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REPORT

HFO IN THE ARCTIC

HFO in the Arctic - Phase 2B

DNV Doc. No./Report No.: 2013-1542-2013-1542-16G8ZQC-6/
Date of Issue: 2013-12-13
Revision:

Project Name: **HFO in the Arctic – Phase 2B**	DET NORSKE VERITAS AS *BDL Environment and Operations* P.O.Box 300 1322 Høvik Norway +47 67 57 99 00 www.dnv.com
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Date of Issue:	Revision No.:	DNV Document No.:	DNV Organisation Unit:
2013-12-13		2013-1542-16G8ZQC-6	BDL Environment and Operations

Project No.:	Report No.:	Report Title:
PP066148		HFO in the Arctic - Phase 2B

Task and Objective:

This study is carried out on behalf of The Protection of the Arctic Marine Environment Working Group (PAME) and it is financed by the Norwegian Ministry of Foreign Affairs.

This report should be considered as an extension to the report HFO in the Arctic-Phase 2 - DNV Doc. No./Report No.: 2013-1542-16G8ZQC-5/1 and the methodology and the assumptions made are all as explained in that report. Upon request from the US, it was decided to apply the same study for ship traffic in the Bering Sea.

Based on AIS based ship movement data for August 2012 – August 2013 in the Bering Sea, the study addresses the following issues:

- Describe a full year of maritime traffic based on satellite AIS recordings in the Bering Sea, including vessel composition (type and size), geographical distribution, sailed distances and operating hours throughout the year.
- Modelling of fuel consumption and consequent emission to air
- Identification of vessels operating on HFO and the carriage of oil cargo
- Hazard identification and a high-level risk analysis of frequencies of incidents leading to oil spill and the consequent likely oil spill (HFO, distillate fuel and oil cargo)

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Signature	Signature	Signature

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Rev. No.:	Date:	Reason for Issue:	Prepared by:	Verified by:	Approved by:
0		First issue signed and verified			

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1 INTRODUCTION

This study is carried out on behalf of The Protection of the Arctic Marine Environment Working Group (PAME). PAME is one of six Arctic Council working groups and is the focal point of the Arctic Council's activities related to the protection and sustainable use of the Arctic marine environment.
During execution of the project Heavy Fuel Oil (HFO) in the Arctic – Phase 2, one of the membership states had objections regarding the geographical delimitation of the study (defined according to the according to the IMO Guideline the Arctic high seas). It was therefor agreed to perform an extension to the study including data from the areas in the Bering Sea south of 60 degrees. This is in line with the definition from the US Arctic Research and Policy Act (ARPA) as shown in Figure 1-1.
Whereas the HFO in the Arctic – Phase 2 study is based on data from 1/1-2012 – 31/12-2012, the HFO-2B study is based on a newly established worldwide set spanning from August 2012 to August 2013. This additional study addresses the following issues:

- Describe a full year (8/2012-8/2013) of maritime traffic based on satellite AIS recordings in the Bering Sea, including vessel composition (type and size), geographical distribution, sailed distances and operating hours throughout the year.
- Identification of vessels operating on HFO and the carriage of oil cargo
- Modelling of fuel consumption and emission to air
- Hazard identification and a high-level risk analysis of frequencies of incidents leading to oil spill and the consequent likely oil spill (HFO, distillate fuel and oil cargo)

The methodology, calculations and the assumptions made for this study are all identical to the HFO-Phase 2 projects. Hence, this report should be regarded as complementary to the Heavy Fuel Oil (HFO) in the Arctic – Phase 2 (HFO-2) report.

Figure 1-1 - Arctic Boundary as defines by the Arctic Research and Policy Act (ARPA)

In this study we are assessing the sea area north of the Aleutian Islands and up to 67 degrees north. In the main study, (HFO in the Arctic – Phase 2) the same area was covered south to 60 degrees. Hence, a certain overlap in the vessel registration will occur and this should be kept in mind if figures from the two part-studies should be combined. The magnitude of the overlap is illustrated in Table 1-1.

Table 1-1 - Comparison figures from traffic north and south of 60 degrees

	N miles	Hours	Fuel	CO2	NOx	SO2	PM	BC
North of 60	797388	310215	39090	124094	2004	167	85	7
	11 %	24 %	5 %	5 %	4 %	2 %	2 %	5 %
South of 60	6727425	1007970	732402	2339684	54305	10908	4788	132
	89 %	76 %	95 %	95 %	96 %	98 %	98 %	95 %

2 SUMMARY

More than twice as many vessels are recorded in the Bering Sea compared to the areas included in the Arctic definition as used in the HFO-2 report. In addition, the sailed distance is significantly higher whereas the operational hours are slightly less.
The vessels demographics is also very different from what was identified in the HFO-2 report. The traffic in the Bering Sea is very much dominated by the intercontinental shipping routes following the great circle between the north-west coast of the USA and Canada and East Asia. This sailing route predominantly comprises large bulk carriers and container vessels, but also a few ro-ro and general cargo vessels, all of which are operating on HFO. This is exemplified by 84% of the vessels in the Bering Sea are identified as HFO users whereas 28% were found to use HFO in the HFO-2 report.

The sailed distance, the size of vessels and the speed of which they operate makes this group responsible for close to 90% of the calculated total fuel consumption throughout the year and subsequently an even higher portion of the combined emissions to air.

Arctic ship traffic is generally identified by huge variations in operational hours and sailed distances throughout the year. However, the dominating intercontinental great circle traffic not affected by sea-ice and is relatively unaffected by the seasonal variations. Hence, only small variations are apparent from the available data material.

In the HFO-2 report, groundings, and groundings of tankers in particular, was identified as the potential main source of accidental oil spill to the sea. Again, the dominating influence of the transcontinental traffic through the Aleuts significantly changes this picture. The grounding risk associated with this transport route is concentrated at the passage through the chain of islands at one end. The remaining part of the great circle route is far from shore and hence no grounding risk is associated with this stretch. The fire/explosion risk and hull/machinery risk is however only related to the sailed distance and hence these risk modes will be relatively more dominant than what is calculated in the HFO-2 report.
In general, an incident leading to oil spill is likely to happen every second year within the Bering Sea.

3 RESULTS

3.1 Unique vessels observed in the Bering Sea

Table 3-1 - Number of unique vessels on the Bering Sea - 8/2012-8/2013

	< 1000 GT	1000 - 4999 GT	5000 - 9999 GT	10000 - 24999 GT	25000 - 49999 GT	50000 - 99999 GT	>= 100000 GT	**Grand Total**
Oil tanker	2	15	4	4	19	6		**50**
Chemical/Prod tanker	3	11	9	35	10			**68**
Gas tanker					1	1	2	**4**
Bulk carrier				367	867	156	8	**1398**
General cargo	1	11	42	56	63			**173**
Container vessel			4	8	92	448	25	**577**
RoRo	2	1	1		66	92		**162**
Reefer	4	46	28	13				**91**
Passenger		4	2	1	2	4	1	**14**
Offshore supply vessel	1	8		1				**10**
Other offshore service vessel				1				**1**
Other activities	59	32	12	11	2			**116**
Fishing vessel	126	130	14					**270**
Total	**198**	**258**	**116**	**497**	**1122**	**707**	**36**	**2934**

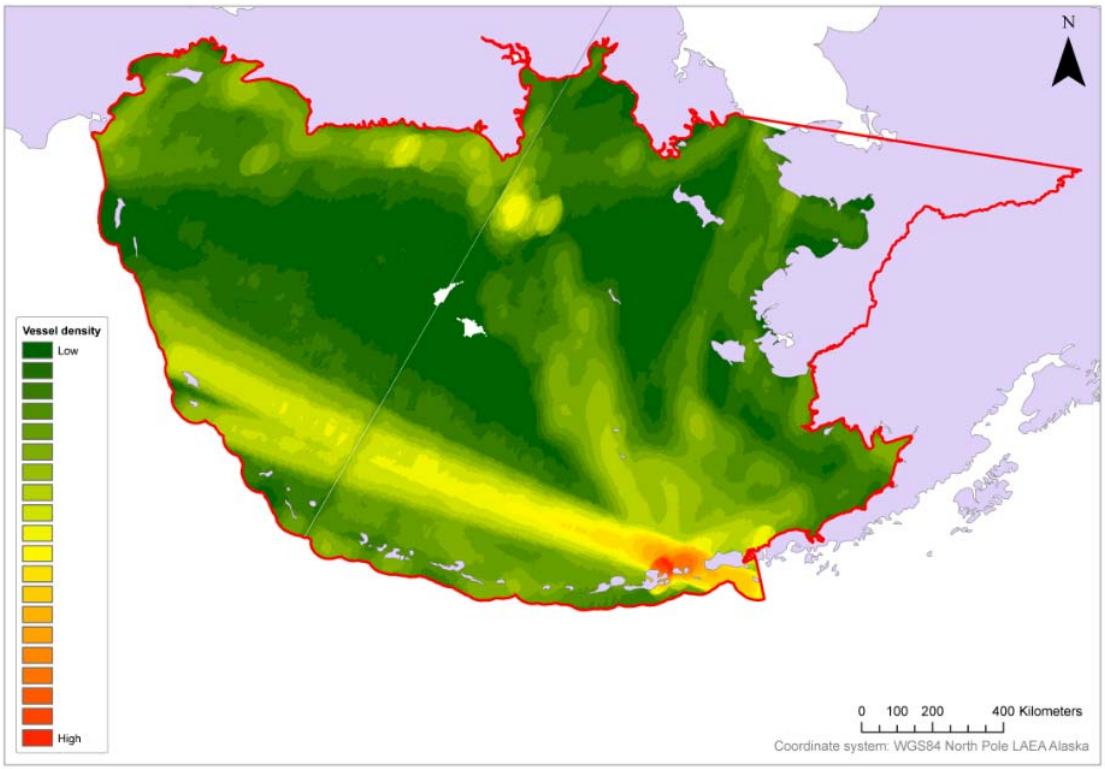

Figure 3-1 - Density plot showing one year of traffic in the Bering Sea

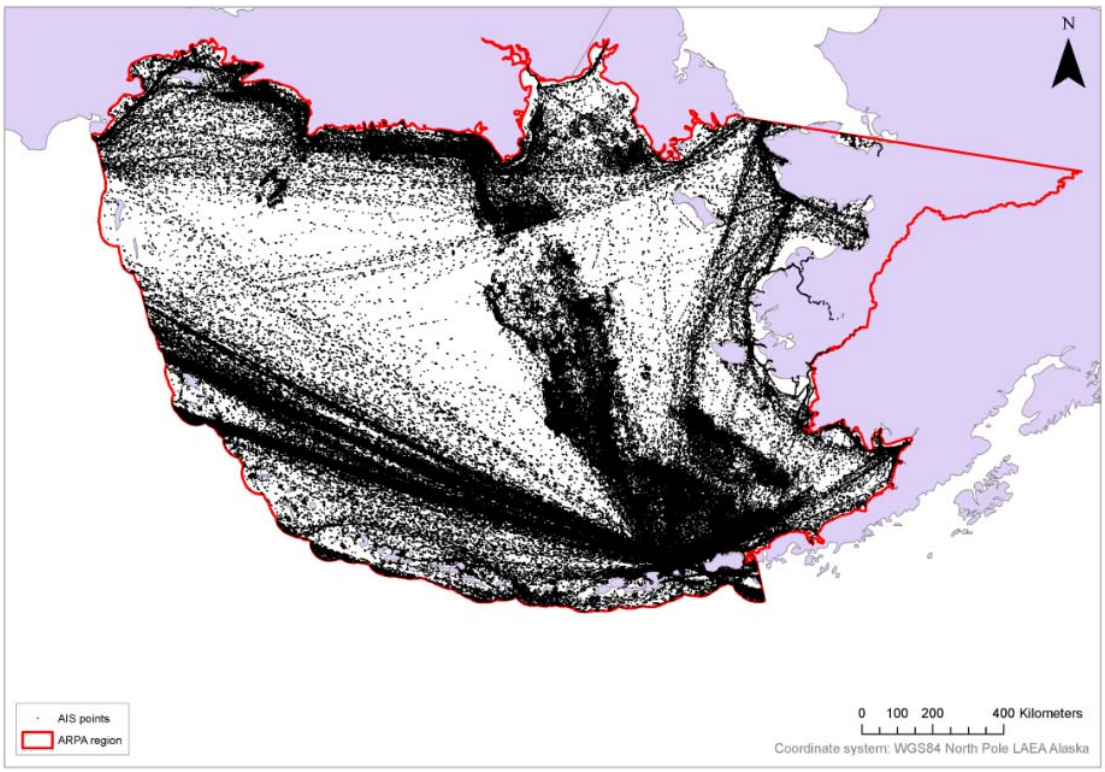

Figure 3-2 - Data points form one year of traffic in the Bering Sea

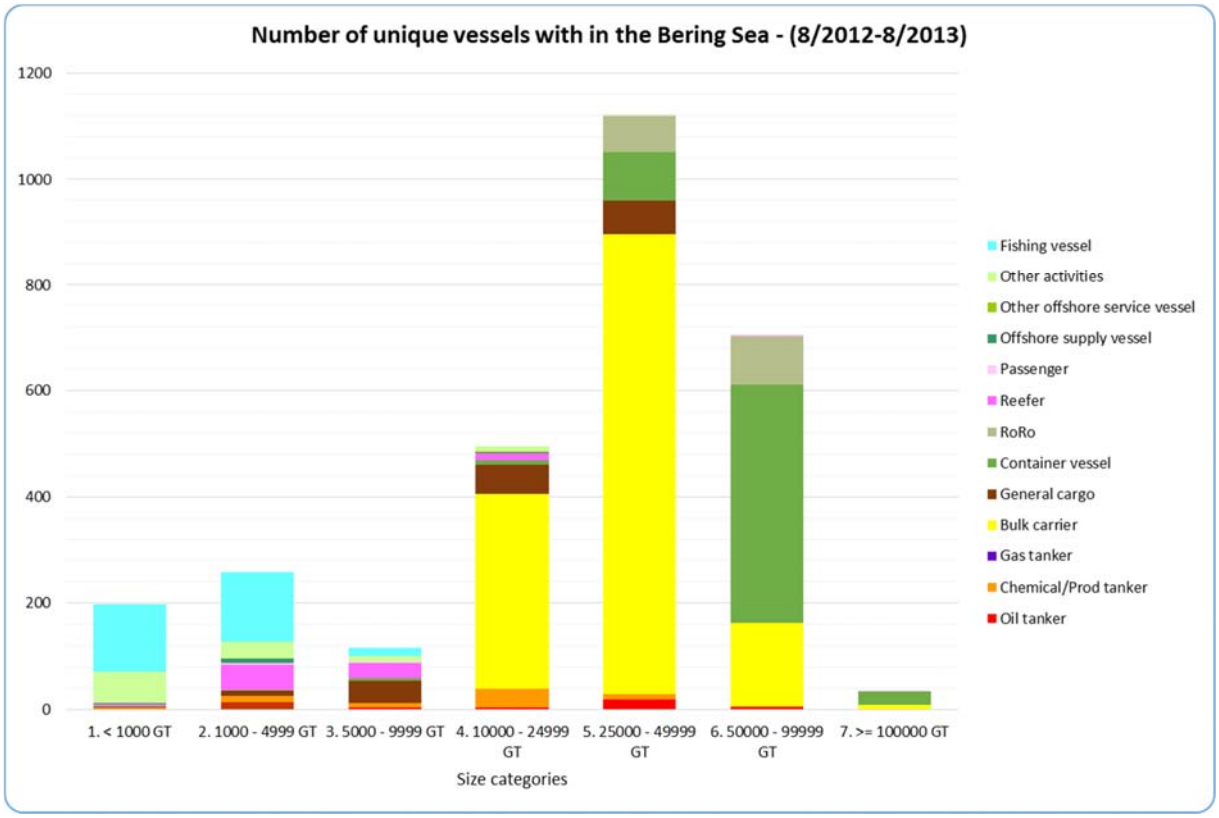

Figure 3-3 - Number of unique vessel in the Bering Sea

3.2 Sailed distances in the Bering Sea – 8/2012 – 8/2013

Table 3-2 - Sailed distance (nm) - Bering Sea

Sailed Distance	1. < 1000 GT	2. 1000 - 4999 GT	3. 5000 - 9999 GT	4. 10000 - 24999 GT	5. 25000 - 49999 GT	6. 50000 - 99999 GT	7. >= 100000 GT	**Grand Total**
Oil tanker	1395	44962	25369	12066	27156	4146		**115093**
Chemical/Prod tanker	5486	42555	24270	72691	16102			**161105**
Gas tanker					993	2872	2901	**6766**
Bulk carrier				889111	1249893	247827	33430	**2420263**
General cargo	4471	39694	124542	103948	137962			**410617**
Container vessel			14441	48428	300295	1633179	60941	**2057284**
RoRo	5820	692	1271		176839	131465		**316087**
Reefer	11247	159162	83538	23873				**277820**
Passenger		15228	4763	715	3196	3091	1302	**28294**
Offshore supply vessel	5003	19420		2244				**26667**
Other offshore service vessel				1795				**1795**
Other activities	214015	81733	21275	31195	1146			**349363**
Fishing vessel	744059	546500	63100					**1353660**
Total	**991496**	**949944**	**362569**	**1186066**	**1913582**	**2022581**	**98574**	**7524813**

