆☆		✓
18	Risk Matrices and Probability-Consequence Diagrams	★☆☆	★☆☆	✓	✓
19	As Low As Reasonably Practicable Principle	★☆☆	★★☆	✓	✓

★☆☆ – Low
★★☆ – Medium
★★★ – High

which tools are used at different stages of the risk assessment process described in this case study, with numbering from the OpenRisk Guideline. The attributes of these tools are presented in Table 2.

The purpose of risk identification is to find, recognize and describe risks that might prevent an organization achieving its objectives. For this stage of the risk assessment process, the Maritime Event Risk Classification Method (ERC-M, No.7) is used for Test areas 1 and 2. In addition, the Functional Resonance Analysis Method (FRAM, No. 13) is used for Test area 2.

The aim of risk analysis is to comprehend the nature of the risks and their characteristics including, where appropriate, the level of risk. This stage of the risk assessment process is conducted by using four different tools: Accidental Damage and Spill Assessment Model for Collision and Grounding (ADSAM C/G, No.8), SpillMod [23], ADIOS [24] and Strength of Evidence Assessment Schemes (SoE No.17)[1]. This stage is limited to cover Test area 1 only.

The purpose of risk evaluation is to support decisions. This involves comparing the results of the risk analysis with the established risk criteria to determine where additional action is required. This final stage of the risk assessment process is implemented in this study by using Risk Matrices and Probability-Consequence Diagrams (RM-PCDS, No.18) and As Low as Reasonably Practicable Principle (ALARP No.19) risk assessment tools. This stage is limited to cover Test area 1 only.

1.5. Establishing the risk assessment process

This section focuses on the risk assessment process. It provides a more detailed description regarding which risk assessment tools provide answers to which risk management questions, and how their results can be combined with one another. This process is schematically presented in Figure 4. Subsequently, the steps of this risk assessment process are explained in more detail.

Risk identification

Step 1. Spatial and temporal risk distribution and variations in system performance

In the beginning of Step 1, the Kernel spatial density analysis tool is used to identify high incident density sea areas (accidental hotspot sea areas) of Test areas 1 and 2, shown in Figure 1. The data used in this part of the Baltic Sea study consists of VTS incident reports and HELCOM accident statistics from the period 2014-2016. Thereafter, the risk of accidental oil spills is assessed for each identified accidental hotspot sea area by using the ERC-M tool, in order to answer risk management questions 1 and 2, shown in Section 1.3 and Figure 4. In addition, the FRAM tool is utilized to answer risk management question 3 for Test area 2.

The main output of this step is the accidental hotspot sea areas of Test areas 1 and 2, including prioritization of these sea areas in terms of where risk scenarios should be further analyzed. The output includes also a temporal risk distribution within these two sub-sea areas as well as the results of the FRAM based risk identification for Test area 2.

Risk analysis

Step 2. Estimating the likelihood of event occurrence

The results of Step 1 are used as a starting point for the risk analysis, as illustrated in Figure 4. The data obtained from VTS Incident reports, HELCOM accident statistics, and HELCOM AIS database are used to answer risk management question 4, shown in Section 1.3 and Figure 4. Using these data sources, incident frequencies are calculated for each identified accidental hotspot sea area, focusing on the frequencies for oil tankers. In addition, the results of ERC-M are taken into account as preliminary information related to the severity of incidents. This is further used as a basis of selecting representative scenarios for estimating the severity of consequences in terms of oil spill sizes.

The output of this step are oil tanker incident frequencies in each of the accidental hotspot sea areas, and a selected number of representative oil tanker collision and grounding scenarios in these areas, which lay the basis for estimation of the further consequences in the subsequent steps.

Step 3. Estimating the severity of consequences in terms of oil spill size

The results of Step 2 are used to select scenarios for evaluating the potential consequences of accidents, as indicated in Figure 4. In this case study, the third step of the risk assessment process is conducted using the ADSAM C/G tool. The focus is here on oil spills resulting from collision and grounding accidents of oil tankers, aiming to answer risk management question 5, shown in Section 1.3 and Figure 4. For each of the selected scenarios, the oil spill calculations are made taking into account the contextual factors such as the size of the vessel, and speed at the time of incident.

The output of this step are the estimated medium-size and large-scale oil spill sizes for the different hotspot sea areas, which are addressed by the HELCOM countries in co-operation according to HELCOM Recommendation 28E/12.

1 The risk assessment tools SeaTrackWeb (No.9) and EPRS-Calculator (No.11) were also tested at this stage, but due to shortages with their input data features, these tools were found unsuitable for this case study. Nevertheless, they can be used for the PPR risk management in a different context.

Risk assessment process

Notes: Risk identification = (blue) Risk analysis = (green) Risk evaluation = (red)

1. Identification of spatial and temporal risk distribution, and variations in system performance	
Questions: 1. Where accidents are likely to happen? 2. When are such accidents likely to happen? 3. Which system functions are responsible for the variation in the system performance?	**Tools:** ERC-M and FRAM **Sea areas:** Test area 1 (ERC-M) Test area 2 (ERC-M & FRAM)
Output: High incident density sea areas and temporal risk distribution, and variations in system performance	

2. Estimating the likelihood of the event occurrence	
Question: 4. What kinds of accidents are likely to happen?	**Tool:** F = Incidents/Y/Nm and ERC-M **Sea area**: Test area 1
Output: Incident frequencies on hotspot sea areas for oil tankers and accident scenarios	

3. Estimating the severity of the occurence in terms of oil spill size	
Question: 5. What would be the likely oil spills in such accidents?	**Tool:** ADSAM C/G **Sea area**: Test area 1
Output: Estimated oil spill sizes for different hotspot sea areas based on oil tanker accident scenarios	

4. Estimating the severity of the occurence in terms of oil spill drift direction	
Questions: 6. Where would the oil drift to in the sea area?	**Tool:** SpillMod and ADIOS **Sea area**: Test area 1
Output: Modelled oil spill drifts for different hotspot sea areas based on estimated spill sizes	

5. Estimating the effectiveness of mechanical recovery system	
Question: 7. How effective would be the response at sea to those risks?	**Expert judgement** **Sea area**: Test area 1
Output: Evaluation on recovered spilled oil based on estimated oil spill sizes and drift models	

6. Assessing of the strength of evidence for the probability and consequence estimation	
Question: 8. How much can results of the risk analysis be relied on?	**Tool:** SoE **Sea area**: Test area 1
Output: Evaluation on reliability of risk assessment results	

7. Combining probability, consequence, and strength of evidence in a risk scale	
Question: 9. How do different scenarios compare to one other in the different dimensions of risk?	**Tool:** RM-PCDS **Sea area**: Test area 1
Output: Rating for different risks with significance level defined and strength of evidence	

8. Evaluating the acceptability of the risks	
Question: 10. Are the risks acceptable?	**Tool:** ALARP **Sea area**: Test area 1
Output: Estimate in which hotspot sea areas the risk is as low as reasonably practicable	

Input to risk treatment

Figure 4. Risk assessment process of the Baltic Sea case study

Step 4. Estimating the severity of occurrences in terms of oil spill drift direction

The estimated medium-size and large-scale oil spills from oil tanker accidents are used as input for Step 4, as illustrated in Figure 4. In this case study, the SpillMod tool is used for estimating the drift and fate of the oil flowing out from the impacted vessel. In addition, the tool ADIOS is used for estimating the oil evaporation and its dissolution with water. This aims to answer risk management question 6, shown in Section 1.3 and Figure 4. The predicted oil spill drifts are modelled by using the data of weather and sea conditions of the year 2000.

The output of this step are modelled drifts of oil spills for different accidental hotspot sea areas. The calculations are conducted for both medium-size and large-scale oil spill sizes.

Step 5. Estimating the effectiveness of response measures

The results of Step 4 are used as a basis for evaluating the effectiveness of risk mitigation, focusing on the pollution response measures at sea in the Gulf of Finland, see Figure 4. The evaluation is based on the expert judgment of Finnish national response authorities. Hence, this step aims to provide answers to risk management question 7, listed in Section 1.3, and shown in Figure 4. The effectiveness of response measures is evaluated for the first three days following the incident. This time limit is based on HELCOM Recommendation 31/1, which defines the aim for the Contracting Parties to respond to major oil spillages.

The output of this step is an evaluation of the effectiveness of pollution response measures in given scenarios.

Step 6. Assessing the strength of the evidence for the probability and consequence estimation

In the final risk analysis stage, the results of Steps 1 to 5 are assessed with respect to how much the results of the analysis can be relied on. This relates to risk management question 8, listed in Section 1.3 and Figure 4. Step 6 is necessary because the previous analysis steps may be based on limited data, or because the tools may have limitations, which leads to some uncertainty in results. Here, the strength of evidence (SoE) assessment scheme is applied, as shown in Figure 4, considering the different evidential categories, reaching an overall rating of the strength of evidence.

The output of this step is an assessment of the strength of evidence of the risk assessment results.

Risk evaluation

Step 7. Combining probability, consequence, and strength of evidence in a risk scale

The results of Steps 1 to 6 are combined in the risk evaluation stage by using the RM tool, see Figure 4. In Step 7, the aim is to rank different accidental hotspot sea areas based on their risk level, including the strength of evidence. By using the risk matrix, this step provides answers to risk management question 9, listed in Section 1.3 and shown in Figure 4.

The output of this step is a risk ranking of each accidental hotspot sea area, with significance level defined and strength of evidence.

Step 8. Evaluating the acceptability of the risk

The results of Step 7 are used as input for Step 8, as illustrated in Figure 4. Here the aim is to evaluate in which accidental hotspot sea areas the risks are too high or intolerable, and in which sea areas the risks are acceptable. Hence, this step provides answers to risk management question 10, indicated in Section 1.3, and shown in Figure 4. In the Baltic Sea case study, this evaluation is performed using the ALARP tool.

The output of this step is an evaluation of the sea areas where risks are acceptable or intolerable, and therefore, where the preparedness level is adequate or where additional response measures are needed.

Stage 2. Risk identification

This chapter of the Baltic Sea case study focuses on the risk identification stage of the risk management process. As elaborated in the OpenRisk Guideline, this stage is used to establish what risks can arise in a system or process. Thus, after establishing the context, the hazards, possible failures and unwanted events associated with the system or activity should be identified. At this stage, the identified risks can be also prioritized for further in-depth analysis.

The purpose of this chapter is to provide answers to the risk management questions 1, 2 and 3 listed in Section 1.3, and as shown in Figure 4. The results show examples of the identified risks in Test areas 1 and 2, shown in Figure 1.

2.1. Spatial risk distribution in Test area 1

This section aims to provide an answer to risk management question 1 in Test area 1: where are accidents likely to happen?

The data used in this Baltic Sea case study for Test area 1 consists of 982 incident reports from the period 2014 to 2016. The data sources include VTS Incident reports from Finland and Estonia as well as the HELCOM accident data. The VTS Incident reports of the Russian Federation and the east coast of Sweden were not available for this study.

The first method applied in this stage of the Baltic Sea case study is the Kernel Density, which is a Geographic Information System (GIS) method to calculate a magnitude-per-unit area from point features that fall within a neighbourhood around each cell [26]. This method is used to determine the high incident density sea areas (accidental hotspot sea areas) in Test area 1, focusing on the risk of environmental damages.

The spatial distribution of incidents is shown in Figure 5, which is visualized using the ArcMap Density Toolset. It is seen that the density is highest in the Gulf of Finland between Helsinki and Tallinn (Sea area 4) and in the Åland Sea (Sea area 1). Densities are also higher near the Kotka-Hamina sea area in the eastern part of Test area 1 (Sea area 5), and near Hanko in the west (Sea area 3). In addition, a high density area can be identified in the Archipelago Sea (Sea area 2). Due to lack of data, the most eastern parts of the study area and the east coast of Sweden are not well covered in the calculations.

The second tool applied in the risk identification stage of the Baltic Sea case study is the ERC-M, which is one of the tools included in the

