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BRISK II

Probability of oil and HNS release

Deliverable 2.6

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This document is developed within the BRISK II project to present the results from the accidents and spills model for the Baltic Sea and submitted by the Core Project team on 31.03.2026 and revised 02.07.2026

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1 Introduction

1.1 Background

This data report is part of the long-term risk analysis for oil and hazardous and noxious substances (HNS) pollution from shipping accidents to the marine environment in the Baltic Sea, in short BRISK II. The BRISK II project comprises the following deliverables on the analyses:

1 Deliverables under work package 1 include project management related reports (e.g. progress reports).

2 Work package 2: Basic analysis
- 2.1 Method note
- 2.2 Data collection note
- 2.3 Traffic analysis
- 2.4 Cargo analysis
- 2.5 Accident and spill model
- **2.6 Probability of oil and HNS release *(this report)***

3 Work package 3: Future damage analysis
- 3.1 Traffic scenarios
- 3.2 Selection of risk-reduction scenarios
- 3.3 Impact mapping of spilt oil and HNS
- 3.4 Mapping of environmental vulnerability
- 3.5 Mapping of environmental damage due to oil
- 3.6 Mapping of environmental damage due to HNS

1.2 Scope

This report presents the probability of shipping accidents and the probability of oil and HNS release, i.e. the probability of spills of different sizes. The probability estimate is based on the work described in the previous deliverables D2.3, D2.4, D2.5 and D3.1, see also Figure 1-1.

The report does *not* deal with the question of how the released substances spread after release, as this is the subject of the separate report D3.3 *Impact mapping of spilt oil and HNS*.

The probability of release is calculated for the following three scenarios:

Table 1-1 Scenarios investigated in this report

Scenario	Traffic (from D3.1)	Prevention measures (from D2.5)
0-0	2024	Existing measures 2024
1-0	2036, unchanged or worsened geopolitical situation (traffic scenario 1)	Planned measures 2036
2-0	2036, improved geopolitical situation (traffic scenario 2)	Planned measures 2036

The traffic scenarios shown in Table 1-1 correspond to those developed in report D3.1 *Traffic scenarios*. The prevention measures in the table correspond to the baseline situation, i.e. the existing situation in 2024 and the expected – i.e. the currently planned – situation in 2036. The prevention measures are described in report D2.5 *Accident and spill model*.

It should be highlighted that additional prevention scenarios – together with response scenarios –will be defined in report D3.2 *Selection of risk-reduction scenarios* at a later point. They will be termed 1-1-2, 2-1 etc. The effect of these scenarios will be reported as part of the final results in report D3.5 and D3.6.

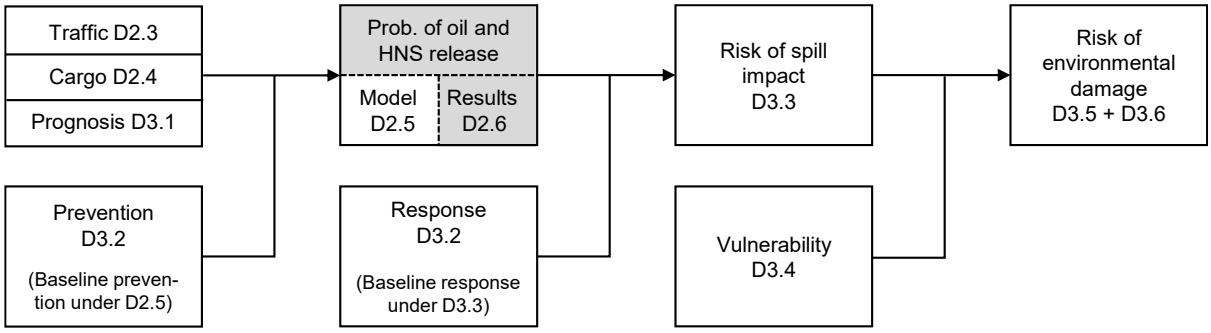

Figure 1-1 *Causal chain of the BRISK II model and corresponding deliverables numbers (The present report is highlighted with grey background)*

The accident and spill model report is divided into the following chapters:

Chapter 2: Sub-regions
Chapter 3: Model calibration
Chapter 4: Annual probability of shipping accidents
Chapter 5: Annual probability of release of oil and HNS

2 Sub-regions

Accident and spill probabilities are presented separately for each of the sub-regions, see Figure 2-1. These sub-regions are the same as used in the BRISK I project (BRISK I, Results, 2012), which helps to contrast current findings with prior results in a systematic way.

Note that the main purpose of the sub-regions is sub-dividing the results of the risk analysis. They are not linked to other geographical sub-divisions that have been defined to structure the input into the model (e.g. the traffic areas in D2.3 or the pilotage areas in D2.5).

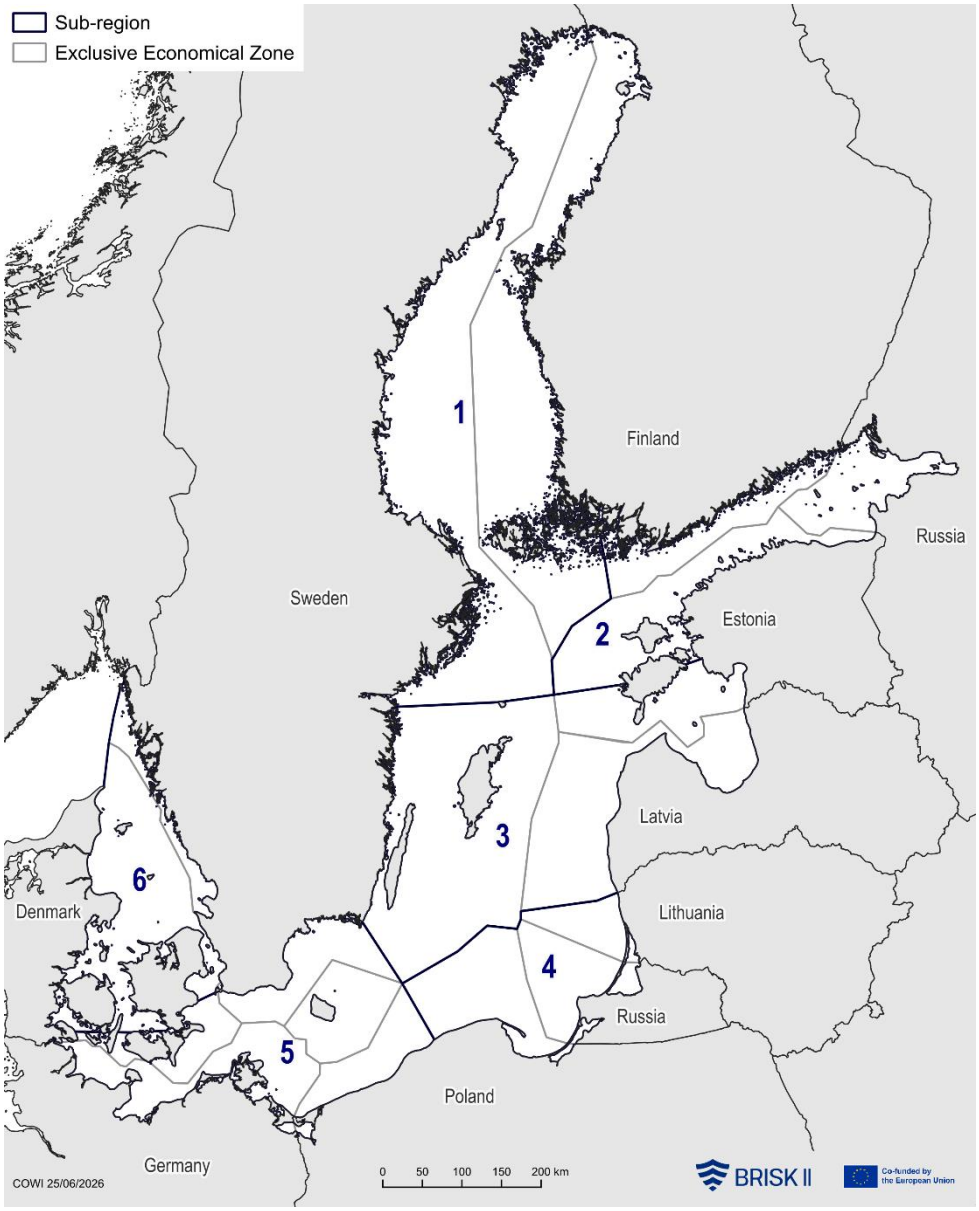

Figure 2-1 BRISK II sub-regions

Note that sub-region 2 and 4 also include the Russian EEZ in the Baltic Sea. In general, accident frequencies and the risk of release of oil and HNS are calculated for the Russian EEZ in the same way as for all other Baltic Sea countries. However, Russia does not participate in the BRISK II project. This means that

some parameters – e.g. those on risk-reduction measures – are based on data gathered during the BRISK I project (specifically the BRISK RU project), see D2.5 Accident and spill model. Other data – such as AIS-based traffic data – are up to date, see D2.3 Traffic analysis. Finally, there are some data where information gathered at other locations. This is especially relevant for cargo data where data gathered by Great Belt VTS plays a central role, see D2.4 Cargo analysis.

3 Model calibration

The accident and spill model and its parameters have been described in Section 3.2 to 3.9 of report D2.5 *Accident and spill model* (BRISK II, Spill model, 2025). Historical accident and spill statistics have been described in Section 3.1 of the same report, where they served as a basis for calibrating the model.

However, some parts of the model are more challenging to calibrate, as calibration requires a full calculation run of the accident and spill model. This is why they were not calibrated beforehand in D2.5 Accident and spill model. This applies to

- The frequency of ship-ship collisions
- The frequency of groundings
- The consequences of collisions with offshore wind farms

The calibration of these three models against historical data is described in this chapter.

3.1 Calibration of the ship-ship collision frequency model

The ship-ship collision model is described in Section 3.3 of report D2.5. As mentioned there, the probability that two ships sailing on collision course do *not* undertake any evasive measures is called causation probability P_C. This quantity was originally defined and described by Fujii (Fujii, 1984).

BRISK I calibration

In the context of the Great Belt Fixed Link project, Fujii's result was adapted to the situation in Danish waters, resulting in a value of $P_C = 3.2 \times 10^{-4}$. A value of $P_c = 3.0 \times 10^{-4}$ was chosen in the analysis of oil and chemical spill risk in Danish waters, because it was found consistent with the observed accident rate (Oil spill DK, 2007). For the BRISK I project, calibration against accidents numbers during the years 2004-2008 resulted in $P_c = 4.0 \times 10^{-4}$ (BRISK I, Spill, 2012). For the specific case of the Drogden channel in the Sound of Copenhagen, a revised factor of $P_c = 1.3 \times 10^{-4}$ was applied based on an earlier location-specific analysis (Drogden, 2001). Using a value of 4.0×10^{-4} would have led to a much higher accident frequency than actually observed.

