BETTER SHIPS, BLUE OCEANS

Sea Shipping Emissions 2017: Netherlands Continental Shelf, 12 Mile Zone and Port Areas

Final Report

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Sea Shipping Emissions 2017: Netherlands Continental Shelf, 12 Mile Zone and Port Areas

Final Report

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GLOSSARY OF DEFINITIONS AND ABBREVIATIONS

Definitions:

Ship characteristics database	IHS-database (Lloyds Register of ships) contains vessel characteristics of over 120,000 seagoing merchant vessels larger than 100 GT operating worldwide. The information includes year of built, vessel type, vessel size, service speed, installed power of main and auxiliary engine.
Netherlands sea area	NCS and 12-mile zone

Abbreviations/Substances:

Methane (CH_4)	Gas formed from the combustion of LNG. Substance number **1011**
VOC	*V*olatile Organic Compounds. Substance number **1237**
Sulphur dioxide (SO_2)	Gas formed from the combustion of fuels that contain sulphur. Substance number **4001**
Nitrogen oxides (NO_x)	The gases nitrogen monoxide (NO) and nitrogen dioxide (NO_2). NO is predominantly formed in high temperature combustion processes and can subsequently be converted to NO_2 in the atmosphere. Substance number **4013**
Carbon Monoxide (CO)	A highly toxic colourless gas, formed from the combustion of fuel. Particularly harmful to humans. Substance number **4031**
Carbon Dioxide (CO_2)	Gas formed from the combustion of fuel. Substance number **4032**
PM	Particulates from marine diesel engines irrespective of fuel type. Substance number **6598**
PM-MDO	Particulates from marine diesel engines operated with distillate fuel oil. Substance number **6601**
PM-HFO	Particulates from marine diesel engines operated with residual fuel oil. Substance number **6602**

Abbreviations/Other:

AIS	Automatic Identification System
EMS	Emissieregistratie en Monitoring Scheepvaart (Emission inventory and Monitoring for the shipping sector)
GT	Gross Tonnage
IHS	IHS Maritime World Register of Ships
IMO	International Maritime Organization
LLI	Lloyd's List Intelligence (previously LLG and LMIU)
m	meter
MMSI	Maritime Mobile Service Identity is a unique number to call a ship. The number is added to each AIS message.
NCS	Netherlands Continental Shelf
nm	nautical mile or sea mile is 1852m
SAMSON	Safety Assessment Model for Shipping and Offshore on the North Sea
TSS	Traffic Separation Scheme

1 INTRODUCTION

1.1 Objective

This study aims to determine the emissions to air of seagoing vessels and fishing vessels for 2017. The results of both the seagoing vessels as the fishing vessels are included in the current document. The totals and the spatial distribution for the Netherlands Continental Shelf, the 12-mile zone, the Wadden Sea and the port areas Rotterdam, Amsterdam, the Ems, the Western Scheldt, Den Helder and Harlingen are all based on AIS data. The emissions for 2017 are determined for CH_4, VOC, SO_2, NO_x, CO, CO_2 and Particulate Matter (PM).

The grid size for the port area emissions, the Wadden Sea and the 12-mile zone is 500 x 500 m, for the Netherlands Continental Shelf area a grid size of 5000 x 5000 m has been used.

1.2 Report structure

Chapter 2 describes the emission databases that were compiled for 2017.
Chapter 3 describes the procedure used for the emission calculation based on AIS data.
Chapter 4 describes the completeness of the AIS data, both with respect to missing files and with respect to spots that are not fully covered by base stations.
Chapter 5 contains the level of shipping activity in the Dutch port areas, and the Netherlands sea area.
Chapter 6 summarises the emissions for 2017 for the Dutch port areas and the Netherlands sea area and makes a comparison with 2016. Both for the previous version of the emission method calculation, as for the new and improved emission calculation method.
Chapter 7 contains the emissions results for 2017 for the fishing activities
Chapter 8 presents conclusions and recommendations.

2 2017 EMISSION DATABASES

2.1 General information

A set of Access databases with the calculated emissions to air from sea shipping have been delivered for:

- the Netherlands sea area (NCS and 12-mile zone);
- the six Dutch port areas Rotterdam, Amsterdam, the Ems, the Western Scheldt, Den Helder Harlingen and the Wadden Sea.

For the information on what can be found in the databases, refer to [1].

2.2 Netherlands sea area and Dutch port areas

The emissions in the Netherlands sea area and the six Dutch port areas based on AIS data have been stored in:

- db_emissionsresults_12Miles_Outof12_v2.accdb
- db_emissionresults_portareas_v2.accdb

The emissions have been calculated on a 5000 x 5000 m grid for the NCS and on a 500 x 500 m grid in the 12-mile zone and in the port areas.

The Netherlands sea area and the port areas are presented in Figure 2-1. The different areas are indicated by plotting the centre points of the grid cells with different colours:

- The red points at sea are the cells outside the 12-mile zone;
- The light blue points at sea are the cells within the 12-mile zone;
- The green, pink, light green, dark blue, light orange and orange points are respectively the port areas Ems, Harlingen, Den Helder, Amsterdam, Rotterdam and the Western Scheldt.
- The Wadden Sea area, here defined as the area between Harlingen and the Ems is added for the calculation of the emissions of fishing vessels.

The six port areas are illustrated in more detail in Figure 2-2 to Figure 2-4. At some places, there are grid points on land. There are several reasons for this. In general, the detail of the charts presented here is such that not all existing waterways and/or quays are visible, though they do exist. Also, it has been observed that the determination of the GPS position is disturbed by container cranes, so that the AIS message is not fed with the correct position. When, for whatever reason, AIS signals are disturbed or lost, positions are extrapolated and this is done before MARIN receives the data.

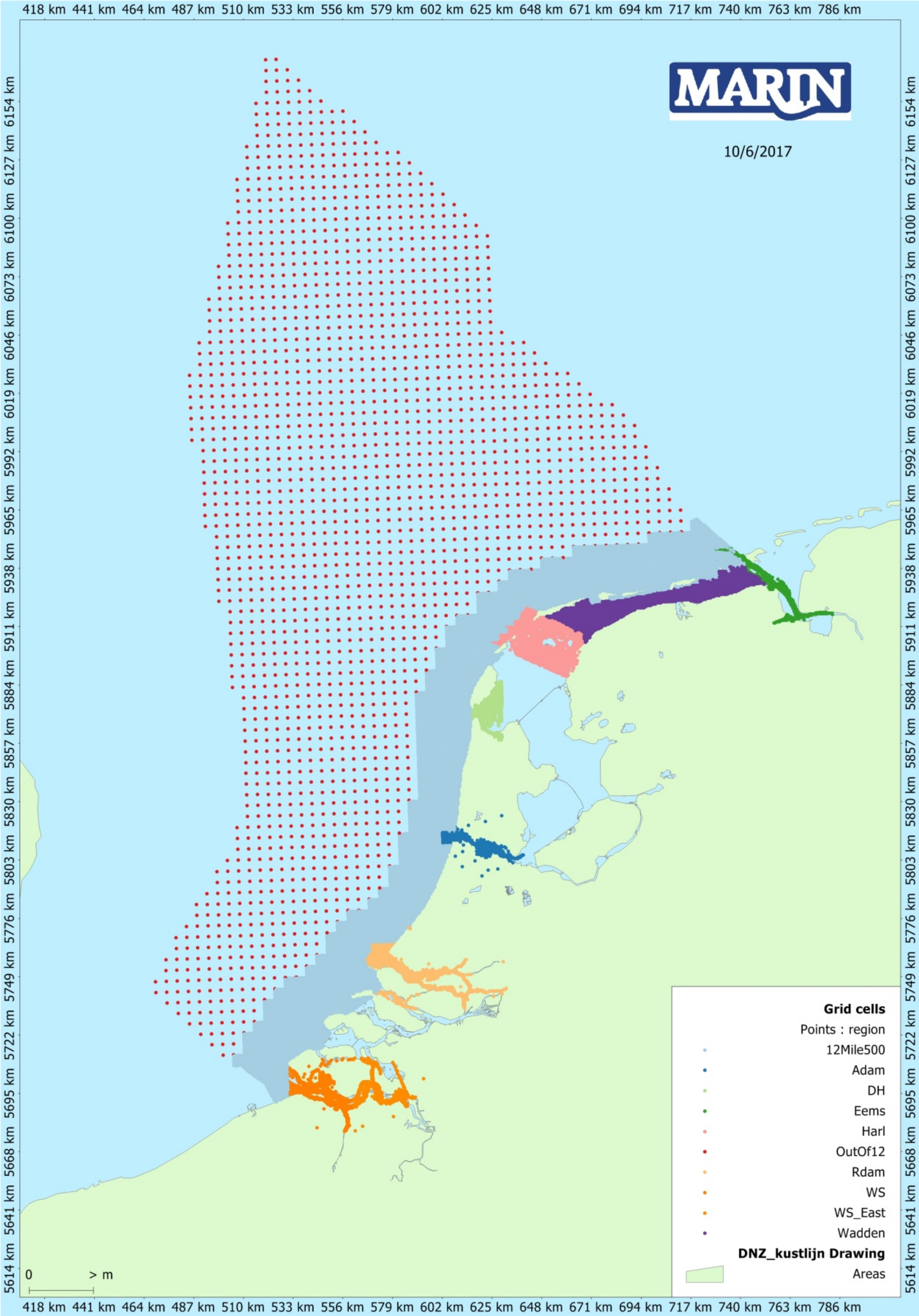

Figure 2-1 **Grid points for The Netherlands Continental Shelf, 12-mile zone, The Wadden Sea and six port areas**

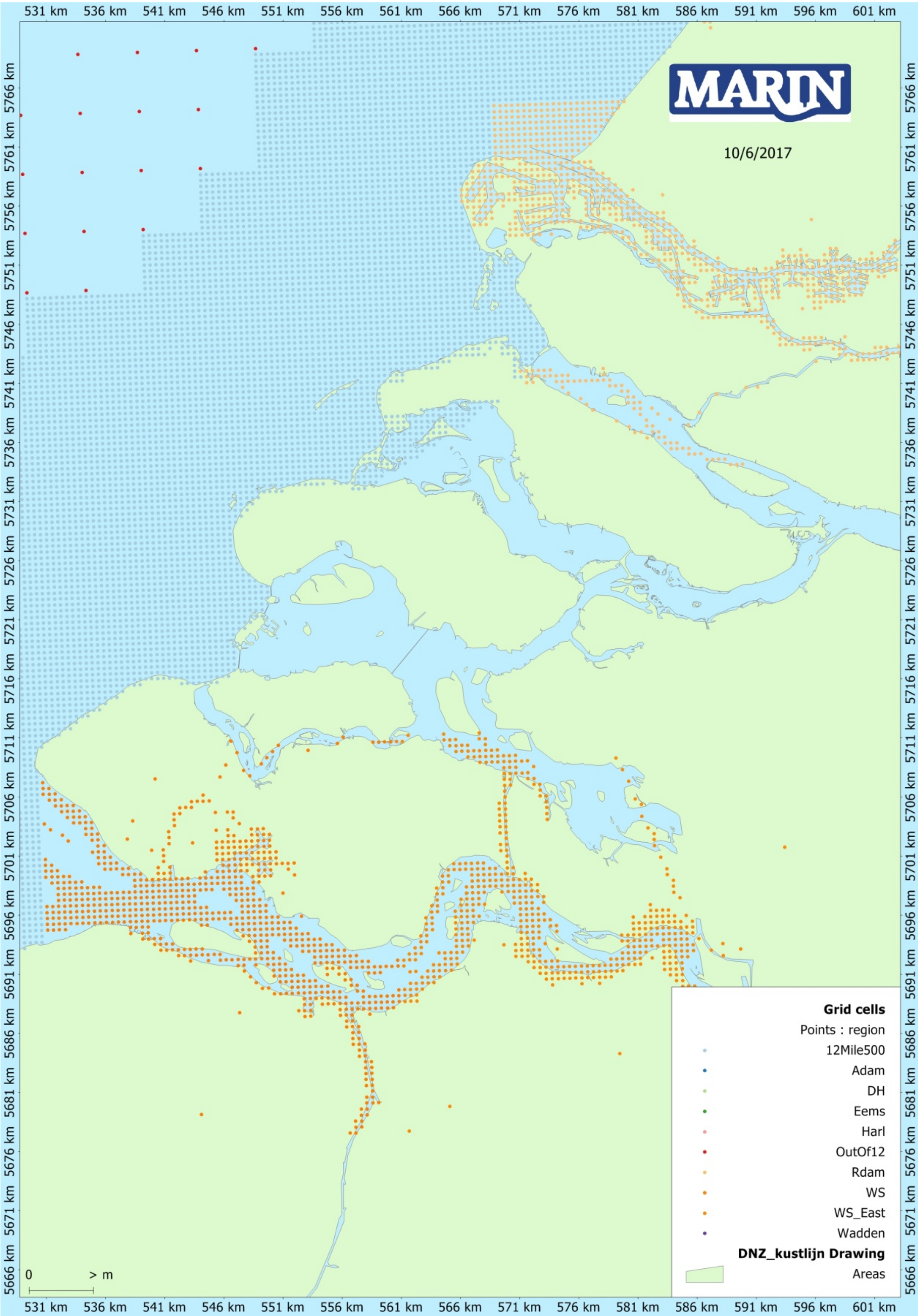

Figure 2-2 **Rotterdam and the Western Scheldt: The points indicate the centres of grid cells for which emissions are calculated**

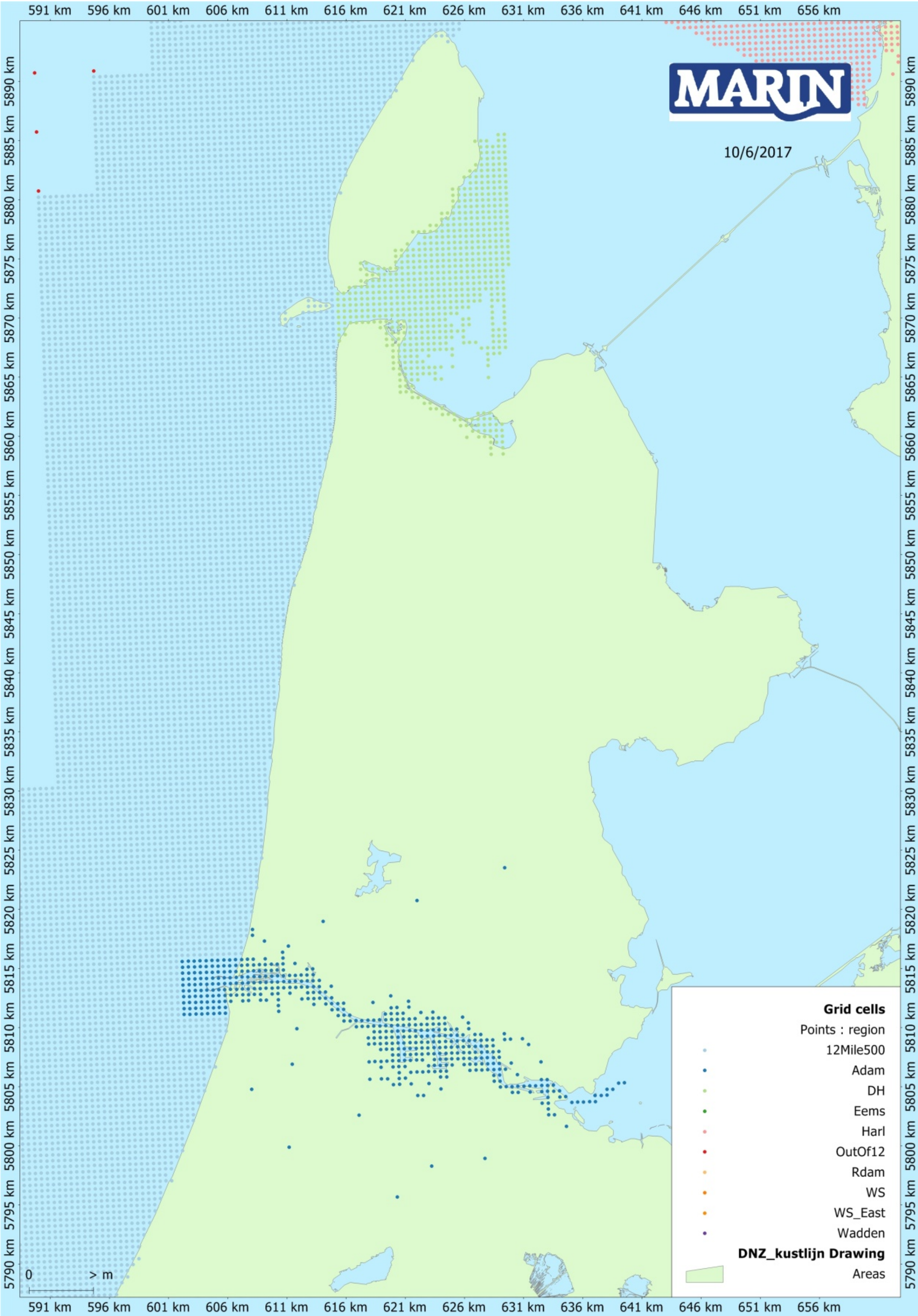

Figure 2-3 **Amsterdam and Den Helder: The points indicate the centres of grid cells for which emissions are included calculated**

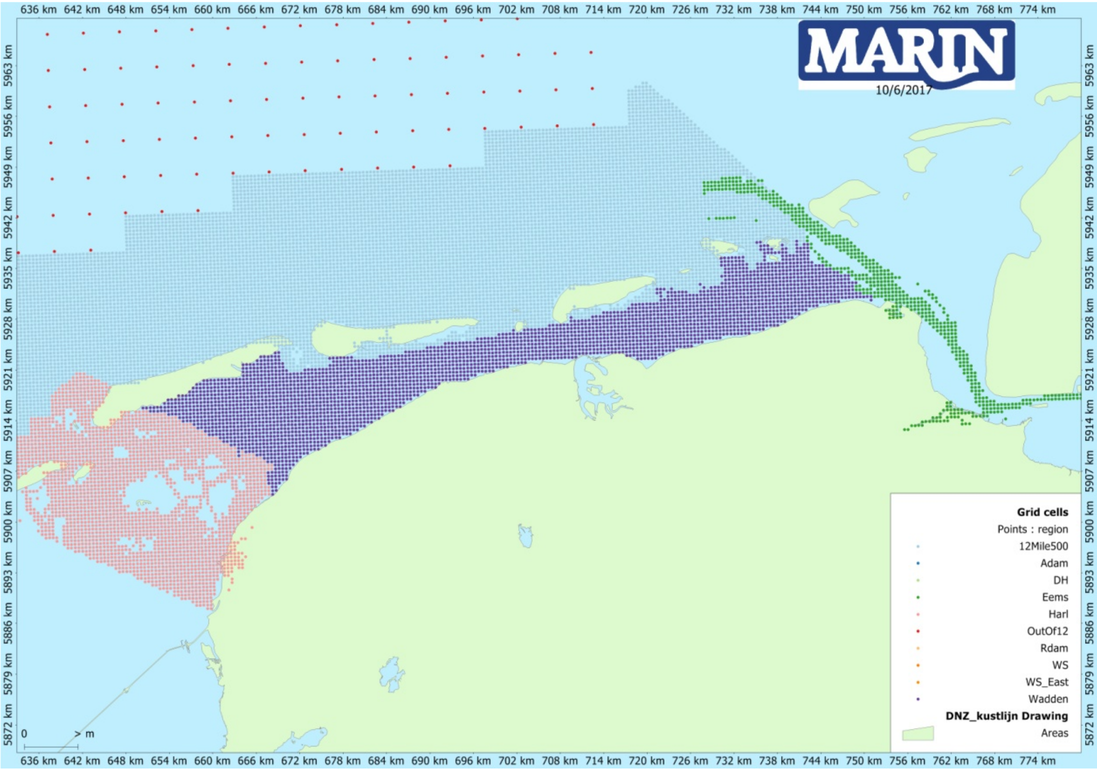

Figure 2-4 **Harlingen, the Wadden Sea and Ems: The points indicate the centres of grid cells for which emissions are calculated**

3 PROCEDURE FOR EMISSION CALCULATION

This chapter describes the procedures for the emission calculation, which is based on AIS data. The AIS data has been used to calculate the emissions for both NCS, the 12-mile zone, the Wadden Sea area and the six Dutch port areas. This year the emissions for the OSPAR region has not been calculated.
The method to calculate the emissions is improved. In section 3.2 it is described how this affected the present emission study.