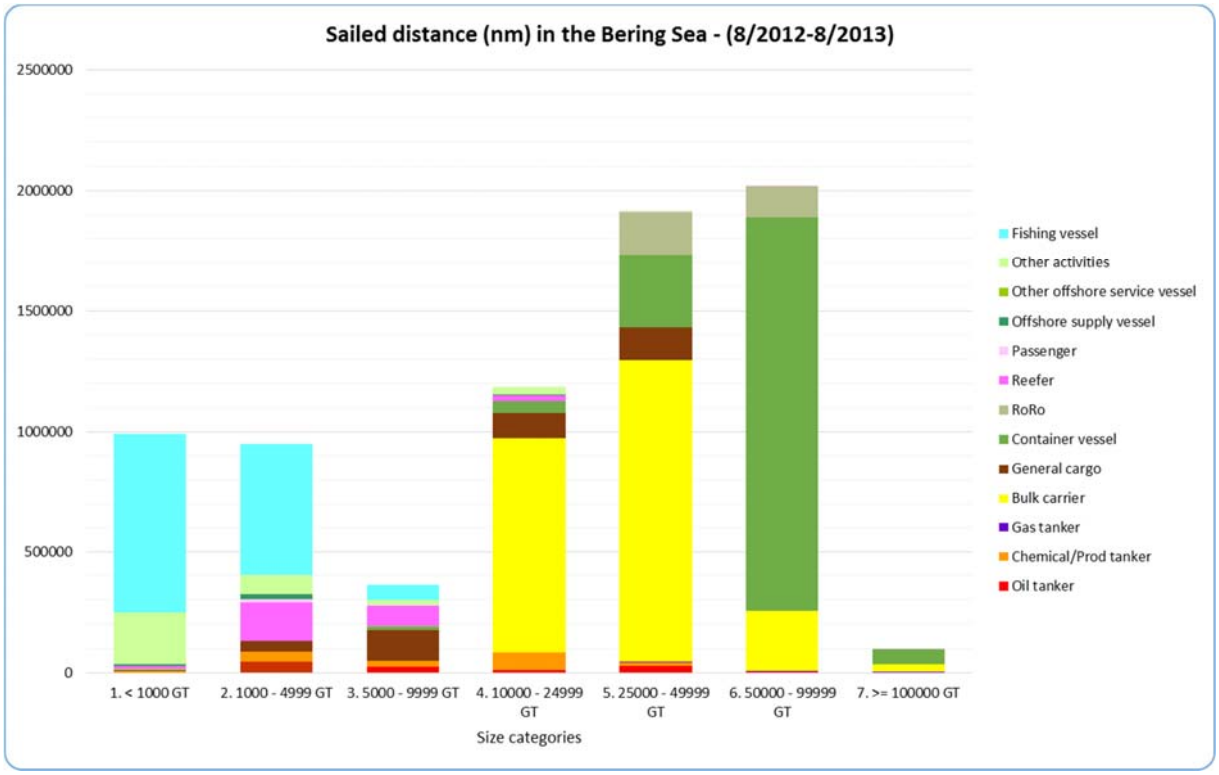

Figure 3-4 - Sailed distance (nm) in the Bering Sea

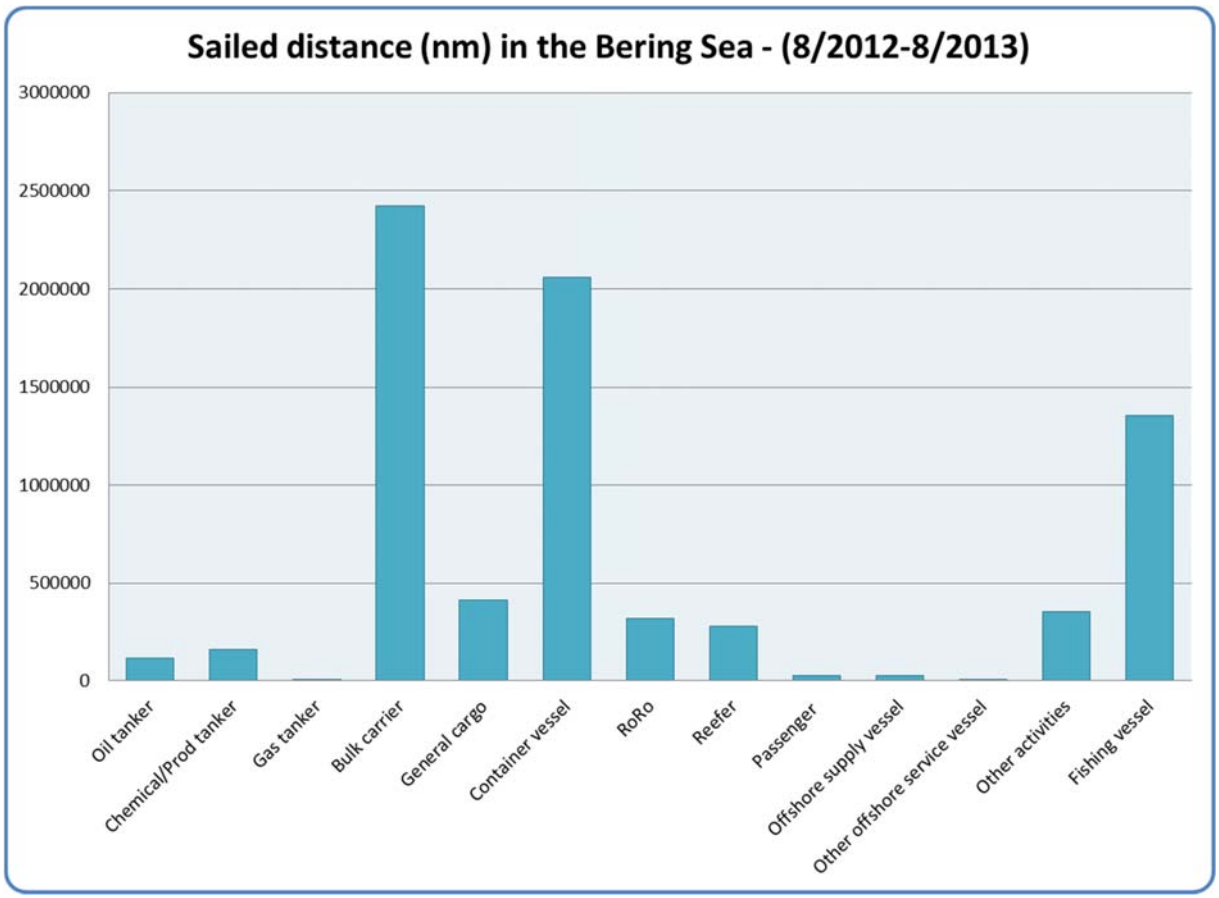

Figure 3-5 - Sailed distance (nm) in the Bering Sea

3.3 Operational hours in the Bering Sea – 8/2012 – 8/2013

Table 3-3 - Operational hours

Op Hours	1. < 1000 GT	2. 1000 - 4999 GT	3. 5000 - 9999 GT	4. 10000 - 24999 GT	5. 25000 - 49999 GT	6. 50000 - 99999 GT	7. >= 100000 GT	Total
Oil tanker	416	9770	5520	1512	3157	350		**20724**
Chemical/Prod tanker	865	9556	7032	6244	1910			**25606**
Gas tanker					70	217	229	**515**
Bulk carrier				79996	108523	22184	2979	**213683**
General cargo	1137	13615	19313	9502	11541			**55109**
Container vessel			2012	4173	20813	99483	3758	**130239**
RoRo	2104	173	458		11778	8385		**22899**
Reefer	4801	63845	25757	10570				**104972**
Passenger		3065	615	73	296	195	68	**4312**
Offshore supply vessel	3088	6639		1134				**10862**
Other offshore service vessel				1232				**1232**
Other activities	98762	32712	13010	8124	921			**153527**
Fishing vessel	331106	213830	29569					**574505**
Grand Total	**442279**	**353204**	**103287**	**122560**	**159007**	**130813**	**7034**	**1318184**

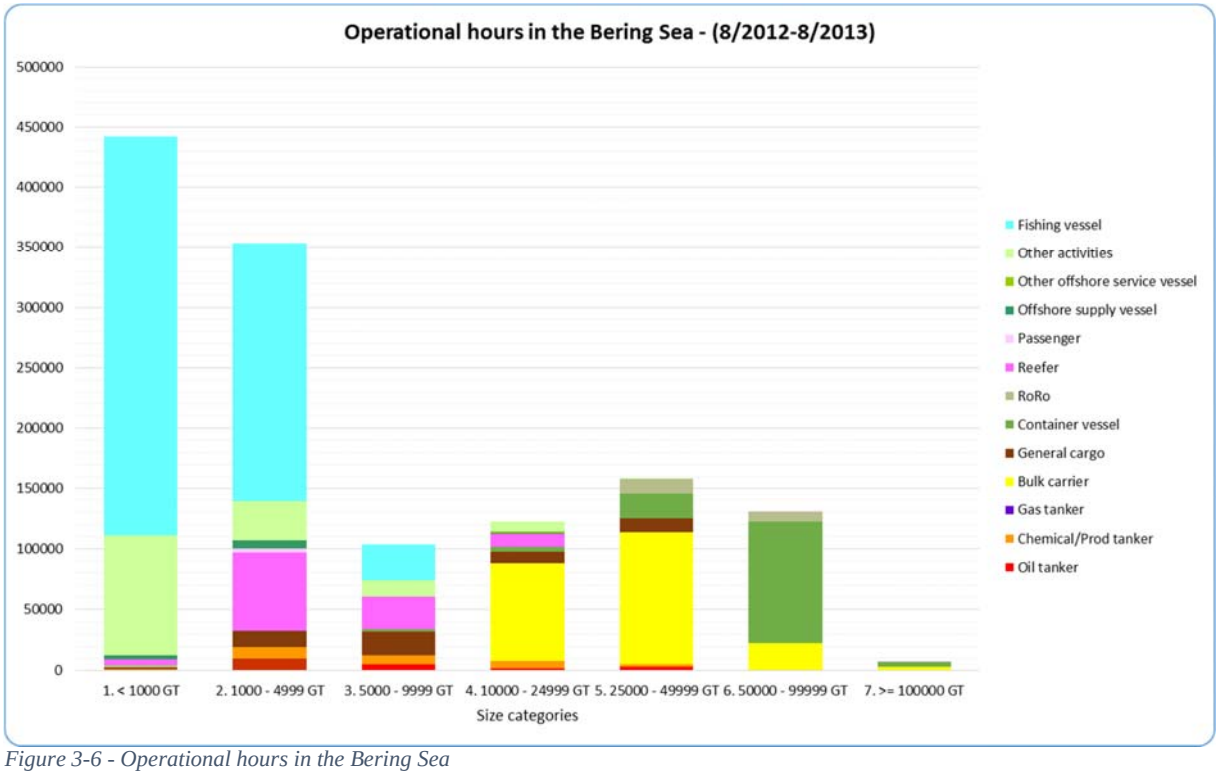

Figure 3-6 - Operational hours in the Bering Sea

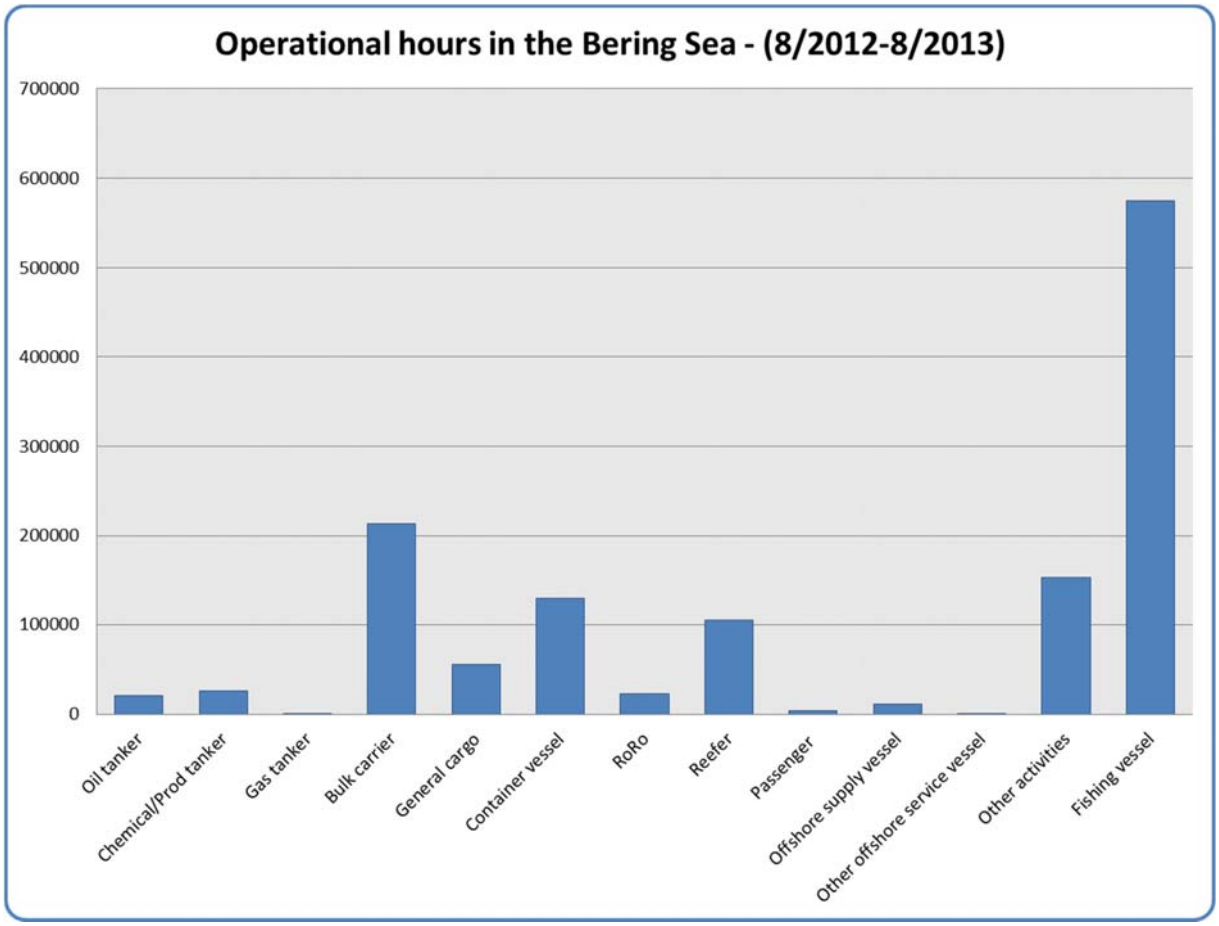

Figure 3-7- Operational hours in the Bering Sea

3.4 Ice Extent and seasonal variations

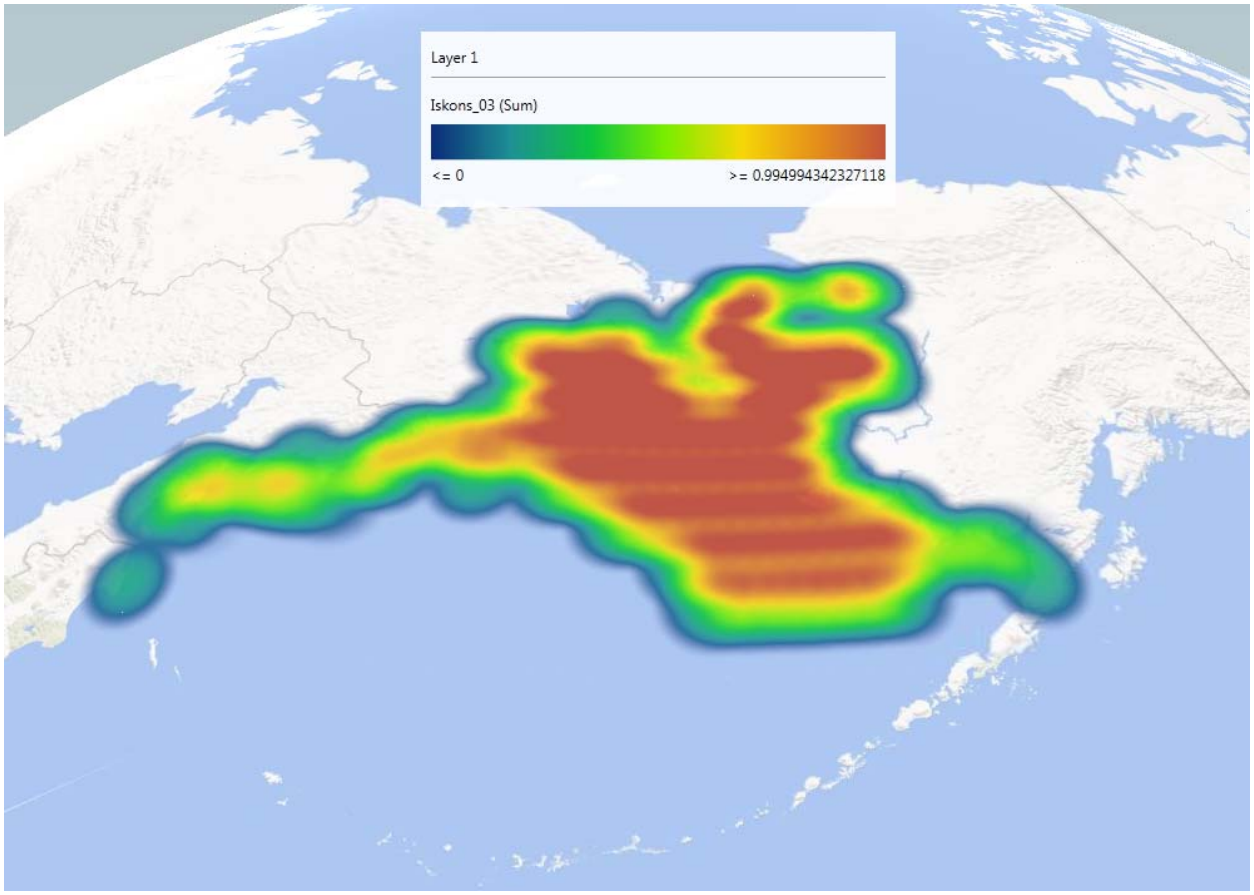

Figure 3-8 - Maximum ice concentration (and extent) through the year (March 2013) (Source:US National Ice Center)