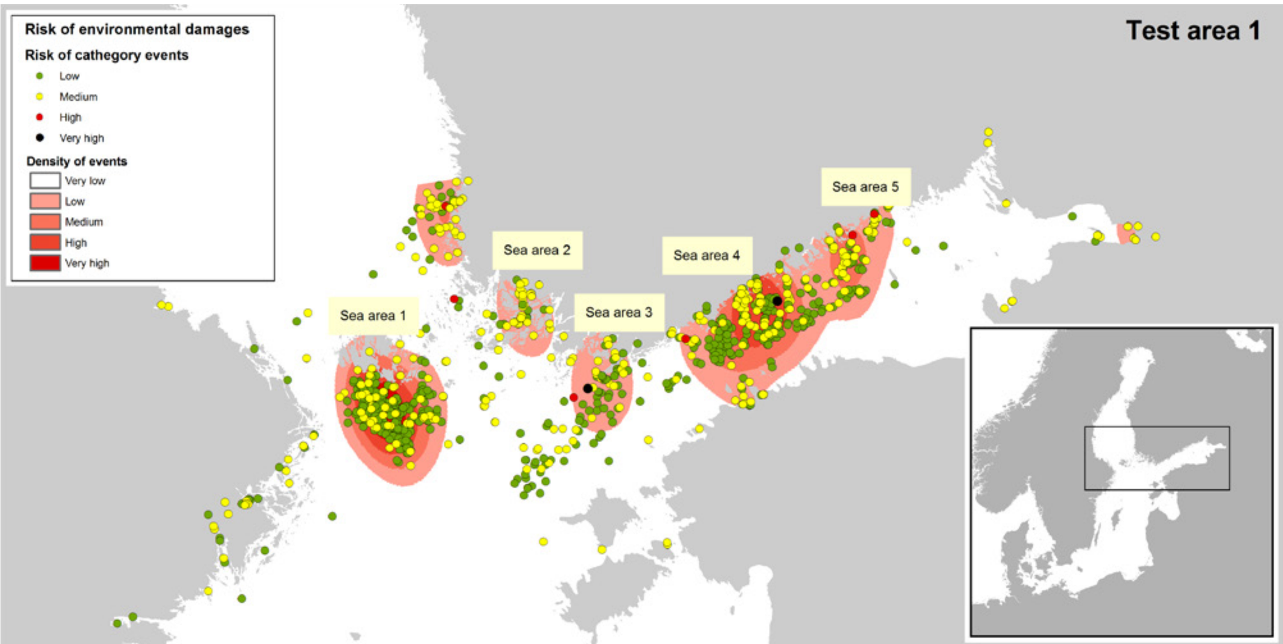

Figure 5. Spatial density of incidents in Test area 1

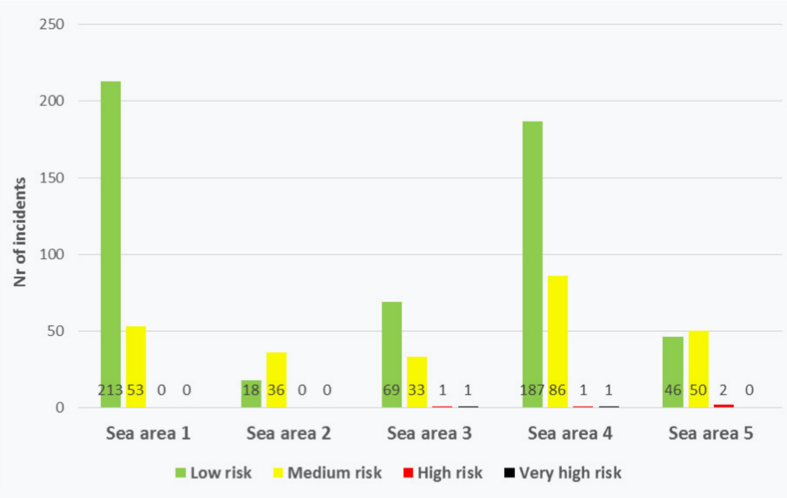

Figure 6. Risk of environmental damages in different hotspot sea areas

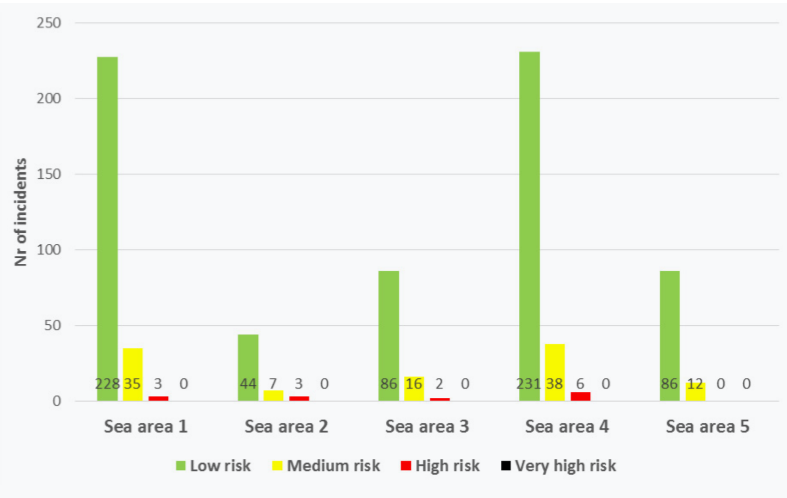

Figure 7. Risk of loss of life or injuries different hotspot sea areas

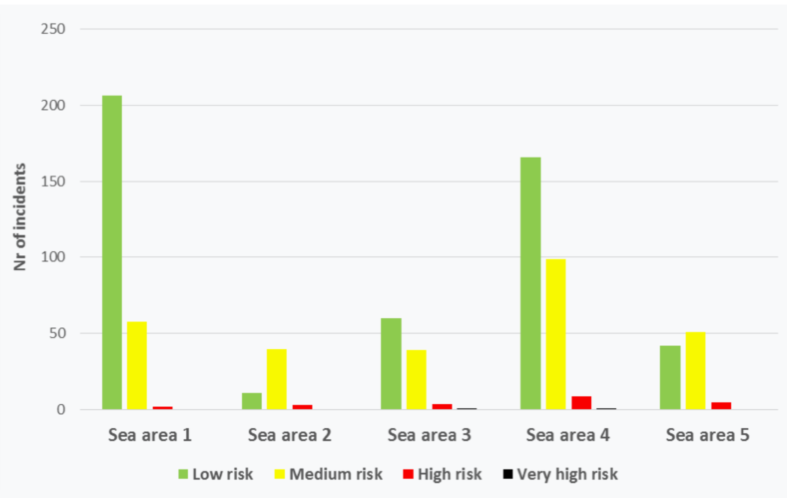

Figure 8. Risk of economic losses in different hotspot sea areas

OpenRisk Toolbox, and described in detail in Section 3.7 of the OpenRisk Guideline.

In this part of the Baltic Sea case study, the ERC-M is utilized for the risk identification of the five accidental hotspot sea areas, shown in Figure 5. During the period 2014 to 2016, a total of 968 incident reports were made of the ships navigating in these sea areas. In this study, each of these reports has been classified with three different ERC-M risk matrices, focusing on the potential damages for environment, loss of lives, and economic losses.

Figures 6 to 8 show that the number of incidents is highest in Sea areas 4 and 1, followed by Sea areas 3, 5 and 2. Based on the ERC-M classification, the incidents with very high or high risk of environmental damages are concentrated in Sea areas 4, 3 and 5, as shown in Figure 6. The risk of loss of life or injuries is distributed more equally. Figure 7 shows that high risk incidents in this respect have occurred in Sea areas 1 to 4. The risk of economic losses is closely related to the risk of environmental damages. Thus, incidents with very high or high risk of economic losses are mainly concentrated in these same sea areas, which can be seen from Figure 8.

The prioritization of these sea areas for further analysis can be derived from the focus of this Baltic Sea case study and the principles of the ERC-M. This case study is focused primarily on the risk of environmental damages, and because of this, the results shown in Figure 6 are the most significant. According to the principles of ERC-M, the risk management should be focused primarily on the high risk events. Therefore, the sea areas where such events have occurred should be emphasized. From this follows that the priority of these sea areas is: Sea area 4, 3, 5, 1 and 2.

2.2. Temporal risk distribution in Test area 1

This section aims to provide an answer to risk management question 2 in Test area 1: when are accidents likely to happen?

The data used in this part of the Baltic Sea case study consists of 982 incident reports from Test area 1 and from the period 2014 to 2016. The method applied is the ERC-M.

Figure 9 shows the monthly distribution of the incidents in Test area 1, with aggregated risk level classifications obtained from application of the ERC-M method. The number is highest in June and December, declining towards the early spring and autumn. The incidents with very high risk of environmental damages are also recorded in June and December.

When comparing different times of the day, the number of incidents is distributed very evenly. The variation is around 25 percent of the total number of incidents. Figure 10 shows that the share of the incidents with very high or high risk of environmental damages is somewhat higher from 04:00 to 10:00 local time.

2.3. Spatial risk distribution in Test area 2

This section aims to provide an answer to risk management question 1 in Test area 2: where are accidents likely to happen?

For Test area 2, only the risk identification stage is conducted in this Baltic Sea case study, as noted earlier. The data used in this part of the study consists of 528 incident reports from the period 2014 to 2016. The data sources include VTS Incident reports from Denmark and Sweden as well as HELCOM accident data. The VTS Incident reports of Germany were not available for this study.

The first phase of this section is conducted with the Kernel Density method, similarly as in Chapter 2.1. With the method applied, the accidental hotspot sea areas in Test area 2 are determined, focusing on the risk of environmental damages. The spatial distribution of the incidents occurred in this sea area is shown in Figure 11. From the results it is seen that the density is clearly highest in the Øresund passage (Sea area 6). Densities are also higher in the Fehmarn Belt, near the entrance of Kiel Canal (Sea area 7) and near the port of Rostock (Sea area 8). However, due to lack of data, the coast of Germany is not well covered in the calculations.

In the second phase of this section, the ERC-M is utilized for the risk identification of the three accidental hotspot sea areas. During the period 2014 to 2016, a total of 224 incident reports were made of the ships passing through these sea areas. As in Chapter 2.1, each of these reports has

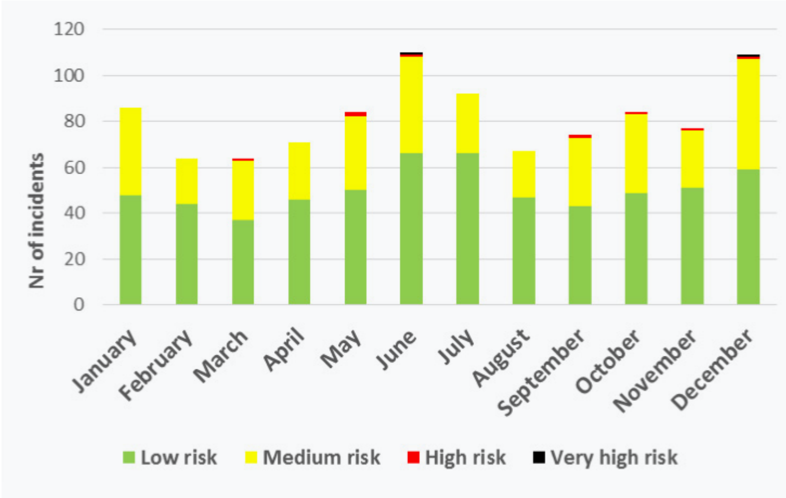

Figure 9. Number of incidents per month in Test area 1 including evaluation of the risk of environmental damages

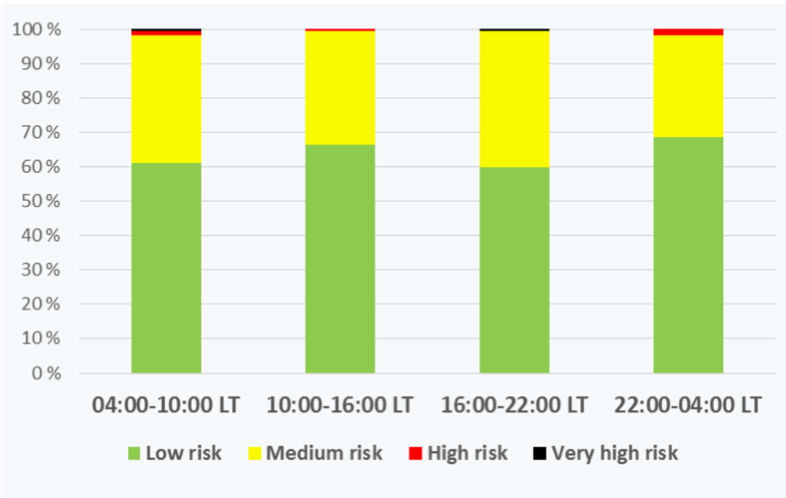

Figure 10. Relative distribution of the risk of environmental damages in Test area 1

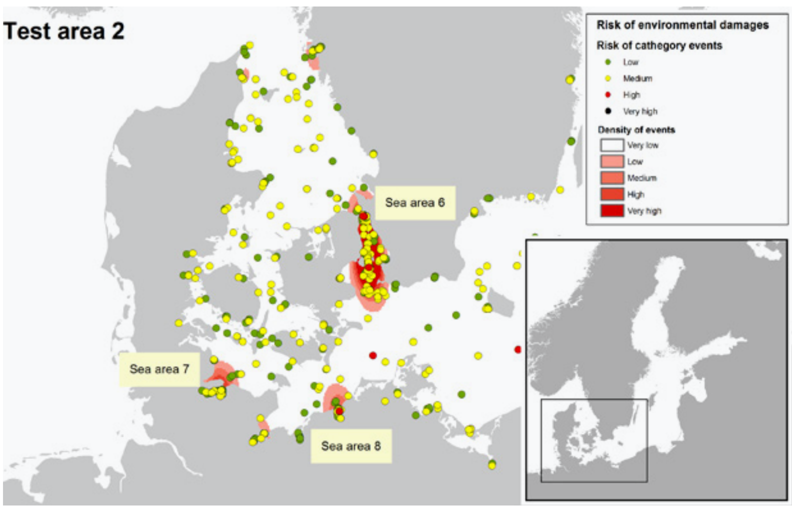

Figure 11. Accidental hotspot sea areas in Test area 2 including the risk of environmental damages

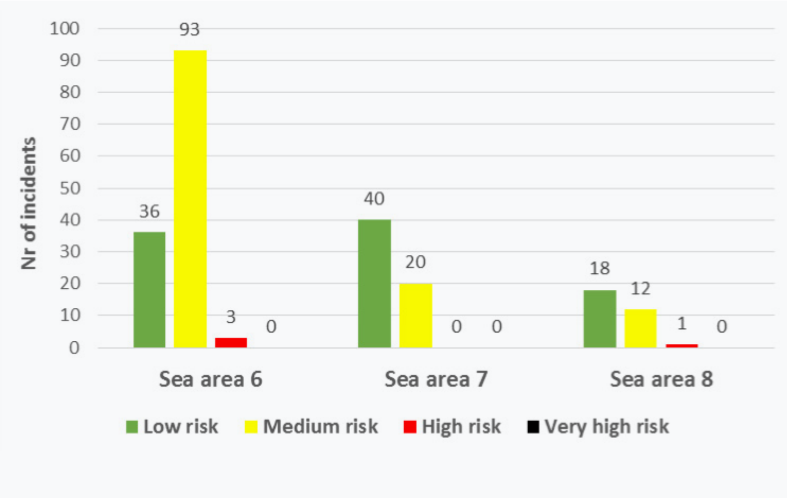

Figure 12. Risk of environmental damages in different hotspot sea areas

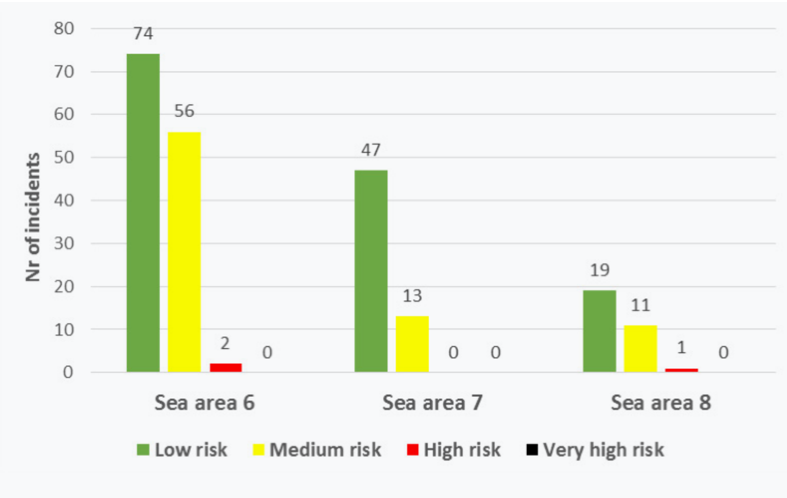

Figure 13. Risk of loss of life or injuries different hotspot sea areas

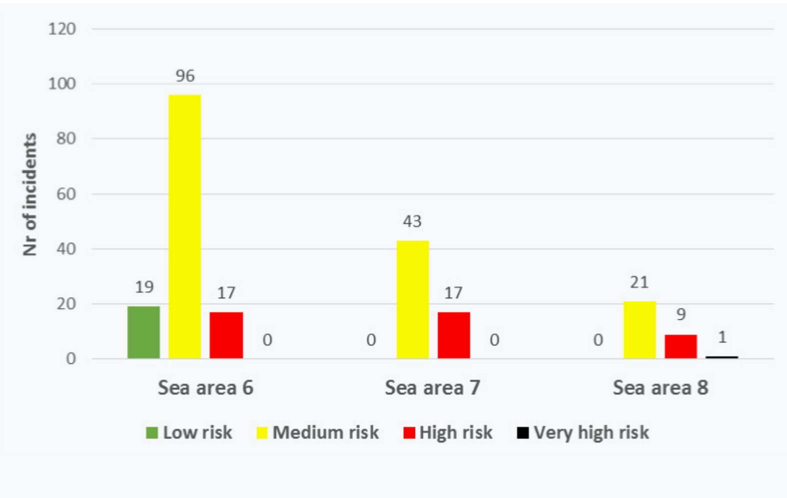

Figure 14. Risk of economic losses in different hotspot sea areas

been classified with three different ERC-M risk matrices, focusing on the potential damages for environment, loss of lives, and economic losses.