3.1 AIS data

AIS data for 2017
In this study, AIS data of 2017 received by the Netherlands Coastguard has been used to calculate the emissions. Refer to [1] for background information about the AIS data.

In the previous study, the AIS data for the Western Scheldt was greatly improved halfway 2016. Also for 2017 the Netherlands Coastguard delivered the data for the complete area of interest of the Western Scheldt emission study. Figure 4-4 shows the coverage of the Western Scheldt based on the AIS data of the Netherlands Coastguard.

IHS and The Port of Rotterdam
Just like in the previous study, the emission calculation of 2016, TNO has calculated emission factors for The Port of Rotterdam, using ship characteristics provided by IHS Maritime World Register of Ships to The Port of Rotterdam. Since the IHS database was available to TNO, the emissions factors for all ships seen in the areas of interest of this study were based on this database.

In the AIS data the identifier for the ship is the MMSI number, not the IMO-number. Therefore, a link is necessary between the MMSI-numbers in the AIS messages and the emission factors based on the ship database of IHS, identified by IMO-number. AIS-data comprised 33,612 individual MMSI. Within these MMSI 12,952 commercial seagoing vessels could be identified of which 959 MMSI were attributed to fishing vessels. About 45% of all messages obtained were sent by the 12,952 commercial vessels that were identified. Samples taken of unidentified MMSI learned that far most of these MMSI could be attributed to non-commercial small vessels and fixed objects (like ATON's, wind turbines and oil and gas installations), which are not directly relevant with respect to shipping emissions. We estimate very roughly that at maximum 250 commercial vessels could not be identified, representing at maximum about 2% of shipping emissions.

3.2 Improved method

This year an improved method has been used to calculate the emissions for the areas concerned in this study. The reason for this was a new study “Ship emission model validation with noon reports” by D.R. Schouten & T.W.F. Hasselaar [4].

The main difference is concerned in the formula which correct the required power for very low speeds. Using data of sea trials MARIN has advised a value of 3.2 for n in this formula. Concerning the choice of a proper value of c no clear data were found in the literature.

fMCR = CRScor * (1-Sea margin) = $([(V_{actual}/V_{design})^n + c] / (1+c)) * (1\text{-Sea margin})$

Following values are used in calculations that are reported:
Sea margin = 15%
n = 3.2 (value was 3.0 in previous reports)
c = 0.1 (value was 0.2 in previous reports)

We recalculated the emissions of several years again (2015, 2016) to compare which method was most useful for the trend analysis with 2017. Finally the updated method has been released that we present here, in addition to the method used last year. TNO provides further explanation about the improved method in Appendix A.

4 COMPLETENESS OF AIS DATA

This chapter describes the completeness of the AIS data. In 4.1 the missing minute files are described, 4.2 describes the analysis of the coverage of the AIS data for the NCS and the Dutch port areas.

4.1 Missing AIS minute files

Each AIS data file contains the AIS messages of all ships received in exactly one minute. The AIS data collection of 2017 is missing several minute files for all areas of interest. In case the gap is less than 10 minutes, this has no effect on the results, because each ship is kept in the system until no AIS message has been received during 10 minutes. The sum of periods missing which are larger than 10 minutes is 1 day. To compensate for the missing period, the results are multiplied with 365/364.

4.2 Bad AIS coverage in certain areas

4.2.1 Base stations

In section 4.1, the number of files received from the Netherlands Coastguard was used to describe the completeness of the data. This doesn't necessarily mean that the available minute files cover the total area all the time. This is illustrated in Figure 4-1, in which all base stations that deliver data to the Netherlands Coastguard are plotted. The circle with a radius of 20 nautical miles around each base station illustrates the area covered by that base station.

4.2.2 Known weak spots

In reality, the covered area varies with the atmospheric conditions. Figure 4-1 shows that some areas are covered by several base stations, while other areas are covered by only one base station and some areas are only covered with favourable atmospheric conditions, when the base stations reach further than 20 nautical miles. This means that there are a few weak spots in the Netherlands sea area and in the Dutch port areas:

- the area in the northern part of the NCS, which is not covered at all. This is not a large shortcoming because the shipping density is very low in this area;
- the Western Scheldt close to the border with Belgium,
- the spot close to the border with the United Kingdom Continental Shelf, southwest of Rotterdam.

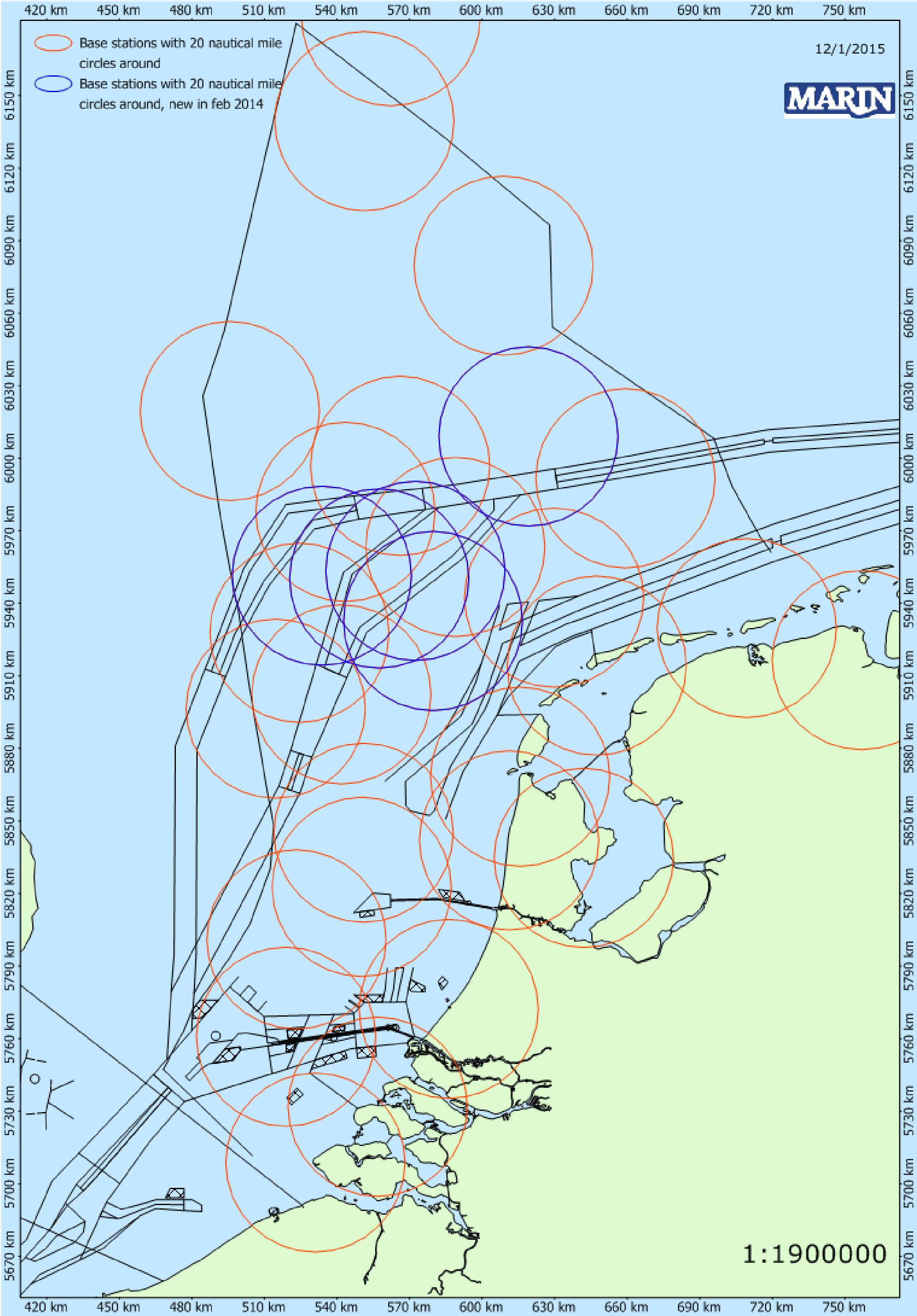

Figure 4-1 **AIS base stations in 2017 delivering data to the Netherlands Coastguard.**

4.2.3 Coverage in the Netherlands sea area

For the Netherlands sea area, the weak spots in the collection of the AIS data are identified by the locations where ships lose contact. After 10 minutes without receiving a new AIS message of a ship, the ship is removed from the system. Figure 4-2 and Figure 4-3 show in each cell of 5x5km the number of ships that lose AIS contact with Dutch AIS base stations relative to the total number of observations of ships in this grid cell. Sometimes the data reception of AIS messages is recovered after some time, which is the case in the center area of the Netherlands sea area. However, on most locations near the border of the Netherlands sea area it means that the ship has left the system until its next journey through the Netherlands sea area. Thus, the figure shows more or less the locations where ships are removed from the system. The ideal situation would be if the ships that leave the system are located outside the Netherlands sea area, which is the case on a large part of the west side of the NCS.

These figures show the coverage for June and September 2017. These months were chosen so that the data can be compared with last year. The overall coverage of AIS data of 2017 seems in most places slightly better compared to the AIS coverage of 2016. However, fluctuations in coverage are expected due to the dependency on atmospheric conditions.

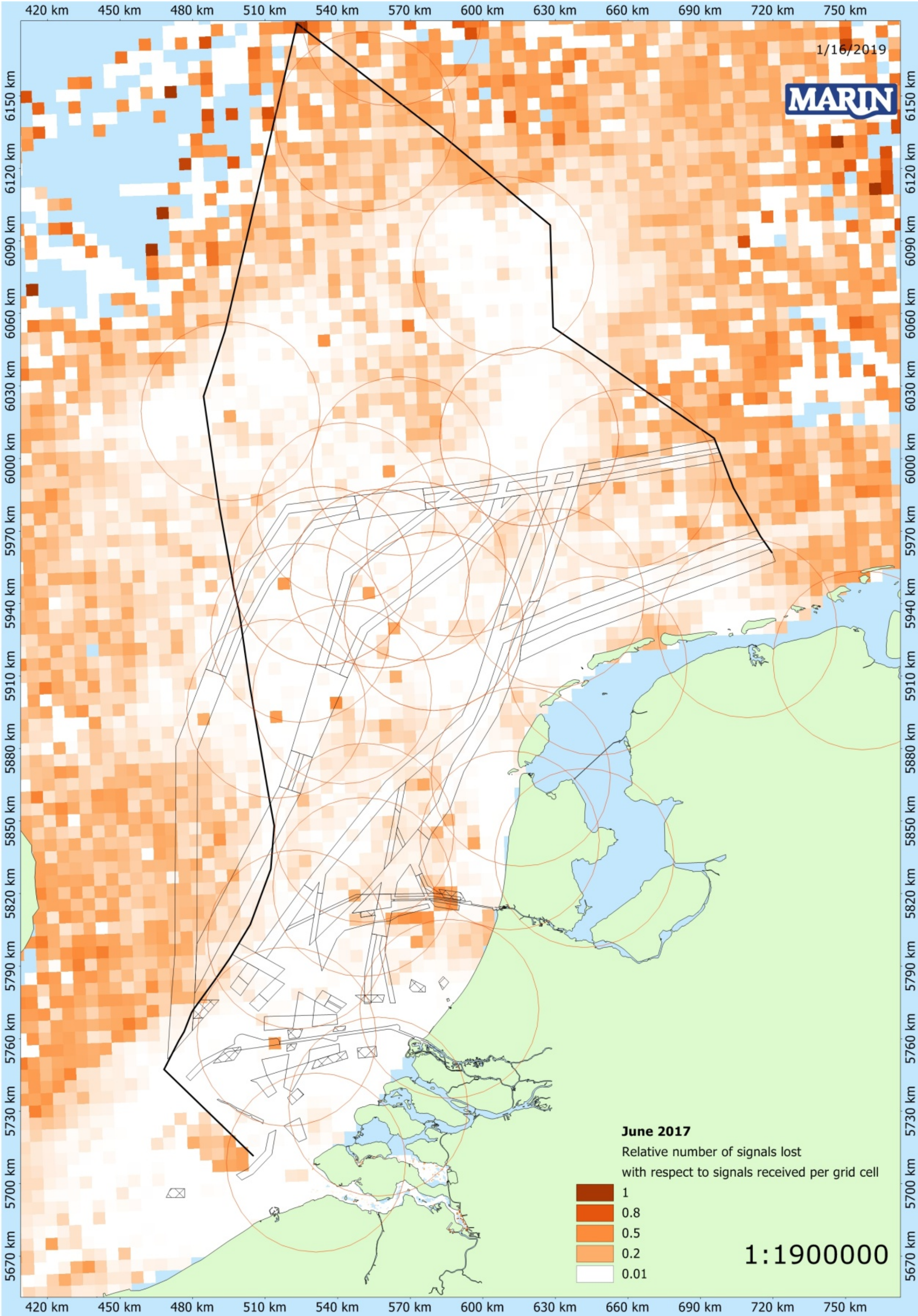

Figure 4-2 **June 2017, relative number of signals lost with respect to signals received per grid cell, circles mark the 20 nautical miles zones around the Dutch base stations**

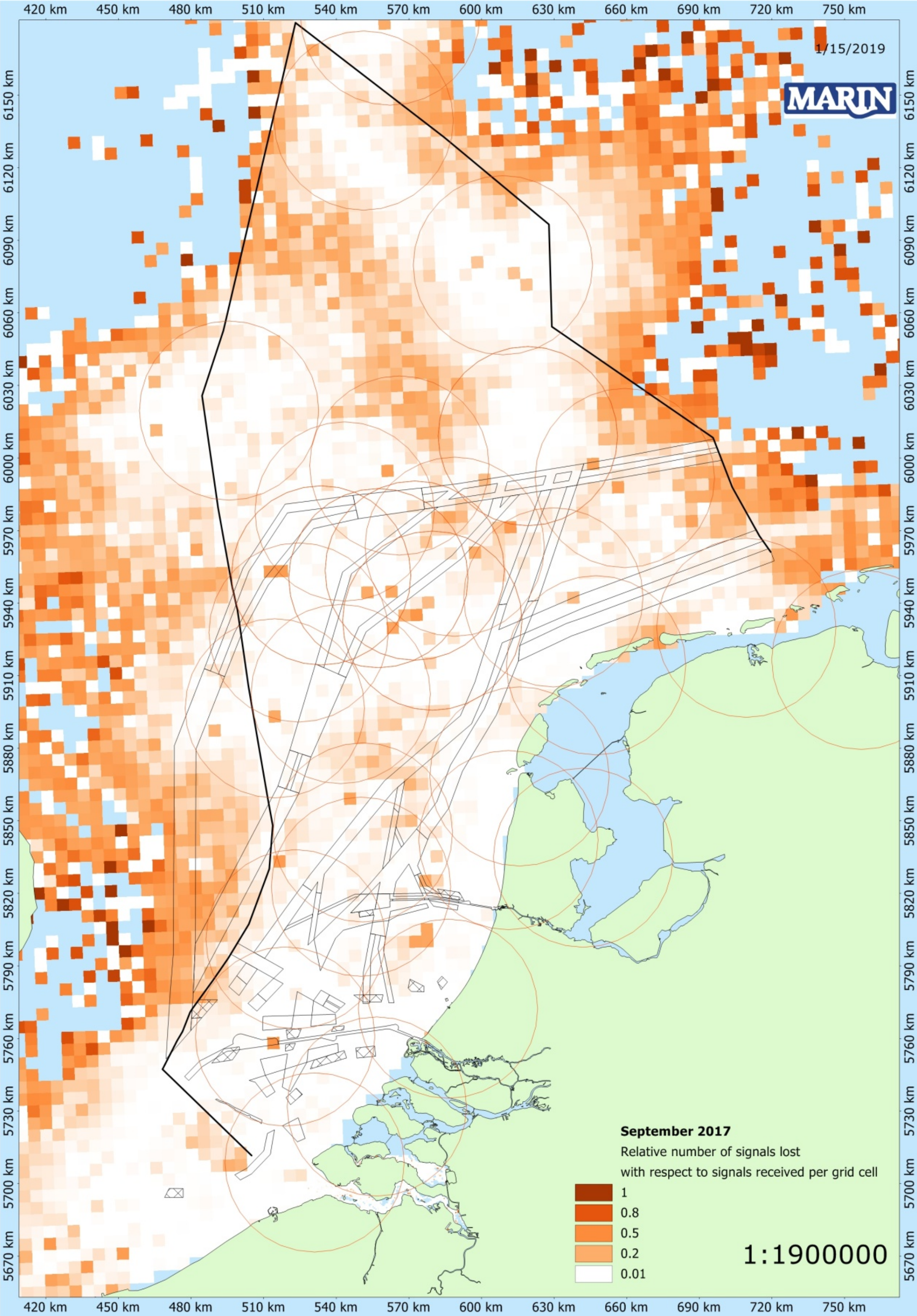

Figure 4-3 **September 2017, relative number of signals lost with respect to signals received per grid cell, circles mark the 20 nautical miles zones around the Dutch base stations**

4.2.4 Coverage in the Western Scheldt port area

Figure 4-4 shows the coverage of the Western Scheldt based on the AIS data of the Netherlands Coastguard. The coverage of the AIS data of the Netherlands Coastguard for the Western Part of the Western Scheldt is improved compared to the second half of 2016. No correction factor was applied to the data, since this area was of similar quality compared to the other areas.