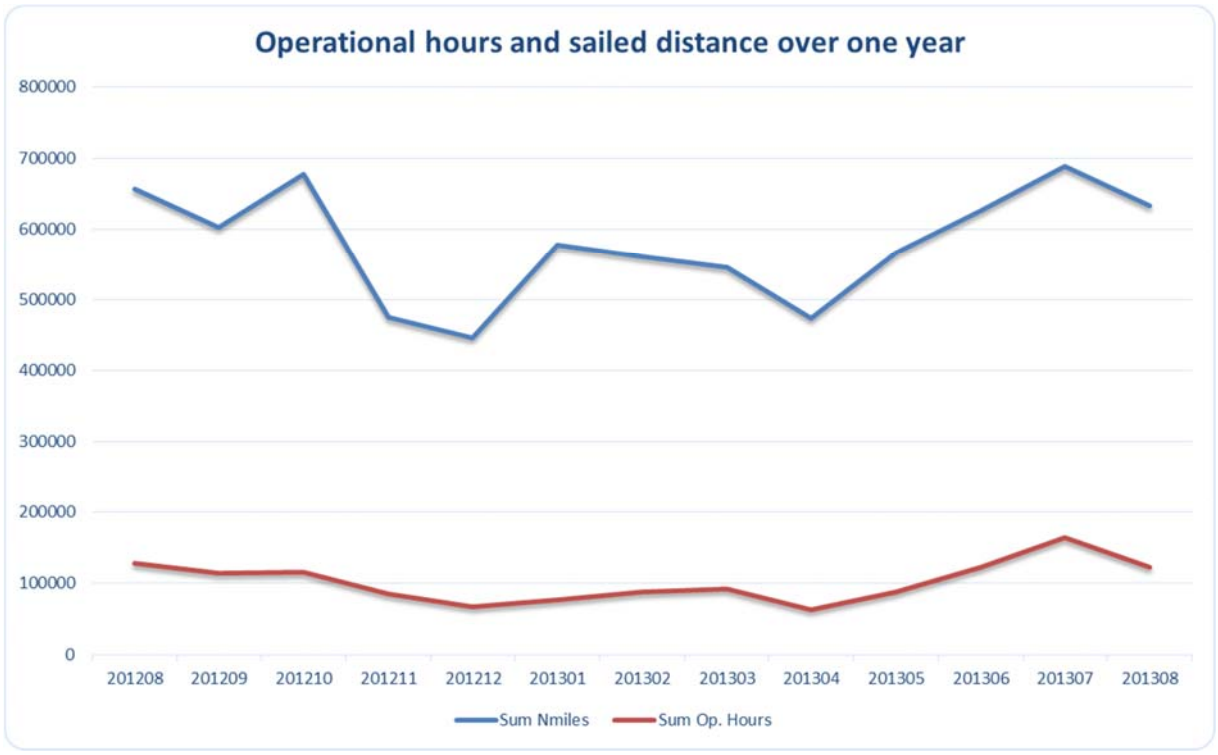

Figure 3-9 - Sailed distance and operating hours throughout August 2012 to August 2013

3.5 Geographical traffic distribution

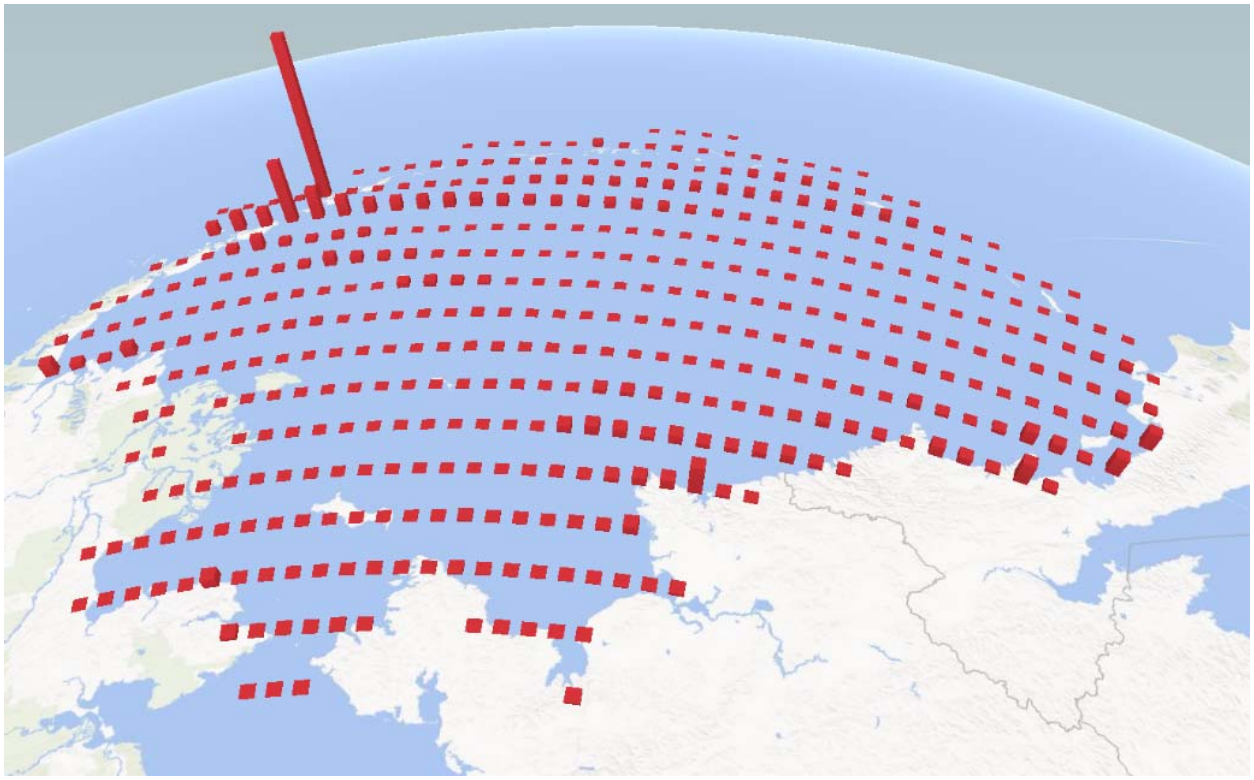

Figure 3-10 - Operational hours in the Bering Sea

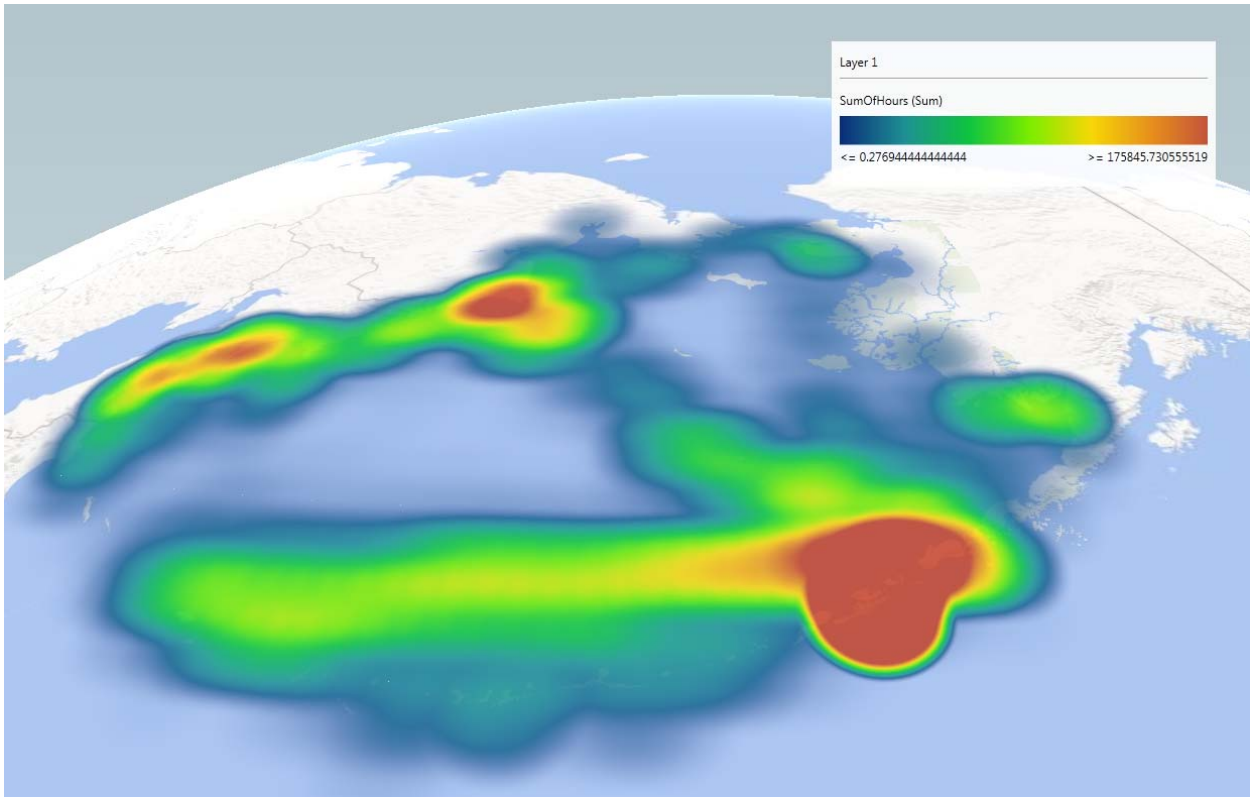

Figure 3-11 - Concentration of operational hours (Hours per 1x1 degree grid cell)

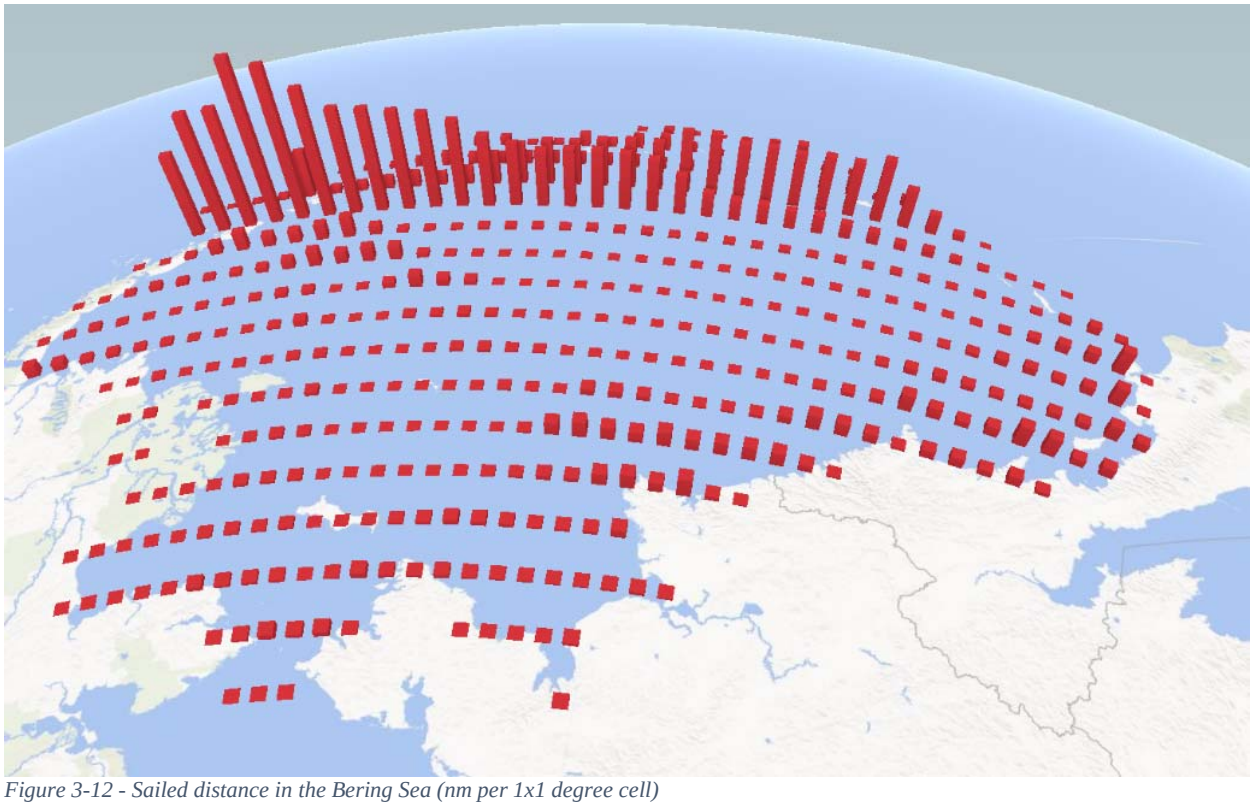

Figure 3-12 - Sailed distance in the Bering Sea (nm per 1x1 degree cell)

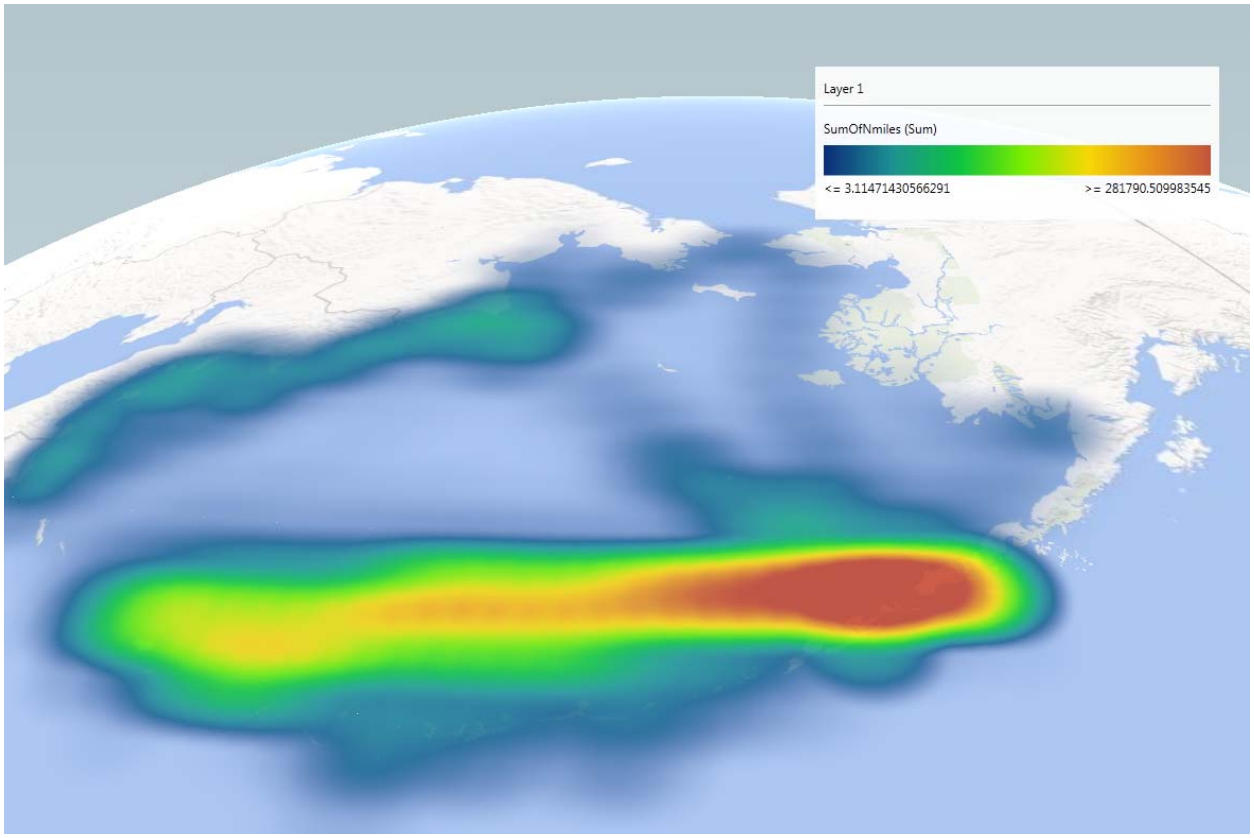

Figure 3-13 - Sailed distance in the Bering Sea (nm per 1x1 degree cell)

4 BUNKER OIL DISTRIBUTION

Table 4-1- Number of unique vessels with vessels identified as HFO users in brackets

	< 1000 GT	1000 - 4999 GT	5000 - 9999 GT	10000 - 24999 GT	25000 - 49999 GT	50000 - 99999 GT	>= 10000 0 GT	**Grand Total**
Oil tanker	2()	15(2)	4(4)	4(4)	19(19)	6(6)		**50(35)**
Chemical/Prod tanker	3()	11(7)	9(8)	35(35)	10(10)			**68(60)**
Gas tanker					1(1)	1(1)	2(2)	**4(4)**
Bulk carrier				367(367)	867(867)	156(156)	8(8)	**1398(1398)**
General cargo	1()	11(3)	42(29)	56(56)	63(63)			**173(151)**
Container vessel			4(4)	8(8)	92(92)	448(448)	25(25)	**577(575)**
RoRo	2()	1()	1(1)		66(66)	92(92)		**162(158)**
Reefer	4()	46(12)	28(26)	13(13)				**91(51)**
Passenger		4()	2(1)	1(1)	2(2)	4(4)	1(1)	**14(6)**
Offshore supply vessel	1()	8(1)		1()				**10(1)**
Other offshore service vessel				1()				**1()**
Other activities	59()	32(1)	12(1)	11(11)	2(2)			**116(15)**
Fishing vessel	126()	130(3)	14()					**270(3)**
Total	**198()**	**258(29)**	**116(74)**	**497(495)**	**1122(1122)**	**707(707)**	**36(36)**	**2934(2457)**