Applied to the BRISK I project area, this would have corresponded to approximately three collisions between ships of at least 300 gross tonnage per year. As a matter of fact, the historical number of accidents were about twice as high, e.g. six collisions per year (2004-2008 average). This would have roughly corresponded to a value of $P_c = 6 \times 10^{-4}$.

However, it was taken into consideration that the historical data also included low-energy events which were not considered by the model. Setting the causation probability up to match the historical data would therefore have resulted in a problematic overestimation of collisions under full vessel speed and thus of the risk of actual spills.

Bearing all these considerations and the values used in earlier analyses in mind, it was neither deemed realistic to use $P_c = 3.0 \times 10^{-4}$ as in earlier cases, nor to set the value as high as $P_c = 6.0 \times 10^{-4}$. As an

alternative to those values, it was deemed reasonable to adopt $P_c = 4.0 \times 10^{-4}$ for the BRISK I project area as a whole and $P_C = 1.3 \times 10^{-4}$ for the Drogden channel in specific.

BRISK II calibration

For BRISK II, historical data from the Baltic Sea for 2015-2024 has been applied, see Section 3.1 in report D2.5, showing 67 ship-ship collisions, i.e. 6.7 per year in the Baltic Sea. When regarding only collisions where both ships had a size of 300 GT or more, the number drops to 44 in total, or 4.4 events per year. When excluding accidents at port approaches (see discussion in D2.5), the number is down to 4.0 events per year.

Similar to BRISK I, this value would indicate a causation factor of 6.5 times per 10,000 situations. However, the arguments from BRISK I for applying a lower value of 4×10^{-4} are still valid: The model does not account for the fact that some events happen at reduced speeds with lower energy, i.e. using a value of 6.5×10^{-4} would lead to an overestimation of the risk of spills resulting from the collisions. Moreover, it is also beneficial to maintain continuity with BRISK I where possible in order to make results more easily comparable.

Thus, the following causation factors are applied for BRISK II:

- $P_c = 4.0 \times 10^{-4}$ for all areas excluding the Drogden channel
- $P_C = 1.3 \times 10^{-4}$ for the Drogden channel

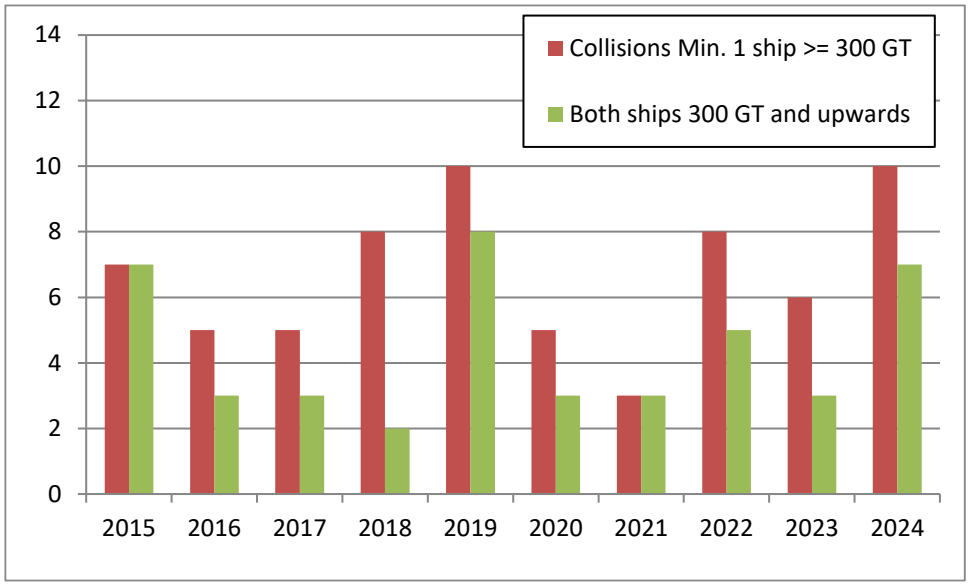

Figure 3-1 Number of ship-ship collisions in the BRISK II area, 2015-2024

3.2 Calibration of the grounding frequency model

In Table B-1 of report D2.5, the raw grounding frequency per nautical mile was established for each of the nine traffic areas (the same nine areas that are used for the cargo model in report D2.4). This frequency

needs to be corrected for the effect of risk-reducing measures (RRMs) in order to obtain the basic grounding frequency without RRMs.

The approach used to determine the basic grounding frequency follows the methodology outlines in Appendix B of report D2.5. It consists of the following steps:

- In a first step, use the raw grounding frequency instead of the basic grounding frequency as calculation input and make a test run.
- Compare the calculation results with the statistical results. The calculation results F_{test} will show a lower frequency than the statistics F_{stat}, which is due to double counting of the RRM effect. The difference can be expressed as a correction factor $x_{corr} = F_{stat} / F_{test}$.
- Calculate the basic grounding frequency as $F_{basic} = F_{stat} \times x_{corr}$.

The basic grounding frequency, i.e. the values after calibration, are shown in Table 3-1. Note that the nine traffic areas are defined for modelling purposes in D2.3 Cargo analysis and serve for various modelling purposes, i.e. the input to the model (grounding model, cargo model etc.). They are not directly linked to the six sub-regions defined in Chapter 2, which serve to structure the output from the model.

Table 3-1 Raw (= uncalibrated) and basic (= calibrated) grounding frequency

Traffic area	Raw grounding frequency per mile (including effect of RRMs)	Implied risk-reduction factor	Basic grounding frequency per mile (without RRMs)
1 Bothnian Bay	2.42×10^{-7}	0.66	3.69×10^{-7}
2 Bothnian Sea and West of Gotland	4.58×10^{-7}	0.74	6.21×10^{-7}
3 E Gulf of Finland[1]	5.69×10^{-8}	0.59	9.60×10^{-8}
4 W Gulf of Finland and Klints Bank	5.69×10^{-8}	0.59	9.60×10^{-8}
5 E Baltic Proper	1.07×10^{-7}	0.85	1.27×10^{-7}
6 South of Gotland	3.06×10^{-8}	0.77	3.95×10^{-8}
7 Slupsk Bank	8.25×10^{-8}	0.73	1.14×10^{-7}
8 Baltic Sea Entrance and Arkona Sea	3.42×10^{-7}	0.64	5.30×10^{-7}
9 Kattegat	5.01×10^{-7}	0.73	6.88×10^{-7}
Average	2.41×10^{-7}	0.69	3.51×10^{-7}

3.3 Calibration of the consequences of collisions with OWFs

Ship collisions with offshore wind farms (OWF) are a novel accident type in BRISK II that was not covered by BRISK I. The applied assumptions are described in Appendix D of report D2.5.

[1] Based on W Gulf of Finland and Klints Bank due to lack of area-specific information

After making the first full model runs, it became evident that the assumptions in report D2.5 are overly conservative, i.e. they lead to an unrealistic overestimation of the spill risk from such collisions. This can be seen from the fact that the consequences in terms of released amount of cargo were almost the same as for ship-ship collisions at intersections (node collisions). It can be demonstrated by the following considerations that is grossly disproportionate:

- The weak part of a ship is its side. Usually, no leakage occurs from a ship striking another object such as a ship or wind turbine with its bow first.

- When one ship strikes another in an intersection, the bow of the striking ships penetrates the side of the struck ship, which can lead to leakage from the struck ship. Typically, this happens at cruising speed. In the BRISK II model, cruising speed is set to 12 to 20 knots depending on the ship type.

- When a ship hits a wind turbine with its side (i.e. not its bow), this is caused by the ship drifting sideways into the turbine. Drifting speeds are generally low and rarely surpass 2 knots.

- Collision energy is a function of the square of speed. Thus, a collision at 2 knots is 36 times less violent than at 12 knots and 100 times less violent than at 20 knots.

The consequence model for collisions with offshore wind farms needs to take this difference into account. This is done by assuming that the damage from such an event is a factor 20 lower than the damage from a ship-ship collision at an intersection. This assumption is still conservative, as it is smaller than the above-mentioned factor of 36 to 100. Thus, assuming a factor 20 will most likely lead to an overestimation of the risk of hitting a turbine. However, it is far more realistic than the original assumption described in report D2.5.

The new assumption has been implemented in Table 3-2 by applying the following changes:

- The probability of medium-sized and large spills over 300 tonnes (spill size class 4 to 7) in case of a collisions has been reduced by one twentieth of the value applying to collisions at intersections

- The probability of no spill (spill size class 0) has been left unchanged

- The probability of small spills up to 300 tonnes (spill size class 1 to 3) have been partly increased so that the sum of all probabilities stays 100 %.

Table 3-2 Calibration of the cargo spill size in case of a collision with an offshore wind farm

Spill size class	0	1	2	3	4	5	6	7	Average spill size [tonnes]
From-to [tonnes]	0	0-1	1-15	15-300	300-5,000	5,000-15,000	15,000-50,000	50,000-150,000	-
Representative spill size [tonnes]	0	0.3	4	67	1,200	8,700	27,000	87,000	-
Collisions with OWF (from D2.5)	93.00%	0.00%	0.00%	0.00%	1.75%	3.50%	1.40%	0.35%	1,008
Node collisions (from full run)	91.68%	0.00%	0.02%	0.25%	3.41%	2.23%	1.97%	0.44%	1,152
Collisions with OWF (new model)	93.00%	0.00%	6.35%	0.25%	0.17%	0.11%	0.10%	0.02%	56

For bunker spills, the same principles were applied. However, the reduction by a factor twenty is also applied to spill size class 3 (300 to 5,000 tonnes). The resulting probability distribution is shown in Table 3-3.

Table 3-3 Calibration of the bunker spill size in case of a collision with an offshore wind farm

Spill size class	0	1	2	3	4	5	6	7	Average spill size [tonnes]
From-to [tonnes]	0	0-1	1-15	15-300	300-5,000	5,000-15,000	15,000-50,000	50,000-150,000	-
Representative spill size [tonnes]	0	0.3	4	67	1,200	8,700	27,000	87,000	-
Collisions with OWF (from D2.5)	97.00%	0.00%	0.00%	1.50%	1.50%	0.00%	0.00%	0.00%	19.0
Node collisions (from full run)	84.78%	0.06%	0.86%	6.94%	7.33%	0.03%	0.00%	0.00%	95.1
Collisions with OWF (new model)	97.00%	1.14%	1.14%	0.35%	0.37%	0.00%	0.00%	0.00%	4.7

4 Annual probability of shipping accidents

This chapter presents the frequency of shipping accidents calculated for the three traffic scenarios, i.e. 2024, 2036-1 (unchanged or worsened geopolitical situation) and 2036-2 (improved geopolitical situation).