Figures 12 to 14 show that the number of incidents is highest in Sea area 6, followed by Sea areas 7 and 8. Based on the ERC-M classification, the incidents with high risk of environmental damages and loss of life or injuries are concentrated in Sea areas 6 and 8 (Figures 12 and 13). The incidents with high risk of economic losses have occurred in all of the accidental hotspot sea areas. In one of the incidents, the risk was even considered as very high from an economic perspective (Figure 14).

Based on the logic descripted in Chapter 2.1 the priority of these sea areas is: Sea areas 6, 8 and 7.

2.4. Temporal risk distribution in Test area 2

This section aims to provide an answer to risk management question 2 in Test area 2: when are accidents likely to happen?

The data used in this part of the Baltic Sea case study consists of 528 incident reports from Test area 2 and from the period 2014 to 2016. The method applied is the ERC-M.

Figure 15 shows the monthly distribution of the incidents in Test area 2, with aggregated risk level classifications obtained from application of the ERC-M method. The number of incidents is highest in January, declining towards spring. Thereafter, no significant changes are evident. The incidents with high risk of environmental damages are recorded in January, April, June, October and November.

When comparing different times of the day, the number of incidents is distributed very evenly. The variation is around 25 percent of the total number of incidents. Figure 16 shows that the share of the incidents with very high or high risk of environmental damages is somewhat higher from 16:00 to 22:00 local time.

2.5. Functions affecting the system performance in Test area 2

This section aims to provide an answer to risk management question 3 in Test area 2: which system functions are responsible for the variation in the system performance?

The data used in this part of the Baltic Sea case study consists of the report of an oil tanker accident, which occurred in Test area 2 [27], and HELCOM Response Manual [28]. The method applied is called FRAM, which is one of the tools included in the OpenRisk Toolbox, and described in detail in section 3.13 of the OpenRisk Guideline.

In this accident scenario, a bulk carrier and an oil tanker collided in the Baltic Sea at the maritime border between Germany and Denmark, shown in Figure 17. The bulb of the bulk carrier struck sharply to the oil tanker at the level of tank 6 that contained approximately 2.700 tonnes of oil. The release of heavy fuel oil began immediately, and thereafter, an emergency plan was implemented. An air survey, organised by the Danish air force, enabled to observe a slick at the sea surface.

Due to the conditions at sea and the extent of the damages to the vessel, the personnel failed to control the release of oil. The slick began to drift with the wind and prevailing ocean currents towards the Danish shoreline. Four days after the accident, the oil collected at sea was estimated around 940 tonnes, 15 vessels were involved in the operations, and the amount of oil collected on the shoreline was estimated around 630 tonnes. A total of 220 persons participated in the cleaning operations.

Figure 18 provides an overview of the input parameters for the execution of the FRAM model, whereas all the functions needed related to the accident can be identified and characterized with six aspects, respectively, which is summarized (numbered in sequence) in Table 3.

Figure 19 shows an example of the FRAM installation for external context of PPR risk management.

As shown in Figure 18 and Table 3, all functions and their aspects are identified to gain insights into how variations in their performance would affect reaching the objectives of the activities. If the personnel of vessels obey COLREG regulations and have more situational awareness on Bridge Team Management, there would be no collisions which result in huge environmental pollution. It can be seen that the aspect 'resource' typically has a significant influence on the performance of F1 (Cargo Tern Sailing) and F3 (Oil Tanker "Baltic Carrier" Sailing). In a similar way to the function F6 (Drift of the slick), crew failed to control the release of oil due to the rough weather conditions and the extent of boat damage (precondition for F6).

Systematic approach is important for describing the function and the interactions between system functions and their aspects. The Baltic Sea case study shows that FRAM is capable of identifying problems in a systematic way and come up with ways to improve the system.

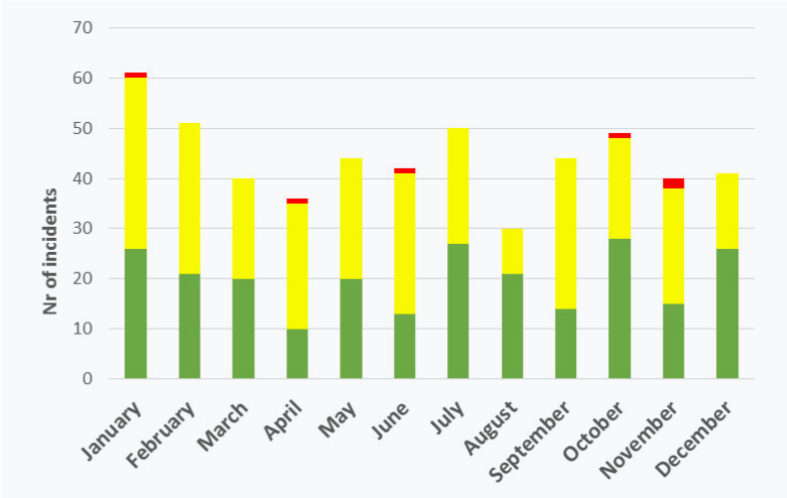

Figure 15. Risk of environmental damages in different hotspot sea areas

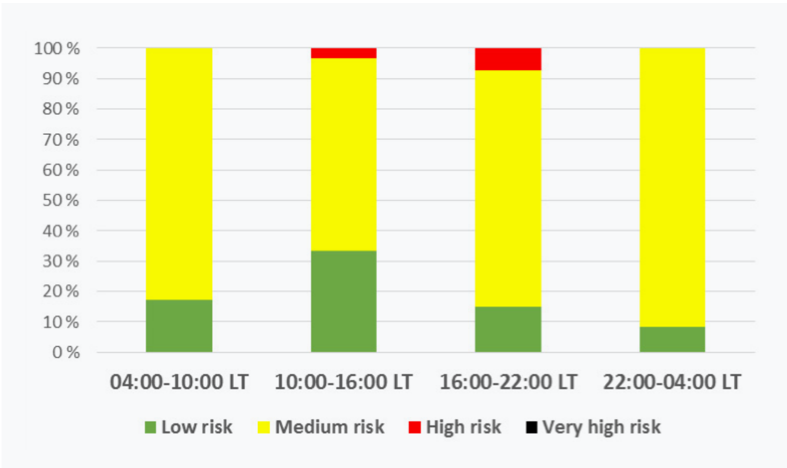

Figure 16. Risk of loss of life or injuries different hotspot sea areas

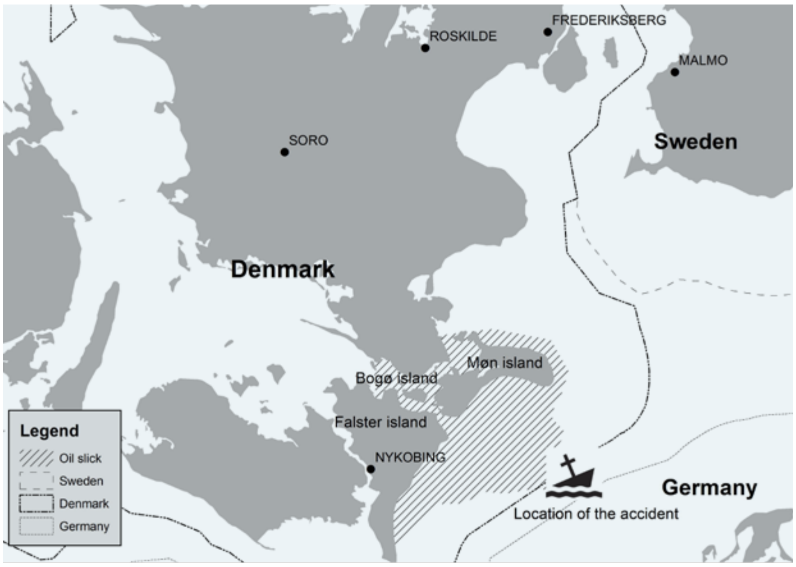

Figure 17. Location of the collision at the maritime border between Germany and Denmark

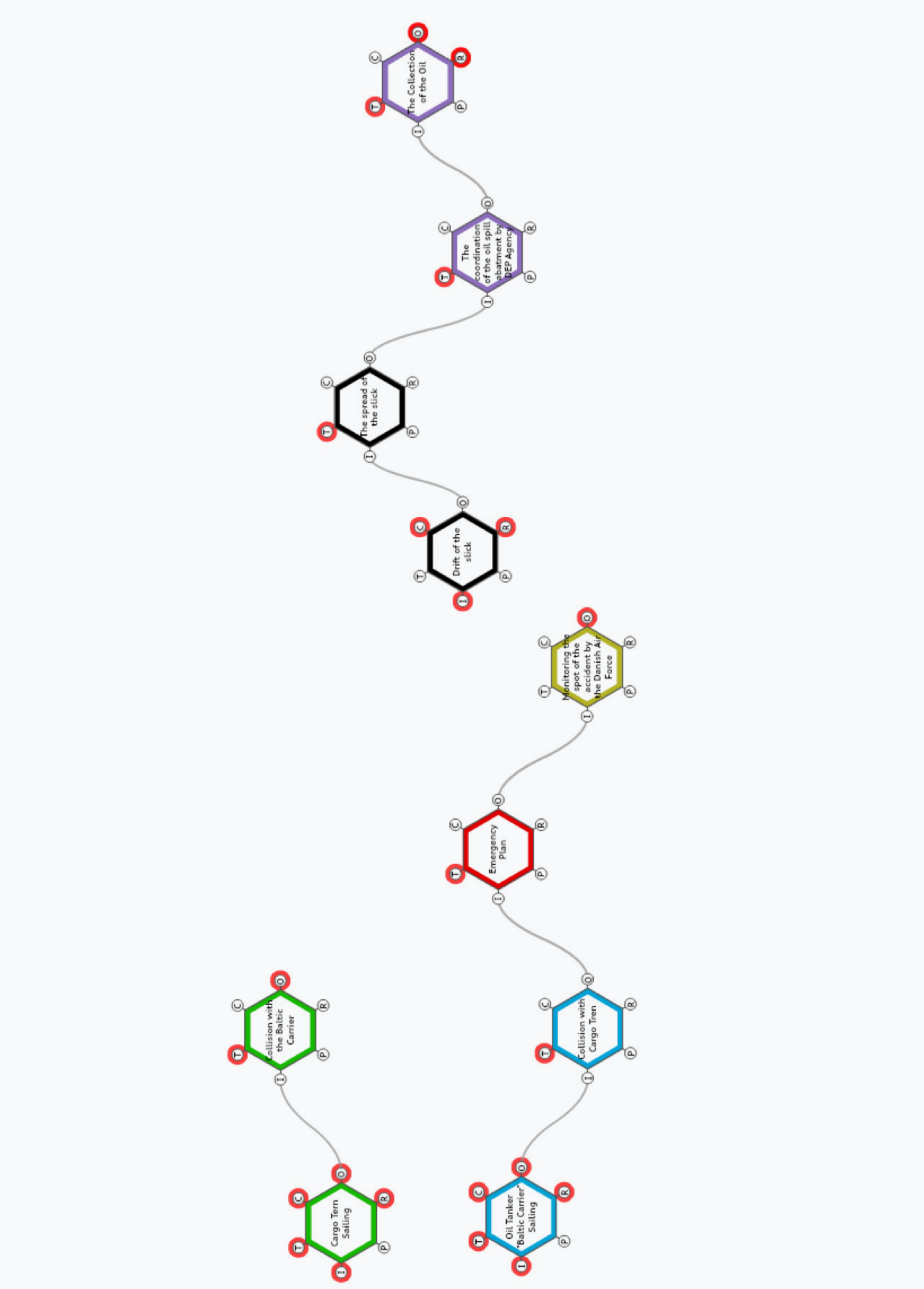

Figure 18. Instantiation of the FRAM model

Table 3. Function descriptions with six aspects

Function	Input	Output	Precon-dition	Resource	Control	Time
F1 Cargo "Tern" Sailing	Carried sugar from Cuba	Sailing to Latvia Collision	N/A	Sugar	Master	29/03/2001
F2 Collision with "Baltic Carrier"	Collision	The bulb of the cargo struck sharply the tanker number 6	N/A	N/A	N/A	00:30 (LT)
F3 Oil tanker "Baltic Carrier" sailing	Carried FO from Estonia	Sailing to Sweden Collision	N/A	Carrying 30.000 Tons of Heavy Fuel Oil	Master	N/A
F4 Collision with cargo "Tern"	Collision	The release of Heavy FO began immediately	N/A	N/A	N/A	00:30 (LT)
F5 Emergency plan	The release of Heavy FO began immediately	Identifying the Oil spill	N/A	N/A	N/A	29/03/2001
F6 Monitoring the spot of the accident by the Danish Air Force	Identifying the Oil spill	An air survey to observe a slick at the surface	N/A	N/A	N/A	N/A
F7 Drift of the slick	Due to the rough conditions at sea and the extent of boat damages, the personnel failed to control the release of the oil	The slick began to drift with the wind and prevailing ocean currents towards Danish shoreline	N/A	Personnel	Task given to the personnel	N/A
F8 The spread of the slick	The slick began to drift with the wind and prevailing ocean currents towards the Danish shoreline	the slick went across the Grønesund strait and reached the coast of Bogø, Møn and Falster islands	N/A	N/A	N/A	17:30
F9 The coordination of the oil spill abatement by DEP Agency	The slick went across the Grønesund strait and reached the coast of Bogø, Møn and Falster islands	organise the collection of the oil that was stranded on beaches Precondition Resource	N/A	N/A	N/A	30/03/2001
F10 Collection of the oil	Organise the collection of the oil that was stranded on beaches	the oil collected at sea was estimated around 940 Tons	N/A	15 vessels were involved in the operations	N/A	N/A
		the amount of oil collected on the shoreline was estimated around 630 Tons		220 persons participated in the cleaning operations.		2 days

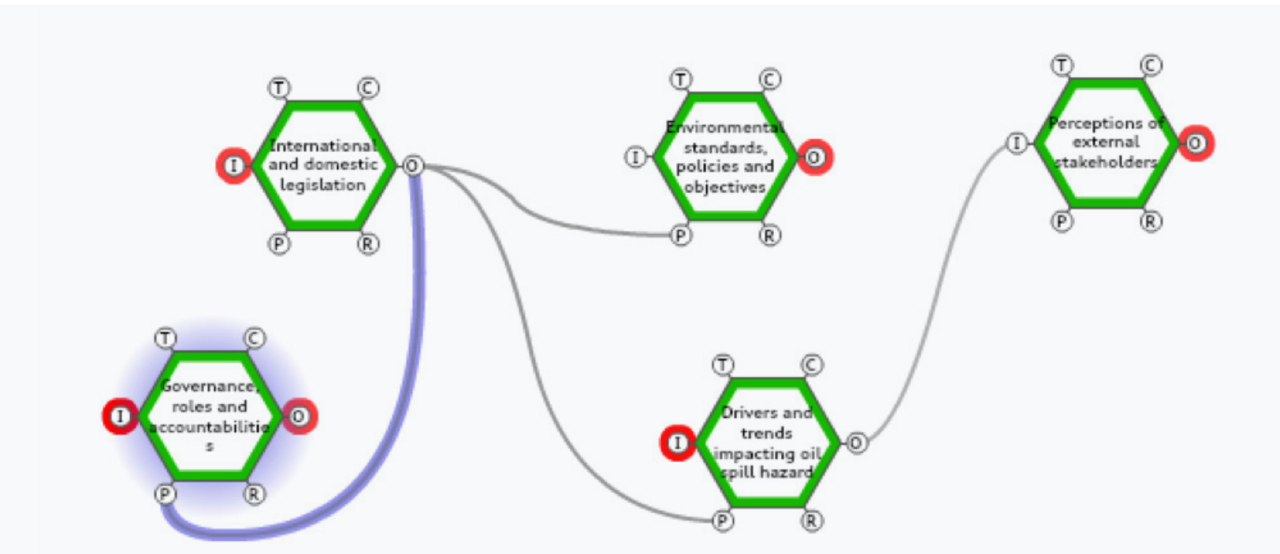

Figure 19. FRAM for External context of pollution preparedness and response risk management


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Stage 3. Risk analysis

This chapter of the Baltic Sea case study focuses on the risk analysis stage of the risk management process. According to the OpenRisk Guideline, this stage is used to determine the relative likelihood and consequences of the identified risks as well as to assess the effectiveness of existing controls for risk mitigation. An important part of the risk analysis stage is also to assess the strength of the evidence.