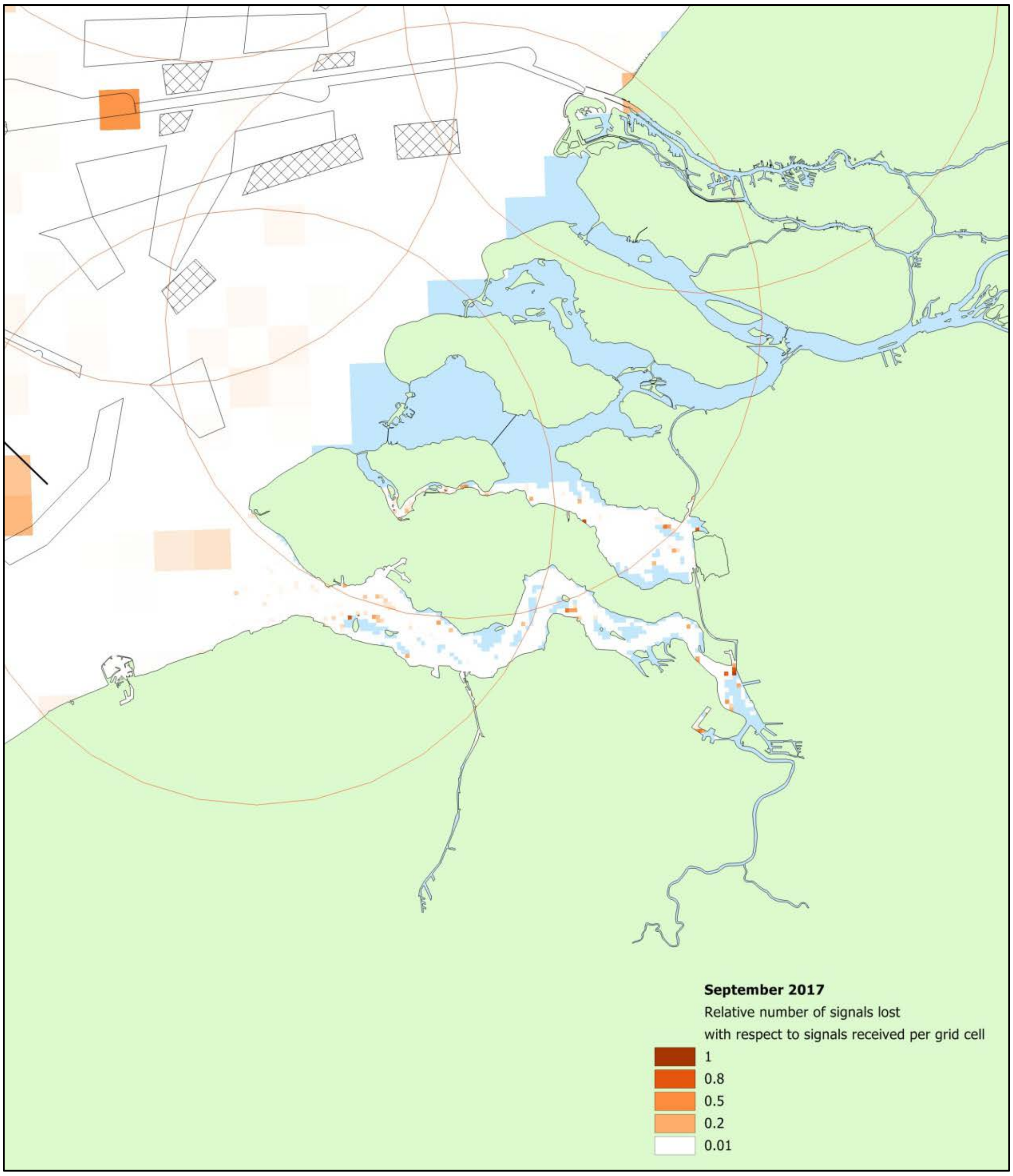

Figure 4-4 **September 2017, relative number of signals lost with respect to signals received per grid cell for the Western Scheldt area.**

5 ACTIVITIES OF SEAGOING VESSELS FOR 2017 AND COMPARISON WITH 2016 FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA

5.1 Introduction

This chapter presents the activities of seagoing vessels for 2017 in the Dutch port areas and in the Netherlands sea area. The activities of 2017 are compared to those of 2016. Section 5.2 describes the activities in the port areas, Section 5.3 the activity in the Netherlands sea area and Section 5.4 the number of ships in these areas.

5.2 Activities of seagoing vessels in the Dutch port areas

Shipping activities in the six Dutch port areas are determined to calculate the emissions in these areas. The activities extracted from AIS are important explanatory parameters for the total emissions. The other parameter is the emission factor, which has been discussed in [1].

Table 5-1 presents activity numbers that could be extracted from the websites of the ports. For the port of Harlingen, Den Helder and Ems no figures are available, therefore, only the activities for the ports Western Scheldt, Rotterdam and Amsterdam are given here. These numbers can be used to check the information on activity as derived from the AIS data. First, the values of 2017 are shown and then the percentages with respect to 2016. The table contains the number of calls and the cargo handling for the main ports in each port area. Table 5-1 shows that there are no significant changes in calls or cargo handling compared to 2016. The numbers for the port of Amsterdam decreases in 2016, and in 2017 it shows an increase of 3% in cargo handling. The number of cargo handling for the port of Antwerp increased again, this year with 4%.

Table 5-1 Number of calls extracted from websites of the ports

Port area	Ports	Number of calls		Cargo handling x 1000 tons	
		2017	2017/2016	2017	2017/2016
Western Scheldt	Antwerp	14,223	100%	223,655	104%
	Zeeland seaports (Vlissingen en Terneuzen)	Not available	-	Not available	-
Rotterdam	Rijn- en Maasmondgebied	29,646	102%	467,400	101%
Amsterdam	Noordzeekanaalgebied	7,011	100%	100,800	103%

The shipping activities of 2017 are presented for each port area in a table per ship type and a table per ship size class and compared with the activities observed in 2016.

Western Scheldt

Table 5-2 and Table 5-3 show the activities of seagoing vessels on the Western Scheldt based on AIS data of the Netherlands Coastguard. This year the hours of moving ships increased with 10.1% compared to 2016 and GT.hours increased with 4.4%.

For berthed ships the hours increased by 18.4% in 2017 and GT.hours increased with 7.7%.

Rotterdam

The activity tables, Table 5-4 and Table 5-5, for Rotterdam show that for the moving activities, the hours increased with 14.7% and the GT.nm (gross tonnage times nautical miles) increased with 7.3% in 2017 compared to 2016. This is due to the calls of small and medium vessels (size 100-1,600 and 10,000-30,000), since the hours of these moving ships increased by over 20%.

Berthed activities, hours and GT.hours, increased with 3.8% and 2.6% respectively.

Amsterdam

The activity tables, Table 5-6 and Table 5-7, for Amsterdam show a slight increase in moving vessels. The increase in hours moving is 1.4% and the increase in GT.nm is 0.6%.

The hours at berth decreased. The berthed activities for Amsterdam, hours and GT.hours, decreased respectively with 27.4% and 34.7%.

Ems

The activity tables, Table 5-8 and Table 5-9, for the Ems area shows that the moving activities, hours and GT.nm, increased by respectively 13.0% and 12.8%.

The number of berthed hours and GT.hours increased respectively by 3.4% and 26.8%.

Den Helder

Table 5-10 and Table 5-11, for Den Helder show that the moving activities decreased. The moving hours and GT.nm decreased respectively by 12.6% and 19.1%. This is mainly due to an decrease of the number of visits of ship type “Miscellaneous”. Apart from that some percentages can vary greatly due to the low absolute numbers.

Compared to 2016, the berthed hours decreased with 16.0% and the berthed GT.hours increased with 9.7%.

Harlingen

The activity tables, Table 5-12 and Table 5-13 show a clear increase in activities in the port of Harlingen. The moving activities hours and GT.nm increased respectively by 96.8% and 180.3%. This is mainly due to an increase of the number of RoRo Cargo and Vehicle carriers.

The berthed hour and GT.hours increased respectively by 27.2% and 32.7%

Table 5-2 Shipping activities per EMS type for the Dutch part of the Western Scheldt

Ship type	Totals for Western Scheldt in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	5,966	198,274,122	6,197	1,661,545,757	9.9	100.10%	89.30%	125.80%	105.20%	98.70%
Chem.+Gas tanker	63,889	711,437,263	42,215	4,587,164,065	10.4	106.50%	91.80%	106.10%	106.30%	97.10%
Bulk carrier	24,996	766,231,356	7,944	1,977,952,944	8.7	149.40%	122.30%	116.00%	106.30%	92.40%
Container ship	4,163	101,156,763	26,156	19,412,964,472	13.0	157.00%	224.00%	105.40%	104.60%	97.00%
General Dry Cargo	88,302	683,598,571	36,568	1,859,450,086	9.5	138.10%	126.10%	113.80%	103.60%	96.30%
RoRo Cargo / Vehicle	10,641	234,912,057	10,315	5,779,329,258	12.2	120.40%	112.20%	102.20%	104.00%	99.80%
Reefer	9,921	121,254,085	1,026	131,595,268	10.5	88.40%	100.20%	92.90%	92.10%	102.90%
Passenger	17,203	30,927,872	5,976	139,816,716	10.1	110.40%	146.30%	102.70%	120.80%	98.10%
Miscellaneous	96,470	190,405,322	25,226	428,697,017	7.5	122.40%	99.10%	107.10%	87.50%	91.50%
Tug/Supply	154,663	261,643,421	24,280	75,760,349	7.1	111.80%	84.90%	122.50%	72.70%	105.30%
Total	476,214	3,299,840,832	185,903	36,054,275,932	9.8	118.40%	107.70%	110.10%	104.40%	96.40%

Table 5-3 Shipping activities per EMS ships size classes for the Dutch part of the Western Scheldt

Ship size in GT	Totals for Western Scheldt in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	218,489	113,847,895	42,191	196,541,573	8.0	122.80%	123.40%	118.90%	107.70%	96.80%
1,600-3,000	76,605	182,851,139	33,457	694,326,956	9.0	106.80%	108.40%	113.80%	106.60%	99.70%
3,000-5,000	42,450	170,182,109	24,823	938,063,035	9.3	129.70%	131.10%	99.50%	95.60%	91.20%
5,000-10,000	37,323	246,288,598	22,098	1,619,314,608	10.4	122.90%	113.20%	119.20%	115.20%	97.90%
10,000-30,000	75,899	1,421,598,079	32,163	7,195,815,512	10.9	122.90%	122.40%	102.70%	100.50%	101.50%
30,000-60,000	21,856	884,582,918	18,882	9,527,270,674	10.6	92.30%	90.00%	98.70%	94.00%	97.90%
60,000-100,000	3,447	258,081,237	8,498	8,207,401,801	12.0	90.20%	87.00%	241.50%	252.30%	105.20%
>100,000	146	22,408,857	4,292	7,756,386,165	11.5	178.00%	170.40%	226.50%	218.10%	101.40%
Total	476,215	3,299,840,832	186,404	36,135,120,324	9.7	118.40%	107.70%	113.50%	132.20%	98.20%

Table 5-4 Shipping activities per EMS type for the Rotterdam port area

Ship type	Totals for Rotterdam in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	31,336	2,293,680,304	4,561	1,741,419,982	7.4	84.40%	84.00%	93.70%	93.50%	96.10%
Chem.+Gas tanker	47,848	727,906,404	22,903	1,993,254,764	7.7	90.00%	93.90%	109.20%	107.60%	96.30%
Bulk carrier	27,891	1,505,492,507	3,467	831,783,085	7.9	84.30%	78.30%	103.30%	90.80%	97.50%
Container ship	124,978	6,771,320,709	32,618	6,417,917,521	8.1	116.30%	115.50%	118.10%	112.60%	96.40%
General Dry Cargo	38,595	215,738,179	22,232	789,745,372	8.6	108.10%	109.00%	107.50%	108.20%	93.50%
RoRo Cargo / Vehicle	19,147	590,768,383	10,972	2,973,153,178	9.7	110.40%	106.30%	117.30%	108.90%	96.00%
Reefer	362	4,394,753	537	55,969,099	9.7	75.60%	82.50%	110.00%	105.50%	116.90%
Passenger	406	18,426,732	613	316,284,097	8.5	144.50%	247.80%	156.00%	123.10%	86.70%
Miscellaneous	44,583	180,021,563	22,994	471,552,129	6.5	97.10%	138.60%	100.30%	110.30%	90.30%
Tug/Supply	228,706	985,685,689	57,771	215,040,180	6.7	107.50%	129.20%	127.90%	104.80%	97.10%
Total	563,852	13,293,435,223	178,668	15,806,119,407	7.5	103.80%	102.60%	114.70%	107.30%	95.20%

Table 5-5 Shipping activities per EMS ships size class for the Rotterdam port area

Ship size in GT	Totals for Rotterdam in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average Speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	245,713	95,132,577	72,222	178,741,683	7.7	110.50%	102.40%	121.00%	106.80%	98.70%
1,600-3,000	28,028	65,096,921	16,593	361,391,158	8.9	101.80%	101.10%	103.60%	100.50%	103.50%
3,000-5,000	21,607	85,626,829	21,854	761,684,944	9.4	93.50%	94.10%	102.90%	99.60%	94.90%
5,000-10,000	63,460	498,417,776	22,391	1,507,167,787	8.4	108.80%	110.70%	110.90%	105.30%	91.30%
10,000-30,000	92,365	1,637,692,159	29,419	4,493,107,210	8.1	104.30%	99.40%	124.20%	113.50%	91.00%
30,000-60,000	36,872	1,654,213,500	6,540	2,142,210,194	7.7	89.10%	98.80%	101.50%	99.10%	96.30%
60,000-100,000	38,110	3,042,020,357	5,746	2,993,753,401	7.0	98.90%	101.70%	111.20%	106.40%	98.60%
>100,000	37,699	6,215,235,105	3,904	3,368,063,031	5.5	86.70%	104.60%	113.90%	109.50%	98.20%
Total	563,854	13,293,435,224	178,669	15,806,119,408	8.1	103.80%	102.60%	114.70%	107.30%	95.80%

Table 5-6 Shipping activities per EMS type for the Amsterdam port area

Ship type	Totals for Amsterdam in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	11,765	501,363,594	1,426	286,237,501	6.1	56.10%	58.80%	101.10%	101.20%	96.80%
Chem.+Gas tanker	42,160	808,333,196	6,905	644,461,733	6.4	58.00%	55.60%	105.10%	101.20%	104.90%
Bulk carrier	40,582	1,832,218,381	2,768	599,143,727	5.8	74.00%	70.90%	107.70%	100.60%	96.70%
Container ship	1,323	10,069,660	309	14,170,426	5.7	342.70%	312.40%	643.80%	919.50%	83.80%
General Dry Cargo	59,010	232,059,368	7,841	165,827,819	6.3	66.20%	72.40%	93.60%	92.30%	95.50%
RoRo Cargo / Vehicle	4,113	156,874,964	1,102	272,281,052	6.3	56.70%	56.70%	98.00%	88.90%	94.00%
Reefer	11,562	60,321,403	508	13,162,340	5.5	62.90%	68.20%	95.30%	100.00%	96.50%
Passenger	8,508	88,564,146	1,335	324,523,210	6.2	122.30%	58.40%	165.80%	123.40%	93.90%
Miscellaneous	17,152	69,622,768	1,852	35,418,841	5.6	61.20%	108.40%	66.80%	62.30%	103.70%
Tug/Supply	119,423	262,123,325	18,564	44,480,144	5.3	87.70%	72.10%	104.20%	88.80%	103.90%
Total	315,598	4,021,550,805	42,610	2,399,706,793	5.8	72.60%	65.30%	101.40%	100.60%	100.70%

Table 5-7 Shipping activities per EMS ships size classes for the Amsterdam port area

Ship size in GT	Totals for Amsterdam in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	108,986	44,119,988	20,655	42,632,344	6.0	78.40%	72.40%	103.80%	98.50%	96.80%
1,600-3,000	55,710	127,746,775	5,819	96,303,949	6.4	71.70%	71.50%	101.60%	98.20%	92.80%
3,000-5,000	20,895	82,009,438	3,089	76,713,886	6.3	60.30%	60.20%	79.20%	76.40%	95.50%
5,000-10,000	32,417	227,131,091	2,786	127,180,753	6.1	99.90%	97.20%	108.30%	103.80%	100.00%
10,000-30,000	46,332	986,206,836	5,437	655,513,030	5.7	61.90%	60.50%	103.30%	100.40%	98.30%
30,000-60,000	39,663	1,613,695,069	3,468	807,873,536	5.6	70.50%	71.50%	100.70%	96.30%	93.30%
60,000-100,000	11,274	903,050,905	1,206	487,930,430	5.4	57.00%	55.40%	108.10%	106.30%	91.50%
>100,000	321	37,590,703	149	105,558,863	5.2	130.50%	120.10%	162.00%	149.80%	94.50%
Total	315,598	4,021,550,805	42,609	2,399,706,791	6.0	72.60%	65.30%	101.40%	100.60%	95.90%

Table 5-8 Shipping activities per EMS type for the Dutch part of the Ems area

Ship type	Totals for Ems in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	182	1,173,557	313	4,767,886	9.3	520.00%	2143.80%	225.20%	240.70%	113.40%
Chem.+Gas tanker	2,423	14,182,483	1,685	103,708,552	10.1	137.20%	212.50%	91.70%	102.10%	97.10%
Bulk carrier	1,597	23,768,296	1,053	187,551,040	8.9	118.20%	127.30%	125.10%	114.00%	94.70%
Container ship	218	1,547,215	16	1,425,030	6.8	573.70%	562.80%	34.80%	21.80%	86.10%
General Dry Cargo	28,325	119,993,713	7,001	285,815,099	9.7	92.10%	104.40%	98.20%	97.80%	93.30%
RoRo Cargo / Vehicle	5,901	187,320,025	8,748	1,653,006,643	11.6	111.20%	119.00%	113.40%	121.50%	95.90%
Reefer	208	931,786	57	1,757,120	8.7	80.90%	154.20%	77.00%	84.20%	94.60%
Passenger	1,188	58,413,349	1,384	65,477,081	14.7	212.10%	258.80%	78.60%	178.30%	119.50%
Miscellaneous	10,464	17,450,542	15,522	262,100,611	7.7	66.70%	105.40%	144.30%	118.30%	98.70%
Tug/Supply	76,429	138,682,359	13,136	177,990,108	8.2	114.00%	129.80%	101.10%	72.80%	84.50%
Total	126,935	563,463,325	48,915	2,743,599,170	9.1	103.40%	126.80%	113.00%	112.80%	92.30%

Table 5-9 Shipping activities per EMS ships size classes for the Dutch part of the Ems area

Ship size in GT	Totals for Ems in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	67,504	21,466,045	17,796	59,008,286	9.7	95.60%	93.20%	107.40%	84.20%	91.50%
1,600-3,000	22,368	51,466,130	10,129	233,155,622	9.0	86.50%	84.80%	84.10%	80.90%	93.80%
3,000-5,000	13,716	55,512,783	11,663	333,613,217	9.5	132.30%	128.40%	228.90%	176.30%	97.90%
5,000-10,000	13,839	99,945,250	4,729	380,063,775	10.2	169.90%	181.40%	76.20%	79.00%	97.10%
10,000-30,000	5,693	92,951,450	2,657	541,342,863	8.8	112.40%	100.90%	143.90%	143.00%	86.30%
30,000-60,000	2,763	139,358,878	1,570	887,017,257	10.0	135.60%	124.40%	126.40%	115.00%	107.50%
60,000-100,000	681	44,522,561	336	257,740,029	11.9	121.20%	123.10%	117.10%	110.80%	156.60%
>100,000	369	58,240,226	34	51,658,123	9.6	254.50%	261.90%	212.50%	253.50%	117.10%
Total	126,933	563,463,323	48,914	2,743,599,172	9.5	103.40%	126.80%	113.00%	112.80%	94.10%