Table 4-2 - Percentage of vessels operating on HFO within each vessel and size category

	< 1000 GT	1000 - 4999 GT	5000 - 9999 GT	10000 - 24999 GT	25000 - 49999 GT	50000 - 99999 GT	>= 100000 GT	**Grand Total**
Oil tanker	0 %	13 %	100 %	100 %	100 %	100 %		70 %
Chemical/Prod tanker	0 %	64 %	89 %	100 %	100 %			88 %
Gas tanker					100 %	100 %	100 %	100 %
Bulk carrier				100 %	100 %	100 %	100 %	100 %
General cargo	0 %	27 %	69 %	100 %	100 %			87 %
Container vessel			100 %	100 %	100 %	100 %	100 %	100 %
RoRo	0 %	0 %	100 %		100 %	99 %		98 %
Reefer	0 %	26 %	93 %	100 %				56 %
Passenger		0 %	50 %	100 %	100 %	100 %	100 %	43 %
Offshore supply vessel	0 %	13 %		0 %				10 %
Other offshore service vessel				0 %				0 %
Other activities	0 %	3 %	8 %	100 %	100 %			13 %
Fishing vessel	0 %	2 %	0 %					1 %
	0 %	11 %	64 %	100 %	100 %	99 %	100 %	84 %

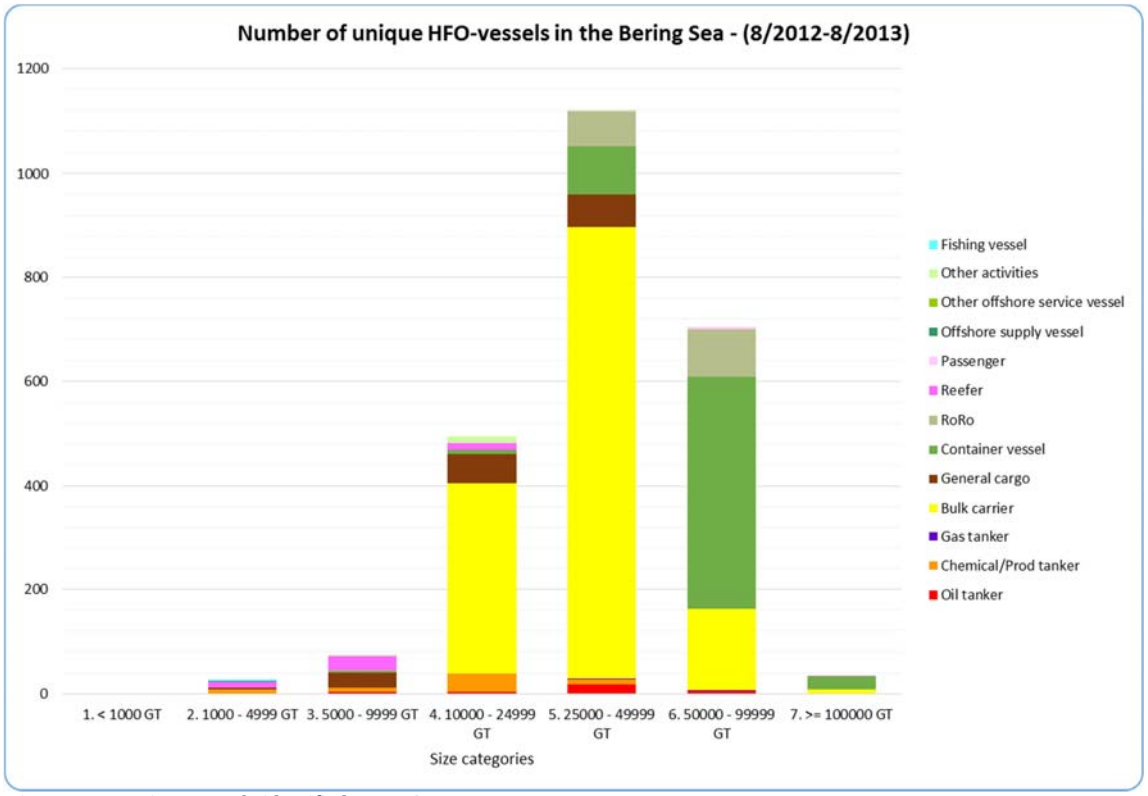

Figure 4-1 - Unique vessels identified as HFO users

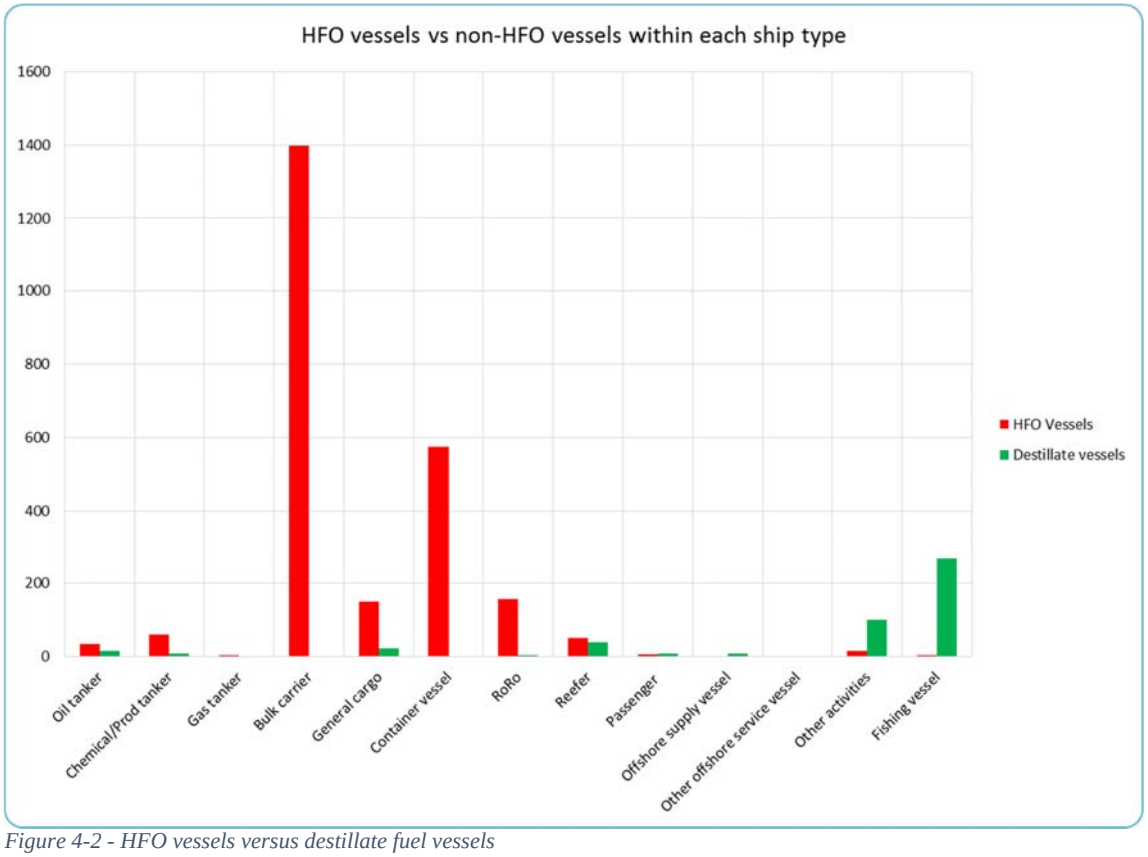

Figure 4-2 - HFO vessels versus destillate fuel vessels

5 EMISSION CALCULATIONS

Table 5-1- Fuel consumption and emissions to air

	Fuel (ton)	CO2 (ton)	Nox (ton)	SO2 (ton)	PM (ton)	BC (ton)
Oil tanker	6187	19734	418	63	33	1,1
Chemical/Prod tanker	10035	31982	651	88	48	1,8
Gas tanker	1101	3518	82	18	7,2	0,2
Bulk carrier	205910	658578	15901	2749	1494	37
General cargo	27561	87370	1906	213	108,9	5,0
Container vessel	410479	1312350	31363	7284	2868	74
RoRo	28045	89672	2145	421	198	5,0
Reefer	17705	56160	862	84	29	3,2
Passenger	2690	8574	175	31	13,0	0,5
Offshore supply vessel	1955	6199	88	5	2,9	0,4
Other offshore service vessel	88	280	5	0	0,1	0,0
Other activities	15937	50519	759	40	19	2,9
Fishing vessel	43799	138843	1955	79	53	7,9
Total	**771492**	**2463778**	**56308**	**11075**	**4874**	**139**