The purpose of this chapter is to provide answers to the risk management questions from 4 to 8 listed in Section 1.3, and as shown in Figure 4. At this stage, the results of the risk identification stage concerning Test area 1 are analysed more in detail.

3.1. Likelihood of maritime accidents

This section aims to provide an answer to risk management question 4: what kinds of accidents are likely to happen?

This is addressed by inspecting the results of the ERC-M method, which are based on the VTS Incident reports and HELCOM accident data. The overview of the risk rating of different incidents is furthermore used to determine a selected number of likely accident scenarios, which are used in the subsequent steps to assess the severity of the consequences in terms of the amount of oil released in collision and grounding accidents. In this analysis, also HELCOM AIS data is used, and expert judgment is applied to deduce relative accident rates from incident rates.

3.1.1 Ship types and likelihood of tanker incidents and accidents

In this Baltic Sea case study, the classification of merchant ships is based on the HELCOM categorization, which includes ship types such as cargo, tanker, passenger ships and the like [29]. In order to answer risk management question 3, it is first explored which ship types are likely to experience maritime accidents, including what is the risk of environmental damage in the case of event occurrence.

To explore this topic, the 982 incidents occurred in Test area 1 during the review period are first classified into different ship categories. In addition, the risk of environmental damage within these incidents is assessed by using the ERC-M tool. The results are presented in Figure 20, which shows that most of the incidents occurred to cargo ships (436), followed by tankers (145) and passenger ships (132). The incidents with very high risk of damage to the environment occurred only to tankers, whereas high risk incidents can be observed in other ship categories as well. Based on these results, it can be argued that ships most likely to experience maritime incidents are cargo ships. But considering also the aspect of risk, it is justified to select tankers for further analysis.

In this second phase, the tanker incidents are analyzed more in detail in order to comprehend their spatial distribution and likelihood. The explored five accidental hotspot sea areas are shown in Figure 5. The likelihoods are calculated as the frequency of tanker incidents per year. The equation is:

$$N_{tiY} = N_{ti} / Y$$

where N_{tiY} is the number of tanker incidents per year, N_{ti} the number of tanker incidents in the specific hotspot sea area during the period 2014-2016, and Y is the total number of years (3). The results are presented in Figure 21, which shows that the likelihood of tanker incidents is highest in Sea area 4 (f = 20,7), followed by Sea areas 5 (f = 7,7) and 1 (f = 7,0). The figure shows also the number of tanker incidents in different ERC-M categories. It can be seen that most of them occurred in Sea areas 4, 5 and 3, including those with high risk of environmental damage. The results of likelihood calculations can be utilized, e.g., when allocating resources for pollution prevention and response. In this Baltic Sea case study they are used in Chapter 4.1, when combining the likelihood, consequences and strength of evidence in a risk scale.

Figure 22 presents an alternative approach for the tanker incident likelihood calculations, which

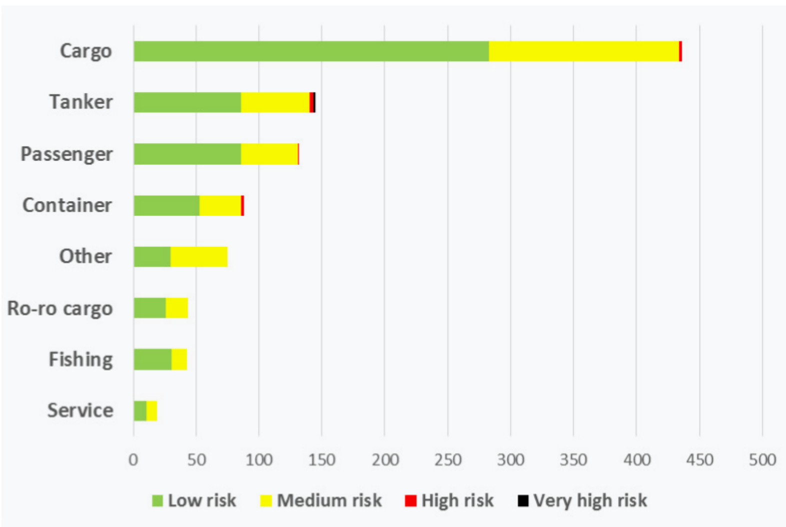

Figure 20. Risk of environmental damages of different ship types in Test area 1

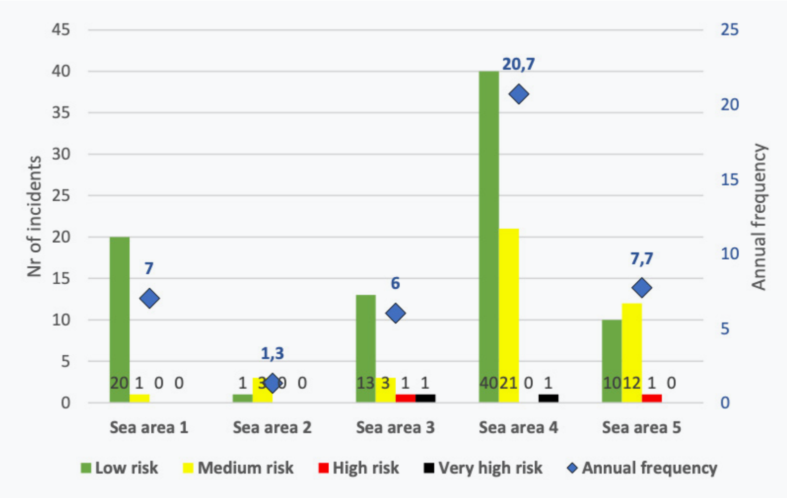

Figure 21. Incident frequencies of oil tankers in different hotspot sea areas including the number of incidents and potential environmental damages

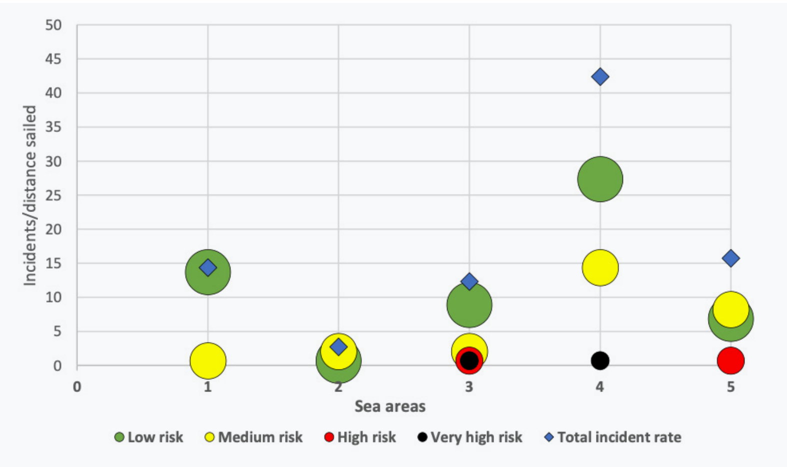

Figure 22. Incident frequencies of oil tankers in different hotspot sea areas based on ERC-M classification of potential environmental damages

Table 4. Likelihood of oil tanker accident in different sea areas of Test Case 1

Sea area	Oil tanker accident likelihood	Justification
1	Low	Relatively many incidents Only incidents with low and medium ERC-M severity rating
2	Very low	Very few incidents Only incidents with low and medium ERC-M severity rating
3	Medium	Relatively many incidents Most Incidents with low and medium ERC-M severity rating Also incidents with high and very high ERC-M severity rating
4	High	Very many incidents Most Incidents with low and medium ERC-M severity rating Also incidents with very high ERC-M severity rating
5	Medium	Relatively many incidents Most Incidents with low and medium ERC-M severity rating Also incidents with high ERC-M severity rating

is also suitable for the pollution preparedness and response needs. In this figure the equation is:

$$N_{ti}NM_t = N_{ti}/NM_t$$

where $N_{ti}NM$ is the number of tanker incidents per nautical miles sailed, N_{ti} is the number of tanker incidents in specific hotspot sea area, and NM_t is the total distance of tankers sailed in the all hotspot sea areas, based on the HELCOM AIS data from period 2014-2016 ($\sum$ = 1,46E+08 NM).

Based on the incident frequencies, and the different severity categories of the ERC-M method for oil tanker incidents, calculated as shown in Figures 21 and 22, a judgment is made about the likelihood of accident occurrence in the different sea areas. This categorization is made considering the purpose of distinguishing the five sea areas for prioritizing response equipment resources. A qualitative ranking is made between these different sea areas. This is considered more appropriate than assigning accident probabilities to the different sea areas, for the given purpose.

A four-level classification scale is applied, from 'very low' to 'high' accident probability, with results shown in Table 4. A brief justification for the assigned rating is given as well.

3.1.2 Size of oil tankers

In this section, the focus is on the size of the tankers navigating in the accidental hotspot sea areas. More specifically, it explores the length distribution of the tankers in order to select applicable scenarios for medium-size and large-scale pollution accidents in Chapter 3.1.4. The data used to explore this topic is obtained from the HELCOM AIS database and covers the review period. The results are shown in Figure 23, which are visualized using the Box Plot diagram. It is seen, for instance, that the median length of tankers sailing in Sea area 4 is approximately 160 meters, and the upper extreme is nearly 330 meters. This information is utilized when selecting scenarios for medium-size and large-scale pollution accidents for Sea area 4.

3.1.3 Accident types

Maritime accidents are typically classified into different categories, such as grounding, collision, machinery damage, etc. [30]. In order to answer risk management question 3, it is secondly explored, which types of maritime accidents are most likely to occur, and what is the risk of environmental damage in the case of event occurrence.

In order to explore this topic, the 982 incidents occurred in Test area 1 during the review period are first classified into different accident categories. In addition, the ERC-M is applied. Of all 982 incidents, 15 percent were maritime accidents. The rest 85 percent were violations, near-miss situations, engine failures, etc. In these kinds of incidents, the classification is based on the most plausible accident scenario within the context of these events. The results of this phase are shown in Figure 24. It is seen that most of the incidents are classified as groundings (309), five of which had a high risk of environmental damage. Collision is the second most common category (288) and, e.g., two of them are classified as very high risk incidents from the environmental point of view. Thus, it can be argued that the most likely accident types to occur in Test area 1 are groundings and collisions. In addition, the risk of environmental damage can be significant in such events.

In this second phase of the section, the focus is on incidents classified as grounding or collision, based on the results shown in Figure 24. The spatial distribution of such incidents is analysed here in detail for selecting applicable representative scenarios in Chapter 3.1.4. The explored five accidental hotspot sea areas are presented in Figure 5. The results of this phase are presented in the following two figures. From Figure 25 it can be seen that incidents classified as grounding have occurred mainly in Sea areas 4, 5 and 1, including those with high risk of damage to the environment. Figure 26 shows the spatial distribution of incidents classified as collision. These kinds of incidents are focused primarily on Sea areas 4, 3 and 1, two of which had a very high risk of environmental damage.

3.1.4 Scenarios

The results of Chapters 2.1 and Chapters 3.1.1-3.1.3 are used as a criteria to select such VTS Incident reports which can be used as scenarios for evaluating the consequences in the next chapter. The procedure of selection is as follows:

In the first phase, the VTS Incident reports are classified based on the five accidental hotspot sea areas, shown in Figure 5. In the second phase, only the reports involving tankers are selected for further analysis, based on the results shown in Figure 20. In the third phase, the length distribution of tankers is used as a criteria to continue selection, see Figure 23. In the fourth phase, only the reports that are classified as either grounding or collision incidents are selected for further analysis, based on the results shown in Figure 24. In the final phase, the remaining VTS Incident reports are studied individually, in order to find the most applicable scenarios for the medium-size and large-scale pollution accidents for each five sea areas.

The key information from these 10 selected incident scenarios, all involving tankers, is shown in Figure 27 and Table 5. This information is further utilized in the estimation of the oil spill sizes, the oil spill drifts, and the response effectiveness. For privacy-related reasons, the identities of these vessels are not specified, and neither are the specific circumstances of the incidents.