Table 5-10 Shipping activities per EMS type for the port area of Den Helder

Ship type	Totals for Den Helder in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	6	323,959	0	13,797	1.5	28.60%	32.90%		364.10%	53.60%
Chem.+Gas tanker	38	418,292	0	4,638	2.1	59.40%	66.90%	0.00%	2.20%	46.70%
Bulk carrier	16	347,687	12	76,724	6.6	61.50%	22.90%	1200.00%	87.50%	183.30%
Container ship	15	855,628	0	8,050	1.5	3.30%	16.20%	0.00%	6.50%	33.30%
General Dry Cargo	237	1,715,746	31	662,130	5.8	11.20%	23.00%	55.40%	54.20%	96.70%
RoRo Cargo / Vehicle	13,397	155,004,814	2,337	251,771,973	8.9	195.40%	171.40%	155.60%	174.10%	130.90%
Reefer	9,814	87,349,582	1,120	120,268,366	7.1	172.10%	140.80%	40.70%	37.70%	107.60%
Passenger	32,330	33,459,757	1,218	7,153,933	5.4	75.70%	101.40%	106.20%	116.10%	117.40%
Miscellaneous	101,023	123,290,655	3,396	29,989,161	5.6	78.40%	74.40%	88.90%	85.80%	93.30%
Total	156,876	402,768,121	8,114	409,950,706	6.7	84.00%	109.70%	87.40%	80.90%	109.70%

Table 5-11 Shipping activities per EMS ships size classes for the port area of Den Helder

Ship size in GT	Totals for Den Helder in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
100-1,600	93,121	35,637,975	2,753	7,158,170	5.7	80.70%	74.30%	101.80%	104.20%	91.90%
1,600-3,000	35,358	79,835,457	1,675	23,295,174	5.9	74.50%	75.70%	81.80%	85.70%	86.80%
3,000-5,000	5,455	19,753,574	222	4,965,888	8.2	51.70%	46.20%	83.50%	78.00%	182.20%
5,000-10,000	10,231	82,914,762	360	21,635,246	4.8	225.20%	228.90%	37.70%	32.50%	88.90%
10,000-30,000	12,679	182,484,798	3,104	352,871,858	5.7	144.40%	140.50%	93.80%	88.40%	109.60%
30,000-60,000	12	464,625	0	16,322	2.0	42.90%	37.90%	0.00%	12.30%	71.40%
60,000-100,000	16	1,164,348	0	8,050	1.5	69.60%	63.00%		6.50%	30.00%
>100,000	156,872	402,255,539	8,114	409,950,708	5.8	84.00%	109.60%	87.40%	80.90%	98.70%
Total	93,121	35,637,975	2,753	7,158,170	5.7	80.70%	74.30%	101.80%	104.20%	91.90%

Table 5-12 Shipping activities per EMS type for the port area of Harlingen

Ship type	Totals for Harlingen in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.hours	Average speed	Hours	GT.Hours	Hours	GT.nm	Average speed
Oil tanker	10	620,634	0	88,438	4.6	47.60%	46.00%	0.00%	8.30%	131.40%
Chem.+Gas tanker	663	3,290,334	21	807,952	6.7	114.70%	126.90%	63.60%	74.60%	95.70%
Bulk carrier	639	2,692,037	60	507,030	4.8	1775.00%	226.60%	750.00%	79.50%	90.60%
Container ship	18	654,481	1	115,663	3.6	41.90%	32.50%	16.70%	8.20%	62.10%
General Dry Cargo	21,004	59,398,596	2,610	50,121,347	8.1	132.40%	146.10%	85.70%	92.60%	101.30%
RoRo Cargo / Vehicle	19,022	48,607,055	8,211	259,252,930	8.0	298.90%	399.30%	667.00%	998.60%	125.00%
Reefer	1,618	7,614,386	216	8,583,656	8.8	141.10%	114.90%	120.00%	109.10%	98.90%
Passenger	10,348	4,535,717	1,005	9,576,111	15.9	494.20%	638.30%	670.00%	1534.90%	182.80%
Miscellaneous	40,156	26,343,790	5,734	48,316,958	7.4	120.00%	110.20%	134.30%	119.90%	102.80%
Tug/Supply	40,773	45,741,460	723	2,293,790	5.7	88.90%	77.40%	140.70%	97.10%	90.50%
Total	134,251	199,498,490	18,581	379,663,875	8.2	127.20%	132.70%	196.80%	280.30%	111.00%

Table 5-13 Shipping activities per EMS ships size classes for the port area of Harlingen

Ship size in GT	Totals for Harlingen in 2017					2017 as percentage of 2016				
	Berthed		Moving			Berthed		Moving		
	Hours	GT.hours	Hours	GT.hours	Average speed	Hours	GT.Hours	Hours	GT.nm	Average speed
100-1,600	79,381	34,848,036	6,865	33,011,562	9.2	114.40%	87.50%	134.10%	115.90%	105.70%
1,600-3,000	39,741	97,411,861	7,463	173,707,560	8.8	137.40%	137.90%	209.30%	256.80%	100.00%
3,000-5,000	11,242	40,901,564	3,625	141,748,227	8.0	286.40%	276.40%	1596.90%	1803.80%	90.90%
5,000-10,000	3,815	22,780,715	622	30,017,981	6.8	123.70%	123.60%	123.90%	113.20%	98.60%
10,000-30,000	34	653,260	6	554,240	5.5	36.20%	44.20%	40.00%	41.70%	110.00%
30,000-60,000	15	656,891	0	53,680	2.6	44.10%	44.00%	0.00%	3.30%	52.00%
60,000-100,000	16	1,239,928	0	88,438	4.6	88.90%	87.80%	0.00%	15.70%	153.30%
>100,000	6	1,006,237	0	482,186	3.9	46.20%	44.60%	0.00%	34.50%	95.10%
Total	134,250	199,498,492	18,581	379,663,874	8.7	127.20%	132.70%	196.80%	280.30%	101.00%

5.3 Activities of seagoing vessels in the Netherlands sea area

The shipping activities in the Netherlands sea area are presented in Table 5-14 and Table 5-15, where the activities of 2017 are compared to the activities of 2016. The tables contain per ship type and size class:

- hours and GT.hours for not moving ships (at anchor), and
- hours, GT.nm and average speed for moving ships.

The activities for moving vessels show an average increase of hours of 2.1% and the GT.nm an increase of 1.7%. For ships at anchor there is an average decrease for both hours and GT.nm of about 14%.

Table 5-14 Shipping activities per EMS type for the Netherlands Continental Shelf and 12-mile zone

Ship type	Totals for NCS and 12-mile zone in 2017					2017 as percentage of 2016				
	Not moving / at anchor		Moving			Not moving / at anchor		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average speed
Oil tanker	97,981	5,790,413,102	71,034	41,063,628,036	9.7	78.20%	88.10%	101.70%	99.50%	97.20%
Chem.+Gas tanker	280,583	3,487,413,163	278,852	35,021,287,734	10.6	83.10%	80.80%	102.70%	101.20%	96.10%
Bulk carrier	78,590	3,878,373,804	107,387	39,114,890,079	9.8	79.00%	73.20%	104.30%	101.50%	98.50%
Container ship	78,419	3,049,366,283	184,697	123,903,118,456	13.1	129.60%	121.80%	109.70%	102.20%	95.80%
General Dry Cargo	81,897	492,683,961	388,101	17,505,444,201	10.6	83.30%	102.40%	98.40%	96.20%	95.50%
RoRo Cargo / Vehicle	15,052	209,015,323	134,573	69,900,546,930	12.8	234.60%	84.70%	107.20%	103.10%	93.30%
Reefer	2,490	23,635,604	11,772	1,356,787,042	11.7	51.60%	68.60%	89.90%	85.80%	94.10%
Passenger	765	1,852,127	9,110	8,688,447,351	12.4	366.00%	73.10%	101.20%	107.80%	94.20%
Miscellaneous	32,108	367,899,436	90,891	2,132,578,514	7.3	121.90%	226.10%	119.40%	123.40%	87.50%
Tug/Supply	75,145	370,089,231	114,986	2,483,027,091	7.7	83.30%	50.00%	87.00%	99.40%	93.50%
Total	743,030	17,670,742,034	1,391,403	341,169,755,434	10.6	87.50%	86.80%	102.10%	101.70%	95.50%

Table 5-15 Shipping activities per ship size class for the Netherlands Continental Shelf and 12-mile zone

Ship size in GT	Totals for NCS and 12-mile zone in 2017					2017 as percentage of 2016				
	Not moving / at anchor		Moving			Not moving / at anchor		Moving		
	Hours	GT.hours	Hours	GT.nm	Average speed	Hours	GT.hours	Hours	GT.nm	Average Speed
100-1,600	40,139	25,201,998	145,017	822,308,157	7.4	96.50%	91.70%	92.90%	94.00%	92.00%
1,600-3,000	91,426	218,879,240	304,065	6,501,018,000	9.1	97.50%	96.40%	98.40%	94.90%	95.50%
3,000-5,000	102,281	409,067,704	184,218	7,477,851,440	10.4	91.00%	91.20%	101.80%	97.60%	94.70%
5,000-10,000	115,184	847,733,810	181,962	15,569,217,004	11.4	81.90%	82.70%	106.00%	101.60%	99.40%
10,000-30,000	208,885	3,948,584,647	300,390	72,574,345,152	12.0	84.20%	83.30%	106.30%	101.90%	93.30%
30,000-60,000	94,985	4,112,913,613	140,435	78,383,415,353	11.6	81.30%	81.20%	99.20%	94.50%	93.10%
60,000-100,000	72,732	5,568,733,671	98,029	88,541,501,295	11.7	97.90%	98.50%	116.20%	113.30%	96.30%
>100,000	17,399	2,539,627,351	37,288	71,300,099,035	11.8	79.30%	79.90%	102.00%	98.30%	99.30%
Total	743,031	17,670,742,034	1,391,404	341,169,755,436	10.5	87.50%	86.80%	102.10%	101.70%	95.60%

5.4 Overview of ships in the port areas and in the Netherlands sea area

The average number of ships per day, in the port areas and at sea, are presented in Table 5-16. Compared to the results presented in the previous study, most remarkable is the increase of berthed and moving ships in the port of Harlingen and the decrease of them in Den Helder. The increase for Harlingen is mainly due to an increase of the number of RoRo Cargo and Vehicle carriers. The decrease of berthed and moving ships in Den Helder might be due to the large dependency on the offshore industry.

For the NCS combined with the 12-miles zone the average number of ships increased slightly for moving ships, and decreased for non-moving ships.

Table 5-16 Average number of ships per day, in distinguished areas, excluding Fishing vessels.

Area	In 2017			In 2017 as percentage of 2016		
	Average # ships/day		Speed	Average # ships/day		Speed
	Not moving	Moving	Knots	Not moving	Moving	Knots
Amsterdam	36	5	6	72.6%	101.4%	100.7%
Den Helder	18	1	7	84.0%	87.4%	109.7%
Ems	14	6	9	103.4%	113.0%	92.3%
Harlingen	15	2	8	127.2%	196.8%	111.0%
Rotterdam	64	20	8	103.8%	114.7%	95.2%
Western Scheldt	54	21	10	118.4%	110.1%	96.4%
NCS + 12-mile zone	85	158	11	87.5%	102.1%	95.5%

6 EMISSIONS FOR THE DUTCH PORT AREAS AND THE NETHERLANDS SEA AREA

6.1 Introduction

This chapter presents the results of the emission calculations for 2017 for the Dutch port areas and the Netherlands sea area. To indicate the change in emissions, all values for 2017 are compared with the values of 2016.

The emissions for the port areas are given in Section 6.2, those for the NCS and 12-mile zone in Section 6.3. Section 6.4 presents the spatial distribution of the 2017 NO_x emissions. Also the absolute and relative change in this spatial distribution compared to 2016 is presented in figures.

For 2017 all emissions were calculated using two versions of the emission calculation method. The first method is the same as was used in the calculations of 2016 and is referred to as method 1, the results of this method are included in Appendix B. The second method follows an improvement in the theory described by TNO and is referred to as method 2. The following paragraphs will present the results of the latter.

6.2 Emissions in port areas

Table 6-1 contains the emissions for the six Dutch port areas, calculated for ships berthed and sailing within the port areas. Table 6-2 contains the same emissions expressed as a percentage of the corresponding emissions in 2016. Similar to the procedure in the previous studies, the values for at berth include all vessels with speed below 1 knots, so also the vessels at anchor.

Regarding the total emission for all port areas Table 6-2 shows a clear decrease of emissions between 2016 and 2017, except for aerosols. For the emissions of CO_2 there is an overall reduction around 18 percent. Emissions in Harlingen and Ems have risen which is in line with a grow of activities in these ports.

The difference between both calculation methods has no impact on the emissions for non moving ships. For moving ships we see an increase of emissions around 10 percent when using method 1 (see Appendix B).

Table 6-1 Total emissions in ton in each port area for 2017, excluding Fishing vessels, EMS-type 11.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	2	1	0	6	16	0	25
	Total	2	1	0	6	16	0	25
1237 VOC	Berthed	46	166	49	10	7	3	280
	Sailing	265	185	29	27	4	9	518
	Total	310	351	78	37	11	12	798
4001 SO_2	Berthed	87	323	92	21	14	7	544
	Sailing	212	128	18	23	4	7	392
	Total	299	451	110	44	18	14	936
4013 NO_x	Berthed	1148	3688	1145	255	191	104	6531
	Sailing	8076	4345	635	793	133	240	14223
	Total	9224	8033	1781	1048	324	344	20754
4031 CO	Berthed	73	294	84	16	10	5	483
	Sailing	486	339	52	44	8	12	941
	Total	560	633	136	60	18	17	1424
4032 CO_2	Berthed	98817	411837	117578	20304	13084	6523	668143
	Sailing	359166	219925	32429	42228	10492	12181	676420
	Total	457983	631762	150007	62532	23576	18704	1344563
6601 Aerosols MDO	Berthed	21	79	23	4	3	2	131
	Sailing	32	28	6	7	1	3	77
	Total	53	107	29	11	4	5	208
6602 Aerosols HFO	Berthed	0	0	1	0	0	0	2
	Sailing	171	109	13	17	3	3	316
	Total	171	109	13	17	3	3	318

Table 6-2 Emissions in each port area (including the total Western Scheldt area) for 2017 as percentage of the emissions in 2016, excluding Fishing vessels, EMS-type 11. The percentages in grey are based on very low absolute numbers, and not very reliable.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	120%	160%	172%	98%	778%		
	Total	120%	160%	172%	98%	778%		
1237 VOC	Berthed	82%	72%	59%	129%	87%	106%	73%
	Sailing	91%	100%	90%	86%	58%	258%	95%
	Total	90%	85%	68%	94%	73%	184%	85%
4001 SO_2	Berthed	82%	71%	63%	138%	88%	106%	73%
	Sailing	79%	84%	76%	81%	54%	252%	81%
	Total	80%	74%	65%	101%	78%	149%	76%
4013 NO_x	Berthed	85%	71%	63%	133%	92%	119%	74%
	Sailing	84%	89%	81%	88%	72%	281%	86%
	Total	84%	80%	68%	96%	83%	199%	82%
4031 CO	Berthed	82%	74%	61%	137%	88%	108%	74%
	Sailing	96%	102%	90%	91%	69%	235%	98%
	Total	94%	87%	69%	100%	78%	172%	88%
4032 CO_2	Berthed	85%	78%	62%	146%	96%	118%	77%
	Sailing	85%	90%	84%	89%	95%	272%	88%
	Total	85%	82%	65%	102%	96%	187%	82%
6601 Aerosols MDO	Berthed	98%	138%	63%	233%	101%	127%	109%
	Sailing	87%	96%	103%	101%	85%	205%	95%
	Total	91%	124%	68%	128%	96%	169%	103%
6602 Aerosols HFO	Berthed	8%	0%	16%	13%	36%	2%	3%
	Sailing	79%	84%	67%	71%	41%	492%	80%
	Total	78%	59%	57%	67%	41%	356%	69%

6.3 Emissions in the Netherlands sea area

The emissions in the NCS and the 12-mile zone are calculated for moving and non-moving ships. Ships are counted as non-moving when the speed is less than 1 knot, just like in the previous studies. Mostly, this concerns ships at anchor in one of the anchorage areas. However, some ships may have such a low speed for a while when waiting for something (for a pilot, for permission to enter a port or for another reason). Based on the observed speed in AIS, the emission has been calculated for the main engine and for the auxiliary engines.

The calculated emissions for 2017 are summarised in Table 6-3. This table also contains a comparison with 2016. In this table the decrease in SO_2, NO_x and CO_2 is clearly visible, approximately ten percent. Compared to previous year, the total average number of ships on the North Sea is of the same order of magnitude. For moving ships, the total average number increased by 2% and for non moving ships it decreased by 13%.

The difference between both calculation methods has no impact on the emissions for non moving ships. For moving ships we see an increase of emissions in tons around 10 percent when using method 1 (see Appendix B).

Table 6-3 Emissions of ships in ton in the Netherlands sea area for 2017 compared with 2016, excluding Fishing vessels, EMS-type 11.

Nr	Substance	Emission in ton in 2017			Emission in ‘17 as percentage of ‘16		
		Not moving	Moving	Total	Not moving	Moving	Total
1011	Methane		32	32		99%	99%
1237	VOC	89	2120	2209	86%	92%	92%
4001	SO_2	209	3940	4148	88%	86%	86%
4013	NO_x	2714	72216	74930	89%	88%	88%
4031	CO	143	3745	3887	88%	97%	97%
4032	CO_2	168327	3245752	3414079	90%	89%	89%
6601	Aerosols MDO	70	227	297	93%	92%	92%
6602	Aerosols HFO	4	1873	1877	19%	84%	83%
Number of Ships		85	158	243	87%	102%	96%

6.4 Spatial distribution of the emissions

Because of the strong relation between shipping routes and location of the emissions, all substances show more or less the same spatial distribution. Therefore, only the spatial distribution of NO_x is presented for the six Dutch port areas and the Netherlands sea area in Figure 6-1 to Figure 6-21.

Three figures are presented for each area. The first figure represents the total emission (emissions of auxiliary and main engine of moving and not moving ships together) expressed as NO_x in ton/km^2. The second one shows the *absolute* change in emission between 2016 and 2017 and the third one shows the *relative* change in emission between 2016 and 2017. To make a comparison between areas easier, the same colour table has been used for all areas. Only for the NCS a different scale has been used to illustrate the absolute difference. This is necessary because at the NCS differences are more smoothed due to the larger grid cells, these are 25 km^2 instead of 0.25 km^2 as used in the port areas.