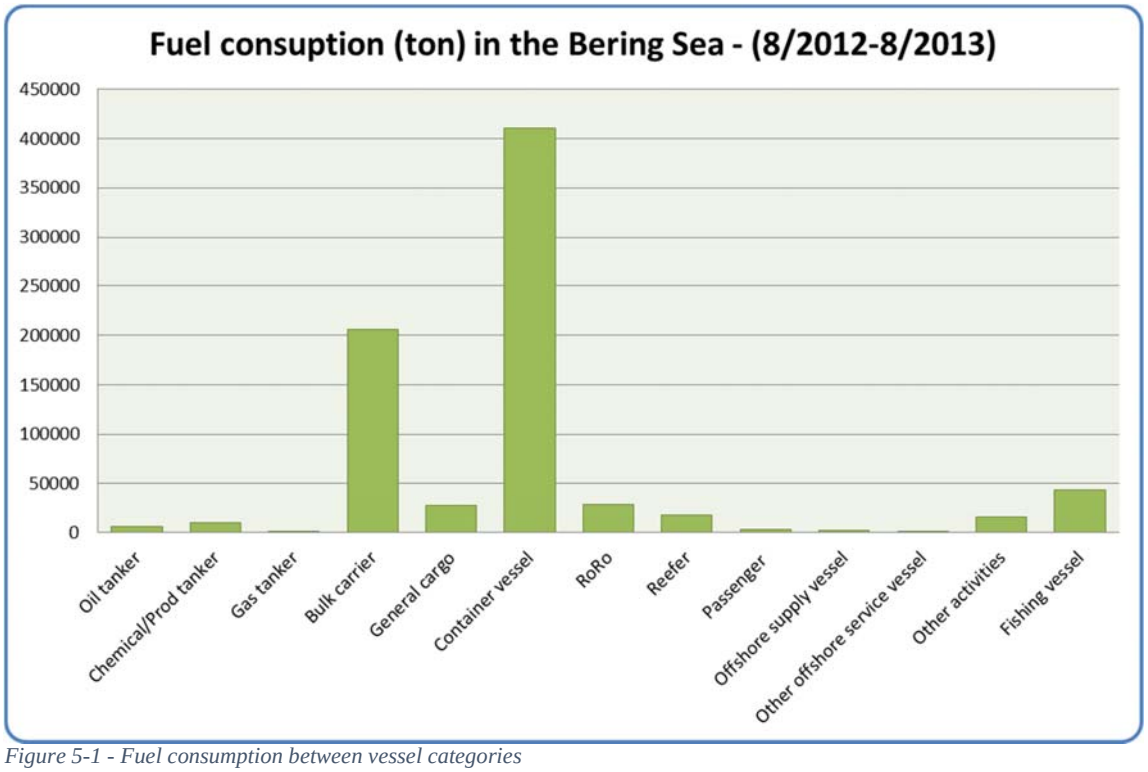

Figure 5-1 - Fuel consumption between vessel categories

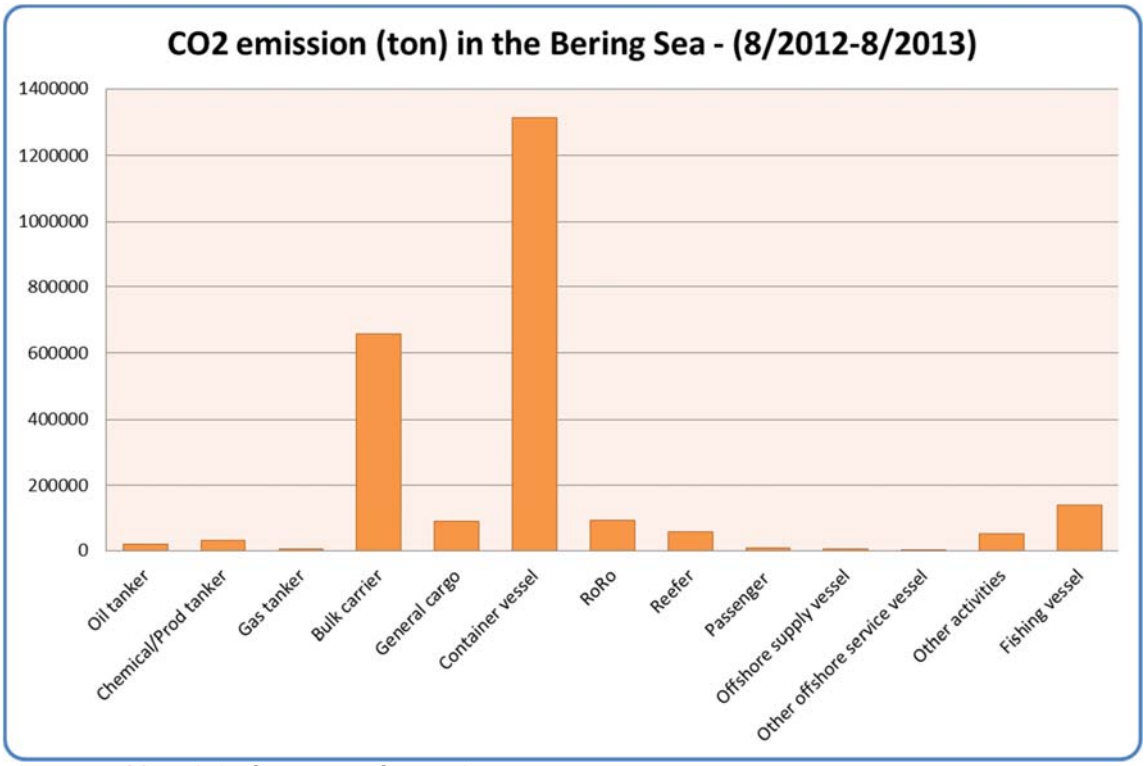

Figure 5-2 - CO2 emission between vessel categories

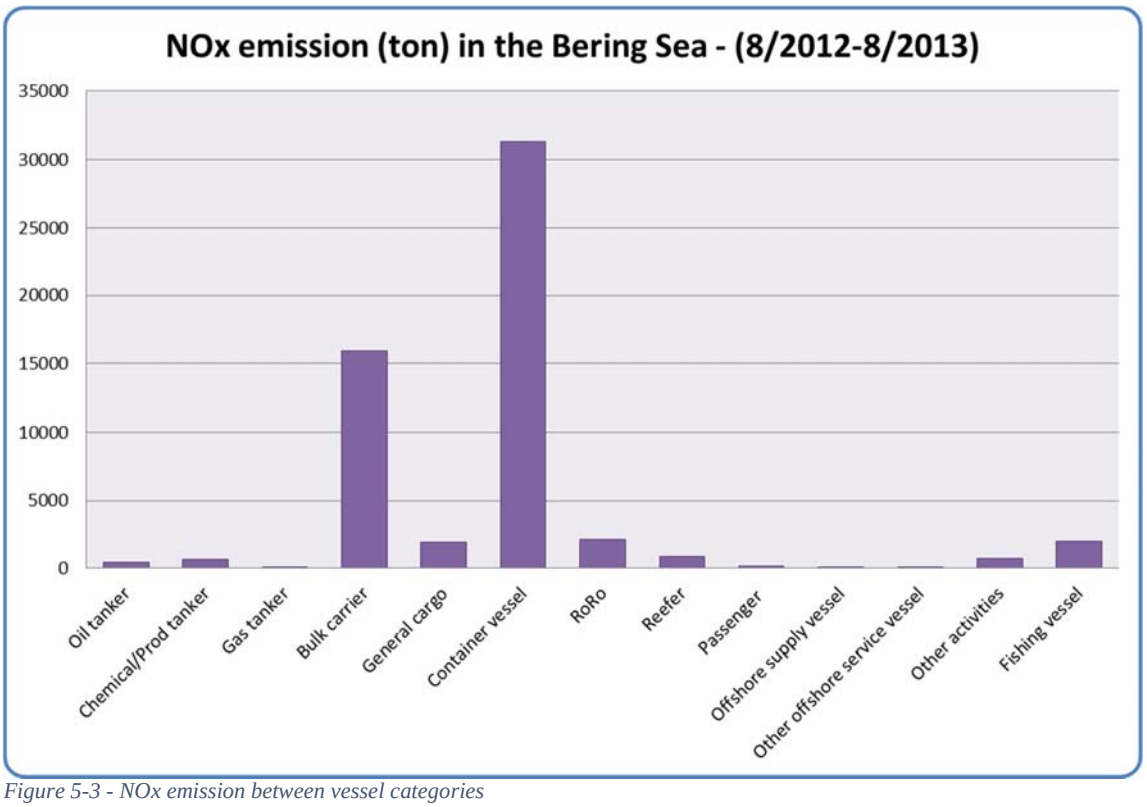

Figure 5-3 - NOx emission between vessel categories

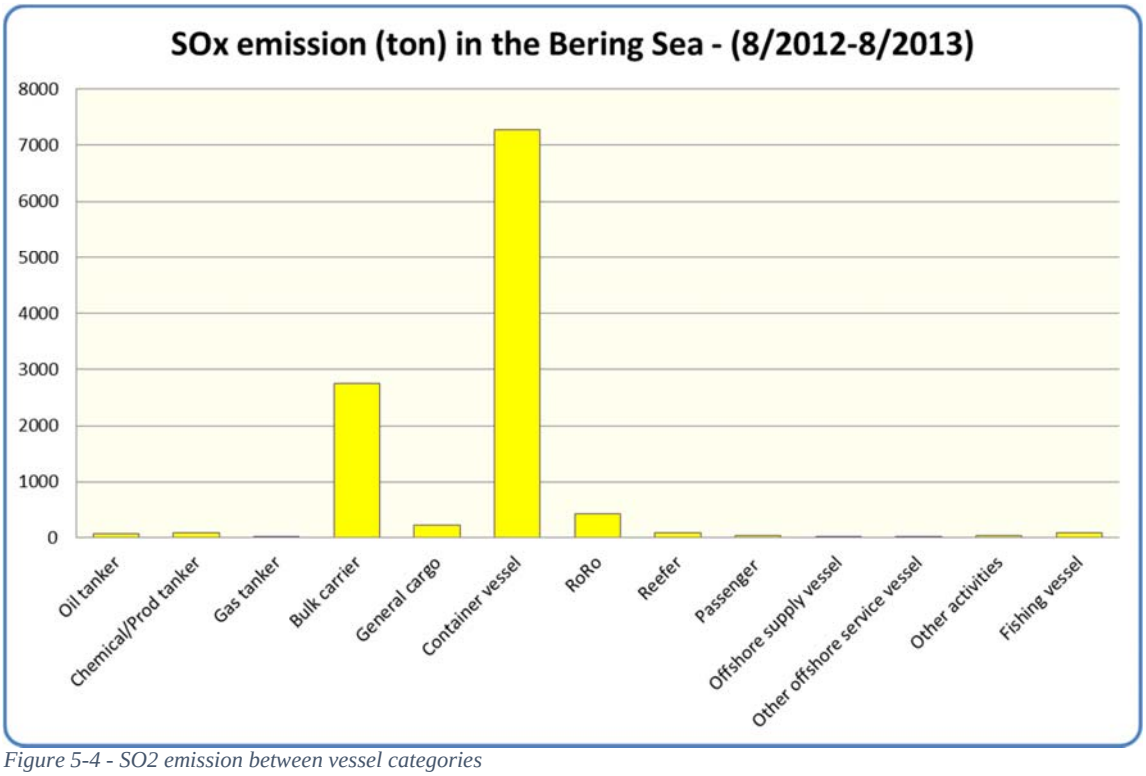

Figure 5-4 - SO2 emission between vessel categories

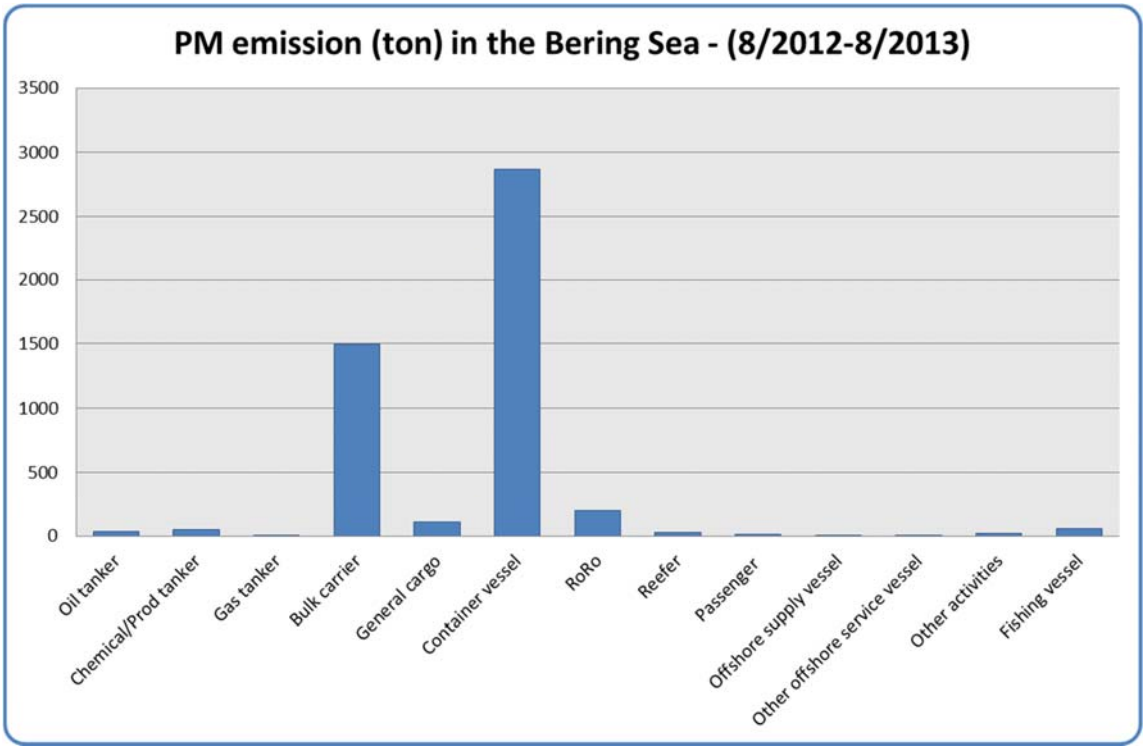

Figure 5-5 - PM emission between vessel categories

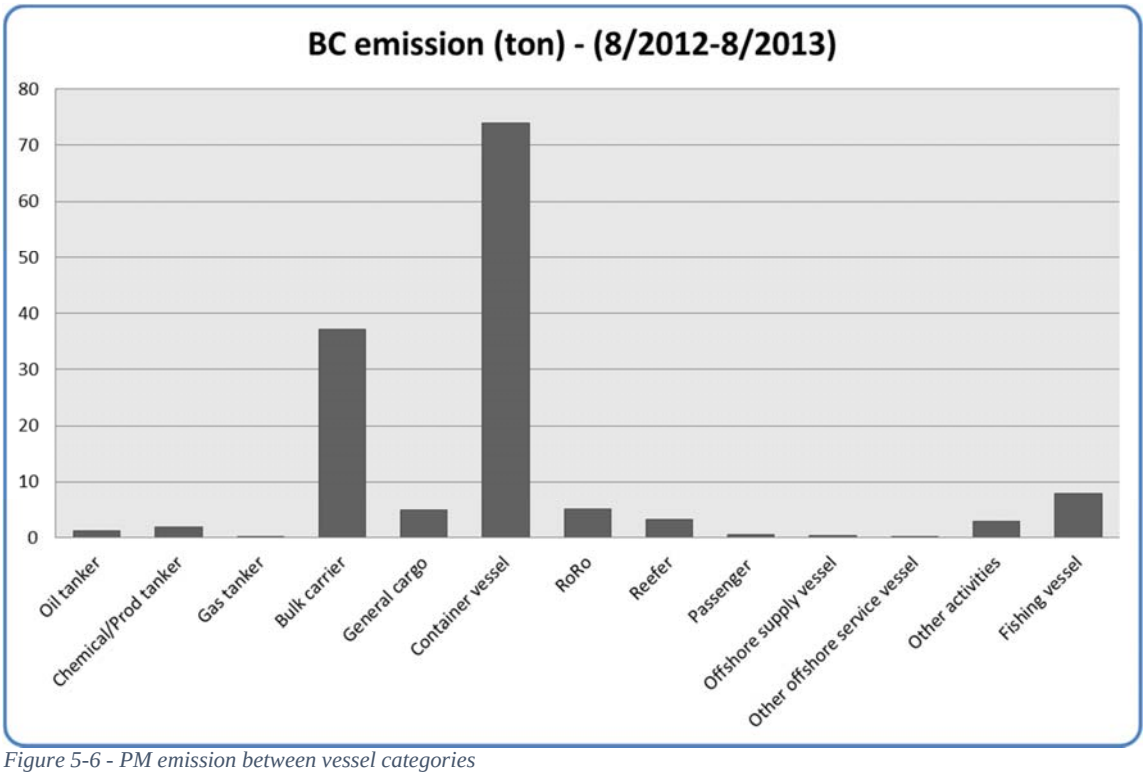

Figure 5-6 - PM emission between vessel categories

5.1 Geographical distribution of emissions

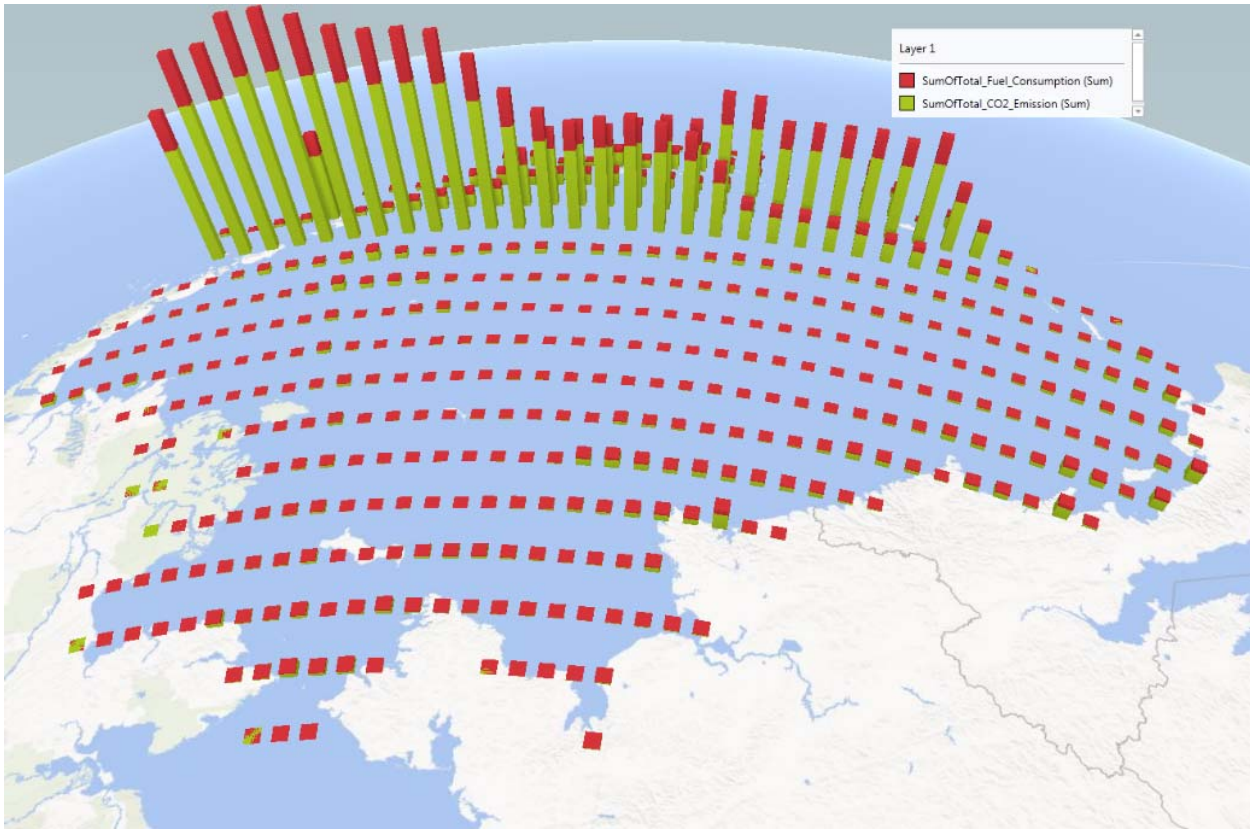

Figure 5-7 - Fuel consumption and CO2 emission in the Bering Sea

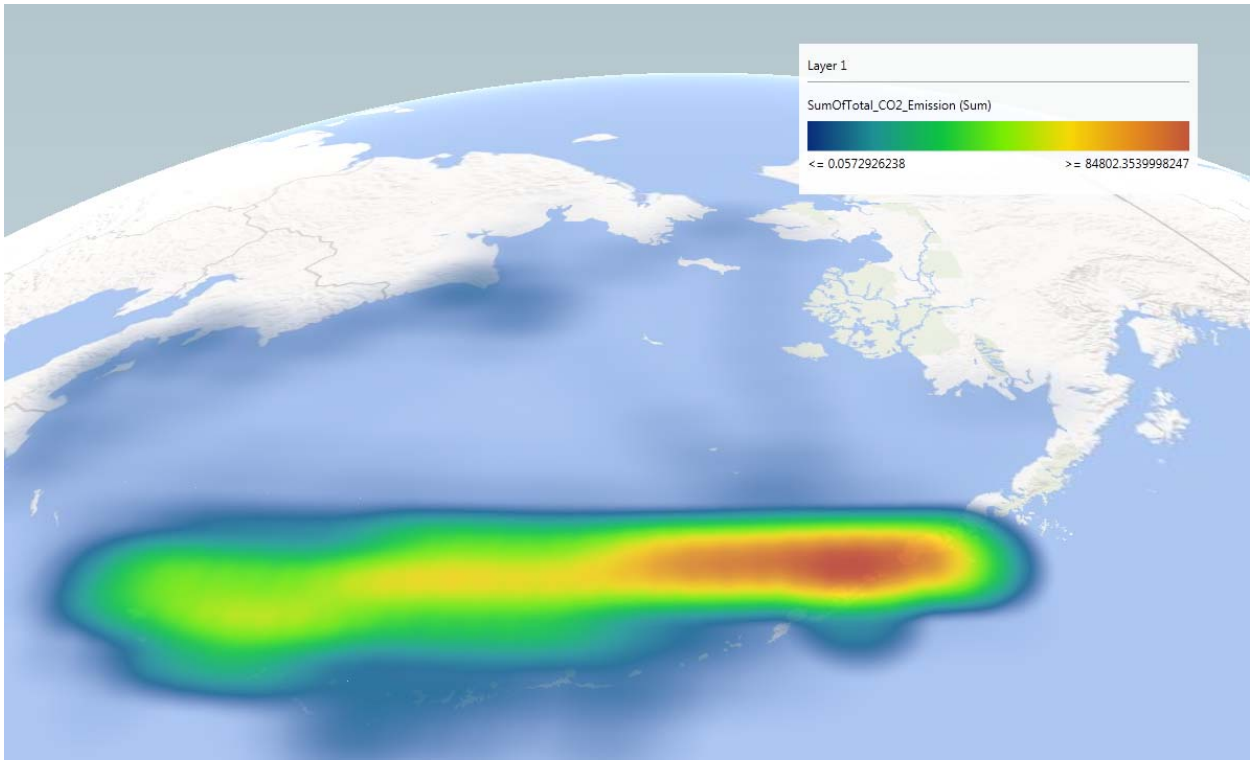

Figure 5-8 - CO2 emission concentration (tons per 1x1 degree cell)