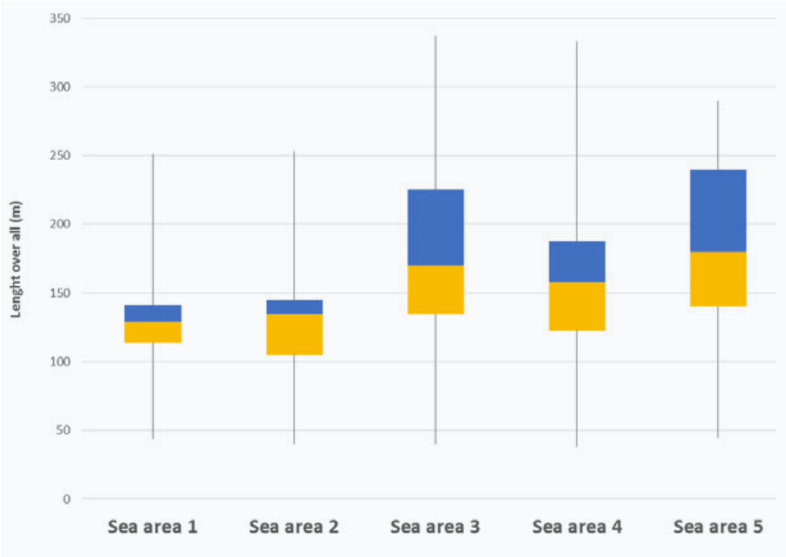

Figure 23. Distribution of oil tanker sizes in different hotspot sea areas

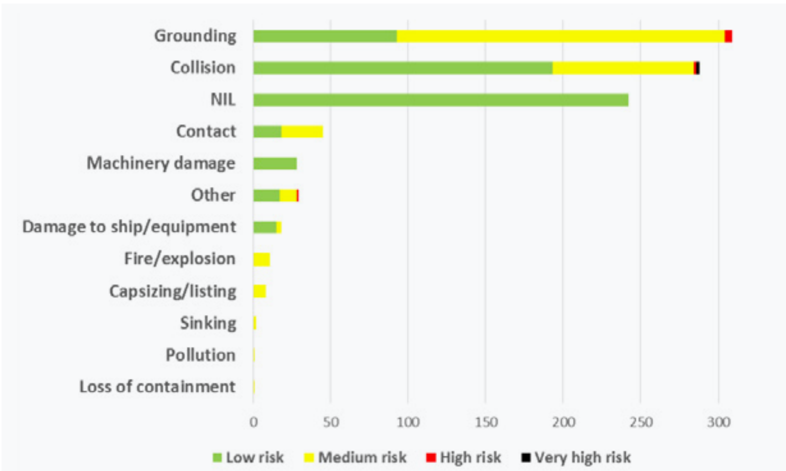

Figure 24. Risk of different types of accidents in Test area 1

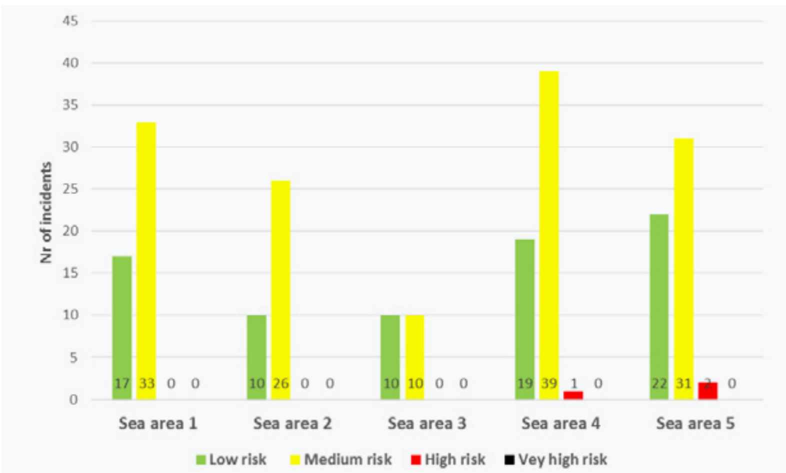

Figure 25. Risk of grounding accidents in different hotspot sea areas including potential environmental damages

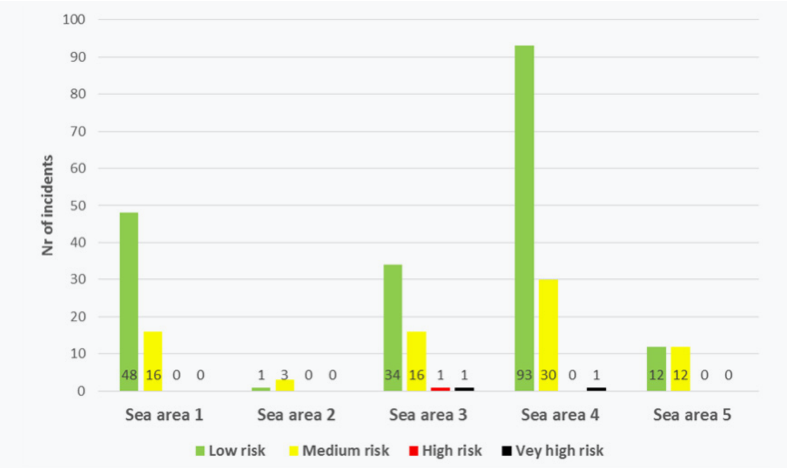

Figure 26. Risk of collision accidents in different hotspot sea areas including potential environmental damages

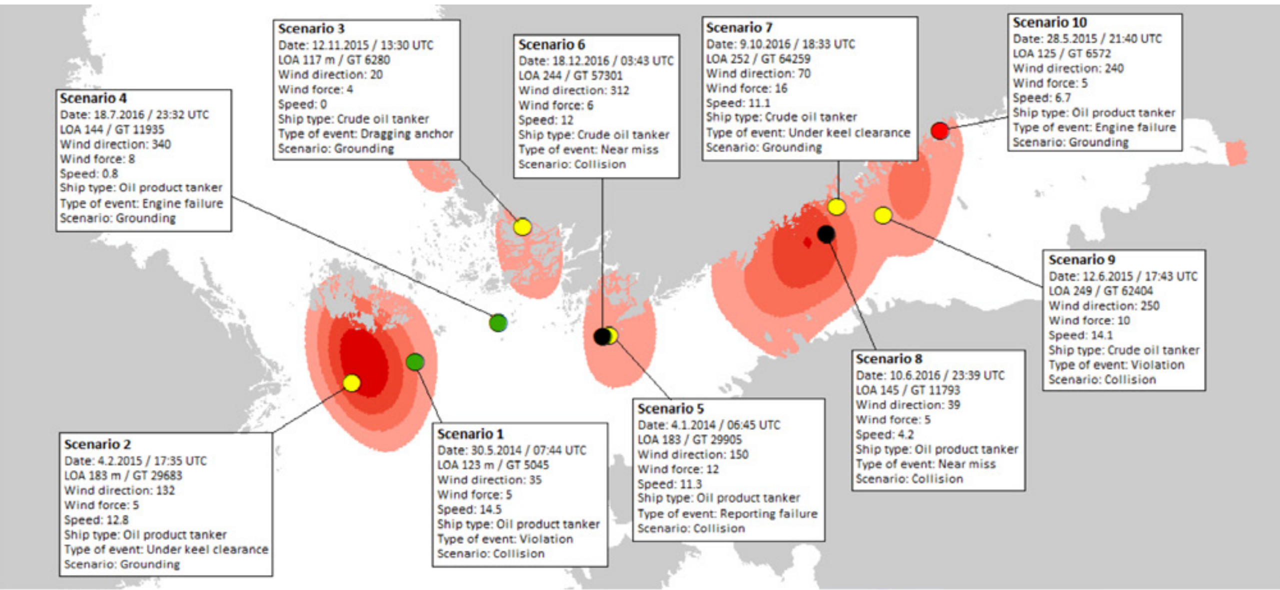

Figure 27. Scenarios for estimating the severity of consequences in case of event occurrence

Table 5. Incident scenarios for estimating the severity of consequences

ID	Latitude	Longitude	Date	Type of event	ERC-M			GT [tonnes]	LOA [m]
					Env.	Hum.	Econ.		
1	59.78111	20.61028	30.05.2014	Traffic zone violation	green	green	green	5045	125
2	59.71972	19.87833	04.02.2015	Under keel clearance	yellow	green	yellow	29683	183
3	60.43528	22.06556	12.11.2015	Drifting	yellow	green	yellow	6280	117
4	59.92833	21.59972	18.07.2016	Engine failure	green	green	green	11935	144
5	59.74861	22.79278	04.01.2014	Reporting violation	yellow	green	yellow	29905	183
6	59.74861	22.71806	18.12.2016	Near collision	black	red	black	57301	244
7	60.20306	25.59694	09.10.2016	Under keel clearance	yellow	green	yellow	64259	252
8	60.06694	25.41194	10.06.2016	Near collision	black	red	black	11793	145
9	60.09806	26.08639	12.06.2015	Traffic zone violation	yellow	green	yellow	62404	249
10	60.48444	26.95000	28.05.2015	Engine failure	red	yellow	red	6572	125

Notes:
Env.: Environmental consequences as per ERC-M, Hum.: Human losses as per ERC-M, Econ.: Economic damages as per ERC-M

3.2. Estimated oil spill sizes

This section aims to provide an answer to risk management question 5 in Test area 1: what would be the likely oil spills in accidents?

The data used in this part of the Baltic Sea case study consists of 10 scenarios presented in Table 5, in combination with expert judgment. The method applied is the ADSAM C/G, which is one of the tools included in the OpenRisk Toolbox, and described in detail in section 3.8 of the OpenRisk Guideline.

As the incident scenarios shown in Table 5 did not actually lead to accidents or oil spills, these scenarios are taken as a starting point to develop plausible accident scenarios. This is done by reading the VTS incident reports, and by altering the storyline in a plausible way using expert judgment, so that an accident would occur where a tanker would ground or collide with another vessel.

As an illustration, two accident scenario narratives are described, with the accident locations shown in Figure 28 (grounding) and Figure 29 (collision). The 10 obtained accident scenarios are listed in Table 6 for collisions and in Table 7 for groundings, along with some key input parameters to assess the consequence using the ADSAM-G and ADSAM-C tools. These inputs are obtained from information given in the VTS Incident reports, AIS data, and nautical charts. Some parameters in the accident scenario, for instance the impact speeds and location on the ship hull, require assumptions, which are based on analyst judgments in view of the VTS Incident reports, or if necessary assuming plausible worst-case conditions. This is also the case for the impact angle between the two vessels in collision cases, and the parameters related to the rock shape and size in grounding cases.

In a first accident scenario (ID 4), a medium size tanker carrying light-medium crude oil suffers an engine problem, such that the engine is stuck in half speed ahead. This occurs in the approach waterway in the Archipelago between Mossakär and Viskär. The vessel navigates out of the fairway, and suffers a subsequent rudder failure. Efforts of dropping the anchor are only partially successful to slow down the vessel, but eventually the vessel grounds near the Vitharu island, shown in Figure 28.

In a second accident scenario (ID 6), a large size tanker carrying diesel oil proceeds in the traffic separation scheme. The vessel is planning to continue her voyage to southwest and wants that a second vessel would alter to starboard and pass her stern. The second vessel says she will alter 10-15 to starboard, and after a few minutes this manoeuvre is executed. At this point, the tanker alters her course to port, upon which the Helsinki traffic centre contacts the vessel asking why she is performing this manoeuvre. The tanker's officer on watch answers that this is because the other

Figure 28. Location of the first accident scenario: grounding near Vitharu island

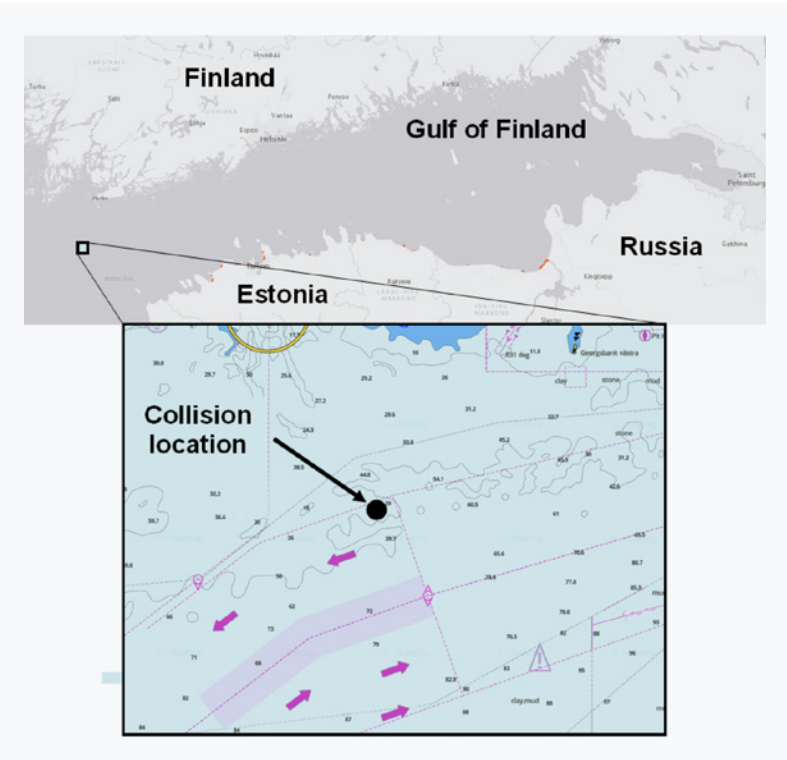

Figure 29. Location of the second accident scenario: collision in the traffic separation area off Hanko

Table 6. Input parameters for application of ADSAM-C model

ID	Latitude [°N]	Longitude [°E]	Tanker size [-]	Impacting vessel size [-]	Oil type [-]	Tanker speed [kn]	Impacting vessel speed [kn]	Impact location [%]	Impact angle [°]
1	59.733263	20.407857	Small (T1)	Small (IV1)	Diesel	6	7	50	90
5	59.518746	22.683690	Medium (T2)	Small (IV1)	Gasoline	6	7	50	90
6	59.564545	22.651422	Large (T3)	Small (IV1)	Diesel	10	7	50	90
8	59.880263	25.321633	Medium (T2)	Medium (IV2)	Diesel	10	12	50	90
9	59.926103	25.830549	Very large (T4)	Small (IV2)	Light-med crude	10	7	50	90

Table 7. Input parameters for application of ADSAM-G model

ID	Latitude [°N]	Longitude [°E]	Impact speed [kn]	Rock size [m]	Penetration depth [m]	Oil type [-]
2	59.733263	19.853940	7	3	3	Light-medium crude
3	60.446166	22.057431	5	3	2	Gasoline
4	59.903222	21.533627	6	10	1.8	Light-medium crude
7	60.010924	25.598107	5	10	3	Light-medium crude
10	60.490699	26.947046	13	10	2	Gasoline

Table 8. Characteristics of different oil types used in ADSAM-C and ADSAM-G calculations

Oil type	ρ_{oil} [kg/m3]	T_{1oil} [°C]	T_{2oil} [°C]	T_{ppoil} [°C]
Gasoline	764	10	10	-40
Diesel	823.7	10	10	-29
Light-medium crude	908.9	10	10	-7.1
Heavy crude	953	10	10	-8.6

Notes: ρ_{oil} = oil density, T_{1oil} = temperature at which oil is transported, T_{2oil} = temperature at which oil flows out from the vessel, T_{ppoil} = pour point temperature of the oil

Table 9. Characteristics of different oil types used in ADSAM-C and ADSAM-G calculations

ID	Sea area [-]	Accident type [-]	Oil type [-]	Spill size [tonnes]	Spill duration [-]
1	1	Collision	Diesel	1000	Immediate
2	1	Grounding	Light-medium crude	491	Immediate
3	2	Grounding	Gasoline	210	Immediate
4	2	Grounding	Light-medium crude	829	Immediate
5	3	Collision	Gasoline	5000	Immediate
6	3	Collision	Diesel	12500	Immediate
7	4	Grounding	Light-medium crude	5451	Immediate
8	4	Collision	Diesel	12500	Immediate
9	5	Collision	Light-medium crude	20000	Immediate
10	5	Grounding	Gasoline	150	Immediate

vessel is not altering to starboard, which clearly is an erroneous judgment. The other vessel alters more to starboard to avoid collision, but after another unfortunate manoeuver by the tanker, the vessels come in a close encounter situation, upon which the second vessel strikes the tanker in its mid-ship area. This occurs in the traffic separation area off Hanko, shown in Figure 29.

Table 6 provides an overview of the input parameters for the execution of the ADSAM-C model, whereas Table 7 presents the parameters for executing the ADSAM-G model. Table 8 summarizes a number of characteristics of the different oil types, needed as input for the ADSAM-G model.

The results of the accidental oil outflow estimations, obtained using the ADSAM-C and ADSAM-G models with the above input parameters, are shown in Table 9. Together with the results of the probability of event occurrence, these provide a baseline of oil spill risk in the hotspot areas identified in Stage 2, see Figure 27.

3.3. Oil spill drift predictions

This section aims to provide an answer to risk management question 6 in Test area 1: where would the oil drift to in the sea area?

The data used in this part of the Baltic Sea case study consists of the results of the estimated oil spill sizes and of the metocean data of the Finnish Meteorological Institute. The methods applied are SpillMod [31] and ADIOS [32]. For an extensive description of this part of the case study, see OpenRisk publication [33].