This chapter only shows the frequency of shipping accidents that are a precursor to a spill. In the next chapter (Chapter 5 Annual probability of release of oil and HNS), all events are shown, i.e. also those that are not accidents (operational spills) and those where the spill is not (or not necessarily) caused by a navigation error such as over-bunkering.

The results are mainly presented in tables. Figures are only shown for the 2024 case, as the visual differences between the three scenarios are too small to be easily distinguishable for the eye.

4.1 Scenario 0-0 (2024)

Table 4-1 shows the expected annual accident frequency in 2024. It is not the accident statistics for the year 2024, but a calculation of what would happen on average after many years if the situation were unchanged relative to 2024.

As in all previous studies including BRISK I (BRISK I, Results, 2012), it is seen that groundings are by far the most frequent type of event, followed by ship-ship collisions. It can also be seen that the relative share of ship-ship collisions is higher where shipping intensities are higher: In the Kattegat (sub-region 6), there are 8 groundings per 1 ship-ship collision, whereas in the Bay of Bothnia and the Åland Sea (sub-region 1) it is 25 groundings per 1 ship-ship collision.

The results are illustrated in Figure 4-1(all accident types) and Figure 4-2 (shown without groundings for better overview).

Table 4-1 Expected annual accident frequency in 2024, by accident type

	Sub-region						
Accident type	1	2	3	4	5	6	Total
Ship-ship collision	0.10	0.32	0.20	0.06	0.83	0.84	2.35
Grounding	2.75	0.53	0.50	0.16	1.11	6.63	11.68
Collision with fixed object	0.002	0.00	0.002	0.00	0.05	0.02	0.08
Sinking	0.04	0.05	0.07	0.02	0.10	0.07	0.35
Total	2.90	0.90	0.77	0.24	2.09	7.56	14.45

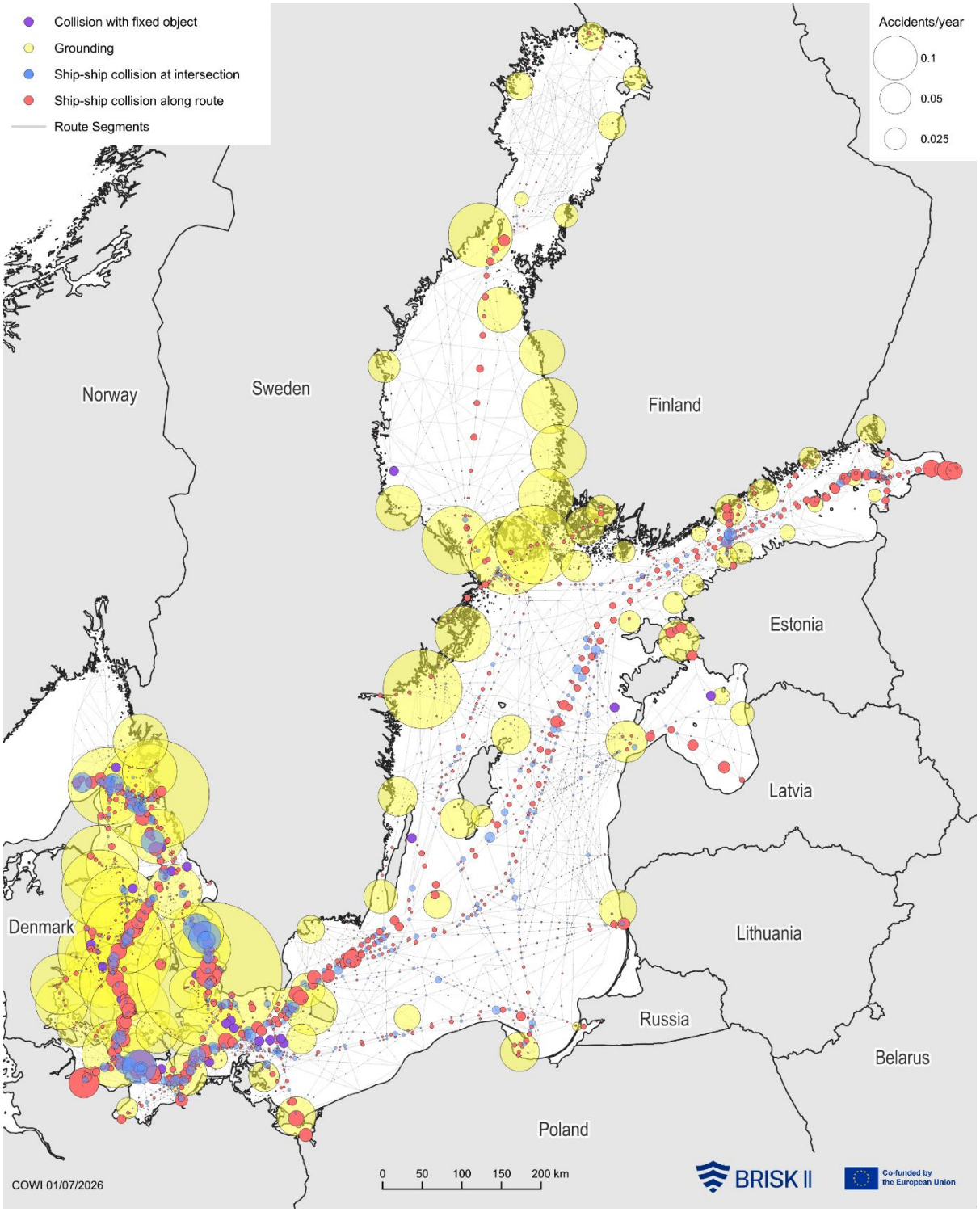

Figure 4-1 Expected annual accident frequency in 2024

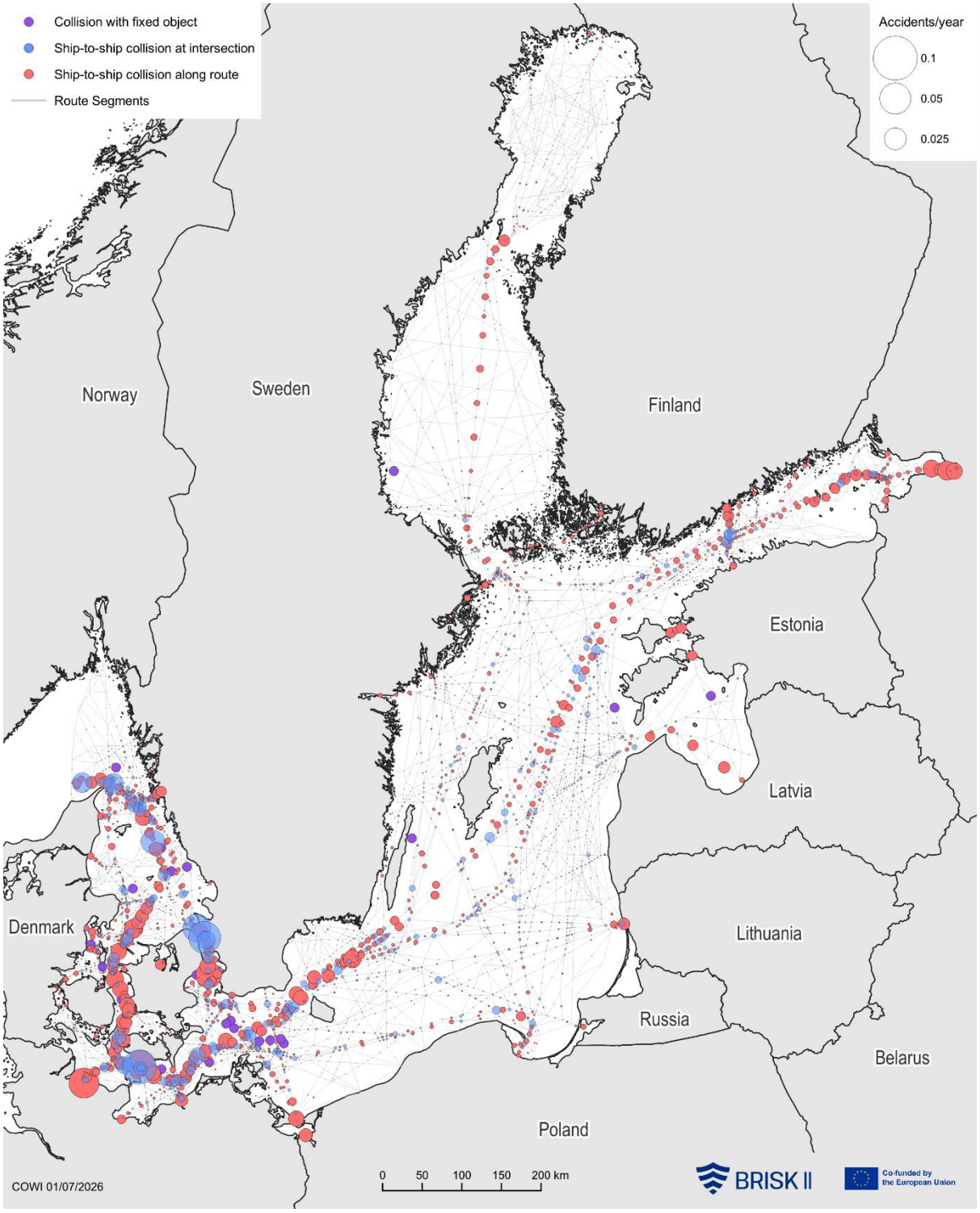

Figure 4-2 Expected annual accident frequency in 2024 (shown without groundings for better overview)

4.2 Scenario 1-0 (2036 unchanged/worsened)

In 2036 with unchanged or worsened geopolitical situation, a decrease in the number of shipping accidents can be seen (Table 4-2): This change is due to a relatively flat development in cargo tonnages in

combination with a growing average ship size, which results in fewer, larger ships than today. This development is described in D2.4 Cargo analysis (BRISK II, Cargo analysis, 2025).

As mentioned in deliverable D2.5 (BRISK II, Spill model, 2026), the numbers on collisions with fixed objects (mainly offshore wind farms) are based on objects existing in 2024 and objects planned for 2036. "Planned" means that the objects have been approved for construction.

Table 4-2 Expected annual accident frequency in 2036, unchanged or worsened geopolitical situation, by accident type

	Sub-region						
Accident type	1	2	3	4	5	6	Total
Ship-ship collision	0.07	0.25	0.14	0.04	0.65	0.65	1.80
Grounding	2.03	0.40	0.36	0.12	0.87	5.22	9.02
Collision with fixed object	0.001	0.00	0.002	0.00	0.05	0.02	0.07
Sinking	0.04	0.04	0.05	0.02	0.08	0.06	0.29
Total	2.14	0.70	0.55	0.17	1.65	5.96	11.18
Relative to scenario 0-0	-26.0%	-22.8%	-28.1%	-26.8%	-20.7%	-21.2%	-22.7%

4.3 Scenario 2-0 (2036 improved)

In 2036 with an improved geopolitical situation, accident frequencies are still lower than in 2024, but at the same significantly higher than with an unchanged or worsened geopolitical situation.