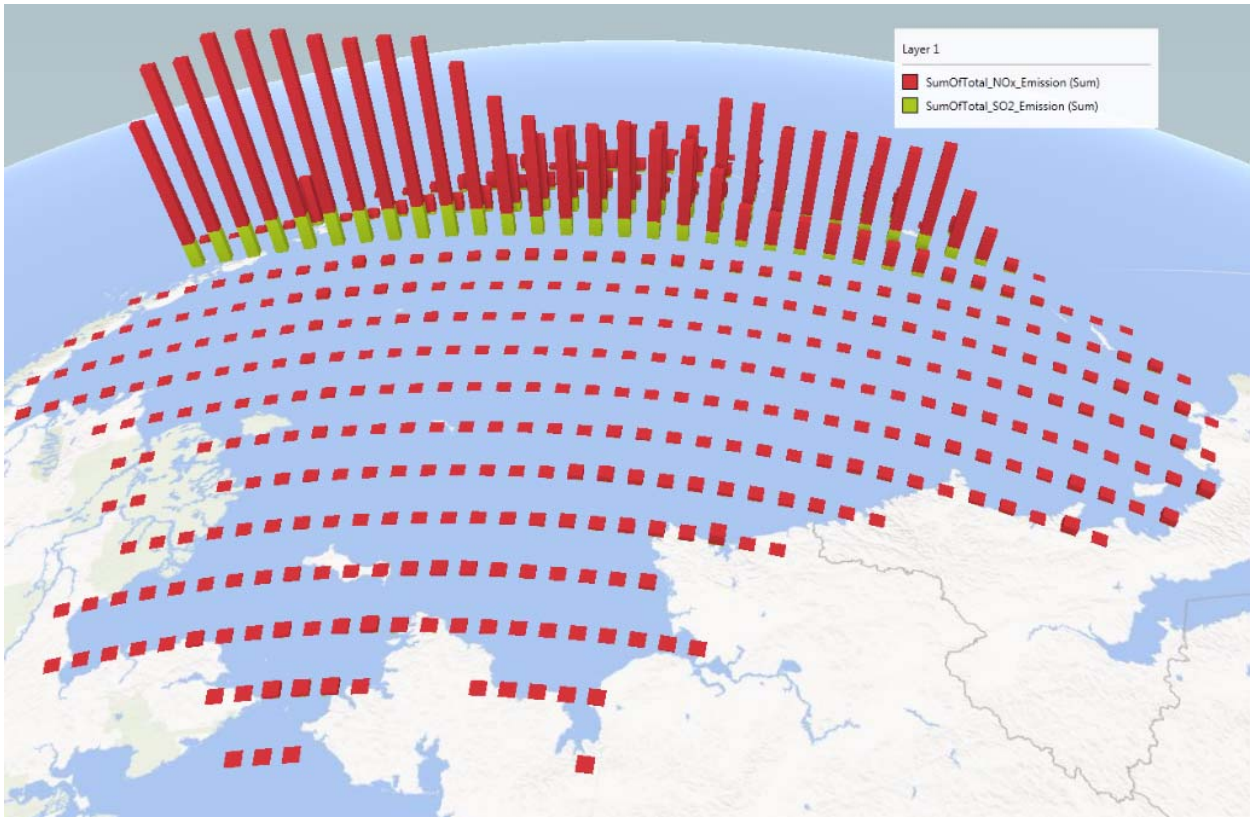

Figure 5-9 - NOx and SO2 emission in the Bering Sea

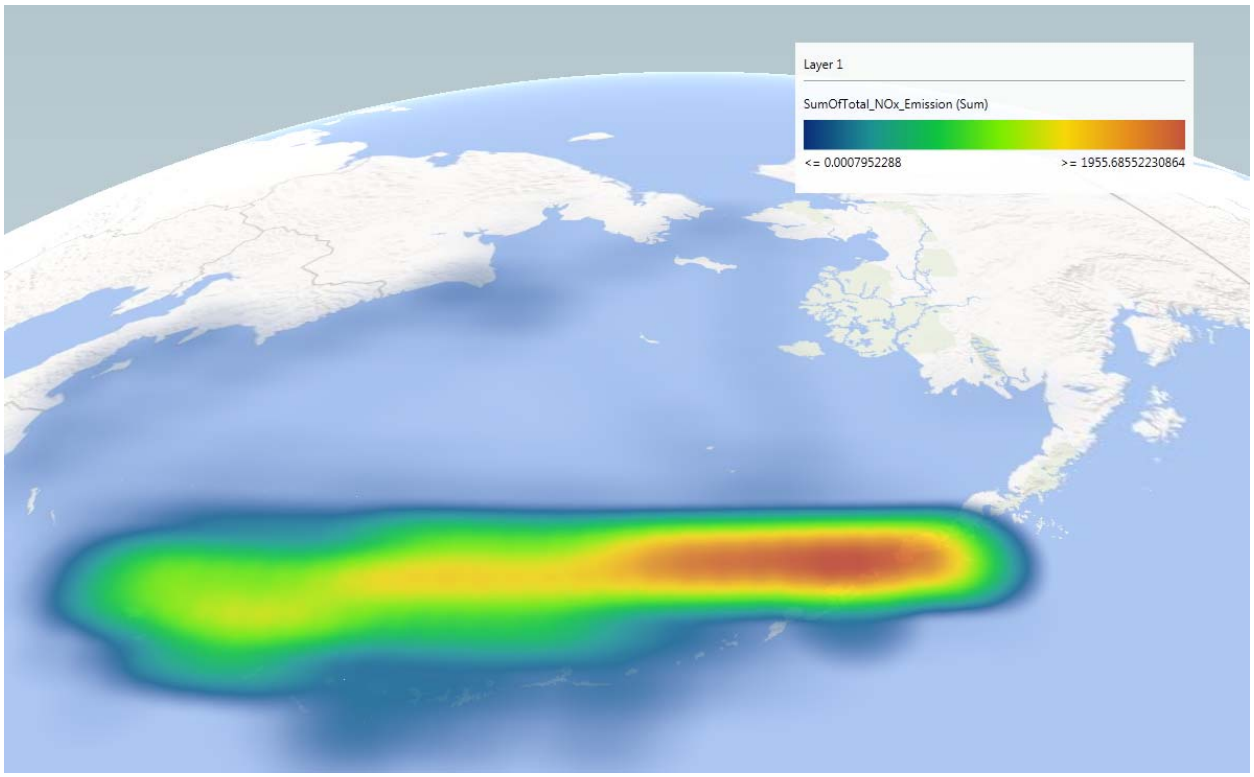

Figure 5-10 - NOx emission concentration (ton per 1x1 degree cell)

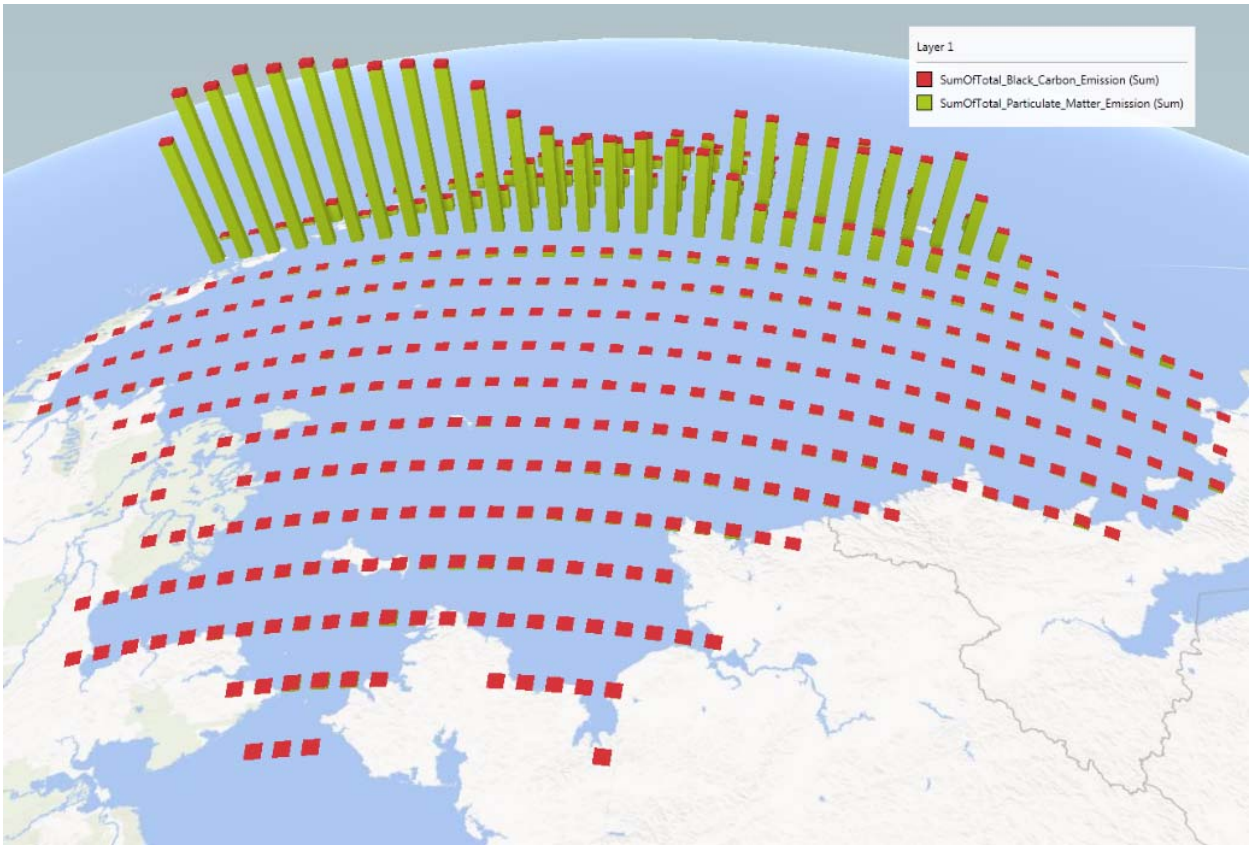

Figure 5-11 - BC and PM emission in the Bering Sea

6 RISK ASESSMENT

6.1 Risk frequencies

Table 6-1 - Yearly likely number of accidents leading to oil spill

	Grounding	Collision	Hull/Machinery	Fire/Explosion	Ice	Total
Oil tanker	0,0098	0,0004	0,0022	0,0040	0,0002	0,0166
Chemical/Prod tanker	0,0112	0,0004	0,0031	0,0056	0,0001	0,0204
Gas tanker	0,0001	0,0000	0,0001	0,0001	0,0000	0,0004
Bulk carrier	0,0487	0,0027	0,0411	0,0436	0,0000	0,1361
General cargo	0,0140	0,0007	0,0070	0,0074	0,0002	0,0292
Container vessel	0,0419	0,0023	0,0350	0,0370	0,0000	0,1163
RoRo	0,0073	0,0004	0,0054	0,0057	0,0000	0,0187
Reefer	0,0121	0,0005	0,0047	0,0050	0,0004	0,0227
Passenger	0,0020	0,0001	0,0005	0,0005	0,0000	0,0031
Offshore supply vessel	0,0011	0,0000	0,0005	0,0005	0,0001	0,0021
Other offshore vess.	0,0001	0,0000	0,0000	0,0000	0,0000	0,0001
Other activities	0,0234	0,0009	0,0059	0,0063	0,0007	0,0372
Fishing vessel	0,0513	0,0024	0,0230	0,0244	0,0018	0,1028
Total	0,2229	0,0109	0,1286	0,1400	0,0034	0,5057

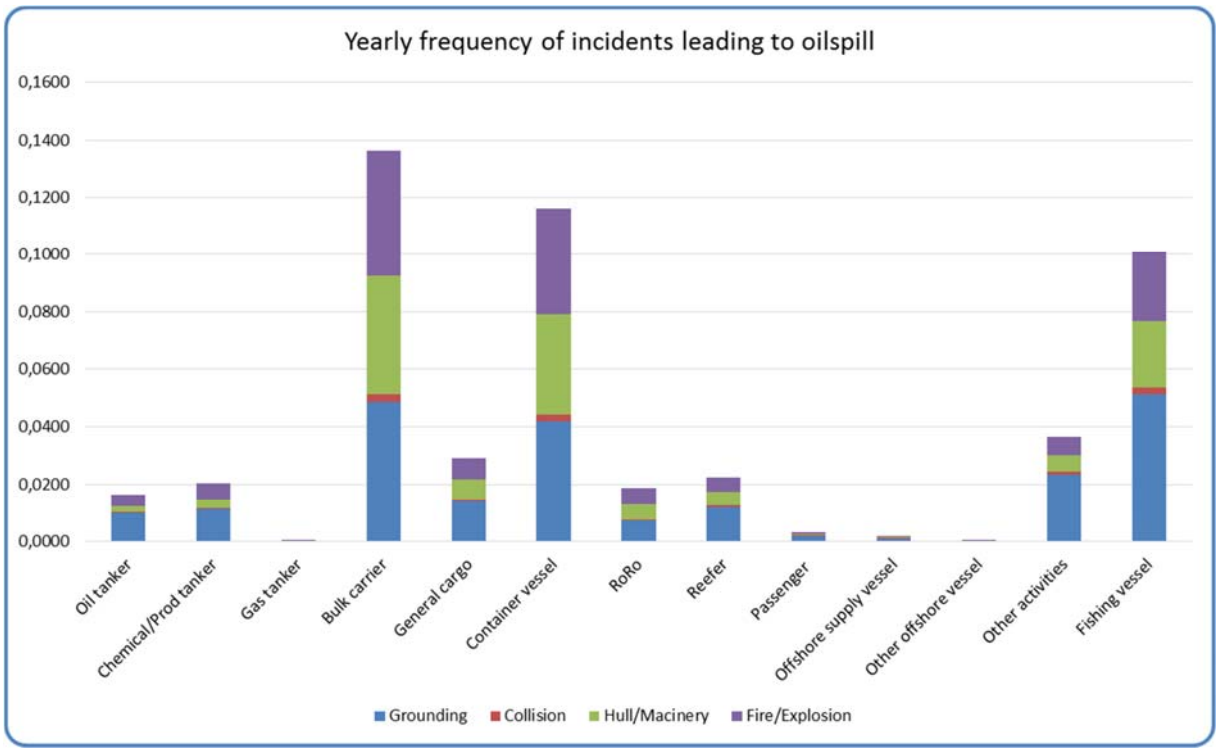

Figure 6-1 – Likely number of yearly incidents leading to oil spill

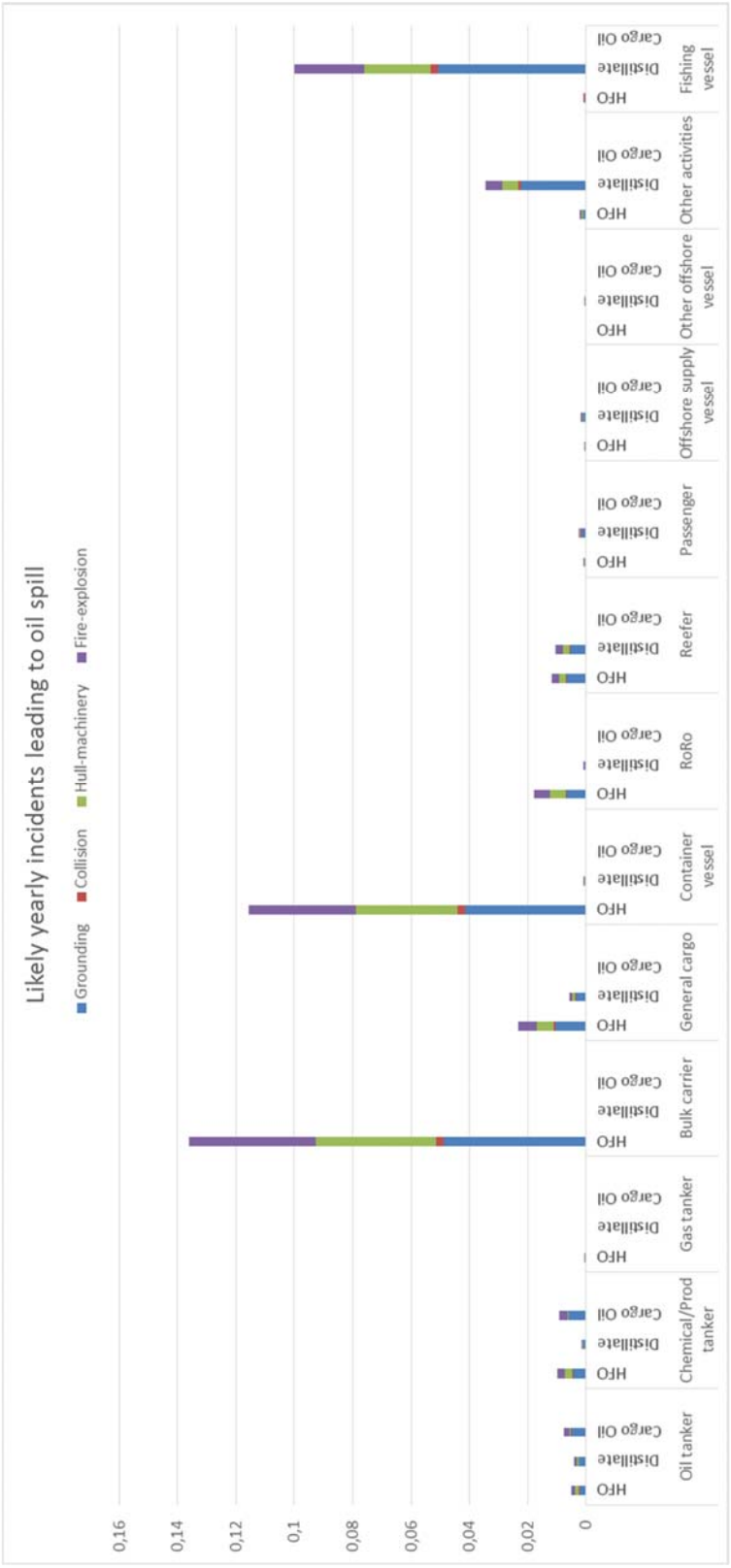

Figure 6-2 - Likely frequency of incidents leading to oil spill

Table 6-2 - Likely return period (years) of incidents leading to oil spill

	Grounding	Collision	Hull/Machinery	Fire/Explosion	Ice	**Total**
Oil tanker	102	2794	449	251	5911	**60**
Chemical/Prod tanker	89	2306	321	179	17660	**49**
Gas tanker	9475	153291	8694	8211	175220	**2820**
Bulk carrier	21	367	24	23	146919	**7.3**
General cargo	71	1522	143	135	5877	**34**
Container vessel	24	429	29	27	33126	**8.6**
RoRo	137	2589	186	176		**53**
Reefer	83	1885	212	200	2585	**44**
Passenger	495	12477	2079	1964		**324**
Offshore supply vessel	952	20974	2206	2083	12892	**474**
Other offshore vessel	17090	370423	32775	30954		**7041**
Other activities	43	1054	168	159	1501	**27**
Fishing vessel	20	425	43	41	544	**9.7**
Total	**4.5**	**92.0**	**7.8**	**7.1**	**292**	**2.0**