In the figures, large differences between 2016 and 2017 are visualized by darker colours. Absolute differences are often larger at locations with high traffic intensity, while relative differences are often larger at locations with low traffic intensity. This has to be kept in mind when interpreting the figures.

Figure 6-2 shows a decrease in absolute NO_x emissions for the main shipping routes in the Western Scheldt.

Figure 6-5 clearly shows the decrease of berthed NO_x emissions, but also an increase of emissions in the Maasvlakte 2.

The decrease of emissions for moving ships in Den Helder is clearly demonstrated in Figure 6-14 and the increase of these in Harlingen in Figure 6-17.

On the NCS the absolute changes are rather small, see Figure 6-20.

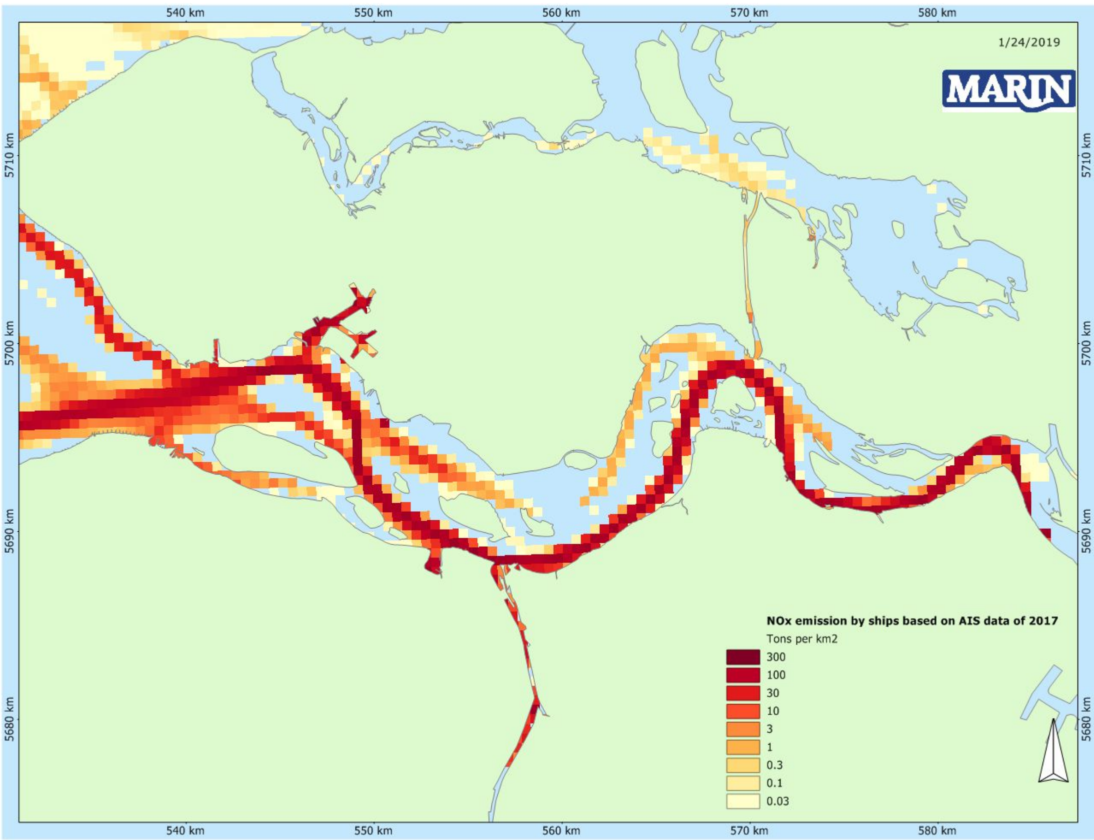

Figure 6-1 **NO_x emission in 2017 in the Dutch part of the Western Scheldt by ships with AIS.**

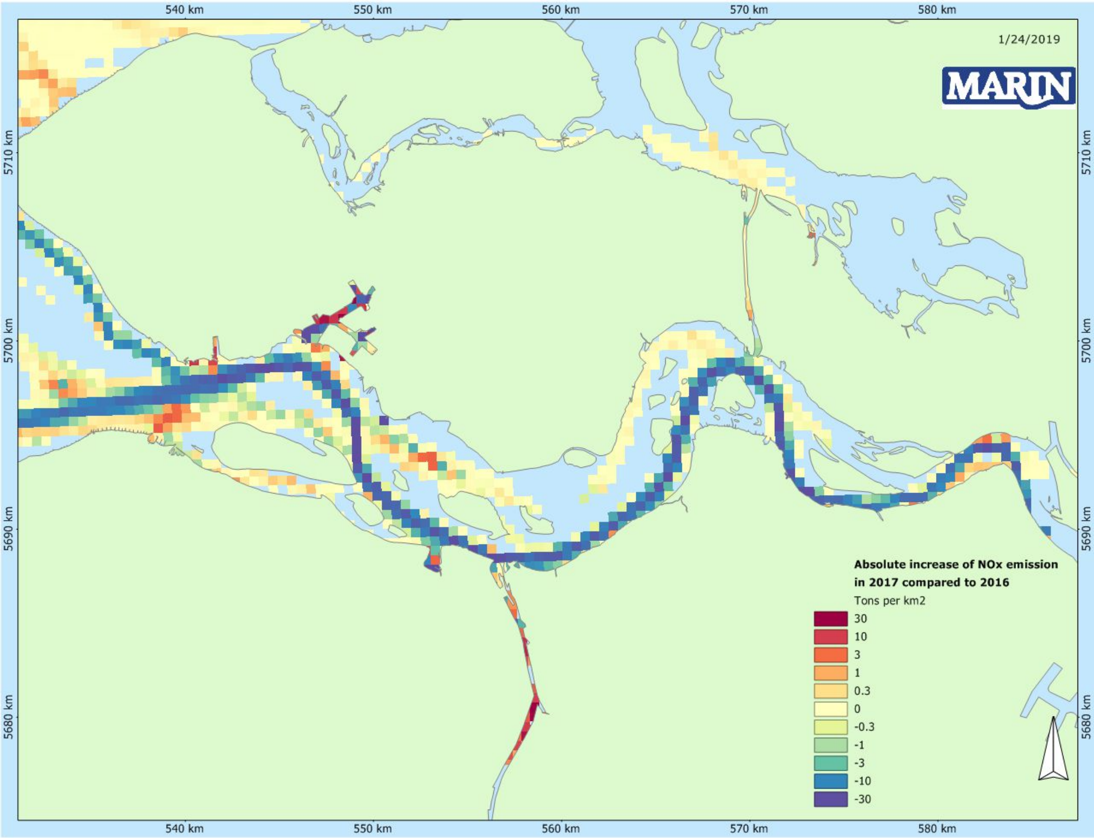

Figure 6-2 **Absolute change in NO_x emission from 2016 to 2017 in the Dutch part of the Western Scheldt by ships with AIS.**

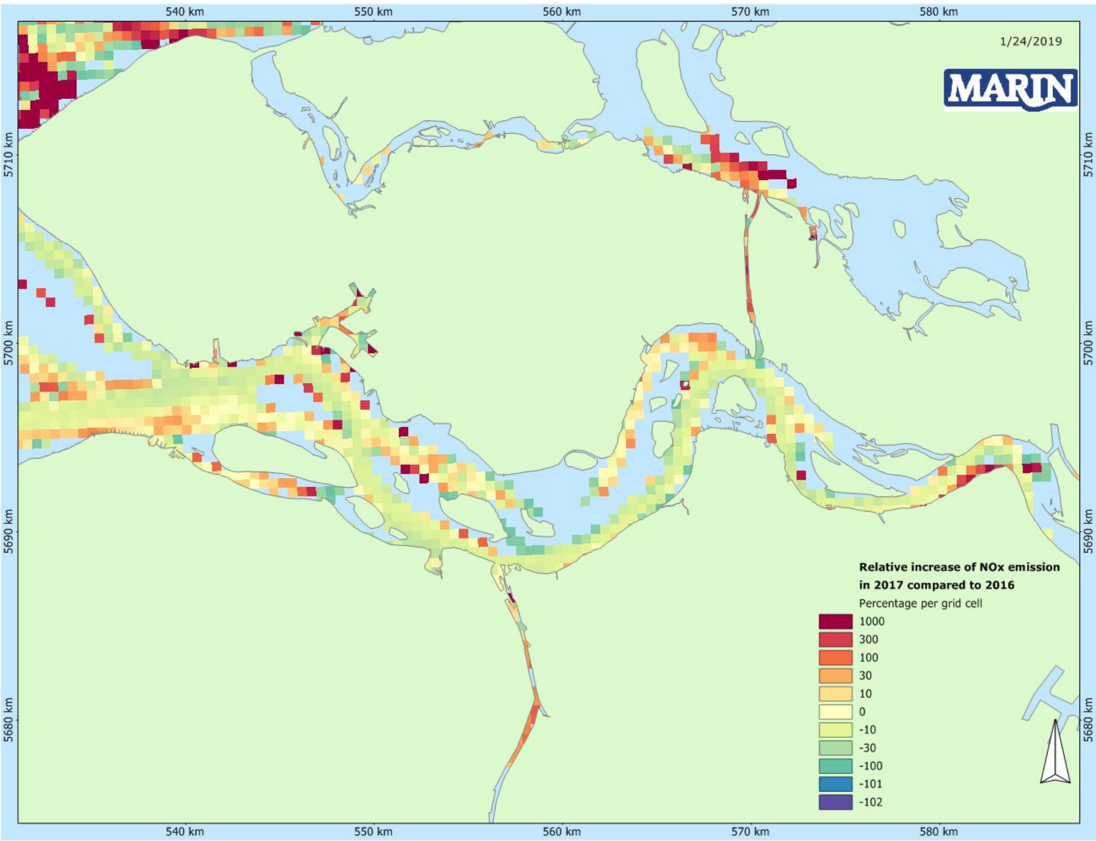

Figure 6-3 **Relative change in NO_x emission from 2016 to 2017 in the Dutch part of the Western Scheldt by ships with AIS.**

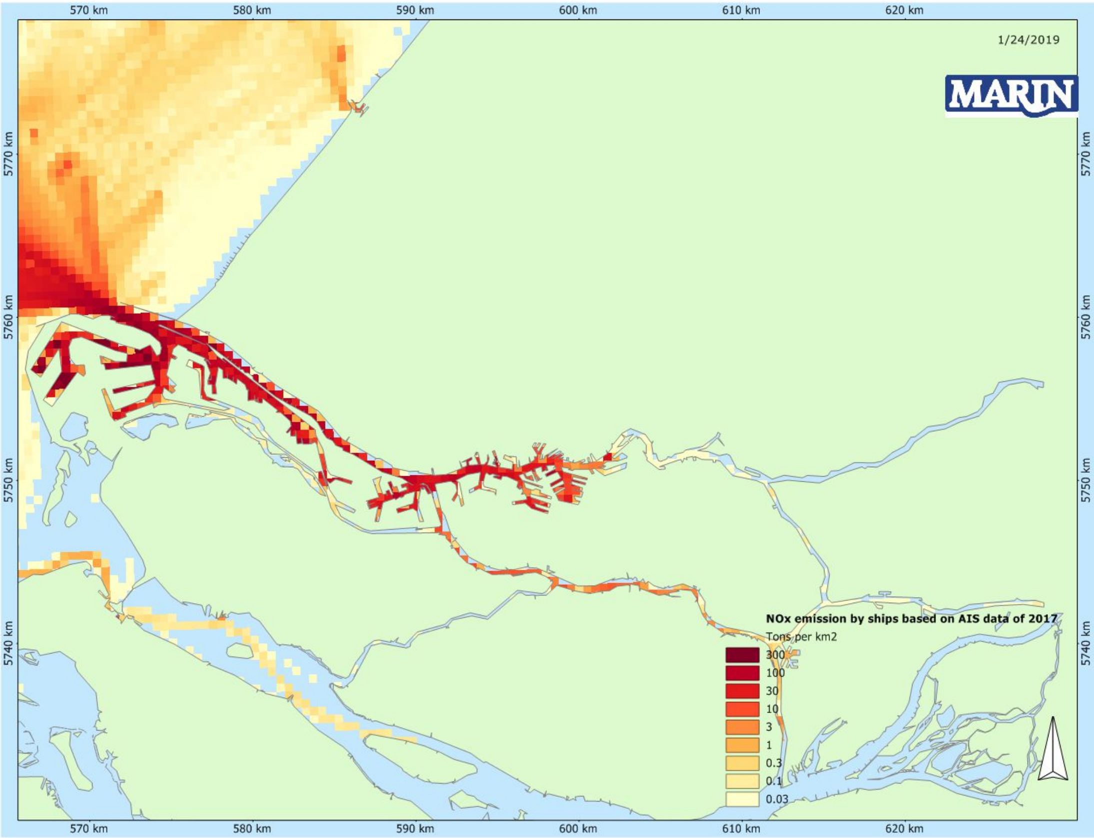

Figure 6-4 **NO_x emission in 2017 in the port area of Rotterdam by ships with AIS.**

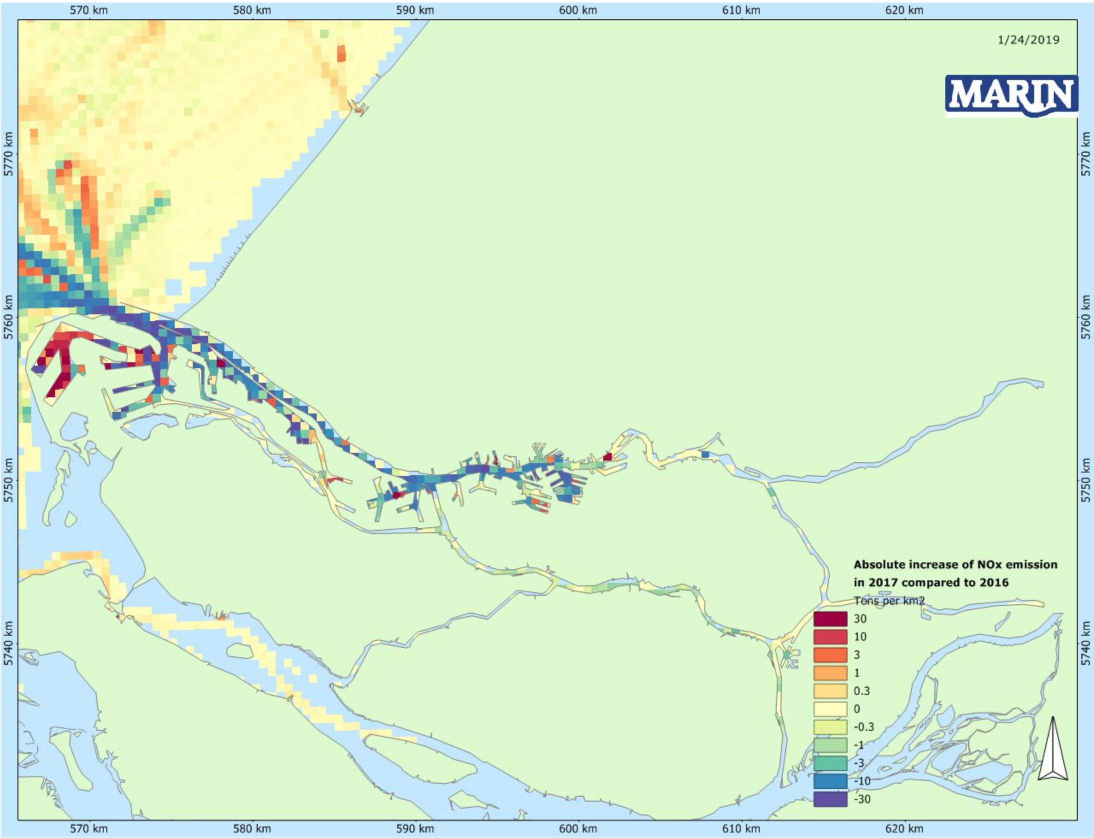

Figure 6-5 with **Absolute change in NO_x emission from 2016 to 2017 in the port area of Rotterdam by ships AIS.**

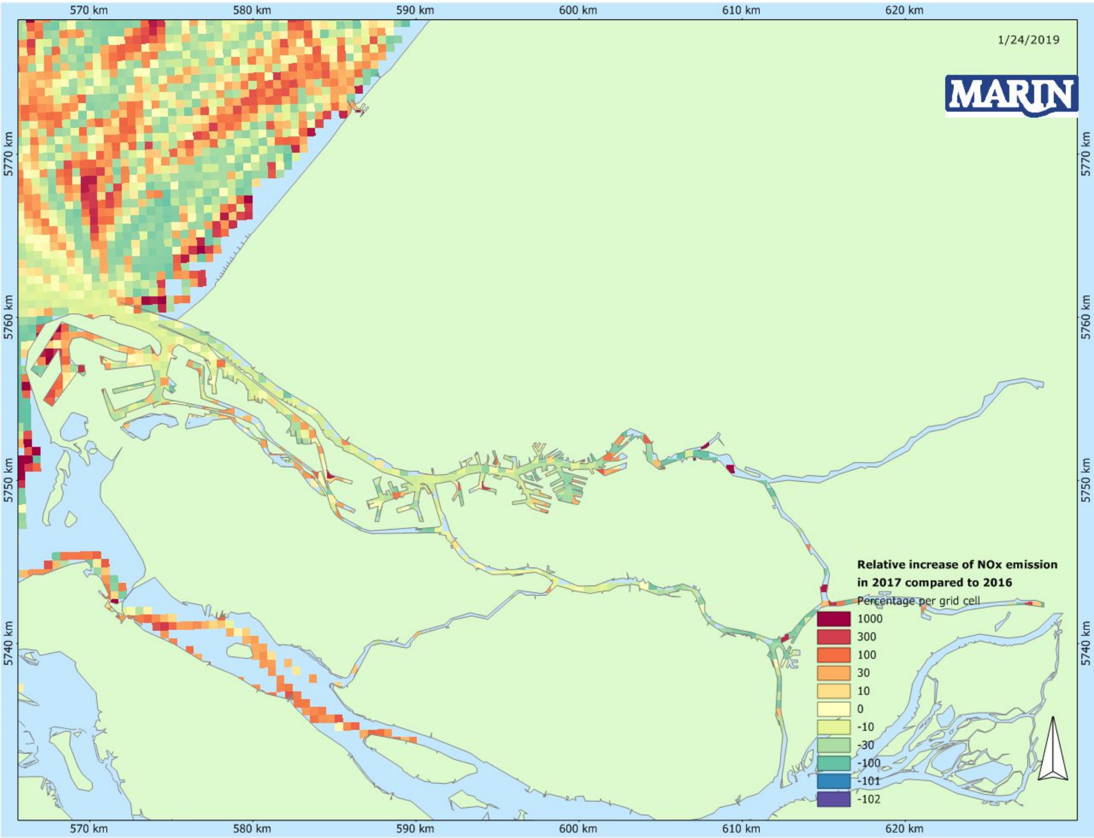

Figure 6-6 Relative change in NO_x emission from 2016 to 2017 in the port area of Rotterdam by ships with AIS.