As described in D2.4 Cargo analysis, a reintegration of Russia into the global trade would lead to a strong and steady increase in container and dry bulk vessels to and from the Russian Baltic Sea ports. Some of this effect is offset by the concurrent trend towards fewer and larger ships, thus explaining the lower numbers compared to 2024. In sub-region 2 (Gulf of Finland), where ships to and from Russia make up a large fraction of the overall traffic, accident rates would however increase by approximately 50 percent.

Table 4-3 Expected annual accident frequency in 2036, improved geopolitical situation, by accident type

	Sub-region						
Accident type	1	2	3	4	5	6	Total
Ship-ship collision	0.07	0.62	0.22	0.05	0.81	0.89	2.67
Grounding	2.10	0.66	0.42	0.14	1.00	5.88	10.20
Collision with fixed object	0.001	0.00	0.002	0.00	0.05	0.02	0.07
Sinking	0.04	0.07	0.07	0.02	0.09	0.06	0.35
Total	2.21	1.35	0.71	0.21	1.96	6.85	13.30
Relative to scenario 0-0	*-23.7%*	*+50.0%*	*-7.4%*	*-9.1%*	*-6.2%*	*-9.4%*	*-8.0%*
Relative to scenario 1-0	*+3.2%*	*+94.3%*	*+28.8%*	*+24.2%*	*+18.2%*	*+15.0%*	*+19.0%*

4.4 Overview

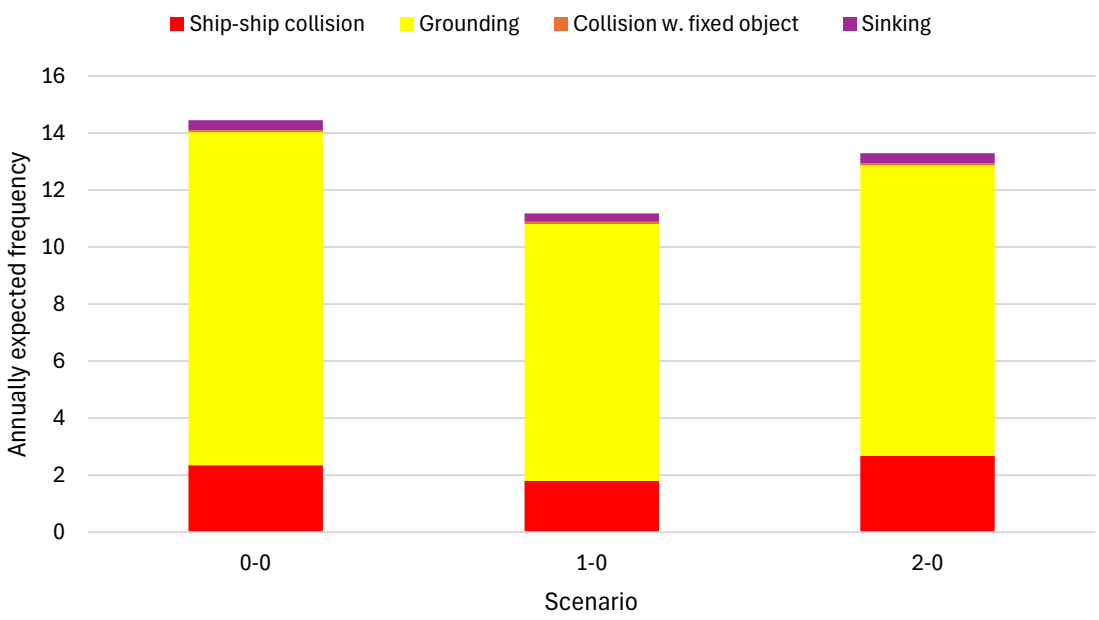

Figure 4-3 *Comparison of the annual accident frequency for all three scenarios*

5 Annual probability of release of oil and HNS

This chapter presents the annual probability of release of oil and hazardous and noxious substances (HNS). The probability is expressed as expected annual spilt tonnage. As an example, one spill of 500 tonnes every 100 years corresponds to an expected annual spill of 500 / 100 = 5 tonnes.

The results are calculated for the three traffic scenarios, i.e. 2024, 2036-1 (unchanged or worsened geo-political situation) and 2036-2 (improved geopolitical situation).

The results are mainly presented in tables. Figures are only shown for the 2024 case, as the visual differences between the three scenarios are too small to be easily distinguishable for the eye.

5.1 Scenario 0-0 (2024)

Table 5-1 shows the expected annual spilt tonnage in 2024. It is not the spill statistics for the year 2024, but a calculation of what would happen on average if the year 2024 were repeated many times.

The results are illustrated in Figure 5-1 (all spills), whereas Figure 5-2 illustrates the difference between spill up to 5,000 tonnes per event vs. spills above 5,000 tonnes per event. The difference is relevant, as national response capacities are generally dimensioned for events up to 5,000 tonnes. Events above this size are rare but nevertheless dominate the risk picture due to their sheer size. The numbers include both oil and HNS carried as cargo and releases from bunker tanks.

Table 5-1 Expected annual spilt tonnage in 2024, by spill size

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	53.0	78.9	87.6	27.0	137.9	165.3	549.7
> 5,000 tonnes	12.4	160.3	121.5	28.0	226.6	396.3	947.3
Total	65.4	239.2	209.1	55.0	364.5	561.6	1,496.9

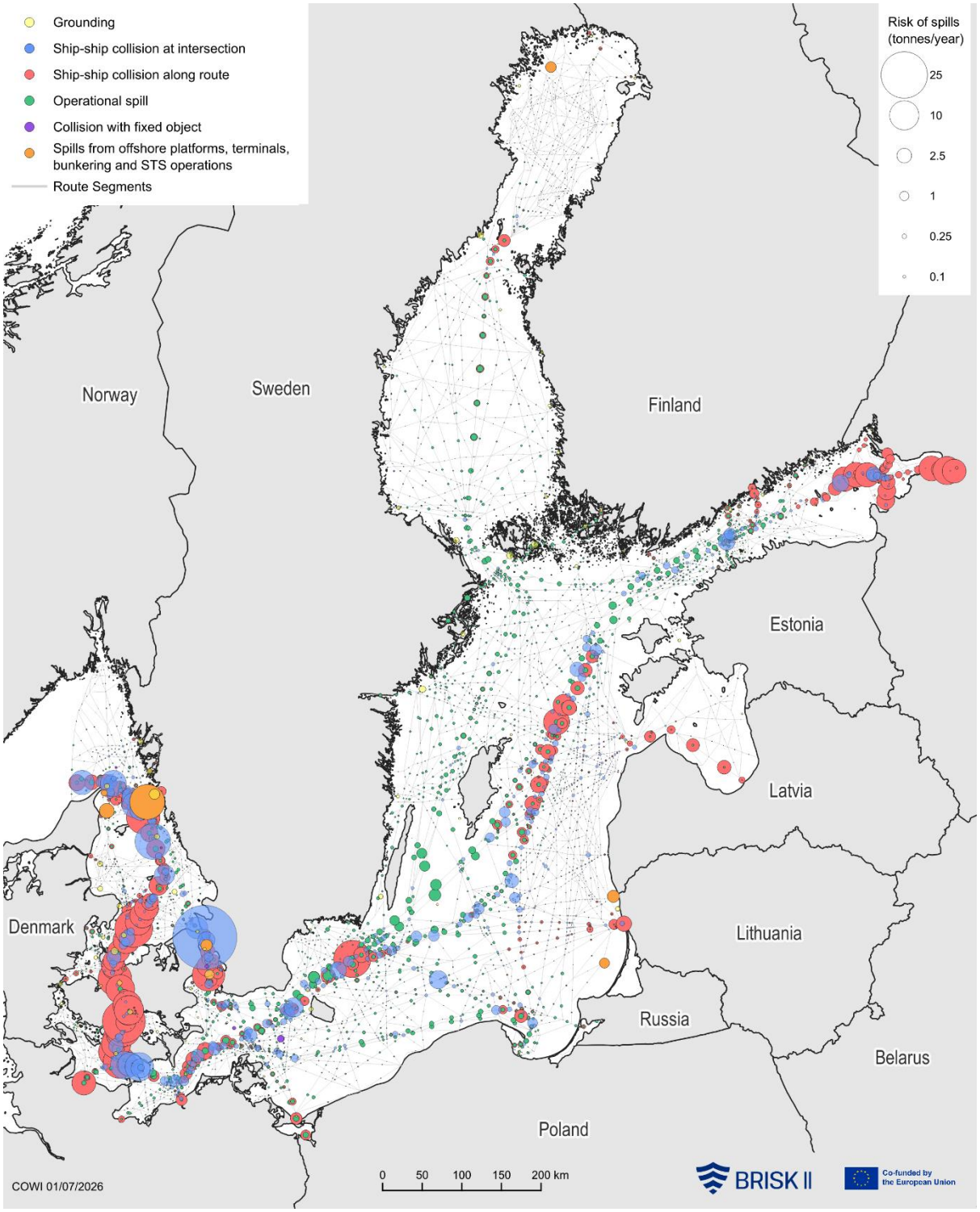

Figure 5-1 Expected annual spilt tonnage in 2024

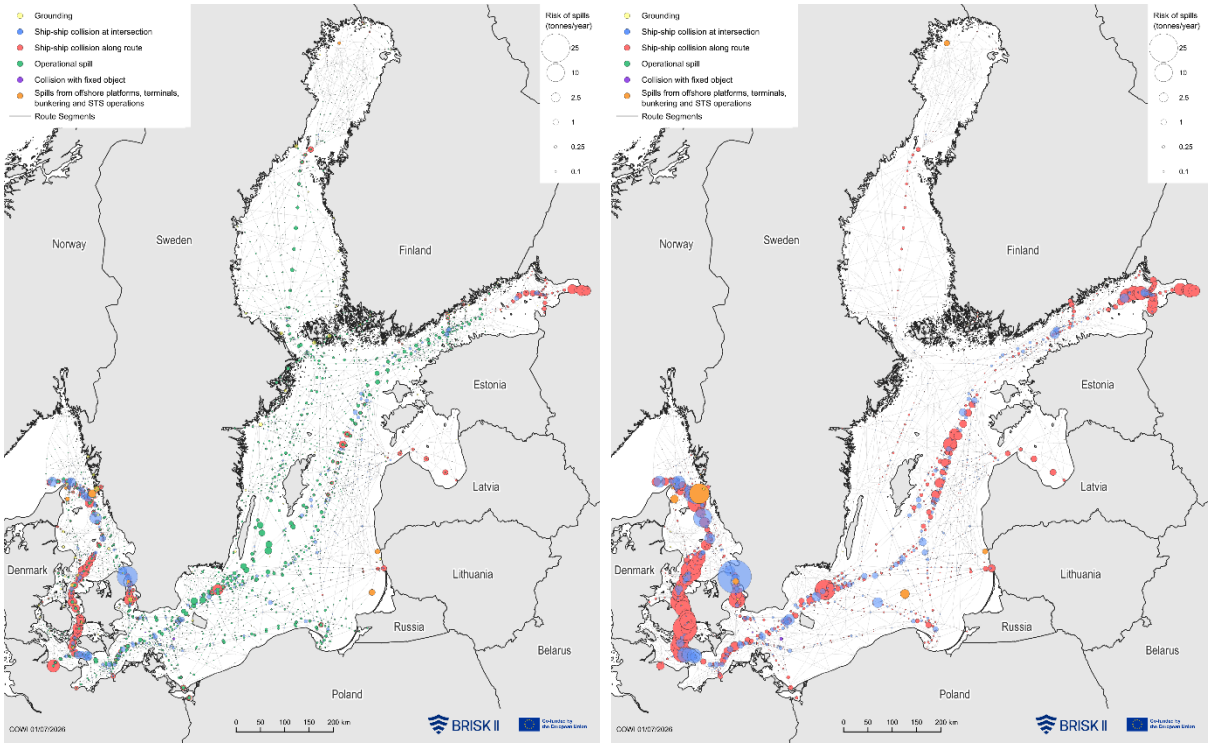

Figure 5-2 *Expected annual spilt tonnage in 2024: Spill up to 5,000 tonnes (left) and over 5,000 tonnes (right). See Appendix A for full size figures.*