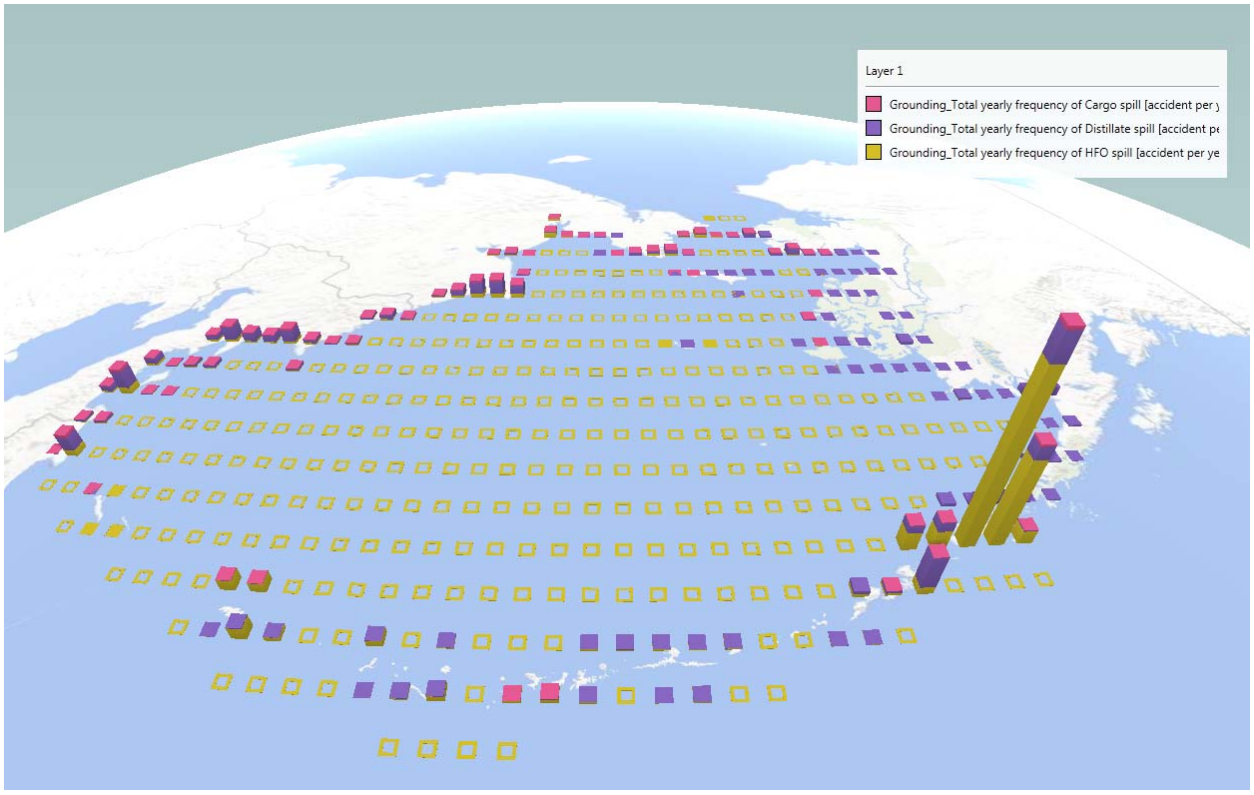

Figure 6-3 - Grounding risk frequencies

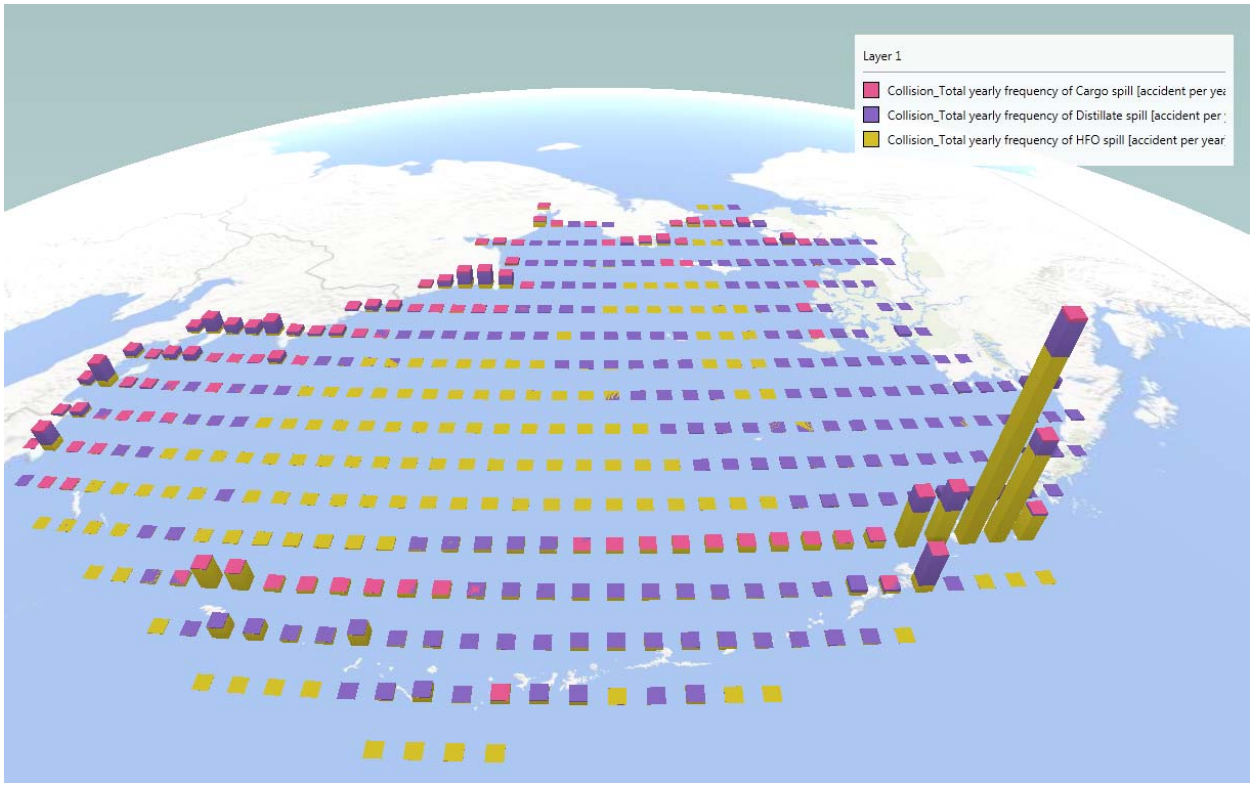

Figure 6-4 - Collision risk frequencies

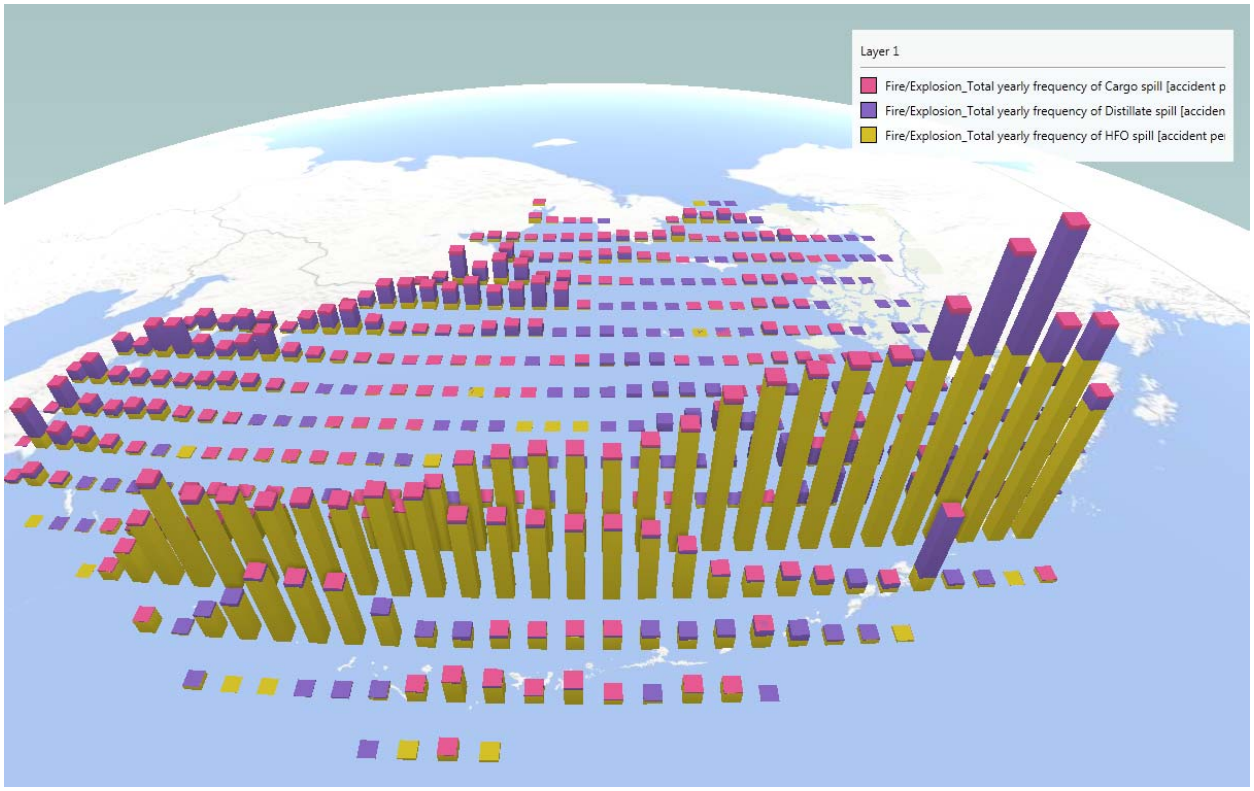

Figure 6-5 - Fire/explosion risk frequencies

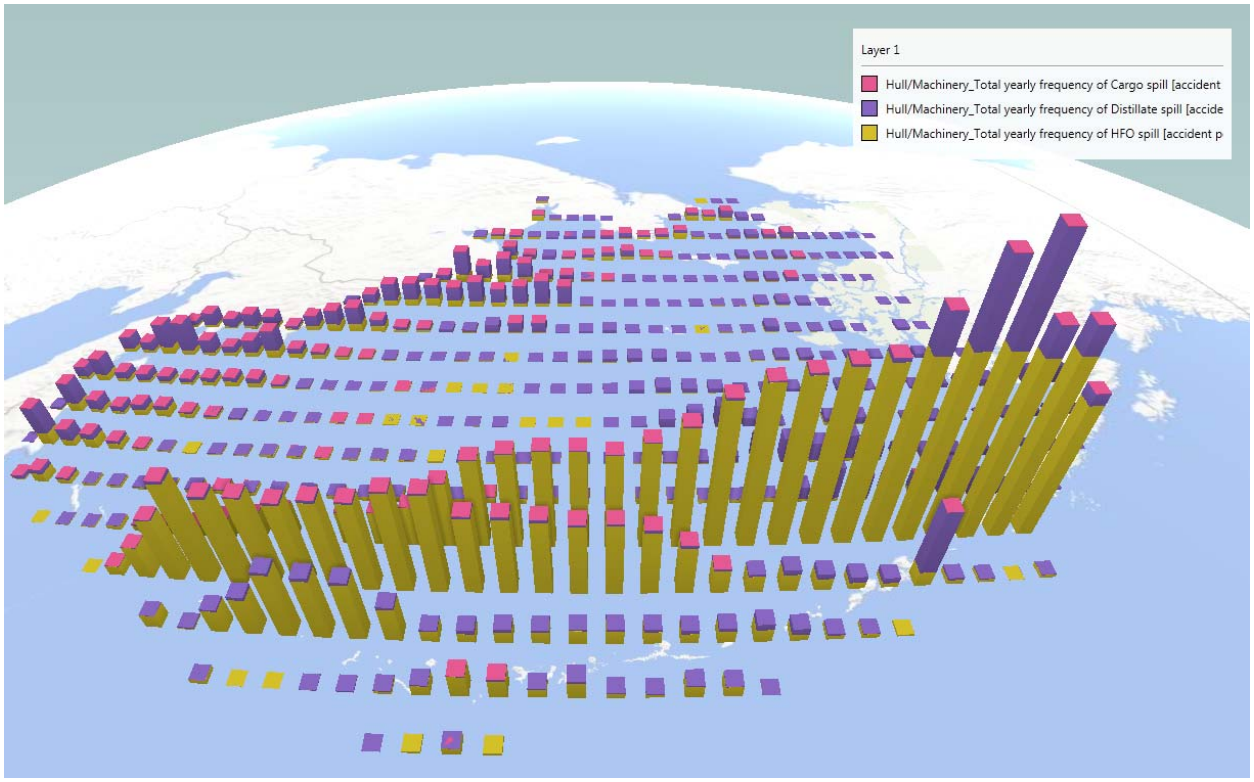

Figure 6-6 - Hull/machinery risk frequencies

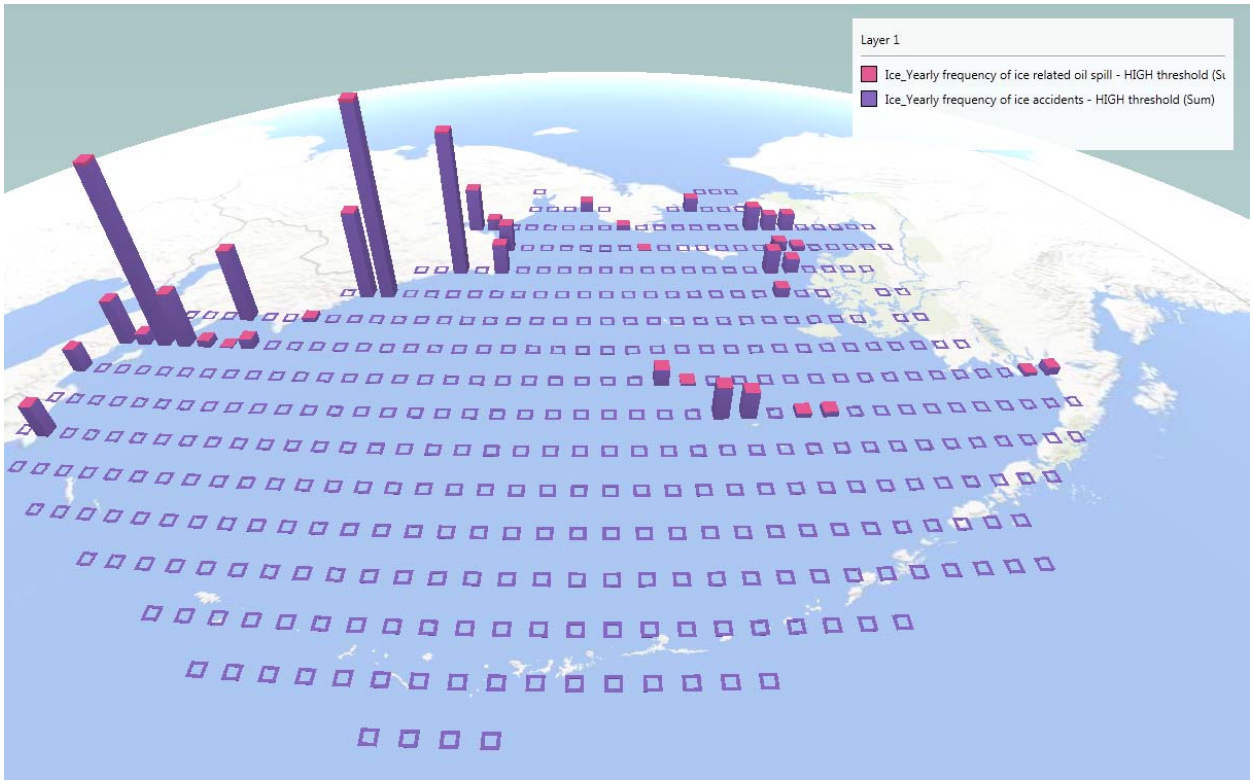

Figure 6-7 Ice risk frequency – damage, and damage leading to oil spill (See Figure 3-8 for maximum ice extent)

6.2 Likely oil spill based on the risk calculations

Table 6-3 - Likely estimated oil spills (ton)

	Grounding	Collision	Hull/Macinery	Fire/Explosion	**Total**
Oil tanker	6,83	0,32	1,70	3,88	**13**
Chemical/Prod tanker	8,99	0,40	1,90	4,41	**16**
Gas tanker	0,06	0,01	0,11	0,07	**0,25**
Bulk carrier	12,58	1,28	17,44	10,80	**42,10**
General cargo	1,38	0,13	1,60	0,99	**4,11**
Container vessel	18,95	1,93	26,51	16,41	**64**
RoRo	2,33	0,23	3,04	1,88	**7,49**
Reefer	0,51	0,04	0,35	0,22	**1,12**
Passenger	0,14	0,01	0,11	0,07	**0,33**
Offshore supply vessel	0,02	0,00	0,02	0,01	**0,06**
Other offshore vessel	0,01	0,00	0,01	0,00	**0,02**
Other activities	0,35	0,03	0,22	0,14	**0,74**
Fishing vessel	0,75	0,06	0,56	0,35	**1,72**
Total	**53**	**4,4**	**53**	**39**	**150**