In this section, the estimated oil spill sizes of 10 scenarios are taken as a starting point for the oil spill drift predictions. The prediction calculations are based on the situation where no response measures are executed. With the SpillMod tool, the oil spill drifts are calculated for each scenario based on their geographical locations and metocean data from the year 2000. In addition, the oil evaporation and its dissolution with water are taken into account, by using, e.g., the ADIOS method. For each scenario, the SpillMod calculations are conducted for each month of the year using three-day timeframe and time interval of one hour. As an illustration, two accident scenarios are described here more in detail. For the rest of the scenarios, a brief overview of the oil spill drift predictions is provided. Due to several assumptions made in the oil spill drift calculations, the results provide only rough indications of reality.

In the first scenario (ID 4), a grounding of an oil product tanker occurs in July near Vitharu Island (Figure 28) resulting in an outflow of 829 m3 crude oil. The wind force at the time of the event is 8 m/s from the direction 340o. As this scenario is timed for the warm summer season, the estimated oil evaporation rate is approximately 40 per cent of the total oil amount. Due to moderate wind force at the time of the event, the formation of oil-water emulsion is estimated as high. Based on these settings, the oil spill drift predictions are calculated using SpillMod tool. Figure 30 shows the results of calculations for each month of the year, which are indicated with different coloured lines. It is seen that in July (green lines), it is likely that the oil would drift towards the coast of Sweden in this scenario.

In the second scenario (ID 6), a large oil tanker collides with another vessel in December off Hanko peninsula (Figure 29), resulting in a massive outflow of 12 500 m³ diesel oil. The wind force at the time of the event is 6 m/s from the direction 312o. As this scenario is timed for the cold winter season, the estimated oil evaporation rate is approximately 40 per cent of the total oil amount. Due to a moderate wind force at the time of the event, the formation of oil-water emulsion is estimated as high. Based on these settings, the oil spill drift predictions are calculated similarly to scenario 4. Figure 31 shows that in this scenario 6, it is likely that the oil would drift towards the Gulf of Finland (orange lines).

The following two figures present the results of SpillMod calculations for the rest of the scenarios. Figure 32 shows the oil spill drift predictions for scenarios 1, 2, 3 and 5. In Figure 33, the focus is on scenarios 7, 8, 9 and 10. The calculation process for producing these figures is similar to the earlier presented two examples. The results are shown for each month of the year, indicated with different coloured lines. It is seen for instance, that in the worst scenario (ID 9) the oil would drift all over the Gulf of Finland regardless of month, whereas in a minor scenario (ID 3) the islands would limit the oil drift to a relatively small sea area.

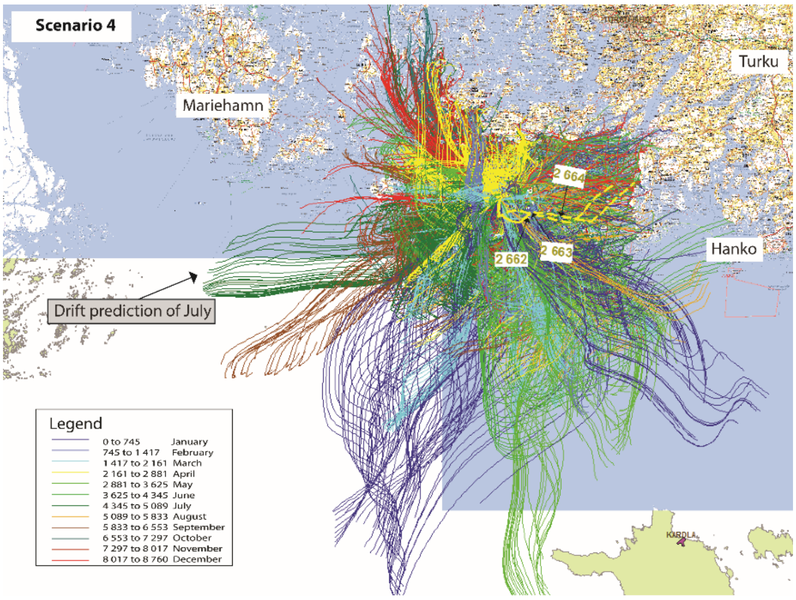

Figure 30. Oil spill drift predictions for scenario ID 4. The trajectories are calculated from the initial point of scenario (59.90 °N / 021.53 °E) for each month by an interval of one hour. The length of the trajectories is 72 hours

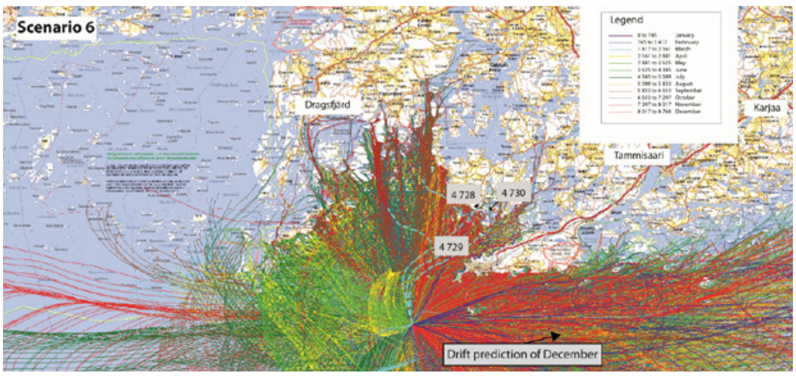

Figure 31. Oil spill drift predictions for scenario ID 6. The trajectories are calculated from the initial point of scenario (59.56°N / 022.65 °E) for each month by an interval of one hour. The length of the trajectories is 72 hours

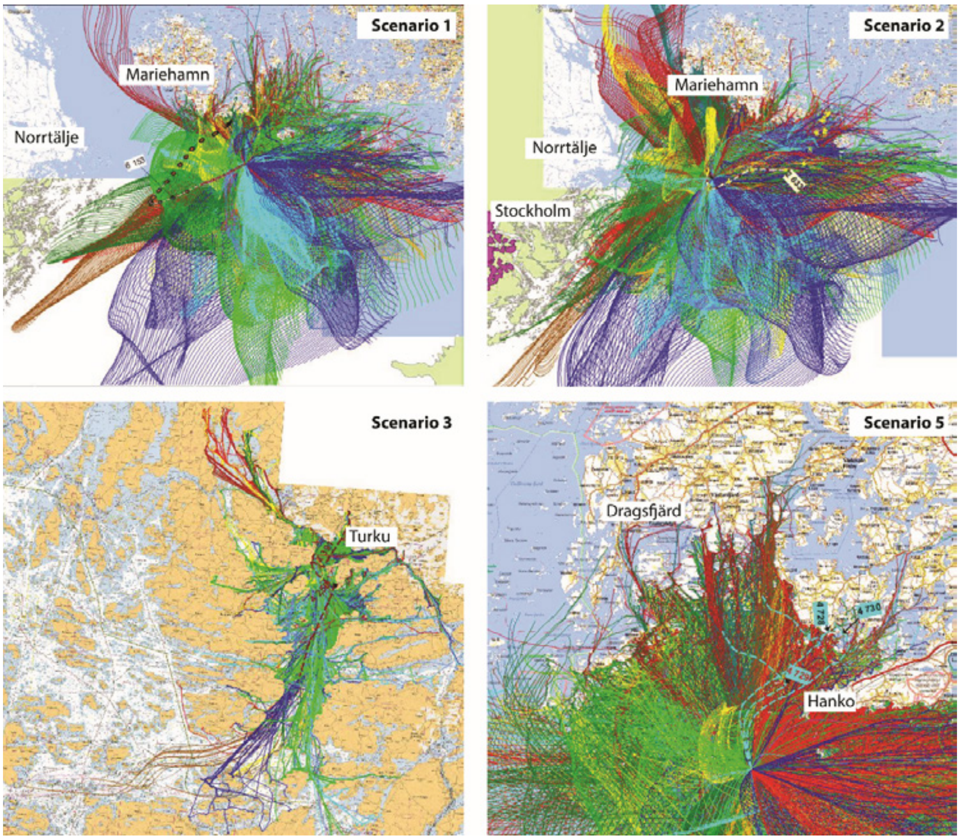

Figure 32. Oil spill drift predictions for scenarios 1, 2, 3 and 5. The trajectories are calculated from the initial point of scenarios for each month by an interval of one hour. The length of the trajectories is 72 hours

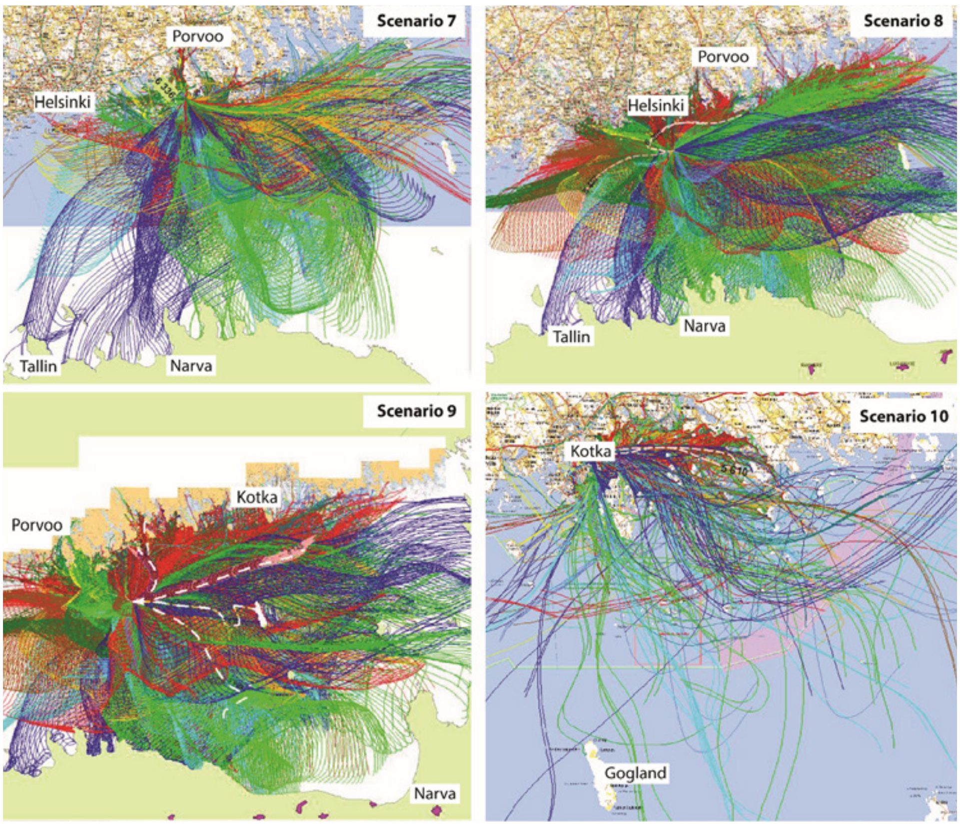

Figure 33. Oil spill drift predictions for scenarios 7, 8, 9 and 10. The trajectories are calculated from the initial point of scenarios for each month by an interval of one hour. The length of the trajectories 72 hours

3.4. Effectiveness of pollution response

This section aims to provide an answer to risk management question 7 in Test area 1: how effective the response at sea would be to those risks?

The data used in this part of the Baltic Sea case study consists of the results of the oil spill drift predictions. The evaluation of response effectiveness is based on the manufacturer's information about the theoretical recovery rate, and especially the expert judgements of the Finnish Environment Institute (SYKE). For an extensive description of this part of the case study, see OpenRisk publication [34].

In this section, the oil spill drift predictions of 10 scenarios are taken as a starting point to evaluate the effectiveness of response performance. As the predictions in the previous section are based on the situation where no response measures are executed, here the aim is to estimate how much of the spilled oil could be recovered within the timeframes of HELCOM Recommendation 31/1. This evaluation is based on the expert judgements of SYKE. It is conducted by using specific oil spill drift trajectories for different scenarios (Figure 34) as well as with the technical data of the Finnish response fleet (Table 10). In addition, some Swedish, Estonian and Russian response vessels are considered in the evaluation. As an illustration, two accident scenario narratives are described in this section more in detail. For the rest of the scenarios, a brief summary is provided at the end of the section. Due to several assumptions within this evaluation process, especially on the environmental conditions after the initial simulated accident, the estimated recovery efficiencies provide only a rough indication of reality.

In the first scenario (ID 4), an accidental oil spill of 829 m3 crude oil occurs in July near the island of Vitharju, and thereafter, the oil spill drifts towards the east coast of Sweden (Figure 30). Following the call from the tanker in distress, the duty officer of SYKE orders response vessels to the accident site. In addition, the PPR authorities of Sweden and Estonia are alerted. When the response vessels arrive on the scene, the on-scene-commander arranges suitable strike forces based on the oil spill formations. Thereafter, the response operations at sea are carried out during the next three days after the accident. In this scenario, it is assumed that the port of Naantali and coastal tankers can be utilized to empty the response vessels storage tanks. Table 11 shows the response vessels which are selected for this scenario, including their theoretical capacity of oil recovery. It is seen that in theory, these vessels could collect 11 473 m3 of oil within three days.

In the second scenario (ID 6), a massive accidental oil spill of 12 500 m3 diesel oil occurs in December off Hanko peninsula, and thereafter, the oil spill drifts towards the Gulf of Finland (Figure 31). The duty officer of SYKE orders national response vessels to the accident site, and sends a request for assisting forces to Sweden and Estonia. As this scenario is timed for winter, the regional response units of Finland have no small size vessels available, and because of this, the oil booms cannot be deployed on shallow waters. In addition, the recovery of diesel oil is much more difficult compared to, e.g., crude oil, which also has a negative effect to the outcome of the combat operation. Table 12 shows the response vessels which are selected for this scenario, including their theoretical capacity of oil recovery. It is seen that in theory, these vessels could collect 2 235 m3 of diesel oil

Figure 34. Example of the specific oil spill drift trajectory from scenario 8, which shows that there is a possibility that oil could drift up to Helsinki area in 48 hours

Table 10. Technical features of the Finnish recovery ships used in the evaluation

Ship [-]	Length [m]	Sweeping width [m]	Brushes		Width of brushes [cm]	Tank capacity [m3]	Sweeping area [km2/12h]	Recovery rate [m3/h]	Max lifting capacity of brushes [m3/h]
			[No]	[cm]					
Halli	60,5	40	18	338	338	1400	1,8	74	108
Hylje	64,3	35	16	300	300	900	1,6	65	96
Kummeli	28,2	25	10	188	188	70	1,1	46	60
Letto	42,7	30	2	110	220	42,7	1,3	56	73
Linja	34,9	23	2	100	200	77,4	1,0	43	67
Louhi	71,4	42	1	30	-	1200	1,9	78	180
Merikarhu	58	32	2	136	272	40	1,4	59	91
Oili I	24,5	21	10	188	188	80	0,9	39	60
Oili II	24,5	21	10	188	188	80	0,9	39	60
Oili III	24,5	21	10	188	188	80	0,9	39	60
Oili IV	19	19	10	188	188	30	0,8	35	60
Otava	34,9	25	8	71	71	100	1,1	46	48
Polaris	100	52	1	40	0	1200	2,3	97	180
Seili	50,5	30	12	225	225	196	1,3	56	72
Sektori	33	25	10	188	188	108	1,1	46	60
Stella	33	25	8	71	71	100	1,1	47	48
Svartnäs	24	21	-	-	-	52	0,9	39	50
Tursas	61,45	30	12	225	225	100	1,3	56	72
Turva	95,9	45	-	-	-	1200	2,0	84	180
Total						**7056**	**25,0**	**1043**	**1625**

Table 11. Recovery ships of scenario 4, their sailing times to the area and estimated recovery capacities during the first three days

Ship [-]	Sailing time [h]	Oil recovery rate per day			Total in three days
		Day 1 [m3]	Day 2 [m3]	Day 3 [m3]	theoretical [m3]
Tursas	6	225	-	-	225
Halli	7	900	900	900	2 700
Turva	10	1 200	1 200	-	2 400
Louhi	12	1 200	1 200	400	2 800
Oili-1	15	80	80	80	240
Oili-3	18	80	80	80	240
Hylje	18	480	900	900	2 280
Seili	14	196	196	196	588
Total					**11 473**

Table 12. Recovery ships of scenario 6, their sailing times to the area and estimated recovery capacities during the first three days

Ship [-]	Sailing time [h]	Oil recovery rate per day			Total in three days
		Day 1 [m3]	Day 2 [m3]	Day 3 [m3]	theoretical [m3]
Turva	5	95	120	120	335
Louhi	6	90	120	120	330
Hylje	9	130	240	240	610
Kindras Kurvits	10	60	120	120	300
Raju	10	60	120		180
KBV I	24	-	120	120	240
KBV II	24	-	120	120	240
Total					**2 235**

within three days. However, the realistic recovery rate of this oil type is estimated to be much less, and consequently, a large part of the spilled oil would drift to shore in this scenario.