Chapter 4 showed that groundings are by far the most numerous type of shipping event. However, their consequences are small on average, which is why ship-ship collisions totally dominate the picture in terms of spill risk, see Table 5-2.

Table 5-2 *Expected annual spilt tonnage in 2024, by accident type*

	Sub-region						
Accident type	1	2	3	4	5	6	Total
Ship-ship collision	16.2	135.0	92.8	23.8	233.8	436.0	937.4
Grounding	4.1	1.1	0.8	0.3	1.2	7.7	15.2
Operational spill	24.0	20.0	36.8	9.2	39.5	19.6	149.1
Collision with fixed object	0.0	0.0	0.1	0.0	0.9	0.4	1.4
STS and bunkering	1.3	0.0	0.0	0.0	0.0	18.8	20.1
Sinking	15.6	60.5	58.2	11.8	66.5	57.6	270.3
Fire and explosion	4.1	22.7	20.3	2.9	22.6	21.6	94.2
Oil platform and loading buoy	0.0	0.0	0.0	7.0	0.0	0.0	7.0
Total	65.4	239.2	209.1	55.0	364.5	561.6	1,494.7

In terms of spill types, oil (both cargo and bunker) is the main contributor to spill risk, followed by soluble HNS, see Table 5-3. Note that the fraction of low-sulphur fuel oil (VLSFO and ULSFO) among spilt cargoes

is relatively modest; however, almost 50 percent of the spilt bunker tonnage are VLSFO and ULSFO (second-last line in the table). Note that the individual types of HNS have been aggregated into a few main groups in the table for the sake of better overview.

Table 5-3 Expected annual spilt tonnage in 2024, by spill type

	Sub-region						
Spill type	1	2	3	4	5	6	Total
Evaporating HNS	1.57	4.17	4.72	0.99	8.92	15.62	36.0
Floating HNS	0.13	3.34	2.28	0.46	3.19	3.84	13.2
Soluble HNS	3.98	32.08	25.77	4.07	28.30	33.04	127.2
Sinking HNS	0.01	0.43	0.33	0.06	0.33	0.41	1.6
Crude oil	2.53	15.14	11.00	7.92	16.13	38.39	91.1
Heavy fuel oil	4.39	6.16	8.16	1.69	22.54	58.04	101.0
Diesel etc.	28.04	79.92	83.46	18.54	123.06	165.46	498.5
Petrol	1.74	51.62	34.67	8.94	79.61	127.94	304.5
VLSFO	0.10	0.23	0.36	0.04	0.36	0.21	1.3
ULSFO	0.01	0.03	0.03	0.00	0.00	0.00	0.1
Bunker (various types)[2]	22.90	46.09	38.19	12.30	82.06	118.62	320.2
Total	65.4	239.2	209.0	55.0	364.5	561.6	1,494.7

[2] 30 % HFSO, 44 % VLSFO, 4 % ULSFO, 22 % marine gasoil

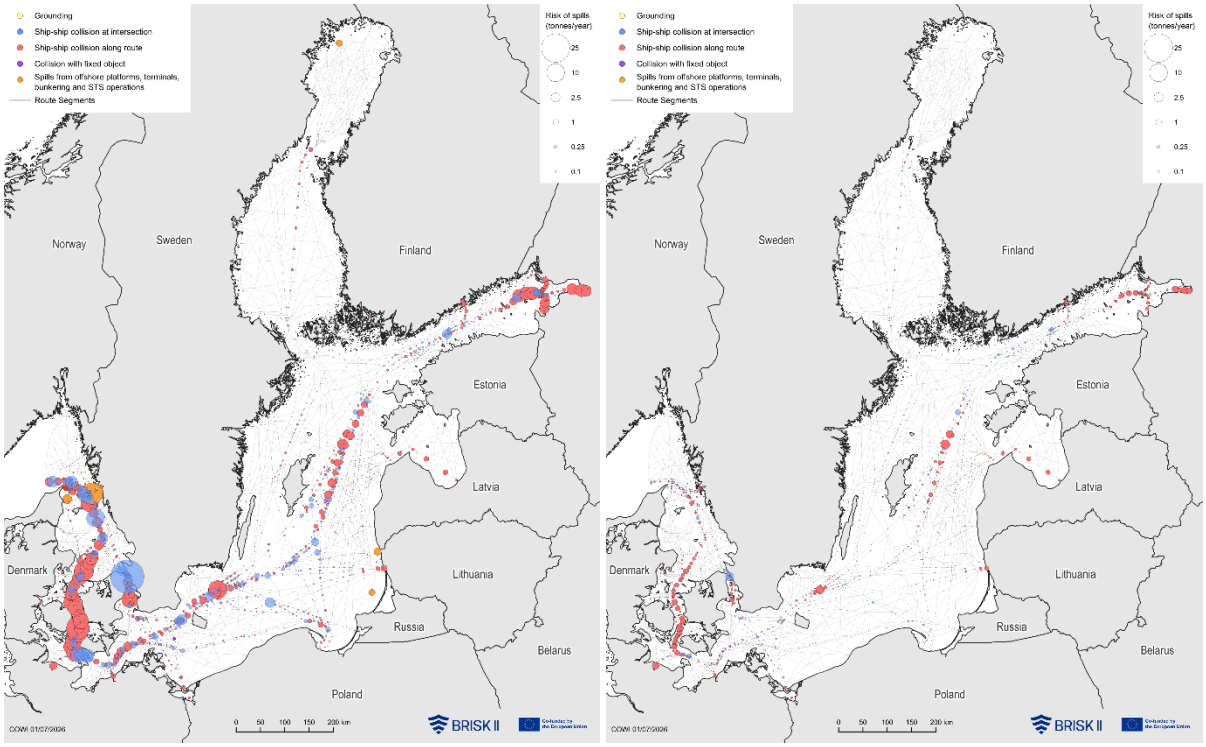

Figure 5-3 *Expected annual spilt tonnage in 2024: Oil and floating HNS (left), soluble HNS (right). See Appendix A for full size figures as well as figure for sinking HNS.*

5.2 Scenario 1-0 (2036 unchanged/worsened)

Table 5-4 shows the absolute spill risk in tonnes in 2036 under unchanged or worsened geopolitical conditions, whereas Table 5-5 shows the relative change compared to 2024. This decrease has been discussed in Section 4.2 and is linked to a more or less stable amount of cargo volume distributed over fewer, but larger ships. However, the drop in spill risk (-16.9 %) is smaller than the drop in shipping accidents (-22.7 %, see Table 4-2). This difference is due to larger ships on average spilling more oil in case of an accident.

Table 5-4 *Expected annual spilt tonnage in 2036, unchanged or worsened geopolitical situation, by spill size*

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	42.9	62.6	67.6	22.0	112.5	132.3	439.9
> 5,000 tonnes	10.4	135.3	101.4	24.1	195.2	336.3	802.7
Total	53.3	197.9	169.0	46.1	307.7	468.7	1,242.7

Table 5-5 Expected annual spilt tonnage in 2036 (unchanged or worsened geopolitical situation) relative to 2024

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	-19.0%	-20.6%	-22.8%	-18.6%	-18.4%	-19.9%	-20.0%
> 5,000 tonnes	-16.4%	-15.6%	-16.5%	-14.0%	-13.9%	-15.1%	-15.1%
Total	-18.5%	-17.3%	-19.2%	-16.2%	-15.6%	-16.5%	-16.9%

The distribution between accident types (Table 5-6) and spill types (

Table 5-7) follows basically the same pattern as in 2024. Note, however, that the contribution of collisions with fixed objects is more or less stable between 2024 and 2036: Although traffic numbers are decreasing, the number of offshore wind farms is increasing. The two trends roughly balance.

Table 5-6 Expected annual spilt tonnage in 2036, unchanged or worsened geopolitical situation, by accident type

	Sub-region						
Accident type	1	2	3	4	5	6	Total
Ship-ship collision	11.8	104.3	68.3	18.2	189.4	356.4	748.3
Grounding	2.7	0.8	0.5	0.2	1.0	6.0	11.3
Operational spill	20.0	16.6	29.3	7.8	33.5	17.0	124.1
Collision with fixed object	0.0	0.0	0.1	0.0	0.9	0.4	1.4
STS and bunkering	1.3	0.0	0.0	0.0	0.0	15.2	16.5
Sinking	13.8	55.1	51.8	11.1	61.7	53.5	247.1
Fire and explosion	3.7	21.0	18.9	2.8	21.1	20.2	87.8
Oil platform and loading buoy	0.0	0.0	0.0	6.0	0.0	0.0	6.0
Total	53.3	197.9	169.0	46.1	307.7	468.7	1,242.6

Table 5-7 Expected annual spilt tonnage in 2036, unchanged or worsened geopolitical situation, by spill type

Spill type	Sub-region 1	2	3	4	5	6	Total
Evaporating HNS	1.20	3.42	3.72	0.70	7.13	12.49	28.7
Floating HNS	0.11	2.75	1.75	0.38	2.65	3.18	10.8
Soluble HNS	3.30	27.35	20.35	3.43	23.67	27.41	105.5
Sinking HNS	0.01	0.34	0.24	0.04	0.26	0.33	1.2
Crude oil	2.32	12.41	9.07	6.78	13.30	31.12	75.0
Heavy fuel oil	4.32	5.56	7.66	1.70	20.30	49.72	89.3
Diesel etc.	22.61	66.04	68.18	15.36	103.63	139.13	415.1
Petrol	1.45	43.86	29.45	7.69	68.34	109.28	260.2
VLSFO	0.09	0.20	0.28	0.03	0.31	0.18	1.1
ULSFO	0.01	0.02	0.02	0.00	0.00	0.00	0.1
Bunker (various types)[3]	17.89	35.93	28.22	9.95	68.07	95.82	256.0
Total	53.3	197.9	169.0	46.1	307.7	468.7	1,242.6

5.3 Scenario 2-0 (2036 improved)

Table 5-8 shows the absolute spill risk in tonnes in 2036 under improved geopolitical conditions, whereas Table 5-9 shows the relative change compared to 2024.