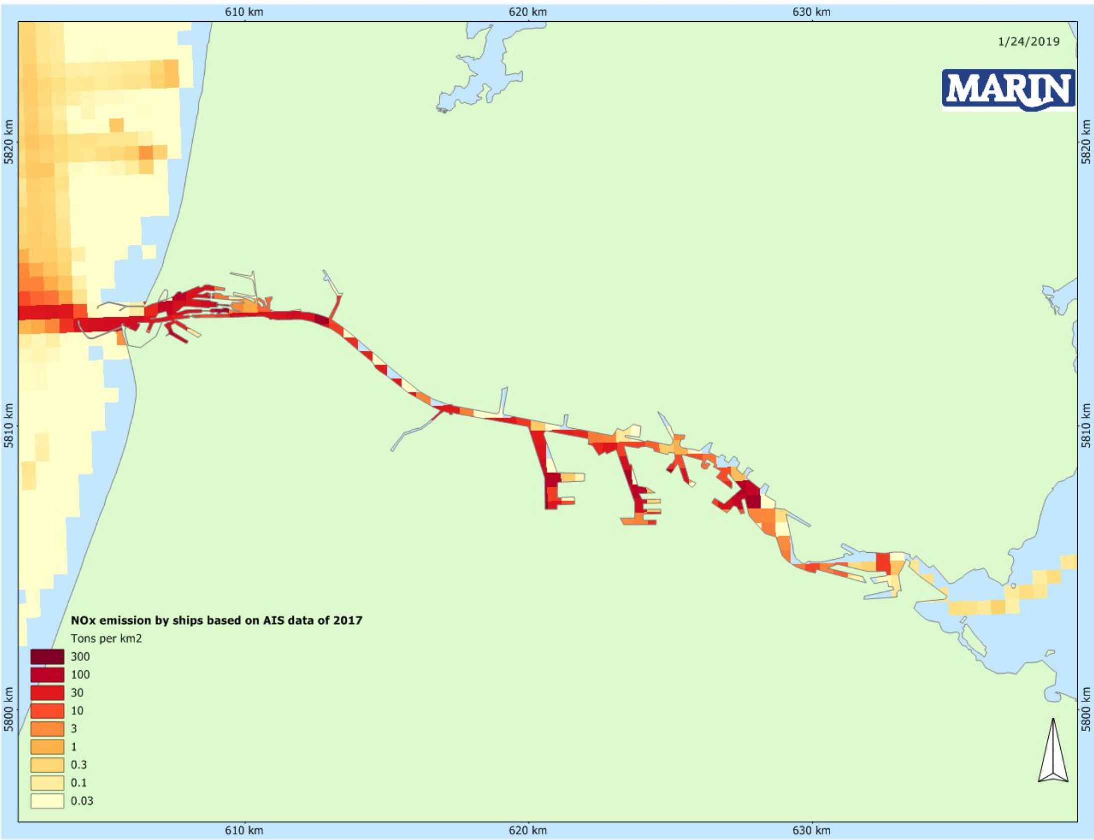

Figure 6-7 NO_x emission in 2017 in the port area of Amsterdam by ships with AIS.

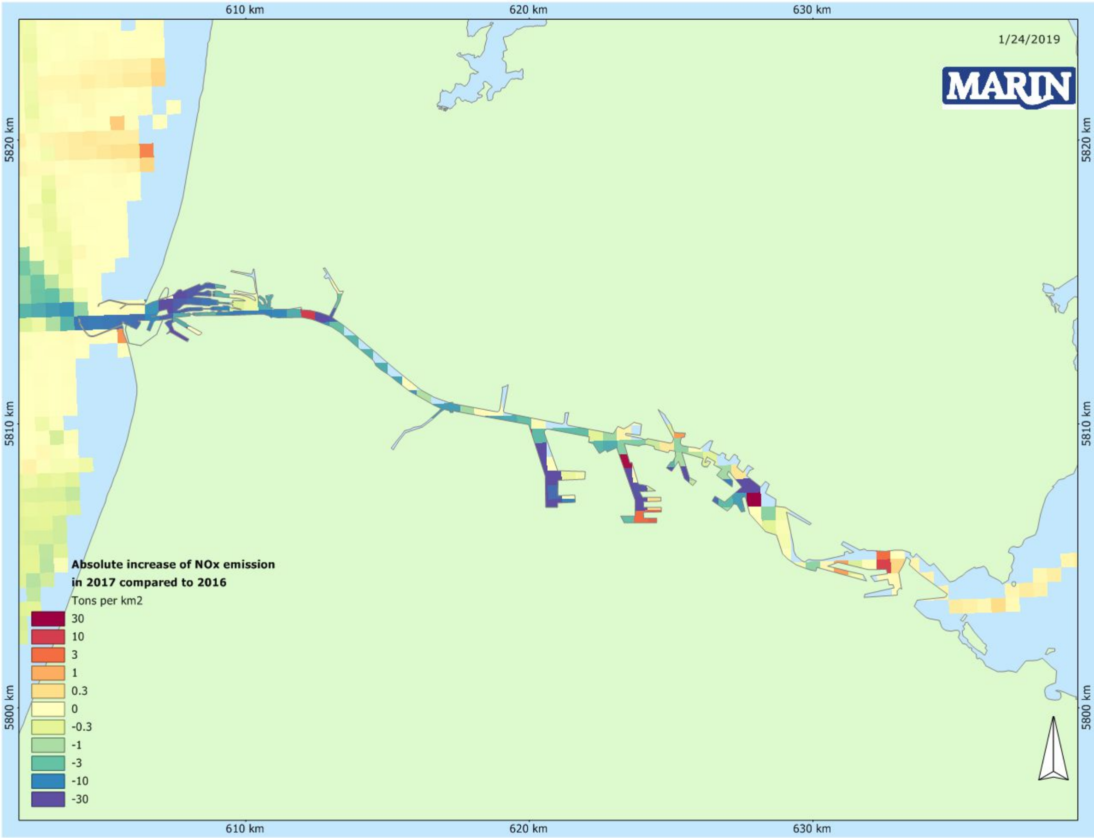

Figure 6-8 Absolute change in NO_x emission from 2016 to 2017 in the port area of Amsterdam by ships with AIS.

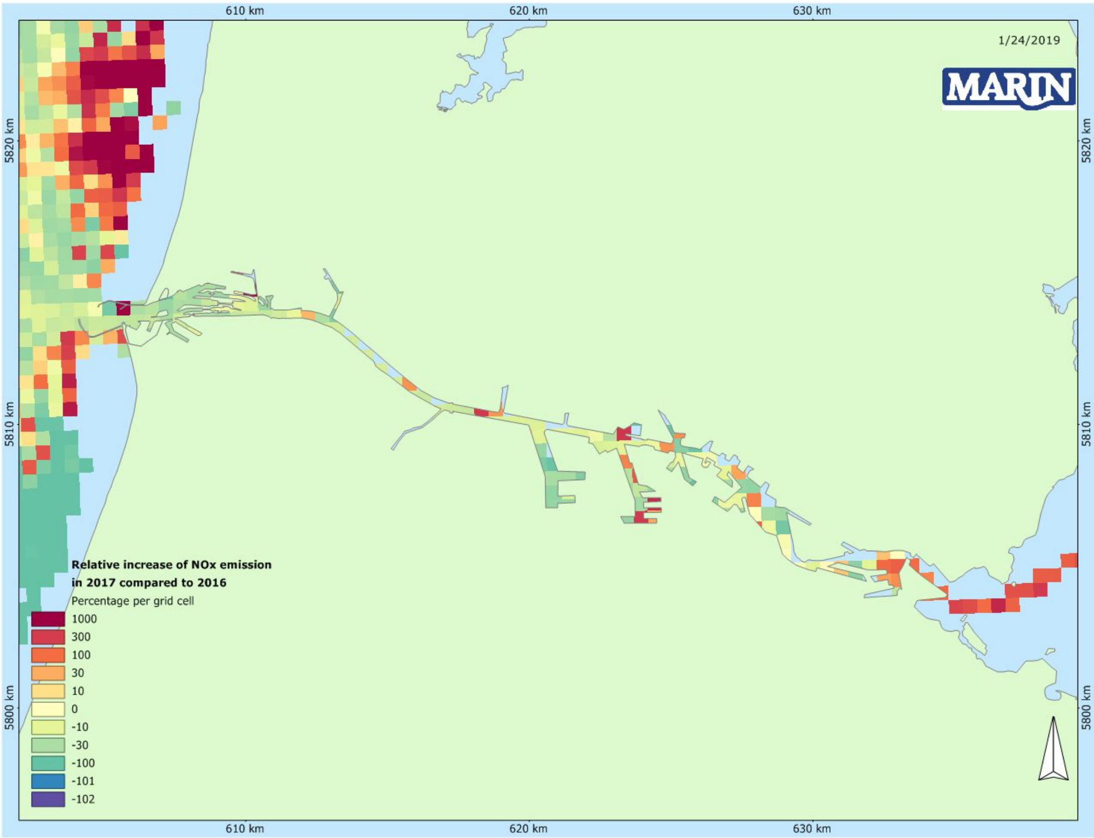

Figure 6-9 Relative change in NO_x emission from 2016 to 2017 in the port area of Amsterdam by ships with AIS.

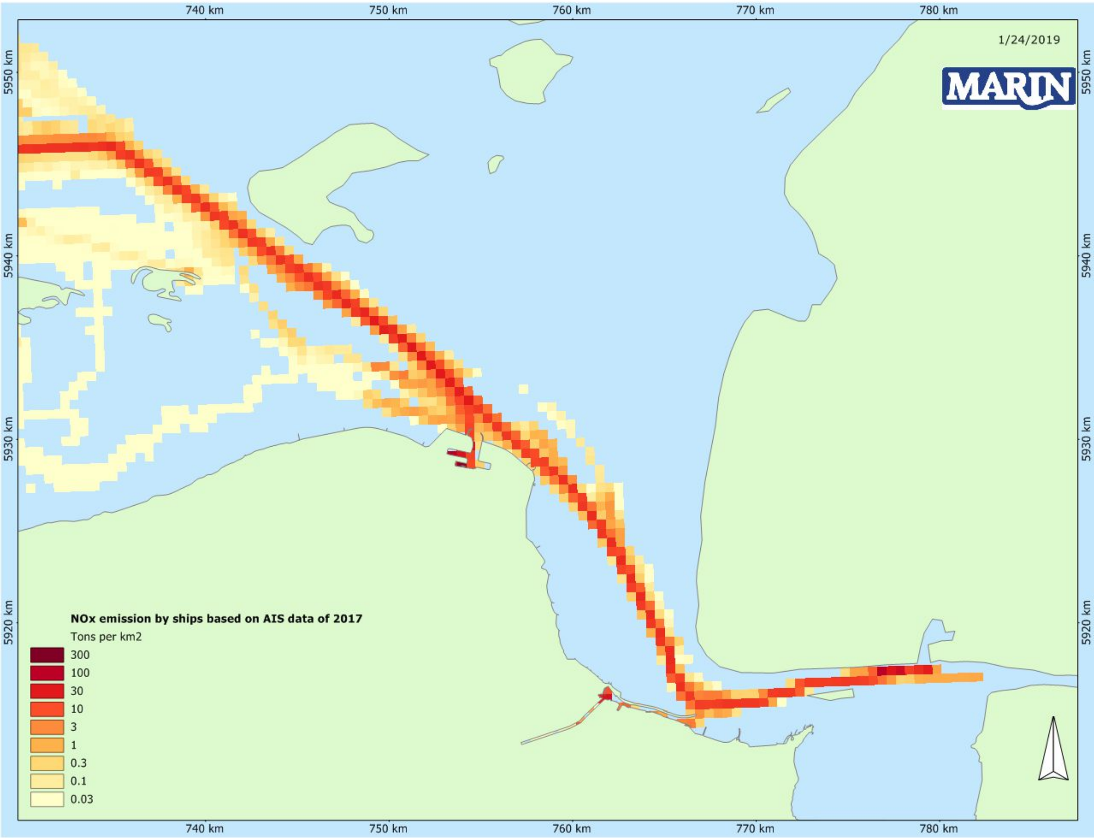

Figure 6-10 **NO_x emission in 2017 in the Ems area by ships with AIS.**

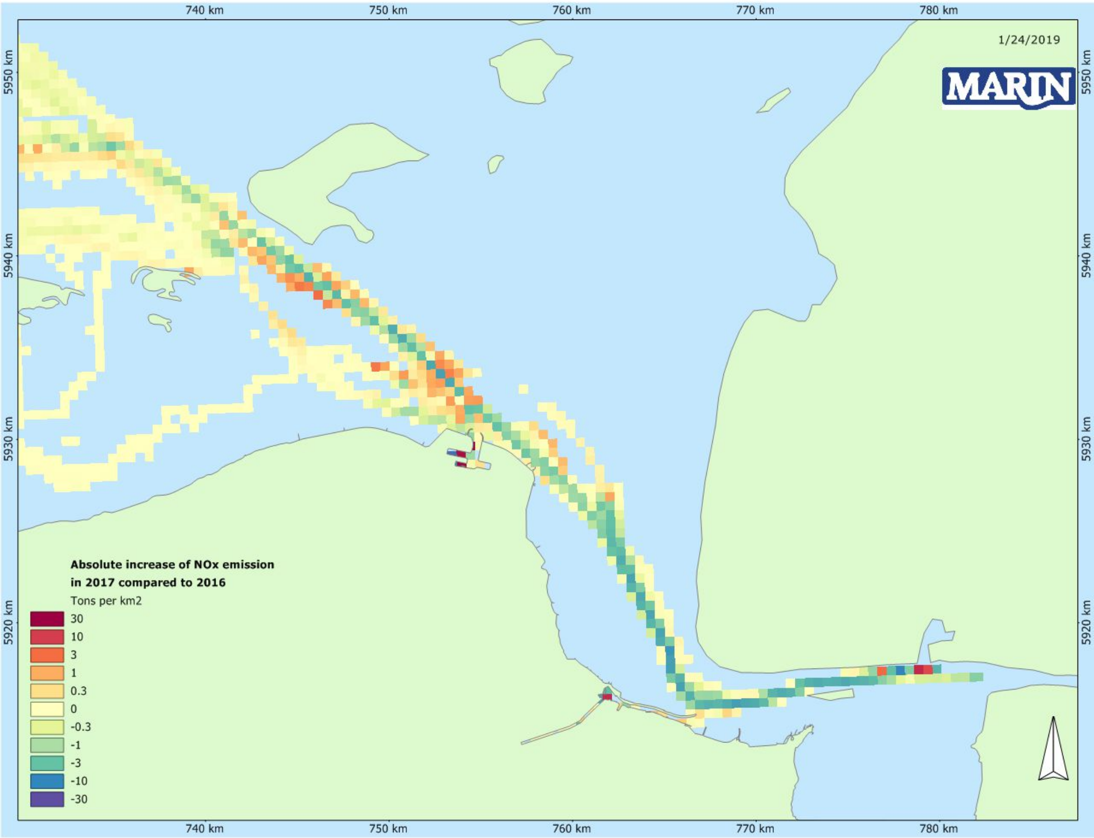

Figure 6-11 **Absolute change in NO_x emission from 2016 to 2017 in the Ems area by ships with AIS.**

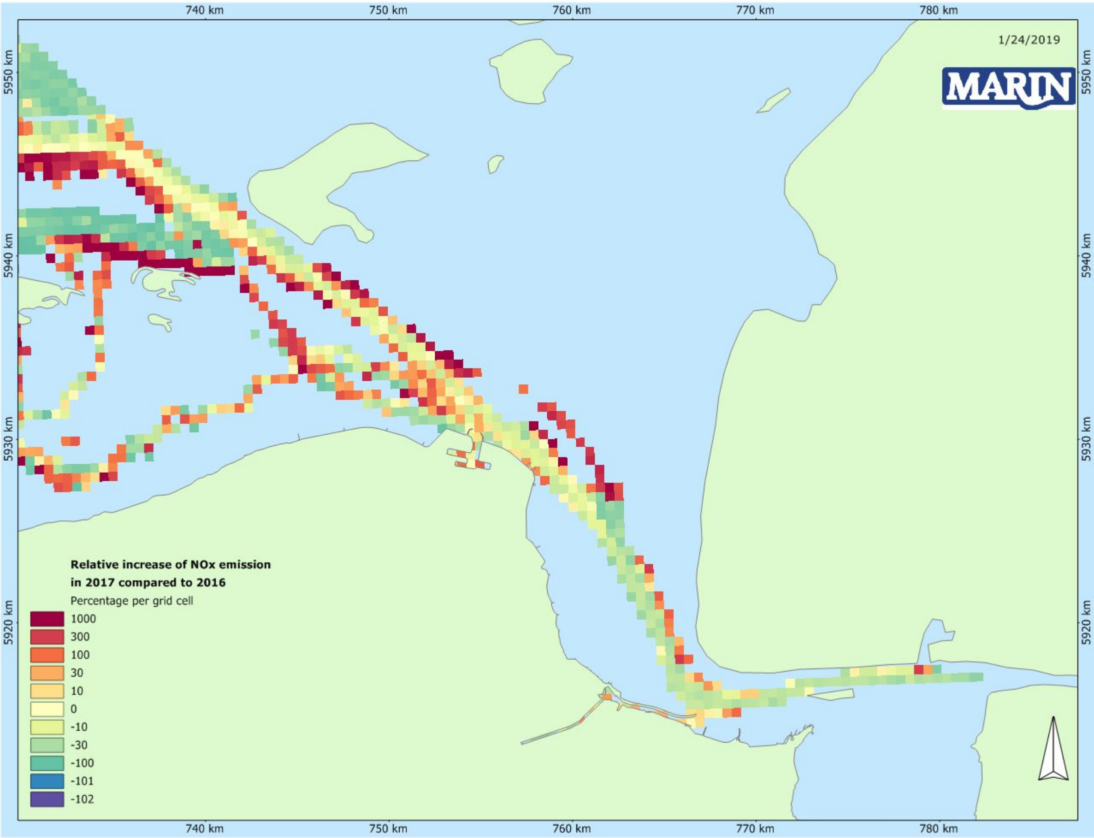

Figure 6-12 **Relative change in NO_x emission from 2016 to 2017 in the Ems area by ships with AIS.**