The results of this section, obtained mainly with the expert judgements of SYKE, are summarized in Table 13. It is seen for instance, that in scenarios 3, 5 and 10 the effectiveness of response measures is estimated to be relatively low, primarily due to the high evaporation rate of gasoline oil. On the other hand, in scenarios 2, 4, 7 and 9, they effectiveness is estimated to be relatively high, due to, e.g., proper equipment for crude oil recovery. The results show also that in the worst scenarios, which are 6, 8 and 9, three days would not be enough for the oil recovery, and furthermore, large sea and coastal areas would be polluted by diesel oil or crude oil if these scenarios would be materialized.

3.5. Estimation of consequences

In this section it is estimated, how serious the environmental consequences could be, if the 10 different scenarios would be materialized. The data used in this part of the Baltic Sea case study consists of the results of Sections 3.3 and 3.4. The estimation is conducted as an expert judgement of SYKE with support of the POLSCALE guideline [35].

The estimation of severity for 10 different oil spill scenarios is made for two options: i) no response measures are executed, and ii) response measures are executed. The purpose of these options is to describe the effectiveness of pollution response as a control for risk mitigation. The main issues used as a base for estimation are the amount of oil that could reach the shoreline, and the size of polluted sea area. The results of this section are shown in Table 14. In scenario 4 for instance, the environmental consequences could be serious, and the dimensions of the oil spill could be international, if no response measures are executed. Correspondingly, by conducting efficient response measures, the consequences related to this same scenario could be somewhat limited compared to the first option.

The results of this section are used in Chapter 4.1, when combining the likelihood, consequences and strength of evidence in a risk scale.

3.6. Strength of evidence for the probability and consequence estimation

This section aims to provide an answer to risk management question 8 in Test area 1: how much can the results of the risk analysis be relied on?

The information used in this part of the Baltic Sea case study is the different types of evidence used to perform the risk analysis, as shown in Sections 3.1 to 3.5. This consists of different data sources, various engineering and natural science models, expert judgments, and assumptions. As outlined in the OpenRisk Guideline, it is important to be aware of the uncertainties in this evidence for the risk analysis. It is common in risk analyses that data is limited, or that simplified models are used. In such cases, uncritical adoption of the analysis results can lead to unwarranted confidence, and to poor decisions.

In order to account for the uncertainties in the evidence base for the risk analysis, the state-of-the-art Strength of Evidence Assessment scheme is applied [36]. This scheme lists the different data types, the models used in the analysis, the judgments made, and the main assumptions in the analysis. For each of these evidential elements, a judgment is made of how strong or weak the evidence is. This is done based on guide phrases focusing on certain tabulated evidential characteristics, distinguishing 'weak' from 'strong' evidence. These are shown in Tables 3.17.1 and 3.17.2 in the OpenRisk Guideline.

For the Baltic Sea case study, this is performed for Test area 1. The results are shown in Table 15. This provides a Strength of Evidence (SoE) rating for each evidence element for each risk analysis step, along with a brief justification of why that rating is selected.

Table 15 provides a summary rating of the main elements of the risk analysis, which are used in the Risk Matrices shown in 4.1.

Table 13. Summary of theoretical oil recovery and estimated scenarios

ID [-]	**Sea area** [-]	**Oil type** [-]	**ADSAM Spill size** [tonnes]	**# of ships** [-]	**Average sailing time** [h]	**Total storage capacity** [m3]	**Theoretical recovery in 3 days** [m3]
1	1	Diesel	1 000	4	18	3 100	888
2	1	Light-medium crude	491	5	12	3305	4 521
3	2	Gasoline	210	-	-	-	-
4	2	Light-medium crude	829	8	13	4781	11 473
5	3	Gasoline	5 000	-	-	-	-
6	3	Diesel	12 500	7	13	4 600	2 235
7	4	Light-medium crude	5451	5	6	3576	7 428
8	4	Diesel	12 500	7	12	4 600	2 421
9	5	Light-medium crude	20 000	12	10	7374	17 978
10	5	Gasoline	150	-	-	-	-

Table 14. Severity of the consequences of different scenarios

ID.	Release [m3]	No response		Response	
		Consequences	Dimensions	Consequences	Dimensions
1	1000	SERIOUS	INTERNATIONAL	MODERATE	LOCAL
2	491	SERIOUS	REGIONAL	MINOR	LOCAL
3	210	MINOR	REGIONAL	MINOR	LOCAL
4	829	SERIOUS	INTERNATIONAL	MODERATE	LOCAL
5	5 000	MODERATE	REGIONAL	MODERATE	LOCAL
6	12 500	CATASTROPHE	INTERNATIONAL	MODERATE	INTERNATIONAL
7	5 451	SERIOUS	INTERNATIONAL	MODERATE	INTERNATIONAL
8	12 500	CATASTROPHE	INTERNATIONAL	SERIOUS	INTERNATIONAL
9	20 000	CATASTROPHE	INTERNATIONAL	SERIOUS	INTERNATIONAL
10	150	MODERATE	LOCAL	MINOR	LOCAL

Table 15. Strength of Evidence Assessment of the evidence used in the risk analysis

Risk analysis step	Section	Evidence element	SoE rating	Justification
Likelihood of maritime accidents	3.1	VTS incident reports	Strong	Much reliable data available High accuracy of recording High reliability of data source
		HELCOM accident data	Medium-strong	Medium amount of data available High reliability of data source Medium number of errors (underreporting)
		HELCOM AIS data	Strong	Much reliable data available High accuracy of recording High reliability of data source
		Expert judgments	Medium	Moderate intersubjectivity Several would have made the same assumptions
Estimated oil spill sizes	3.2	VTS incident report	Strong	Much reliable data available High accuracy of recording High reliability of data source
		Expert judgment	Medium	Moderate intersubjectivity Several would have made the same assumptions
		ADSAM-C/G models	Medium-Strong	Some experimental confirmation Experiments agree well with model output Model theoretically expected to lead to good predictions
Oil spill drift predictions	3.3	SpillMod	Medium-Strong	Some experimental confirmation Experiments agree well with model output Model theoretically expected to lead to good predictions
		ADIOS	Medium-Strong	Some experimental confirmation Experiments agree well with model output Model theoretically expected to lead to good predictions
		Metocean data	Strong	Much reliable data available High accuracy of recording High reliability of data source
Effectiveness of pollution response	3.4	Response equipment manufacturer specifications	Medium	Little reliable data available High accuracy of recording Medium reliability of data source
		Expert judgments	Medium	Moderate intersubjectivity Several would have made the same assumptions
Estimation of conse-quences	3.5	Oil spill drift predictions	Medium-Strong	See justification for 3.1 to 3.3
		Estimated response effectiveness	Medium	See justification for 3.4

Stage 4. Risk evaluation

This chapter of the Baltic Sea case study focuses on the risk evaluation, which is the final stage of the risk assessment process. As elaborated in the OpenRisk Guideline, the aim of this stage is to evaluate whether the risk values are acceptable or not, whether risk control options would need to be implemented, and which ones.

The purpose of this chapter is to provide answers to risk management questions 9 and 10 listed in Section 1.3, and as shown in Figure 4. At this stage, the results of risk analysis stage concerning Test area 1 are evaluated in terms of acceptability.

4.1. Combining probability, consequences and strength of evidence in a risk scale

This section aims to provide an answer to risk management question 9 in Test area 1: how do different scenarios compare to one other in the different dimensions of risk?

This comparison accounts for the relative likelihood of oil tanker accident occurrence in the different sea areas, the severity of consequences in those areas, and the effectiveness of the response. Also the strength of evidence for making those estimates is accounted for. To facilitate the evaluation of the risk acceptability in Section 4.2, a distinction is made between the baseline risk level and the PPR controlled risk. The baseline risk level corresponds to the likelihood of tanker accident occurrence, and the spill consequence severity, assuming that no response is taken. The PPR controlled risk corresponds to the likelihood and consequence severity of oil spills due to tanker accidents, accounting for the Finnish response at sea. By making this distinction, it can be evaluated to what extent the Finnish response system adequately can address the marine oil spill risks at sea, and for which scenarios additional (e.g. regional) response resources would be required, or for which areas shore-response and clean-up should be prioritized to make the risk levels acceptable.

The data used in this part of the Baltic Sea case study consists of the results of Section 3. The following results are used in the scenario comparison to support pollution preparedness and response decision making:

— results of the accident likelihood estimation for tankers, shown in Section 3.1;
— oil spill consequences (spill size and drift), with and without response, shown in Section 3.5;
— strength of evidence assessments, shown in Section 3.6.

The method applied is the Risk Matrices, introduced in Section 3.18 of the OpenRisk Guideline. The Risk Matrix for the baseline risk level is shown in Figure 35 on the left. The Risk Matrix for the PPR controlled risk level is shown in Figure 35 on the right. In each

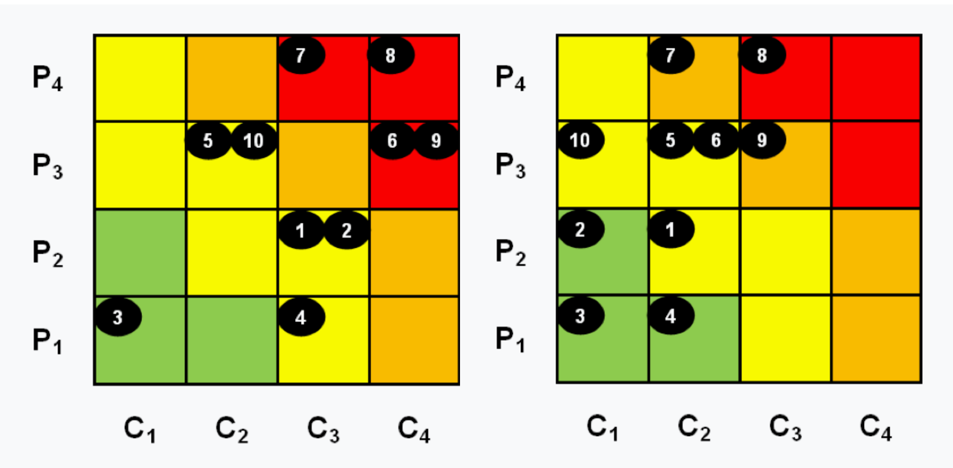

Figure 35. Risk matrix for the 10 spill scenarios defined in Section 3.1.4, along with occurrence likelihood estimations as per Section 3.1.1 and consequence estimations as outlined in Section 3.5. Left: baseline risk; Right: PPR controlled risk

risk matrix, the 10 oil spill scenarios of Section 3.1.4 are shown. Each scenario is assigned a qualitative rating showing their likelihood of occurrence, obtained for the different sea areas as shown in Section 3.1.1. The scenarios are also given a consequence severity rating, using the results of Section 3.5. In Figure 35, the consequence severity levels C1, C2, C3, and C4 correspond to the classifications 'minor', 'moderate', 'serious' and 'catastrophic', see Section 3.5. The likelihood levels P1, P2, P3, and P4 correspond to the classifications 'very low', 'low', 'medium', and 'high', see Section 3.1.1.

From Figure 35, it is evident that the spill scenarios represent a mix of minor to catastrophic events. The risk matrices also show that there are large differences between likelihood and severity of different plausible spills in the different sea areas. For example, the likelihood of accidental oil spills from tankers in Sea area 2 of Figure 5 (scenarios 3 and 4) is very low, and baseline spills vary from minor to serious. In contrast, the likelihood of oil spills in Sea area 4 (scenarios 7 and 8) is high, and their consequence severity ranges from serious to catastrophic. The difference between baseline risks and the PPR controlled risks also clearly shows that pollution response activities at sea always reduce the consequence severity levels. The spill response is very effective for some scenarios, e.g. for scenario 2 the severity is reduced from serious to minor. However, for other scenarios, existing response capacity at sea is not fully effective at mitigating the consequences. This is e.g. for scenario 8, for which response operations reduce the severity level from catastrophic to serious.

Figure 35 is accompanied by Table 16, where the strength of evidence assessment ratings for these different scenarios are shown, both for the baseline risk level and the PPR controlled risk level. The information used to make these overall ratings is given in Table 15 in Section 3.6. For all scenarios, the same ratings are found, as there are no differences in the quality of the underlying evidence in the different sea areas of Figure 5. However, in Table 16, the ratings for all scenarios are shown, to raise awareness that the strength of evidence is not necessarily identical for all scenarios, e.g. if incident data is known to be unreliable or systematically underreported in a particular sea area. The table shows that the strength of evidence is 'medium-strong' for all scenarios, for the baseline risk levels. This implies that decision makers can confidently rely on these results in evaluating the risks. The table, however, also shows that the PPR controlled consequence severity rating is only 'medium', which is due to the fact that the assessment of response effectiveness of Section 3.4 relies heavily on expert judgment, where some disagreement between experts may be expected. In the decision making context, it means that the risk-reducing effects of the response activities at sea should be carefully considered in the decision making, not relying too heavily on the rating.

Table 16. Strength of Evidence Assessment for the scenarios of Figure 35

Scenario	Baseline		PPR controlled	
	SoE Likelihood	SoE Consequences	SoE Likelihood	SoE Consequences
1	Medium-Strong	Medium-Strong	Medium-Strong	Medium
2	Medium-Strong	Medium-Strong	Medium-Strong	Medium
3	Medium-Strong	Medium-Strong	Medium-Strong	Medium
4	Medium-Strong	Medium-Strong	Medium-Strong	Medium
5	Medium-Strong	Medium-Strong	Medium-Strong	Medium
6	Medium-Strong	Medium-Strong	Medium-Strong	Medium
7	Medium-Strong	Medium-Strong	Medium-Strong	Medium
8	Medium-Strong	Medium-Strong	Medium-Strong	Medium
9	Medium-Strong	Medium-Strong	Medium-Strong	Medium
10	Medium-Strong	Medium-Strong	Medium-Strong	Medium

4.2. Evaluating the acceptability of the risks in the different sea areas

This section aims to provide an answer to risk management question 10 in Test area 1: are the risks acceptable?