On total, the risk increases by a mere 1.8 %. However, some additional model runs showed that this number is the result of two strong, contrasting trends:

- The increase of traffic due to a reintegration of Russia into earlier global trading patterns corresponds to an overall risk increase by roughly 20 %
- However, the expected exchange of the shadow fleet by “normal” ships corresponds to a risk reduction by roughly 18 %.

The increase in spill risk by 1.8 % is contrary to the accident frequency, cf. Table 4-3, which in fact is decreasing by -8.0 %. This divergence can be explained by the strong increase in cargo volumes. This means that the trend toward larger ships outweighs the trend towards fewer ships.

[3] 30 % HFSO, 44 % VLSFO, 4 % ULSFO, 22 % marine gasoil

Table 5-8 *Expected annual spilt tonnage in 2036, improved geopolitical situation, by spill size*

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	43.3	115.6	93.1	25.2	138.5	175.5	591.3
> 5,000 tonnes	10.4	178.7	117.6	26.7	215.1	382.0	930.4
Total	53.7	294.3	210.7	51.9	353.5	557.5	1,521.7

Table 5-9 *Expected annual spilt tonnage in 2036 (improved geopolitical situation) relative to 2024*

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	-18.3%	+46.5%	+6.4%	-6.5%	+0.4%	+6.2%	+7.6%
> 5,000 tonnes	-16.5%	+11.5%	-3.2%	-4.7%	-5.1%	-3.6%	-1.6%
Total	-17.9%	+23.1%	+0.8%	-5.6%	-3.0%	-0.7%	+1.8%

Table 5-10 shows the spill risk in 2036 under improved geopolitical conditions relative to an unchanged or worsened situation in the same year. Due to the additional traffic, the risk of spill is significantly increased. The expected disappearance of the shadow fleet – i.e. its replacement by normal standard ships – reduces some of the risk but not enough to offset the general increase in traffic numbers.

Table 5-10 *Expected annual spilt tonnage in 2036 (improved geopolitical situation) relative to 2036 (unchanged or worsened geopolitical situation)*

	Sub-region						
Spill size	1	2	3	4	5	6	Total
≤ 5,000 tonnes	+0.9%	+84.7%	+37.8%	+14.8%	+23.1%	+32.7%	+34.4%
> 5,000 tonnes	-0.2%	+32.1%	+15.9%	+10.8%	+10.2%	+13.6%	+15.9%
Total	+0.7%	+48.7%	+24.7%	+12.7%	+14.9%	+19.0%	+22.5%

The distribution between accident types (Table 5-11) and spill types (Table 5-12) follows basically the same pattern as in 2024.

Table 5-11 Expected annual spilt tonnage in 2036, improved geopolitical situation, by accident type

Accident type	Sub-region 1	2	3	4	5	6	Total
Ship-ship collision	12.0	185.0	100.0	22.6	233.3	447.9	1,000.8
Grounding	2.8	1.0	0.6	0.3	1.0	5.9	11.6
Operational spill	20.1	25.0	37.5	8.9	38.0	18.9	148.3
Collision with fixed object	0.0	0.0	0.1	0.0	0.9	0.4	1.4
STS and bunkering	1.3	0.0	0.0	0.0	0.0	15.2	16.5
Sinking	13.8	63.3	55.3	11.5	61.3	51.5	256.6
Fire and explosion	3.7	20.1	17.3	2.6	19.0	17.8	80.5
Oil platform and loading buoy	0.0	0.0	0.0	6.0	0.0	0.0	6.0
Total	53.7	294.3	210.7	51.9	353.5	557.5	1,521.7

Table 5-12 Expected annual spilt tonnage in 2036, improved geopolitical situation, by spill type

Spill type	Sub-region 1	2	3	4	5	6	Total
Evaporating HNS	1.20	4.16	4.51	0.81	8.09	14.31	33.1
Floating HNS	0.11	2.66	2.07	0.44	2.42	2.83	10.5
Soluble HNS	3.30	25.22	23.79	4.09	20.96	22.84	100.2
Sinking HNS	0.01	0.30	0.29	0.06	0.22	0.26	1.1
Crude oil	2.32	20.39	11.39	6.94	16.82	36.61	94.5
Heavy fuel oil	3.65	7.30	8.08	1.68	21.09	52.29	94.1
Diesel etc.	23.36	93.33	81.17	17.48	116.89	164.37	496.7
Petrol	1.45	63.13	34.73	8.48	77.14	127.29	312.2
VLSFO	0.09	0.22	0.35	0.04	0.33	0.19	1.2
ULSFO	0.01	0.02	0.03	0.00	0.00	0.00	0.1
Bunker (various types) [4]	18.18	77.59	44.23	11.91	89.58	136.52	378.0
Total	53.7	294.3	210.7	51.9	353.5	557.5	1,521.7

[4] 30 % HFSO, 44 % VLSFO, 4 % ULSFO, 22 % marine gasoil

5.4 Overview

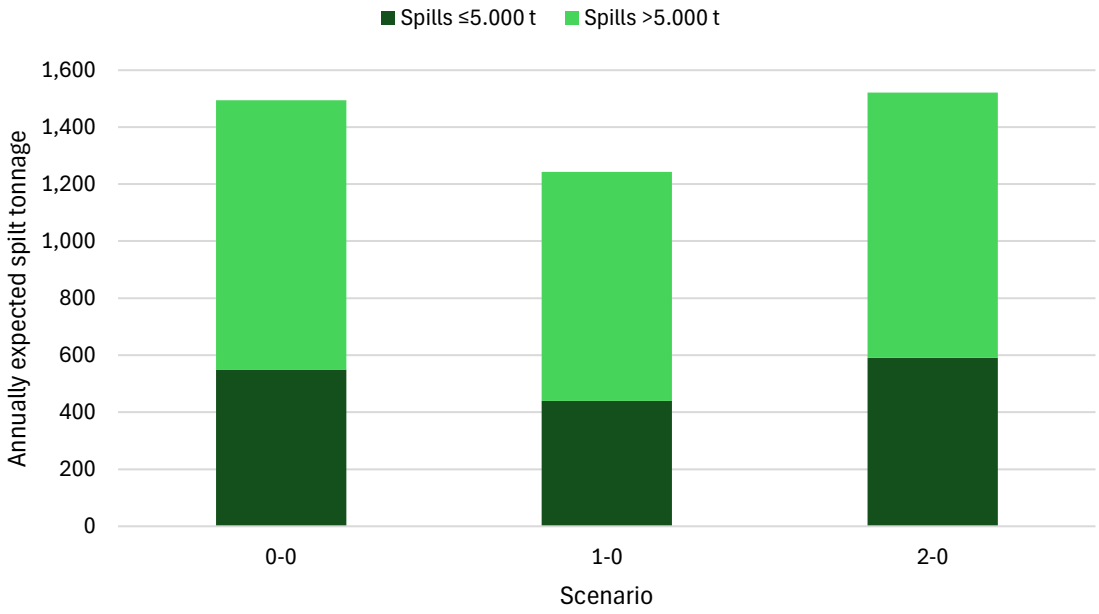

Figure 5-4 *Comparison of the annually expected spilt tonnage for all three scenarios*

6 Abbreviations

HNS	Hazardous and noxious substances
OWF	Offshore wind farm
RRM	Risk-reducing measure
STS	Ship-to-ship transfer
VLSFO	Very Low Sulphur Fuel Oil
ULSFO	Ultra-Low Sulphur Fuel Oil

7 References

BRISK I, Traffic, 2012	BRISK, Model report: Part 2 - Transport of oil and hazardous substances, 2012
BRISK I, Spill, 2012	BRISK, Model report: Part 4 - Frequency and quantity of spill of oil and hazardous substances, 2012
BRISK I, Results, 2012	BRISK, Risk model result report, 2012
BRISK II, Method note, 2025	BRISK II, Method note, deliverable D2.1, 2025
BRISK II, Traffic analysis, 2025	BRISK II, Traffic analysis, deliverable D2.3, 2025
BRISK II, Cargo analysis, 2025	BRISK II, Cargo analysis, deliverable D2.4, 2025
BRISK II, Spill model, 2026	BRISK II, Probability of oil and HNS release, deliverable D2.6, 2026
BRISK II, Impact, 2026	BRISK II, Risk of oil and HNS impact, deliverable D3.3, 2026
Fujii (1984)	Fujii, Y. et al, Survey on vessel traffic management systems and brief introduction to marine traffic studies, Electronic Navigation Research Institute Papers no. 45, Japanese Ministry of Transport, 1984

Appendix A Spill risk maps in full scale

This appendix shows all maps from Chapter 5 at full scale.