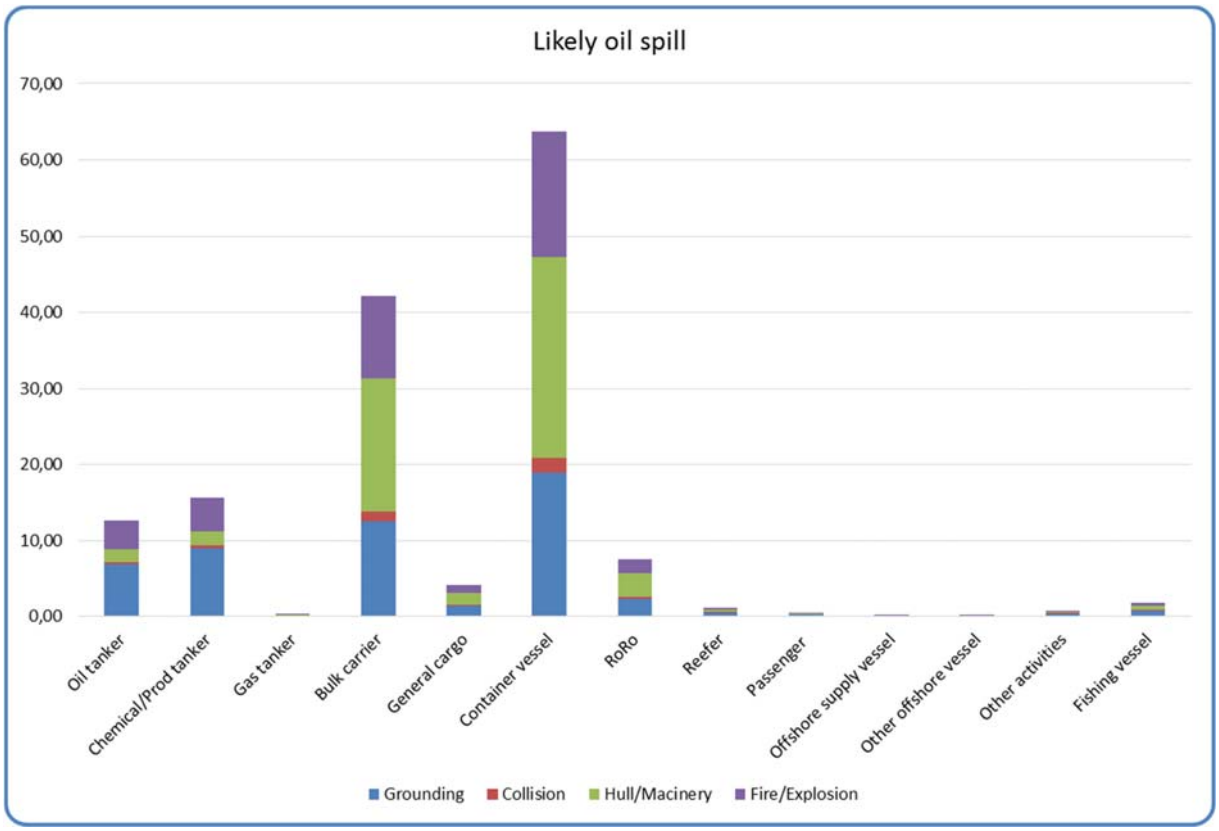

Figure 6-8 - Likely estimated oil spill

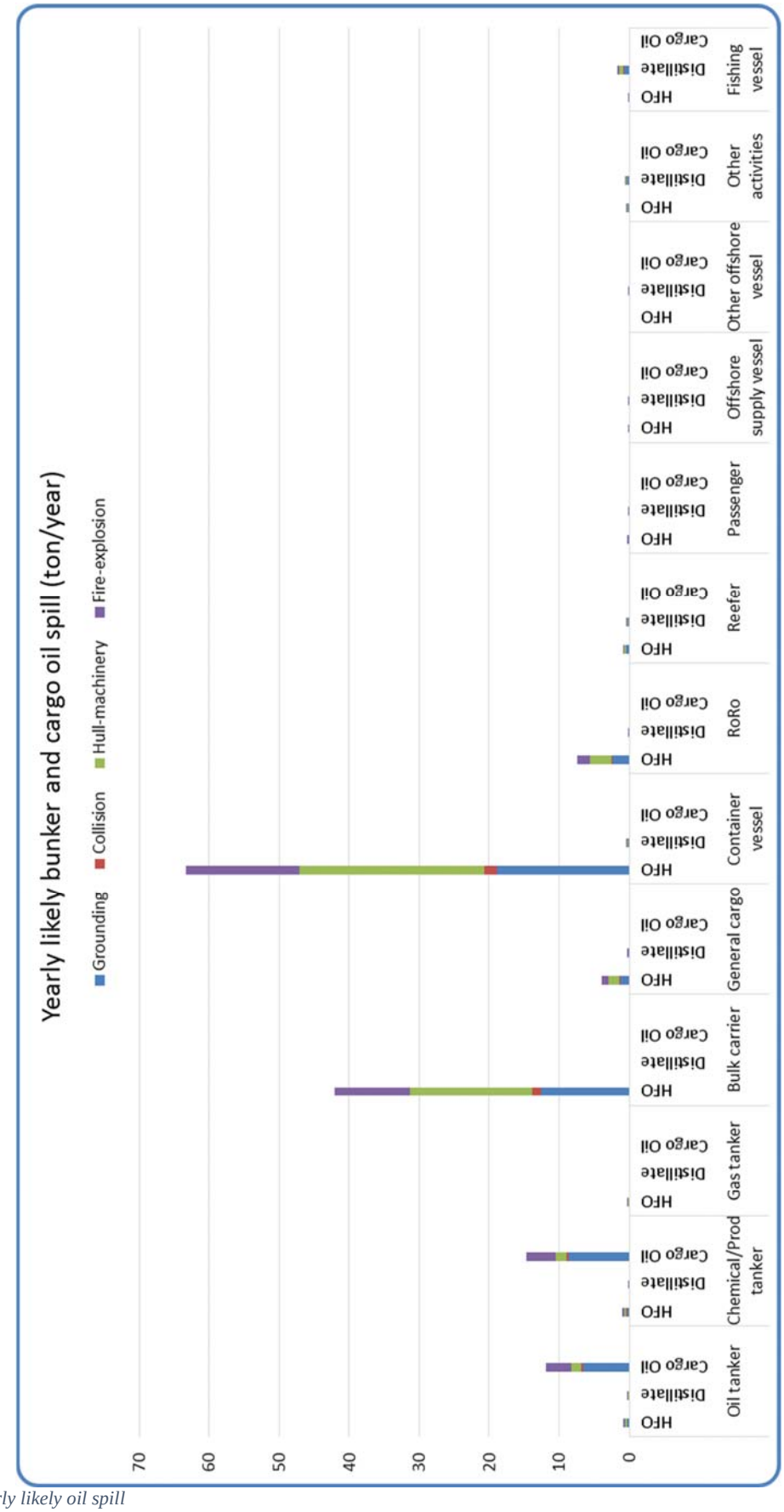

Figure 6-9 . Yearly likely oil spill

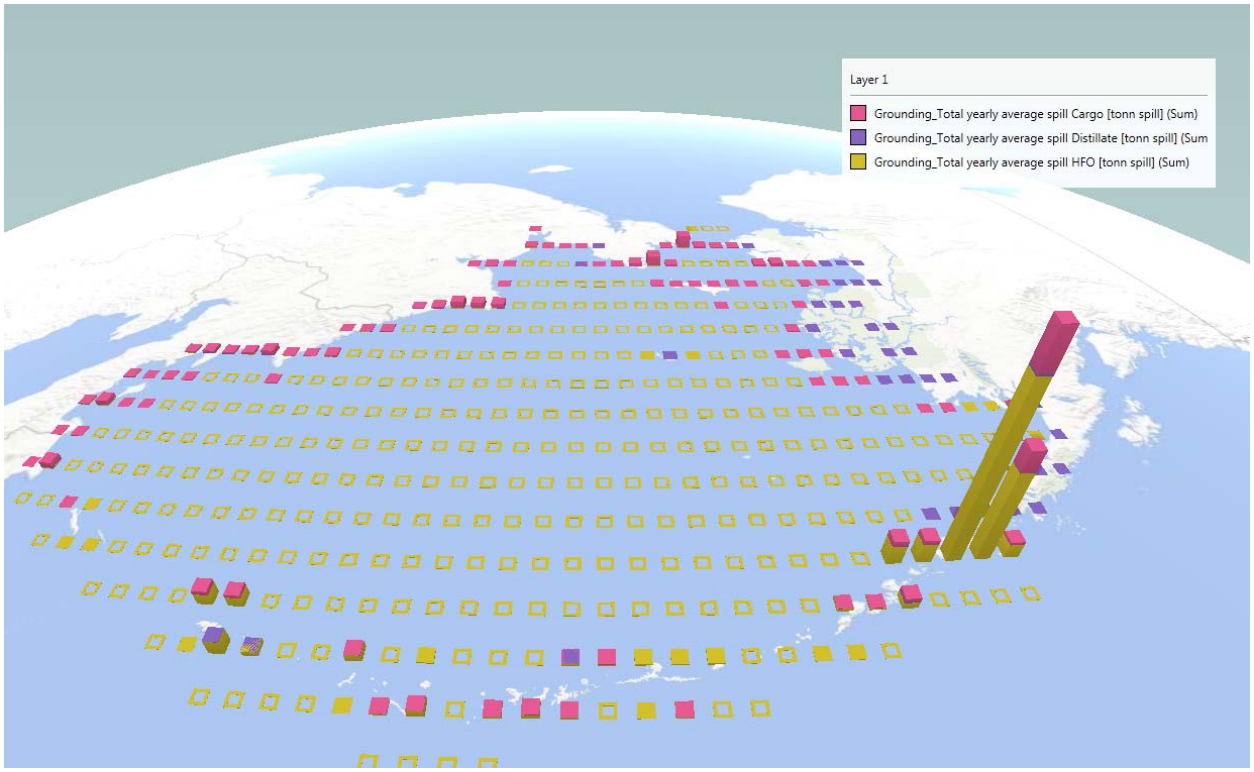

Figure 6-10 - Likely oil spill from grounding

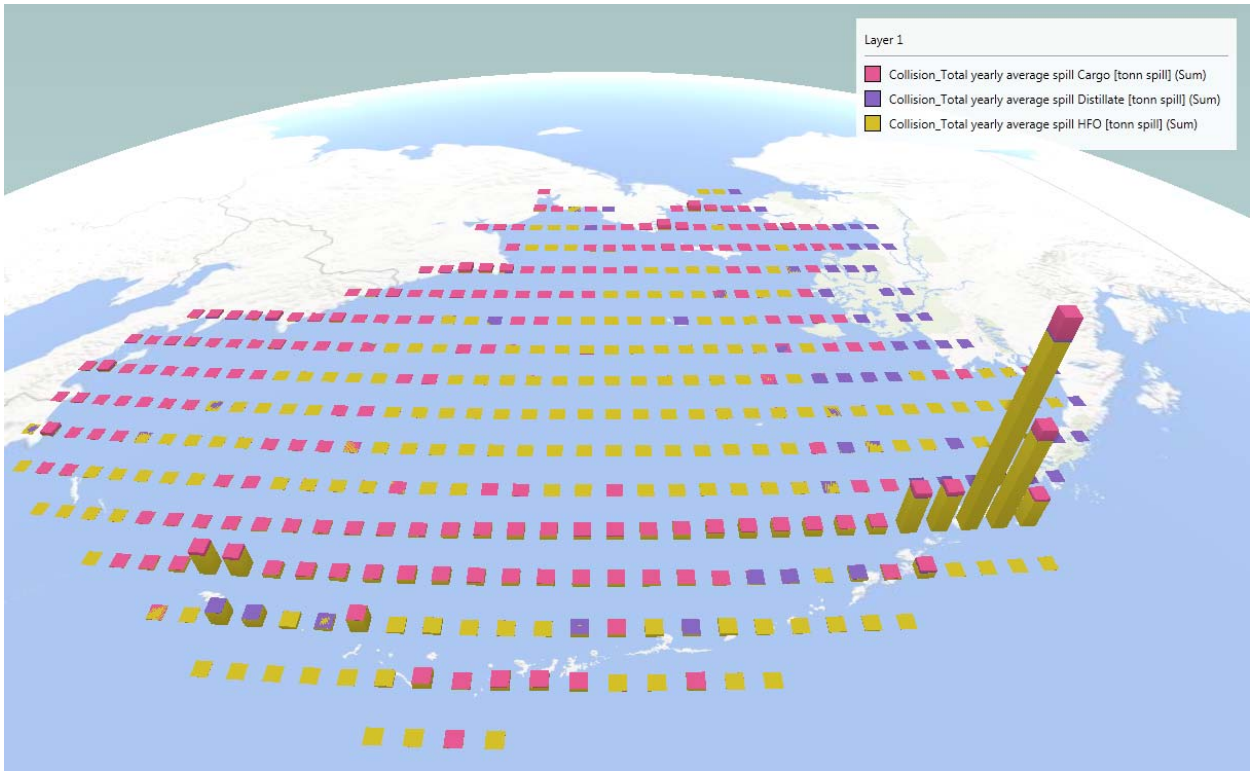

Figure 6-11 Likely oil spill from collisions

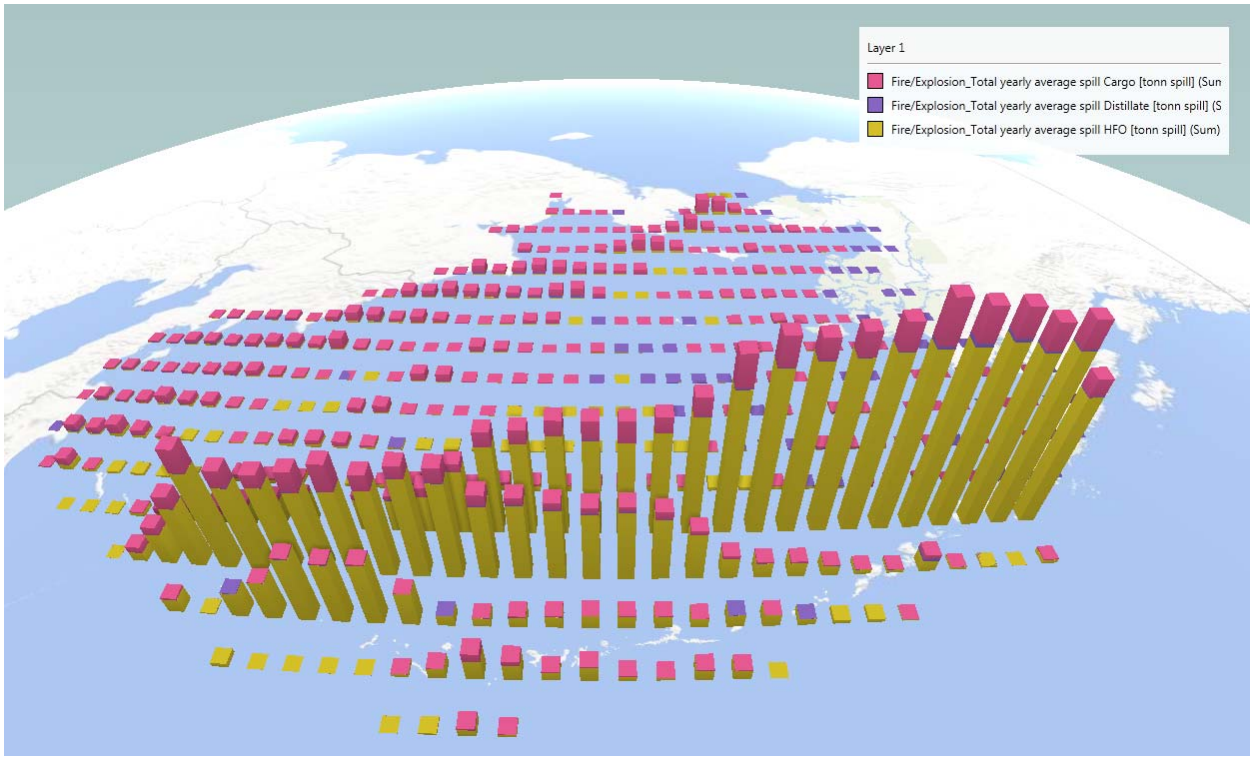

Figure 6-12 - Likely oil spill from Fire/Explosion

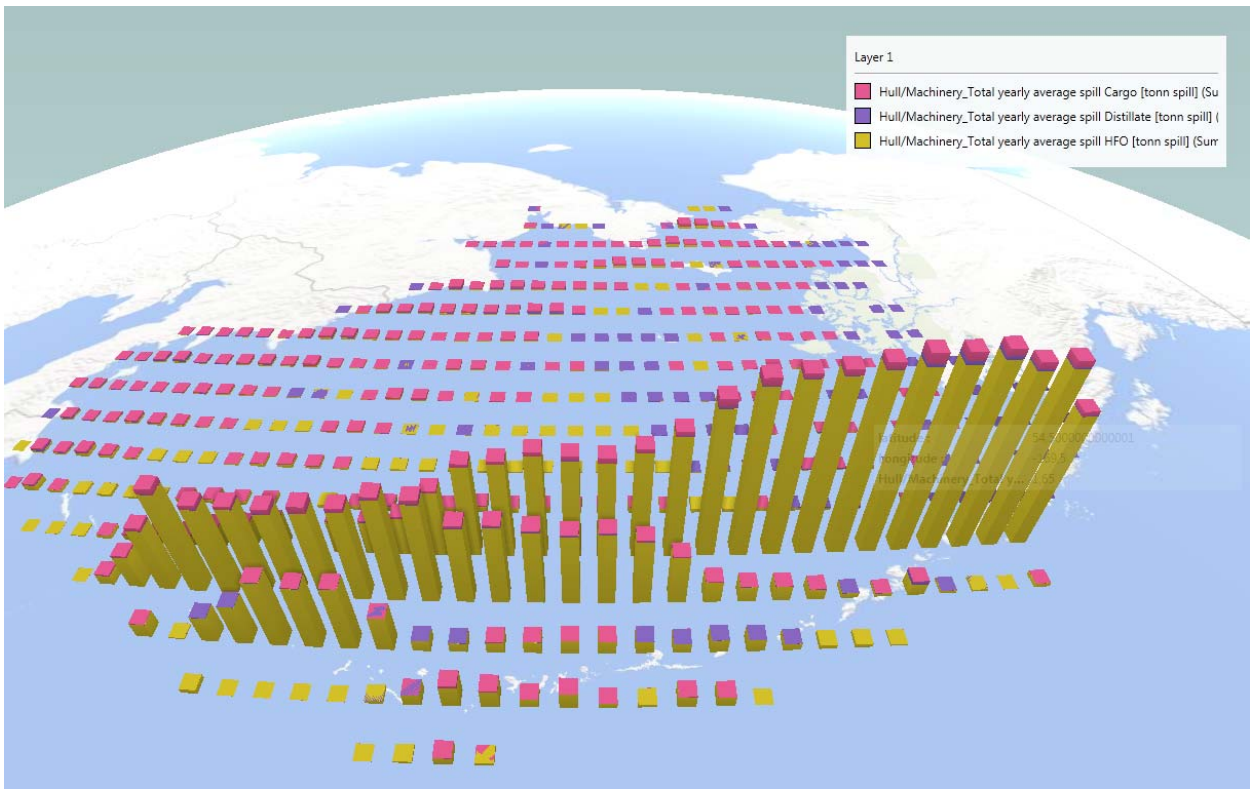

Figure 6-13 - Likely oil spill from hull/machinery damage

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