The data used in this part of the Baltic Sea case study consists of the results of Chapter 4.1. The method applied is the As Low As Reasonably Practicable Principle, which is a guiding principle underlying the evaluation of the different scenarios of Section 4.1, to assess whether those are acceptable, for which scenarios additional risk treatment may be needed, and where that should be prioritized. In this case study, no firm risk acceptability criteria are set in advance, as no such criteria are known to have been set by responsible authorities. Rather, the results of the risk analysis are intended to be used in a deliberation, where the likelihood and severity of different scenarios is considered, both in terms of the baseline risks and the PPR controlled risks.

The colouring of the cells in the risk matrices of Figure 35 qualitatively indicates the relative acceptability of the risks. Red cells correspond to scenarios of which the risks are least acceptable, green areas correspond to scenarios which are most acceptable. According to the ALARP principle, all scenarios should be brought to a level which is as low as reasonably practicable. The scenarios in red cells should be prioritized for risk reduction, then those in orange and yellow. Scenarios in the green cells can be considered acceptable. In considering further risk reduction actions, the ALARP principle would usually be accompanied with Cost-Benefit Analysis, as outlined in the OpenRisk Guideline Section 3.20. For the different risk controls, their implementation cost would then be compared with the expected risk reduction effect, and an assessment would be made whether costs are reasonable.

In the Risk Matrices, certain scenarios clearly stand out in terms of their likelihood of occurrence, and their consequence severity. For the baseline risks in Figure 35 (left), these are scenarios 6, 7, 8, and 9. Figure 35 (right) shows that even with the PPR controlled risk levels, scenario 8 is at a level which likely is not acceptable. Scenarios 9, 7, 6, and 5 should also be prioritized for further risk reduction, e.g. through additional or differentiated response options, or by implementing shore-based response operations. This should be considered through a cost-benefit analysis, where costs of oil spills (in various aspects including ecological damage and socio-economic costs) should be weighted against the costs of implementing further risk-control options. On the other hand, the risk matrix of Figure 35 also shows that certain scenarios (e.g. 2, 3, and 4) already are at an acceptable level with the pollution response at sea in place, or at least that those are not a priority for further risk reduction.

Stage 5. Risk treatment

This chapter of the Baltic Sea case study provides a brief overview concerning the risk treatment options of HELCOM Response in the context of the intermittent risk management process. As noted in the OpenRisk Guideline, if after the risk evaluation stage the risk level is deemed to be too high or unacceptable, appropriate risk control and mitigation measures should be implemented to reduce either the probability or the consequences of unwanted events.

As noted earlier, in the intermittent risk management process, decisions concerning HELCOM Response activities should focus on relatively small adjustments to the fleet or operational procedures, within already available budgets, see Table 1. Therefore, based on the results of this Baltic Sea case study, the following risk treatment options could be considered, for instance:

- updating of the HELCOM Response Manual and the Contracting Parties' fleet equipment to cope better with the large-scale diesel oil spills;
- developing flexible ways to increase response capacity at sea and to empty response vessels storage tanks during the combat operation;
- developing further the shore-based response measures including the criteria to prioritize these measures;
- organizing frequent tabletop exercises to define the usefulness of selected response measures and to evaluate the impacts of different tactical alternatives;
- reinforcing the cooperation with other maritime authorities and relevant stakeholders to reduce the likelihood of accidental maritime oil spills.


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Stage 6. Parallel activities

This chapter of the Baltic Sea case study focuses on the parallel activities of the risk management process, which includes consultation and communication, and monitoring and review of the adequacy of implementation of the five risk management stages.

The purpose of this chapter is to provide a brief overview of the parallel activities related to HELCOM Response in the scope of the intermittent risk management process.

6.1. Consultation and Communication

The purpose of communication and consultation is to assist relevant stakeholders in understanding the risk, the basis on which decisions are made and the reasons why particular actions are required. The stakeholders may also have an important role in all stages of the risk management process, as stated in the OpenRisk Guideline.

When conducting a risk assessment process, it is rather common that the risk analysis produces information and lead to risk assessment findings where other actors have the authority to implement changes in the system. This is especially the case in large-scale, distributed systems such as shipping industry, where legal and operational responsibilities are divided between the private sector and public authorities. The following figures are examples of such findings.

Figure 36 presents the tanker incident likelihood calculation method, which is more suitable for the accident prevention needs. In other words, for the needs of VTS authorities, Port State Control, the private sector and the like. The approach presented in this figure is different from Figure 22, which is designed primarily for the PPR needs. In this figure the equation is:

$$N_{ti}NM_l = N_{ti}/NM_l$$

where $N_{ti}NM$ is the number of tanker incidents per nautical miles sailed, Nti is the number of tanker incidents in a specific hotspot sea area, and NM_l is the distance of tankers sailed in nautical miles in the specific hotspot sea area, based on the HELCOM AIS data from period 2014-2016. From the figure it can be seen, for example, that the incident frequency in Sea area 4 is lower than the incident frequency of Sea area 2, when the distance sailed in the corresponding sea area is used as a reference instead of the distance sailed in all hotspot sea areas like in Figure 22.

Figures 37 and 38 are other examples of findings, which could be also of interest for the stakeholders. They are produced simultaneously, when analysing the data used for this Baltic Sea case study. The methods applied are Safety Factors [37] and ERC-M. The negative values in these figures show the number of events when a particular Safety Factor (e.g. Competencies) has failed in different analysed incidents, whereas the positive values shows the number of events where particular Safety Factors have prevented the situation from getting worse. Such information may not be useful for PPR authorities, but it could be interesting for the stakeholder working with safety of the shipping industry, and hence should be communicated.

6.2. Monitoring and review

As described in the OpenRisk Guideline, monitoring and reviewing is another important parallel activity in the risk management process. This cuts across the different stages, including the establishment of the context, and the various risk assessment stages, and risk treatment.

One aspect of this focuses on quality management activities, to ensure that the information processed in the different stages is adequately utilized to establish the context and to perform the risk assessment, and that appropriate risk control options are implemented.

Another aspect focuses on the quality of the risk assessment in terms of the quality of reports, their timeliness as well as their usefulness for decision

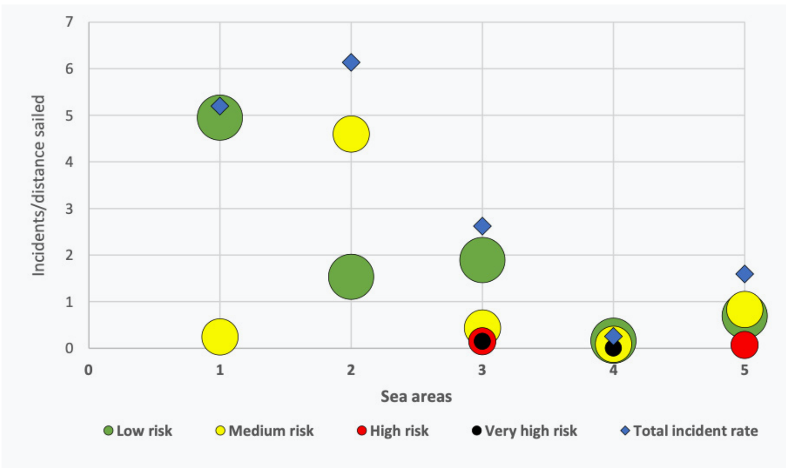
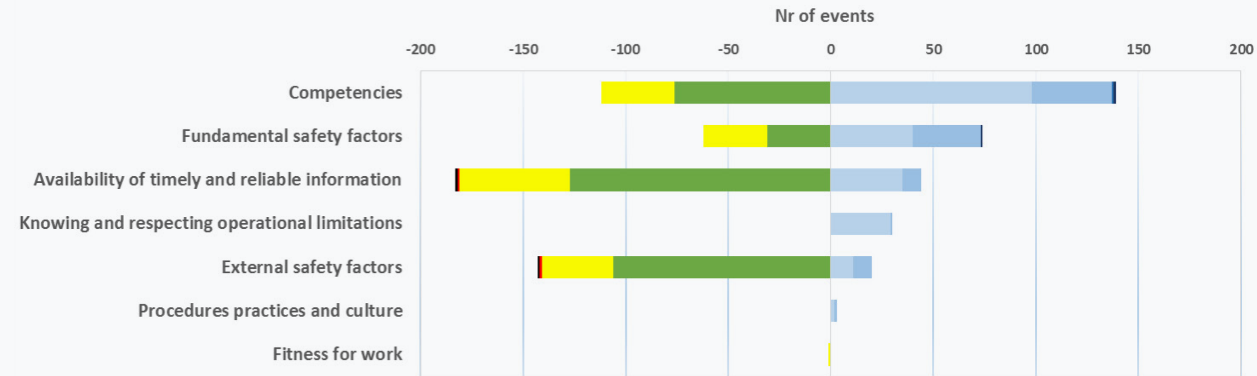


Figure 36. Incident frequencies of oil tankers in different hotspot sea areas based on ERC-M classification of potential environmental damages

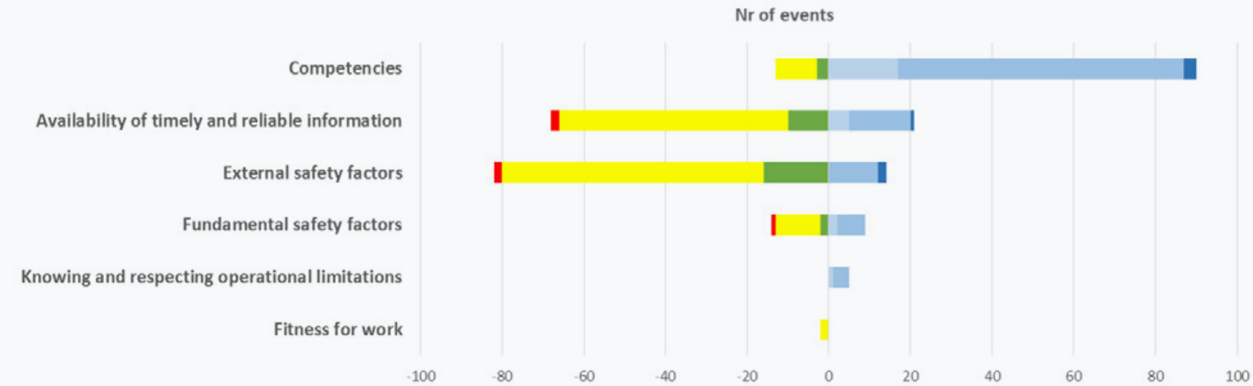
makers for making good risk management decisions, and their interest to other stakeholders.

Finally, the monitoring and review activity focuses on the issue that systems, as well as the nature of the activities and processes within the system, and their environment, change over time. As it is important that risk management is up-to-date, this requires a periodic re-evaluation of the adequacy of the applied tools and information sources. This is related to the continuous improvement of the overall risk management framework, outlined in the OpenRisk Guideline.



	Fitness for work	Procedures practices and culture	External safety factors	Knowing and respecting operational limitations	Availability of timely and reliable information	Fundamental safety factors	Competencies
Low risk	0	0	-106	0	-127	-31	-76
Medium risk	-1	0	-35	0	-54	-31	-36
High risk	0	0	-1	0	-1	0	0
Very high risk	0	0	-1	0	-1	0	0
Low positive value	0	2	11	29	35	40	98
Medium positive value	0	1	9	1	9	33	39
High positive value	0	0	0	0	0	0	1
Very high positive value	0	0	0	0	0	1	1

Figure 37. Safety factors in Test area 1



	Fitness for work	Knowing and respecting operational limitations	Fundamental safety factors	External safety factors	Availability of timely and reliable information	Competencies
Low risk	0	0	-2	-16	-10	-3
Medium risk	-2	0	-11	-64	-56	-10
High risk	0	0	-1	-2	-2	0
Very high risk	0	0	0	0	0	0
Low positive value	0	1	2	0	5	17
Medium positive value	0	4	7	12	15	70
High positive value	0	0	0	2	1	3
Very high positive value	0	0	0	0	0	0

Figure 38. Safety factors in Test area 2

7. Conclusions

This Baltic Sea case study has illustrated how the OpenRisk Guideline can be applied for managing the risks related to oil spill preparedness and response. After establishing the external and internal context, the case study focused on two test areas in the Baltic Sea area.

For these areas, specific risk management questions were formulated, and answers to these were sought in the context of the intermittent risk management process defined in the OpenRisk Guideline. The focus was on accidental oil spills from shipping accidents, and the scope of the study was limited to two test areas. The risk identification, risk analysis, and risk evaluation was performed using tools included in the OpenRisk toolbox, which are introduced in the OpenRisk Guideline. The risk treatment, and the parallel activities of consultation and communication, and monitoring and review, were only briefly described in this case study, as these are specific to particular organizations and their context.

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Annex I

Table A. External and Internal context of pollution preparedness and response risk management

External context	
International and domestic legislation on oil pollution preparedness, response and co-operation	Helsinki Convention (Annex VII) Domestic regulations of the HELCOM countries Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 1990)
Drivers and trends impacting oil spill hazard	Maritime transport: increase in ship sizes (e.g. container ships over 20 000 TEU), different types of cargoes and changes in volumes Compliance with international rules and regulations including control Other drivers and trends (unmanned ships, new oil terminals, windmill farms, new low sulphur fuels etc.)
Governance, roles and accountabilities on oil spill prevention, detection and combat	Legislation and administration of the HELCOM countries, including international agreements IMO, EMSA, DG ECHO CECIS, Clean Sea Net, Safe Sea Net, THETIS
Perceptions of external stakeholders regarding the oil hazard	Shipping companies P&I Clubs, Vetting companies and Classification societies Other authorities (Port State Control, VTS, CPA, etc.) NGOs (WWF, etc.)
Environmental standards, policies and objectives to be achieved	HELCOM Baltic Sea Action Plan
Internal context	
Capabilities on oil spill prevention, detection and combat	National capacity of the Contracting Parties and EMSA fleet and equipment BALEX DELTA Exercises HELCOM joint airborne surveillance activities (CEPCO) and EMSA
Oil spill contingency plan	HELCOM countries in accordance with the Helsinki Convention (Annex VII)
Standards, guidelines and models adopted by the organization	HELCOM Response Manual (Vol. 1 & 3)
Goal and objectives of the oil spill risk management	Medium size target spill and tanker 150 000 DWT target spill versus HELCOM Recommendations 28E/12 and 31/1, including location.
Responsibilities in the risk management process	HELCOM countries
Define the way performance and effectiveness are evaluated in the management of risk	KPIs for PPR risk management, e.g. RETOS
View of the stakeholders regarding hazards, impacts and risk determination method	Observers in HELCOM meetings Participation in Workshops Assistance in response (WWF shore response)
Identifying information/instruments needed for a better risk management	HELCOM Response Group meetings