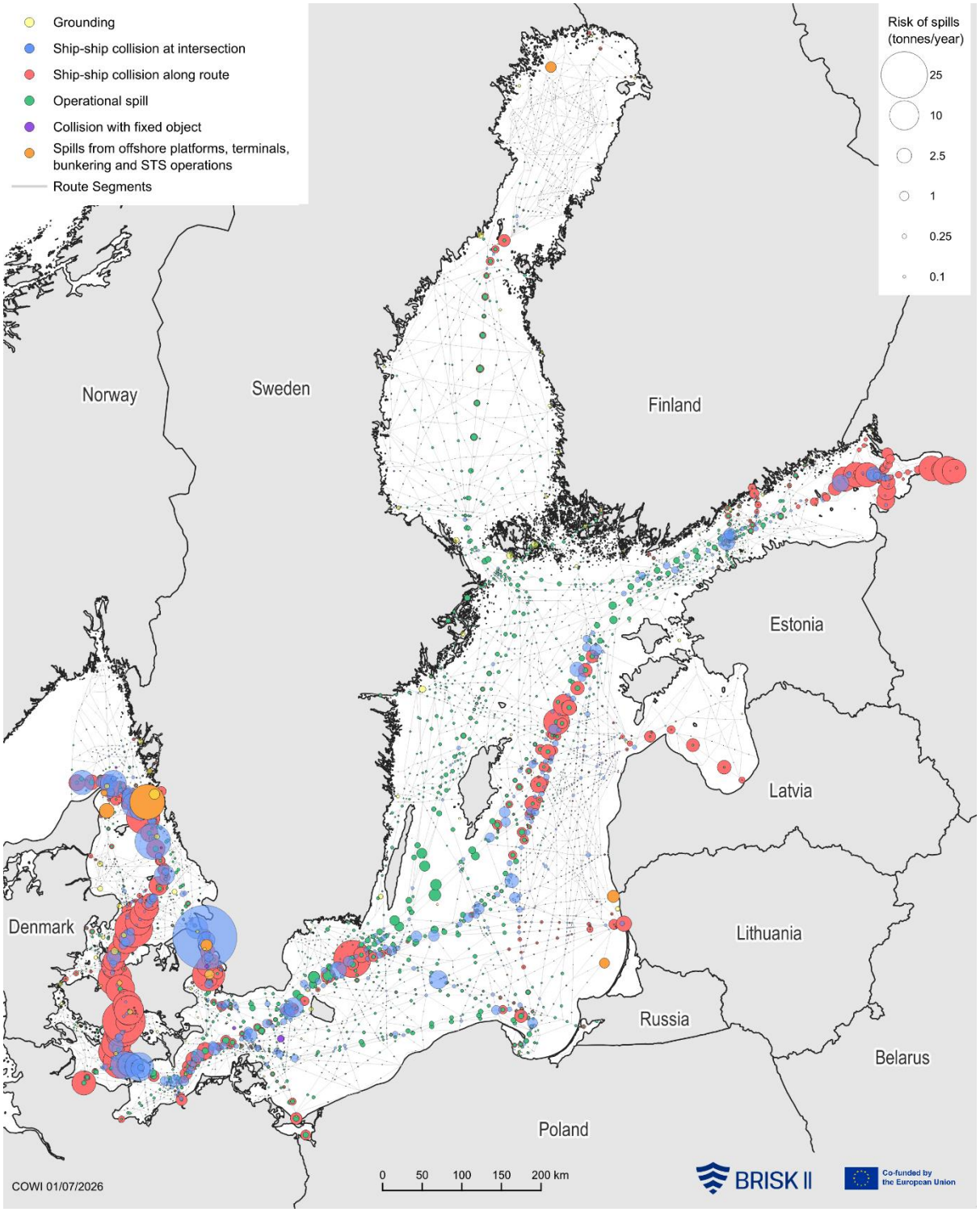

Figure A-1 Expected annual spilt tonnage in 2024

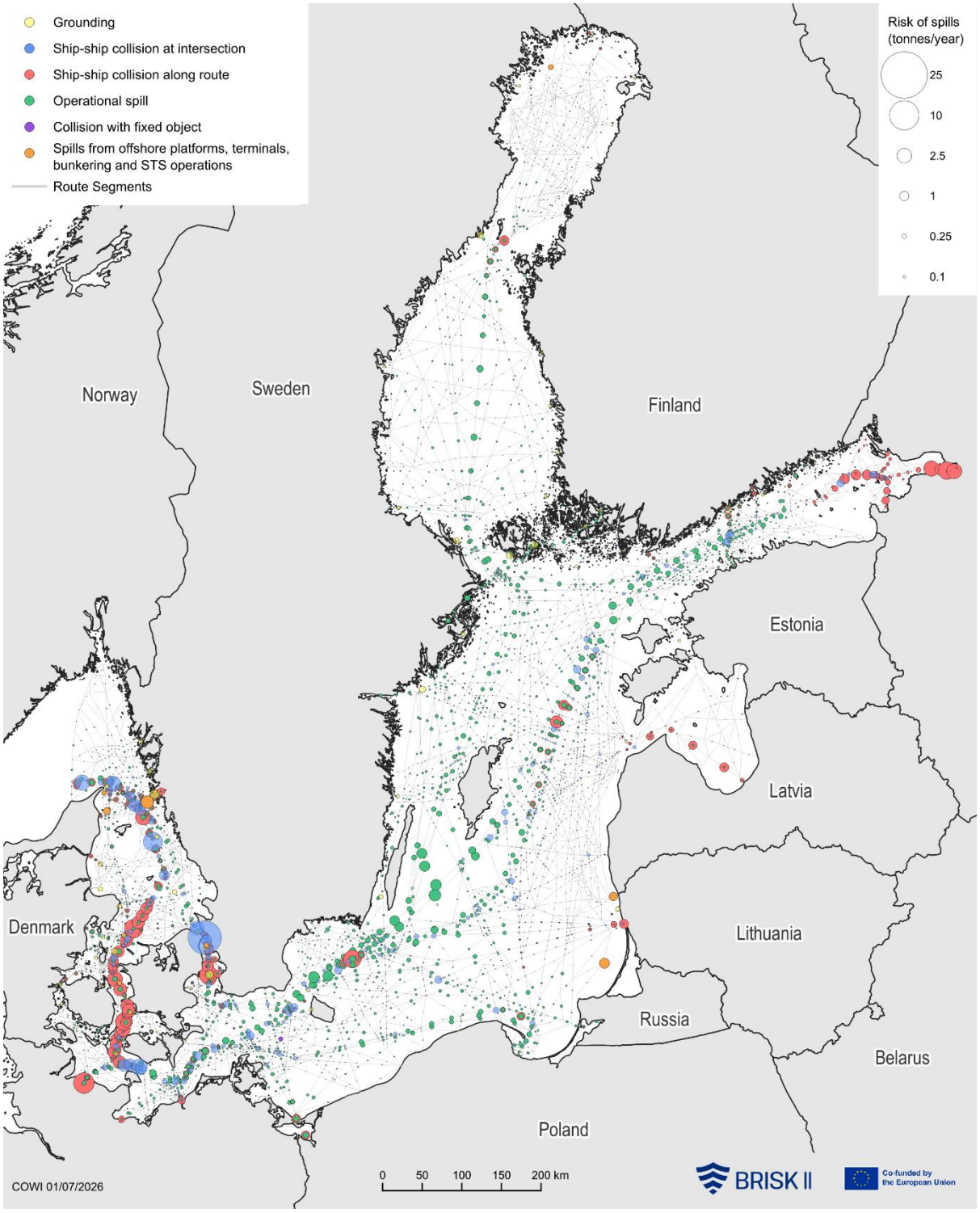

Figure A-2 *Expected annual spilt tonnage in 2024: Spills up to 5,000 tonnes*

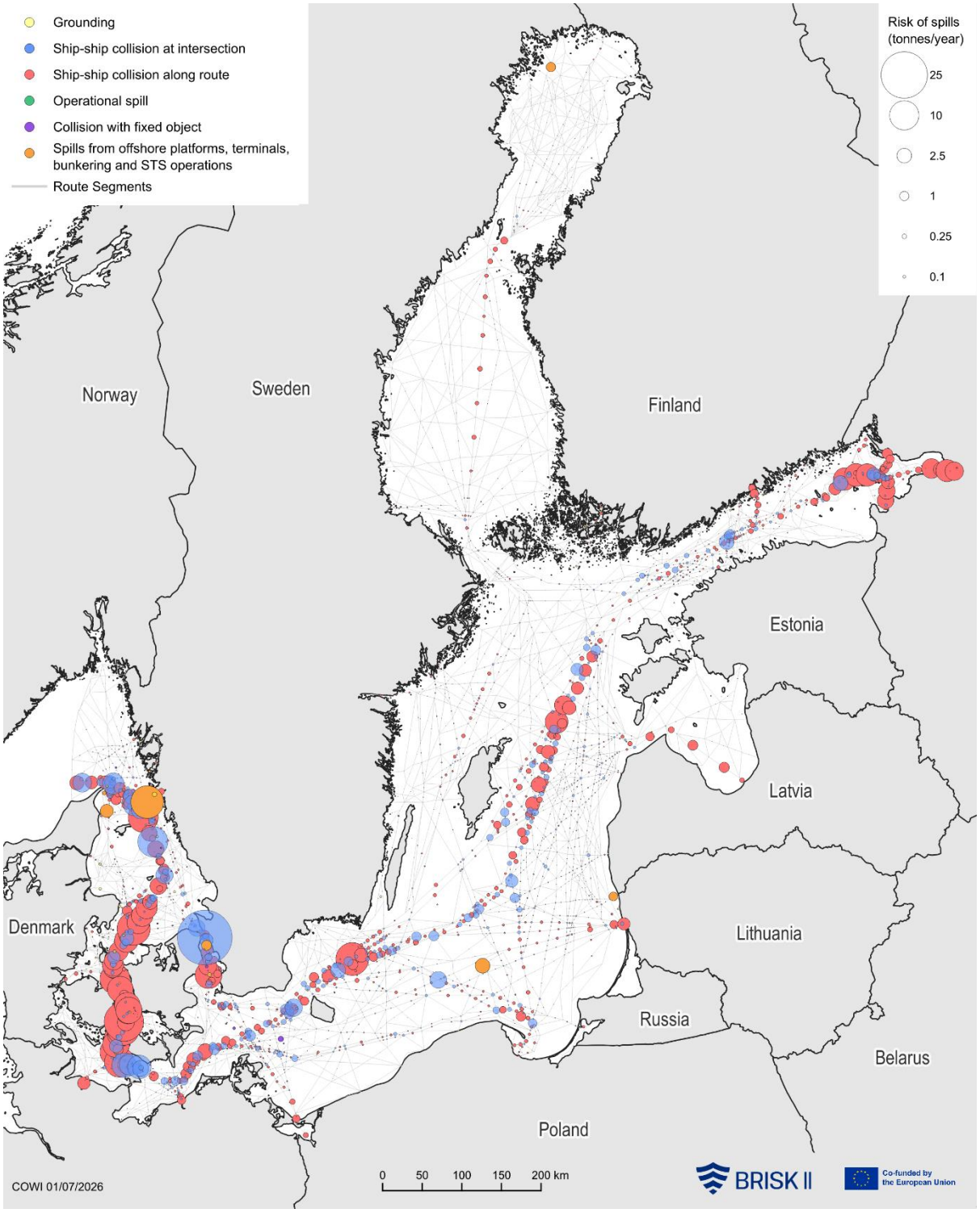

Figure A-3 *Expected annual spilt tonnage in 2024: Spills over 5,000 tonnes*

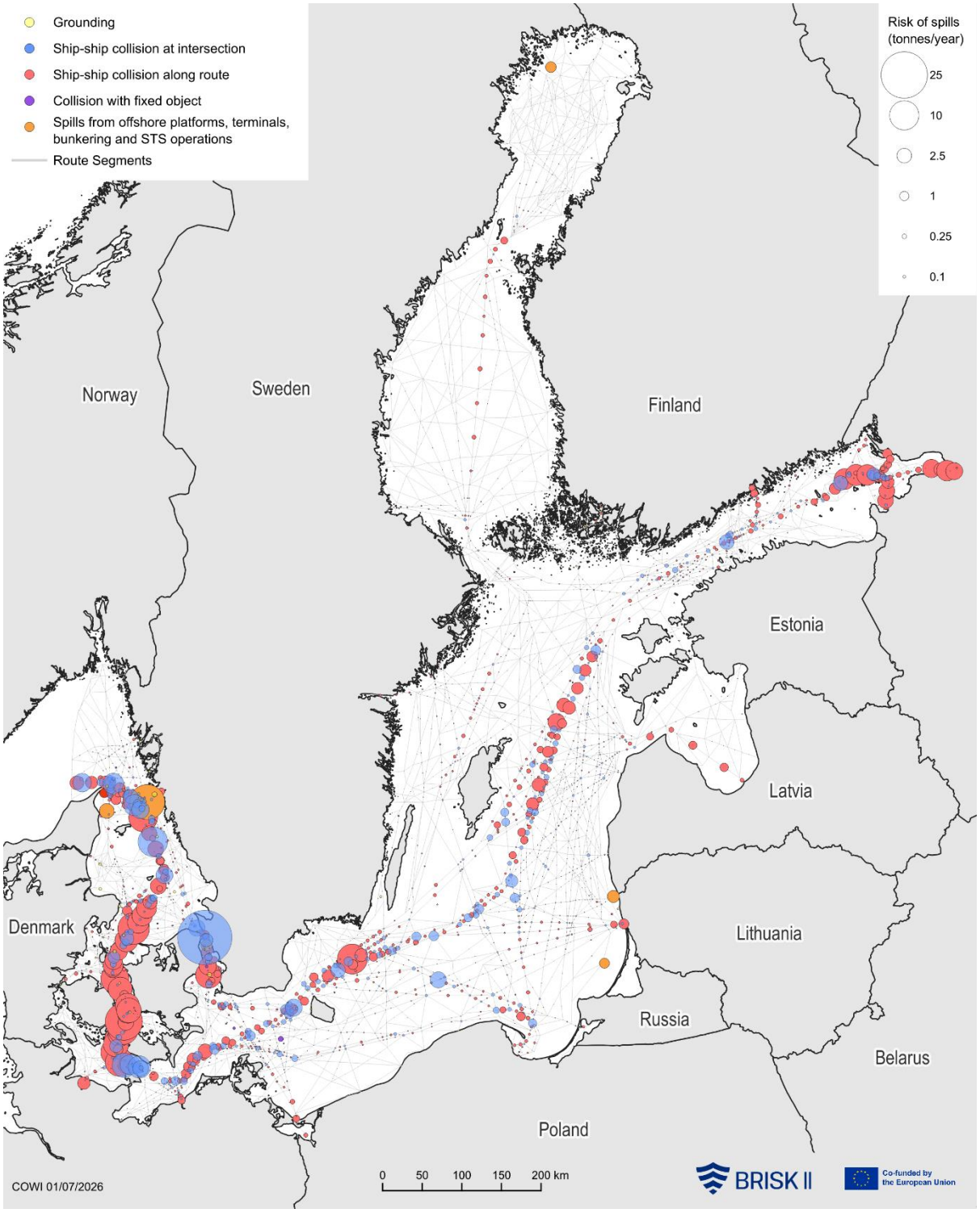