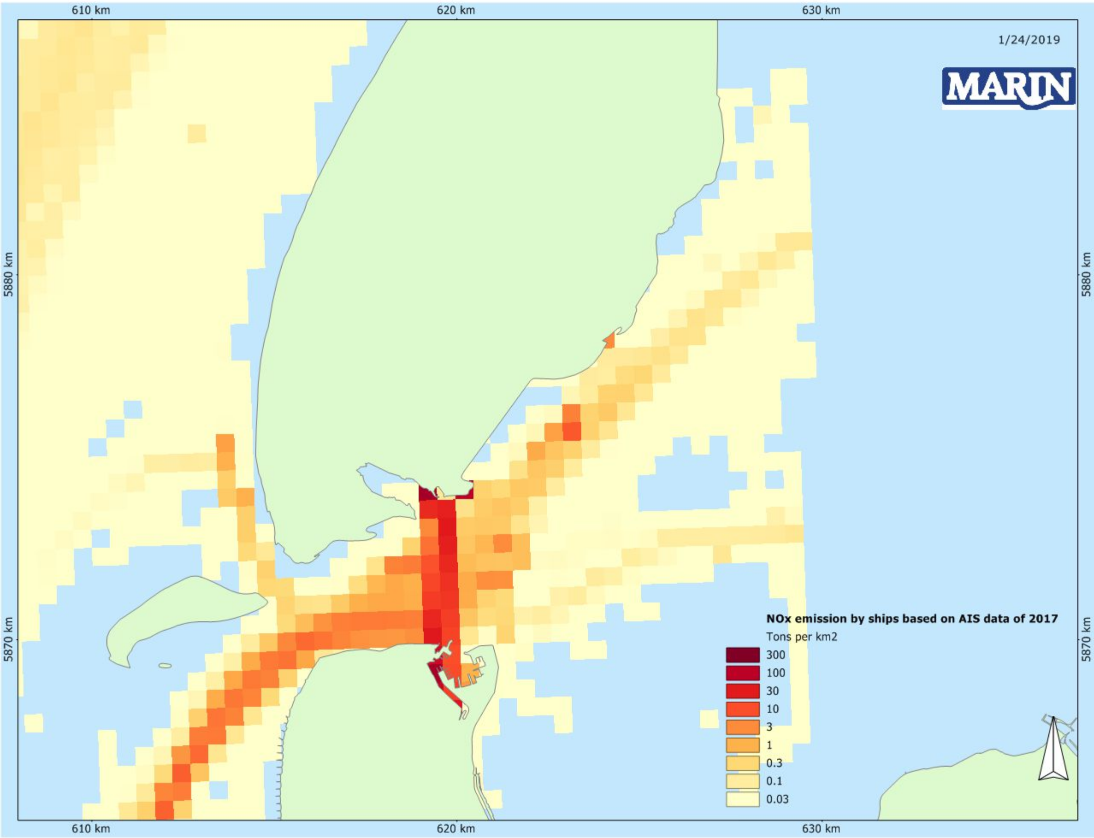

Figure 6-13 **NO_x emission in 2017 in the port area of Den Helder by ships with AIS.**

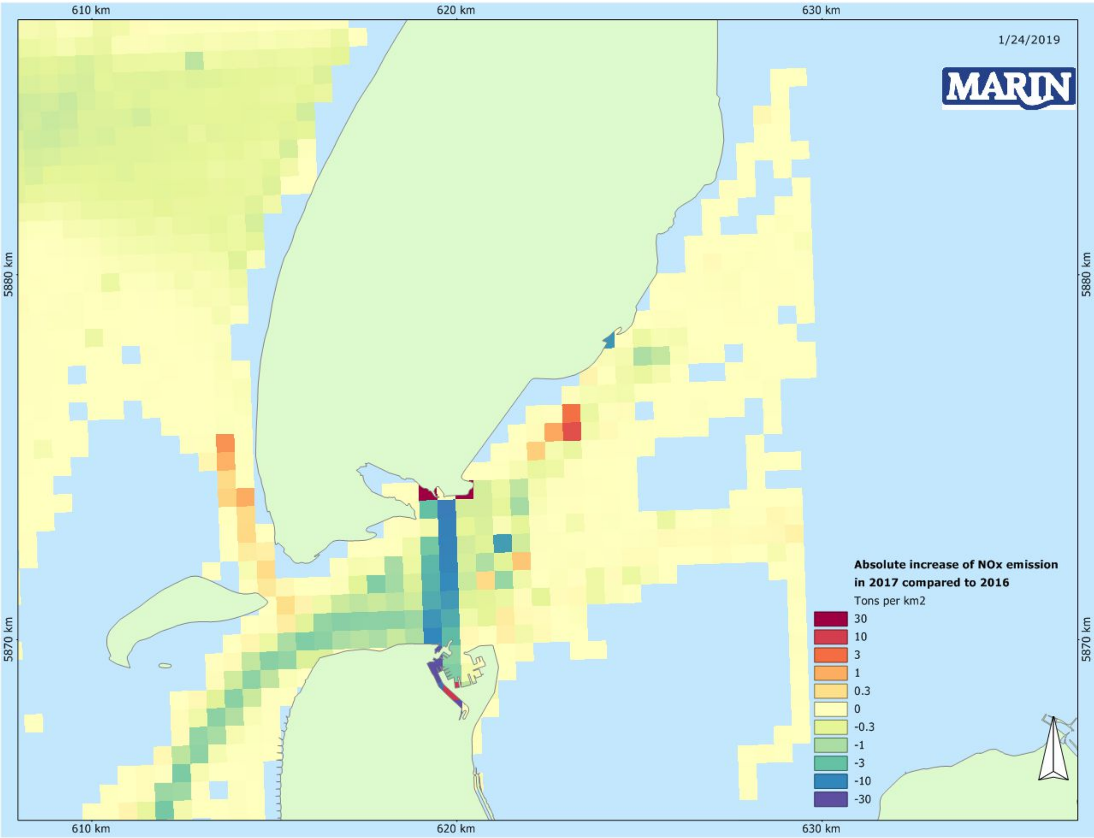

Figure 6-14 **Absolute change in NO_x emission from 2016 to 2017 in the port area of Den Helder by ships with AIS.**

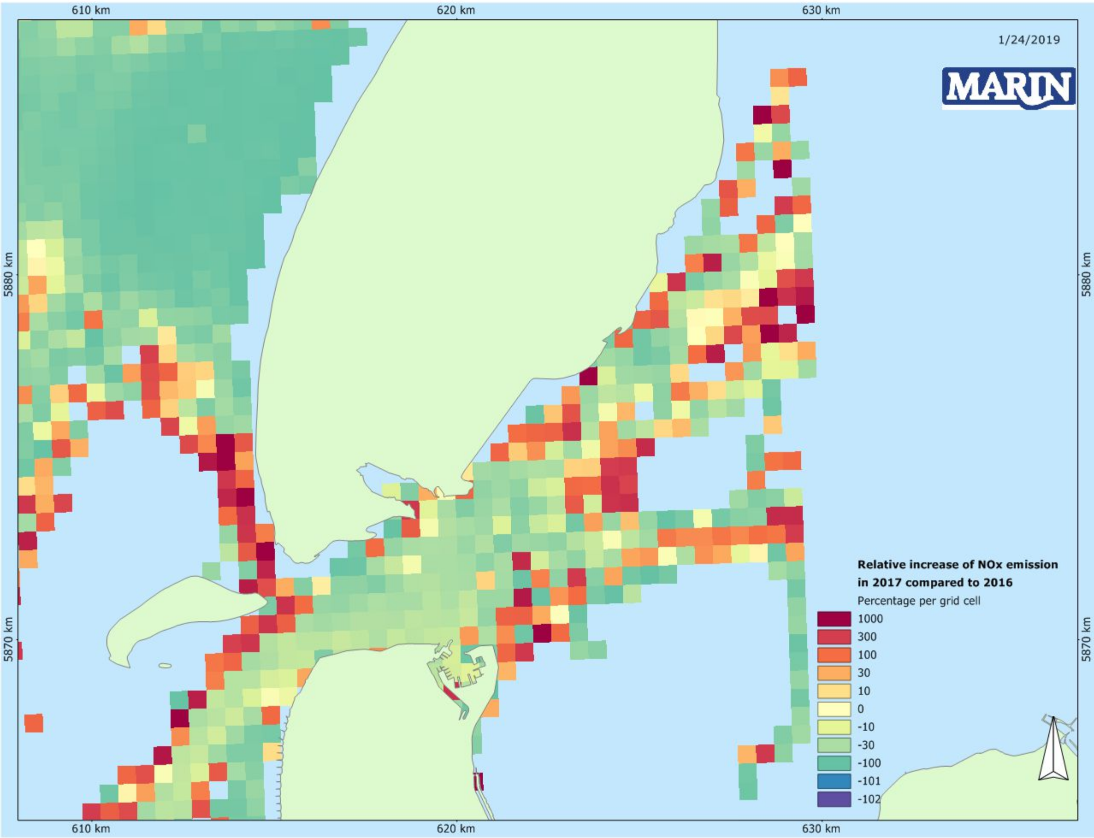

Figure 6-15 **Relative change in NO_x emission from 2016 to 2017 in the port area of Den Helder by ships with AIS.**

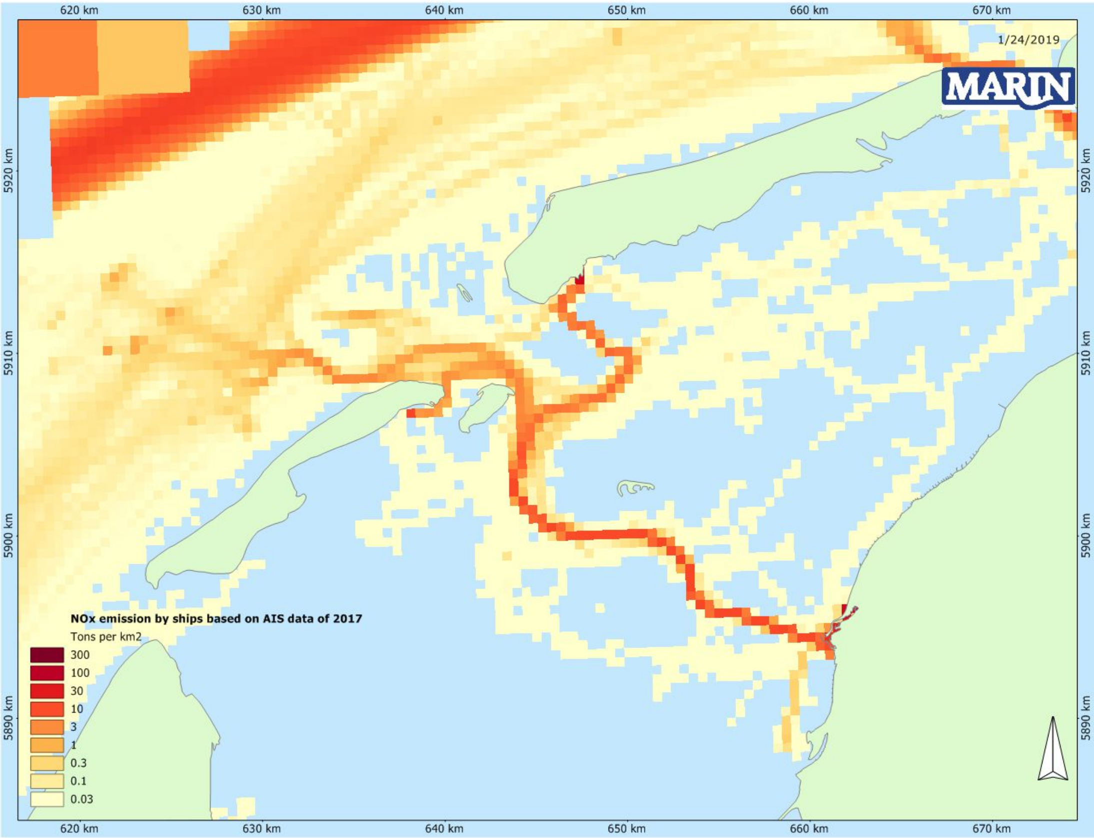

Figure 6-16 **NO_x emission in 2017 in the port area of Harlingen by ships with AIS.**

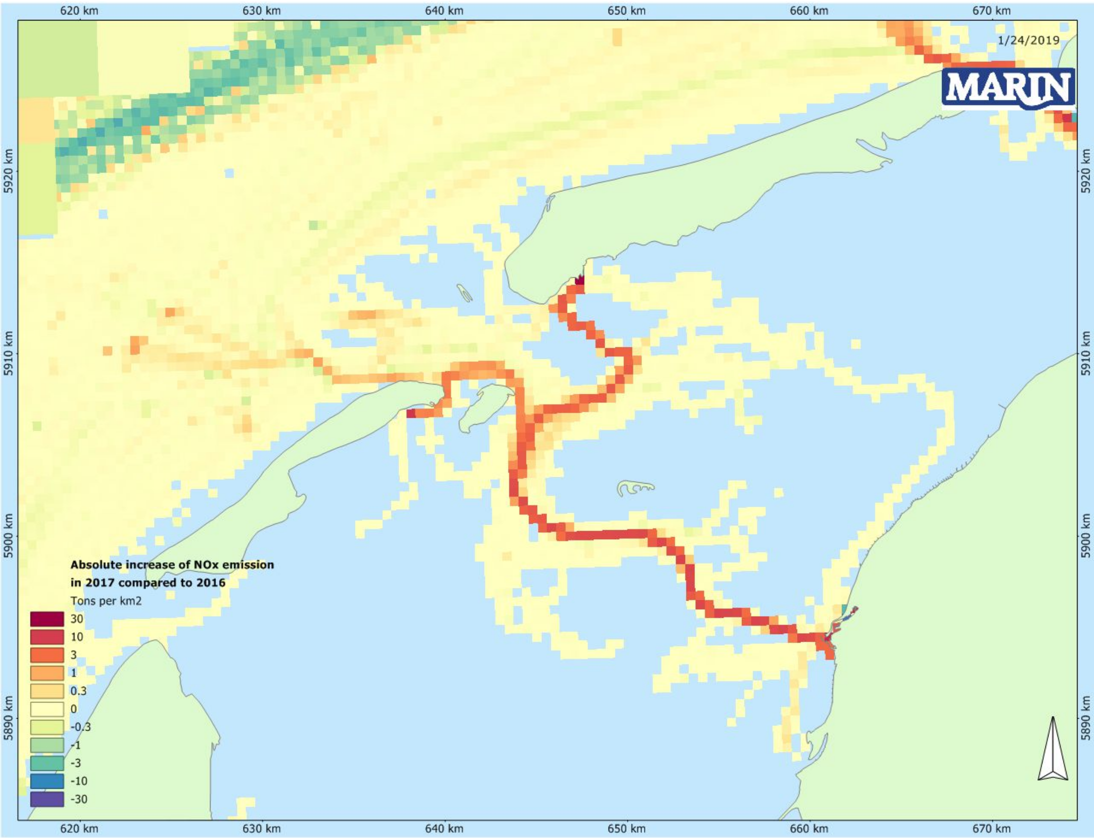

Figure 6-17 with **Absolute change in NO_x emission from 2016 to 2017 in the port area of Harlingen by ships AIS.**

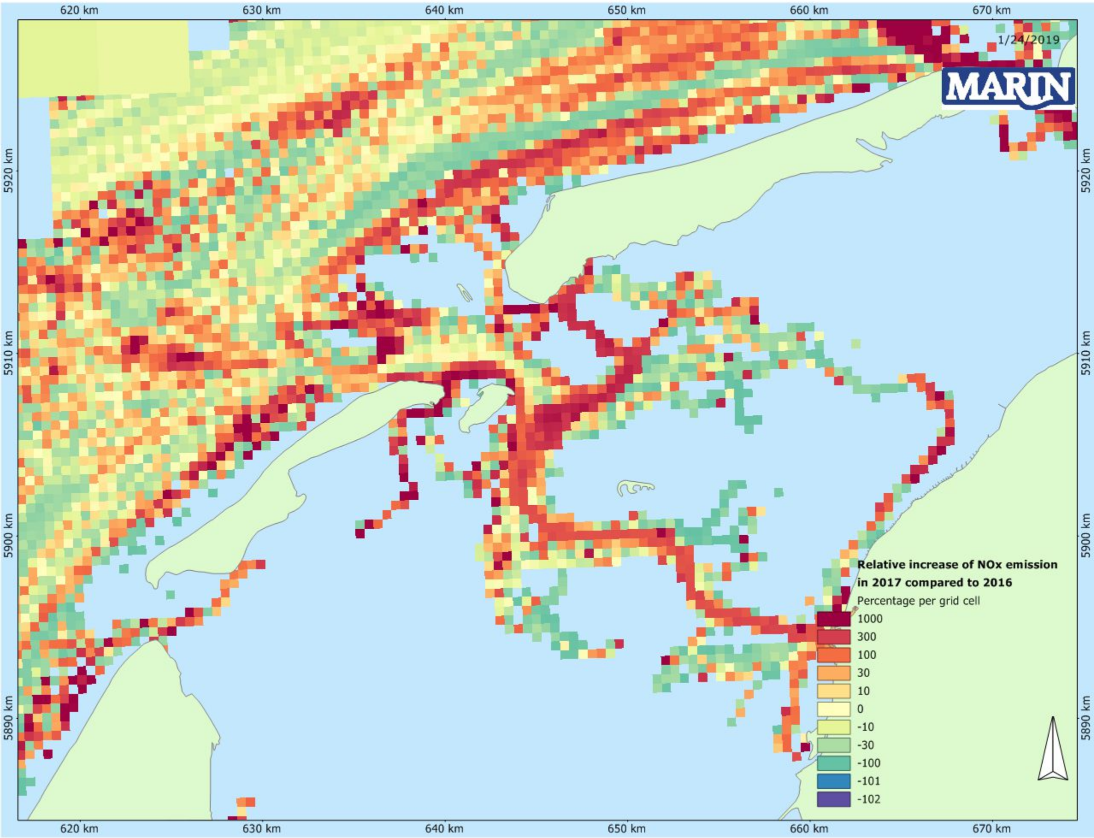

Figure 6-18 **Relative change in NO_x emission from 2016 to 2017 in the port area of Harlingen by ships with AIS.**