Figure A-4 Expected annual spilt tonnage in 2024: Oil and floating HNS (without operational spills)

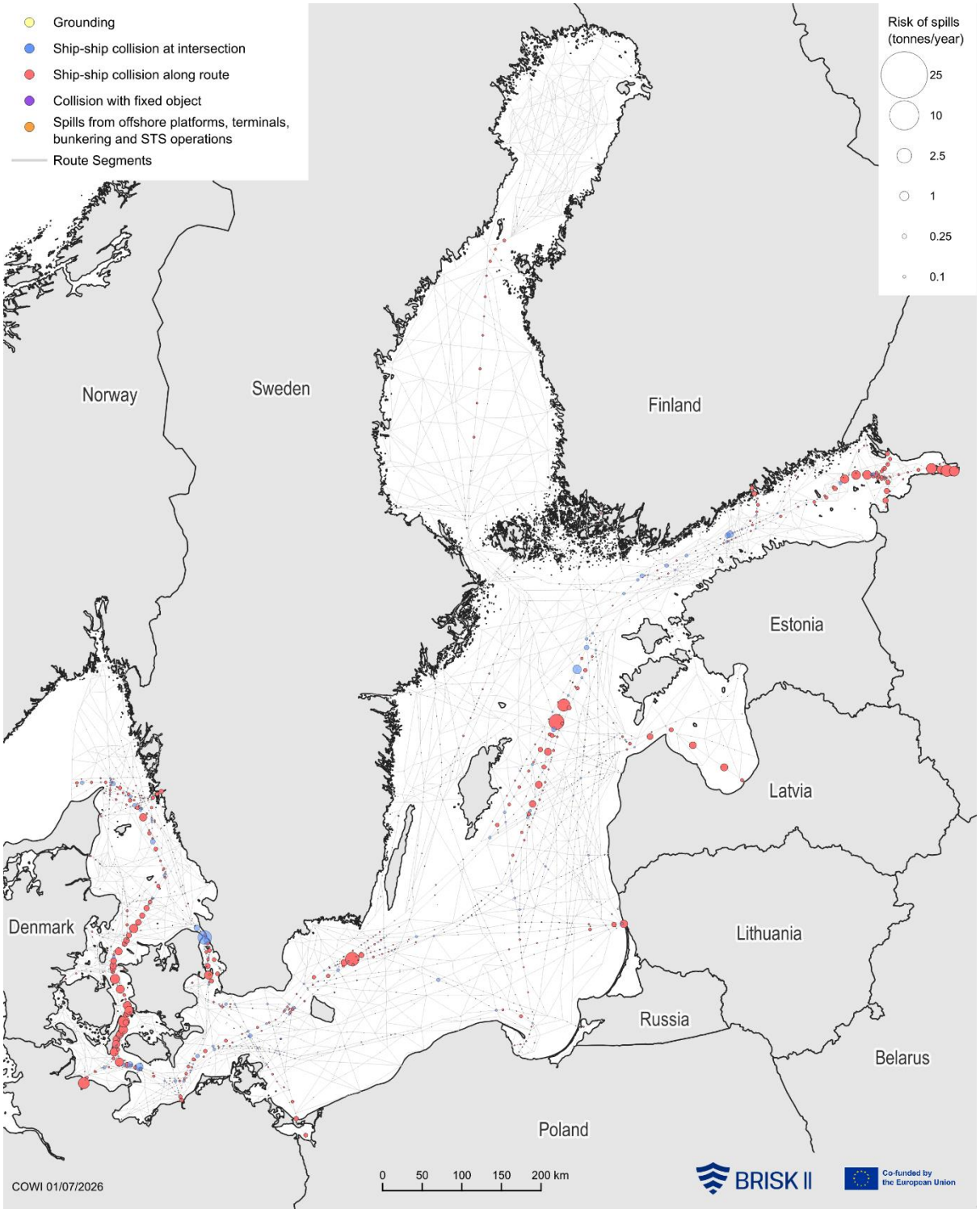

Figure A-5 Expected annual spilt tonnage in 2024: Soluble HNS

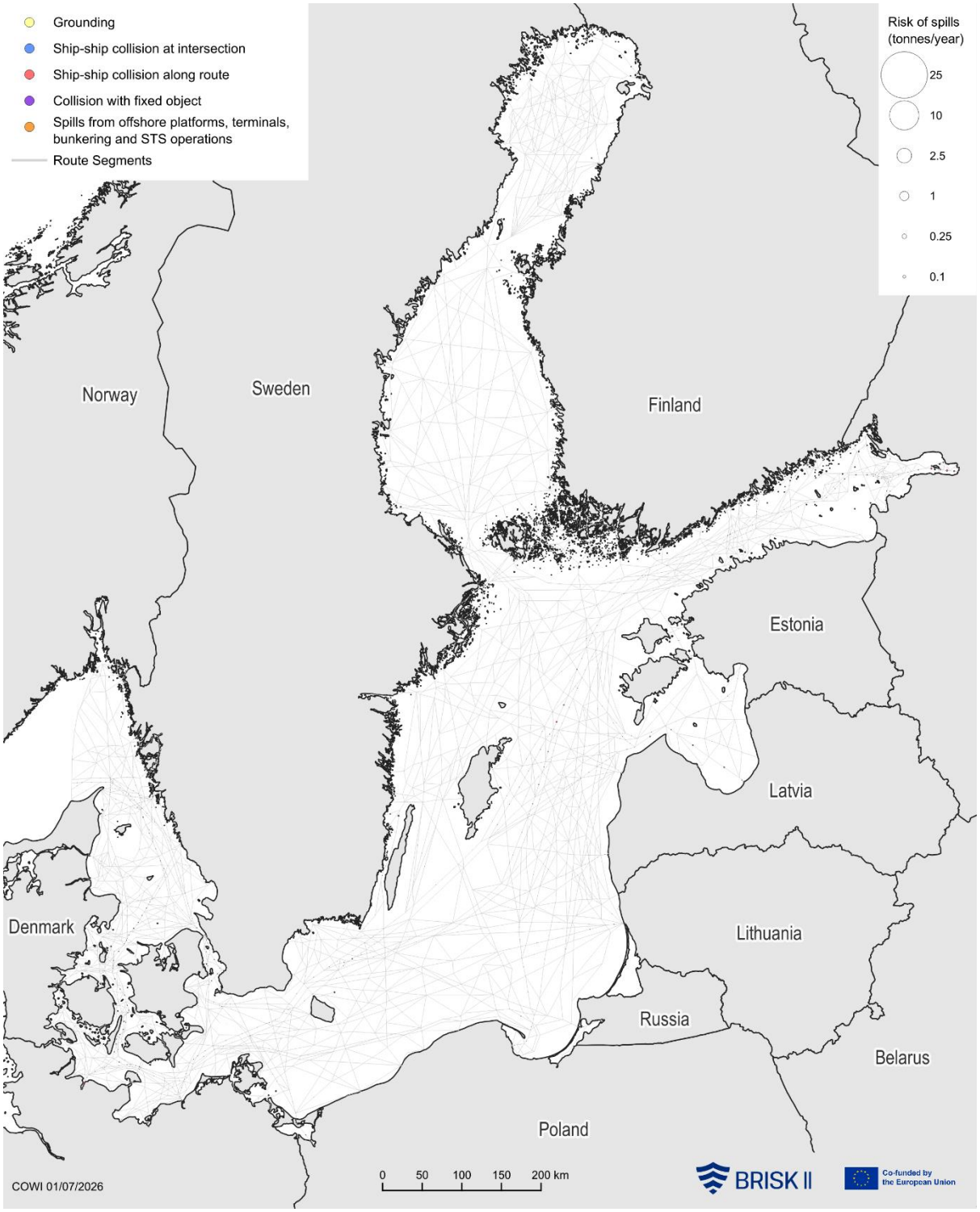

Figure A-6 *Expected annual spilt tonnage in 2024: Sinking HNS.*

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