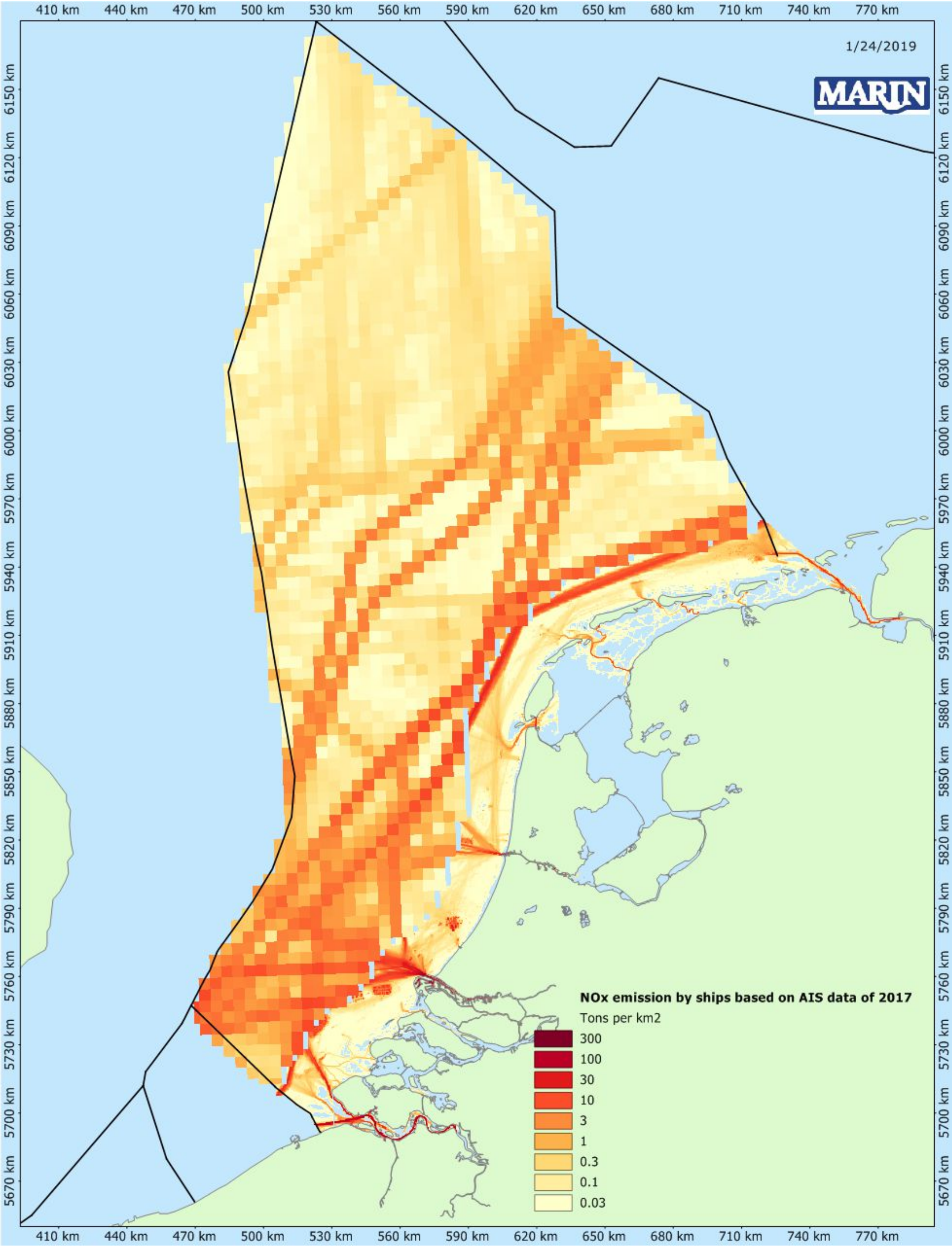

Figure 6-19 **NO_x emission in 2017 in the NCS, the 12-mile zone and the Dutch port areas by ships with AIS.**

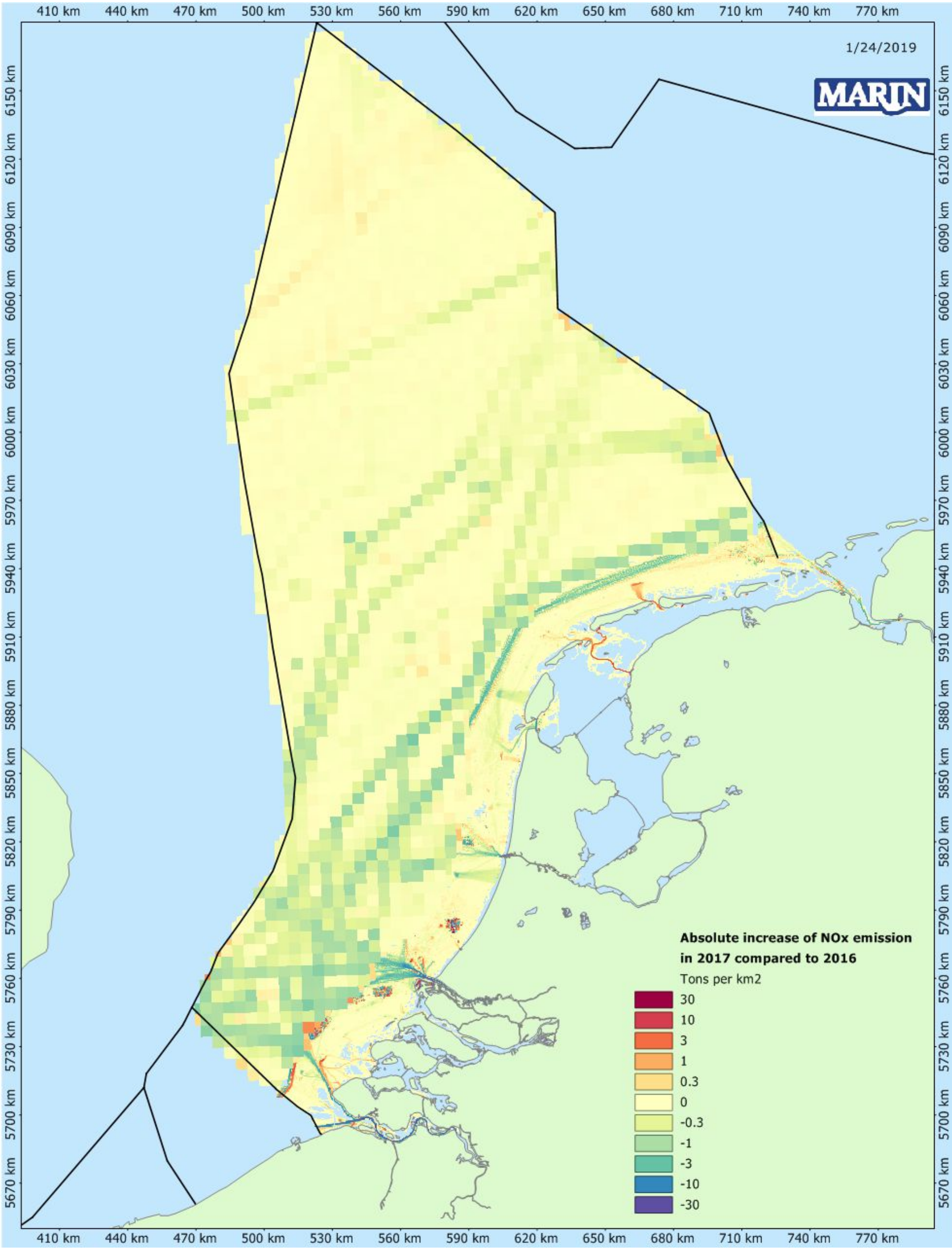

Figure 6-20 **Absolute change in NO_x emission from 2016 to 2017 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.**

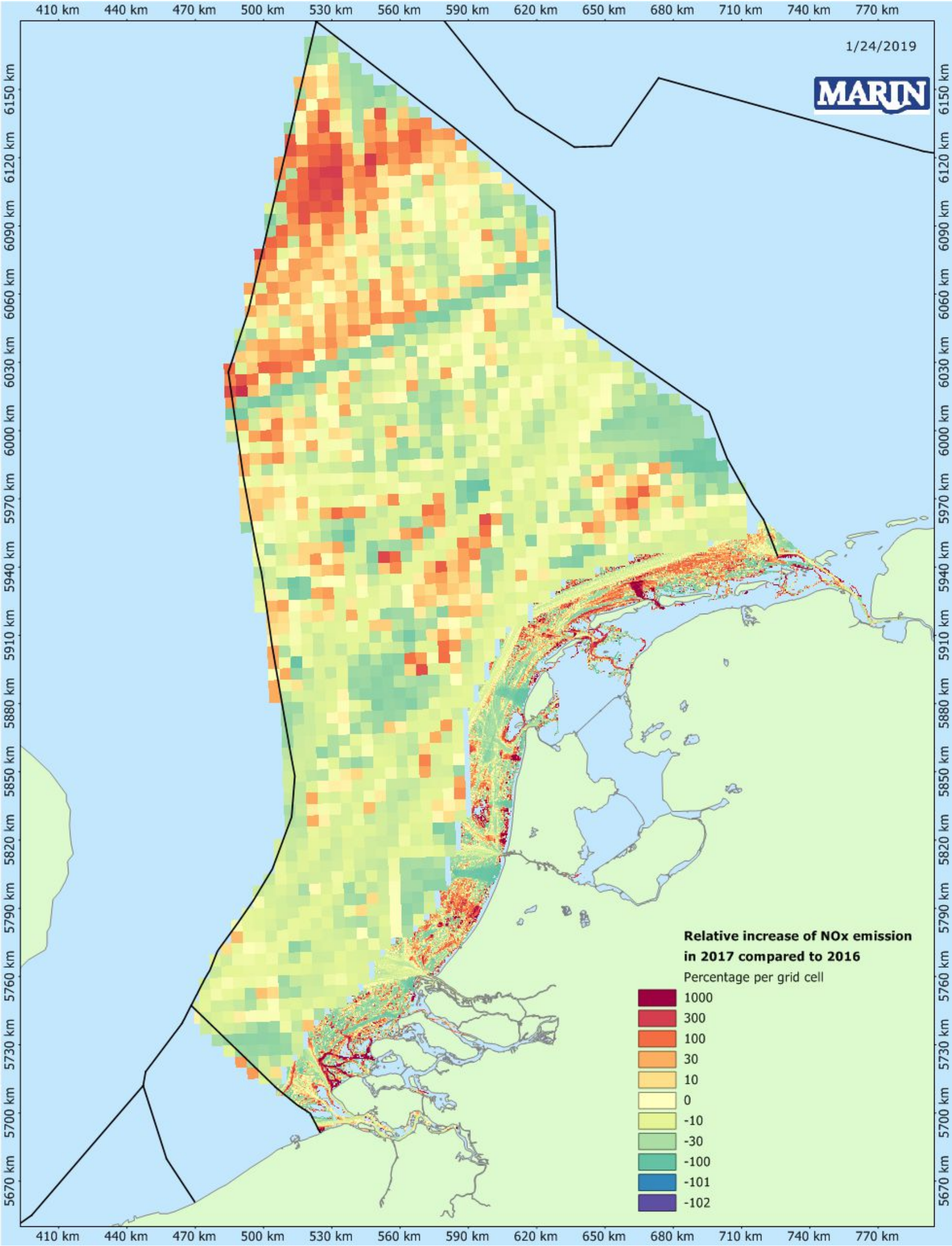

Figure 6-21 **Relative change in NO_x emission from 2016 to 2017 in the NCS, the 12-mile zone and in the Dutch port areas by ships with AIS.**

7 EMISSIONS FOR THE FISHING ACTIVITIES IN THE DUTCH PORT AREAS, THE WADDEN SEA AND THE NETHERLANDS SEA AREA

7.1 Introduction

This chapter presents the results of the emission calculations for 2018 for the fishing activities in the Dutch port areas, the Wadden Sea and the Netherlands sea area. The emissions of fishing vessels were introduced in the previous study, and the method and results were reported by TNO in reference [3] and in the Appendix A3.

7.2 Emissions of fishing vessels (EMS type 11)

In Table 7-1 he total emissions of fishing vessels are given in ton for each port area and the Wadden Sea and Table 7-2 presents the percentages compared with the previous year. Table 7-3 gives the total emissions of fishing vessels for the 12 miles zone and the NCP and Table 7-4 presents the percentages compared with 2016. Figure 1 up to figure 6 presents the spatial distribution of CO_2 for the NCS and the Dutch Wadden Sea.

It is clear from both the table and the figures that the contribution of CO_2 emissions by fishing vessels is largest in Harlingen, WesternScheldt and Den Helder. Compared to the previous year there is a clear increase of CO_2 emissions in WesternScheldt and a clear decrease in the port of Den Helder. For all ports together we see a clear decrease of CO_2 emissions, around 18 percent.

For the NCP and the 12-miles zone the average decrease of CO_2 emissions by fishing vessels is around 14 percent.

Overall a decrease of emissions can be seen for fishing vessels. This might be due to the ‘Masterplan Duurzame Visserij’ (MDV) since 2015 and the construction of new innovative fishing vessels with economic diesel engines or hybrid power systems [5].

Table 7-1 Total emissions in ton in each port area for 2017, fishing vessels including trawlers.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	4	2	3	1	2	4	0	16
	Sailing	1	1	1	1	2	7	1	13
	Total	5	2	4	1	4	11	2	29
4001 SO_2	Berthed	1	0	3	0	0	0	0	5
	Sailing	0	0	0	0	0	0	0	1
	Total	1	0	4	0	0	0	0	6
4013 NO_x	Berthed	96	51	81	13	52	116	9	417
	Sailing	36	13	20	13	43	178	27	331
	Total	132	64	101	26	95	294	37	748
4031 CO	Berthed	16	9	8	3	10	22	2	69
	Sailing	6	2	3	2	9	34	5	62
	Total	22	11	11	5	18	57	7	131
4032 CO_2	Berthed	6460	3847	4572	951	3689	8338	670	28528
	Sailing	2434	933	1289	1006	3170	13445	2031	24307
	Total	8894	4780	5861	1957	6859	21783	2701	52834
6598 Aerosols MDO/HFO	Berthed	2	1	1	0	1	3	0	10
	Sailing	1	0	0	0	1	6	1	10
	Total	3	2	1	1	3	9	1	20

Table 7-2 Emissions in each port area for 2017 as percentage of the emissions in 2016, fishing vessels including trawlers. The percentages in grey are based on very low absolute numbers, and not very reliable.

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Wadden	Total
1237 VOC	Berthed	151%	91%	38%	94%	38%	105%	198%	70%
	Sailing	150%	220%	102%	55%	56%	70%	95%	77%
	Total	151%	104%	44%	70%	45%	81%	109%	73%
4001 SO_2	Berthed	91%	74%	36%	67%	53%	260%	588%	44%
	Sailing	238%	100%	79%	171%	102%	152%	336%	123%
	Total	101%	76%	37%	115%	68%	183%	370%	48%
4013 NO_x	Berthed	163%	99%	40%	99%	42%	117%	217%	76%
	Sailing	166%	232%	105%	57%	57%	76%	101%	81%
	Total	164%	113%	46%	72%	48%	88%	117%	78%
4031 CO	Berthed	185%	102%	45%	99%	40%	114%	211%	84%
	Sailing	148%	245%	125%	51%	57%	74%	90%	78%
	Total	173%	116%	55%	68%	46%	86%	106%	81%
4032 CO_2	Berthed	177%	104%	39%	102%	42%	119%	221%	79%
	Sailing	173%	238%	116%	60%	58%	80%	106%	85%
	Total	176%	117%	46%	75%	48%	92%	121%	82%
6598 Aerosols MDO/HFO	Berthed	124%	79%	19%	90%	35%	97%	179%	61%
	Sailing	134%	197%	51%	53%	53%	71%	98%	73%
	Total	127%	92%	23%	66%	42%	78%	109%	66%

Table 7-3 Total emissions in ton in the 12 mile zone and the NCP for 2017, fishing vessels including trawlers.

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	2	0	3
	Sailing	18	33	52
	Total	21	34	55
4001 SO_2	Berthed	3	0	3
	Sailing	3	13	16
	Total	6	13	18
4013 NO_x	Berthed	63	10	73
	Sailing	456	919	1375
	Total	519	929	1448
4031 CO	Berthed	6	1	8
	Sailing	78	147	225
	Total	84	149	233
4032 CO_2	Berthed	3720	670	4391
	Sailing	32958	61996	94954
	Total	36679	62666	99345
6598 Aerosols MDO/HFO	Berthed	1	0	1
	Sailing	14	22	36
	Total	15	22	37

Table 7-4 Emissions in 12 miles and NCP for 2017 as percentage of the emissions in 2016, fishing vessels including trawlers. The percentages in grey are based on very low absolute numbers, and not very reliable.

Substance	Source	12 Miles	NCP	Total
1237 VOC	Berthed	88%	73%	86%
	Sailing	75%	75%	75%
	Total	76%	75%	76%
4001 SO_2	Berthed	81%	55%	78%
	Sailing	94%	55%	59%
	Total	87%	55%	61%
4013 NO_x	Berthed	91%	77%	89%
	Sailing	80%	84%	83%
	Total	81%	84%	83%
4031 CO	Berthed	95%	81%	92%
	Sailing	72%	89%	82%
	Total	73%	89%	82%
4032 CO_2	Berthed	91%	78%	89%
	Sailing	83%	87%	86%
	Total	84%	87%	86%
6598 Aerosols MDO/HFO	Berthed	22%	38%	25%
	Sailing	70%	52%	58%
	Total	64%	52%	56%

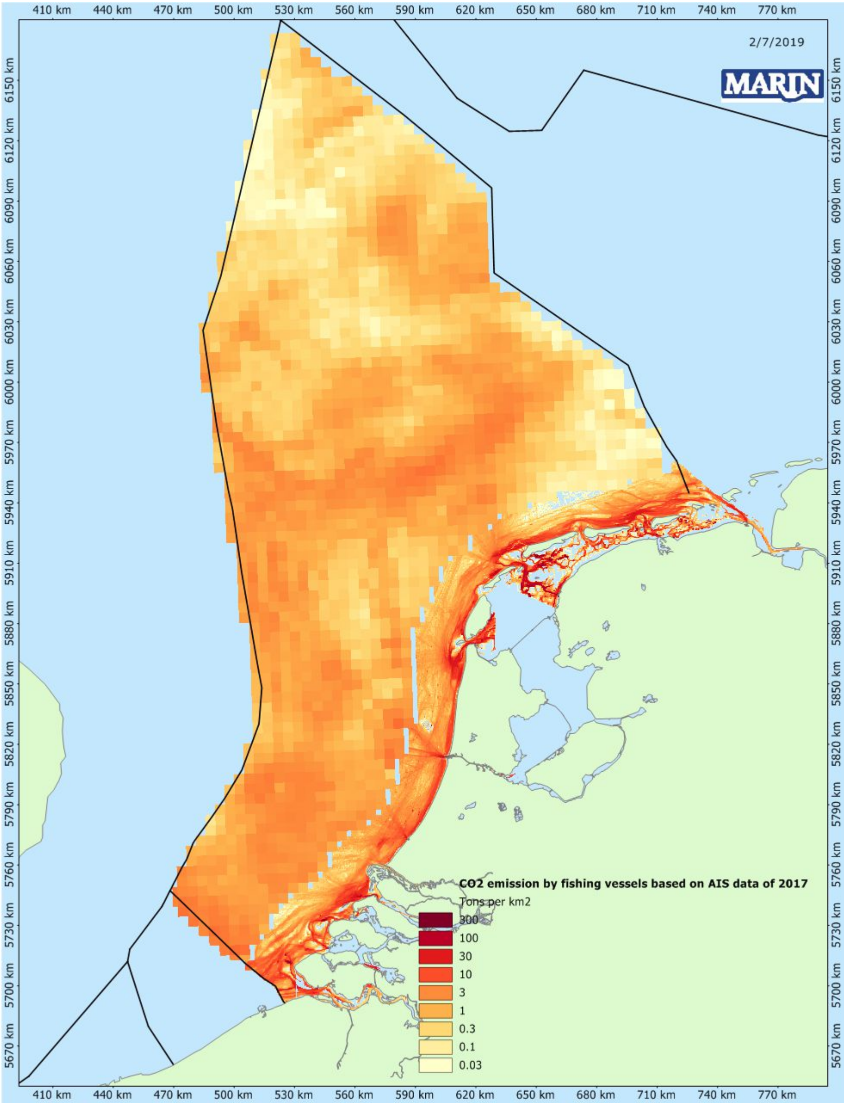

Figure 7-1 CO_2 emission observed in the NCS, fishing vessels including trawlers, based on AIS data of 2017

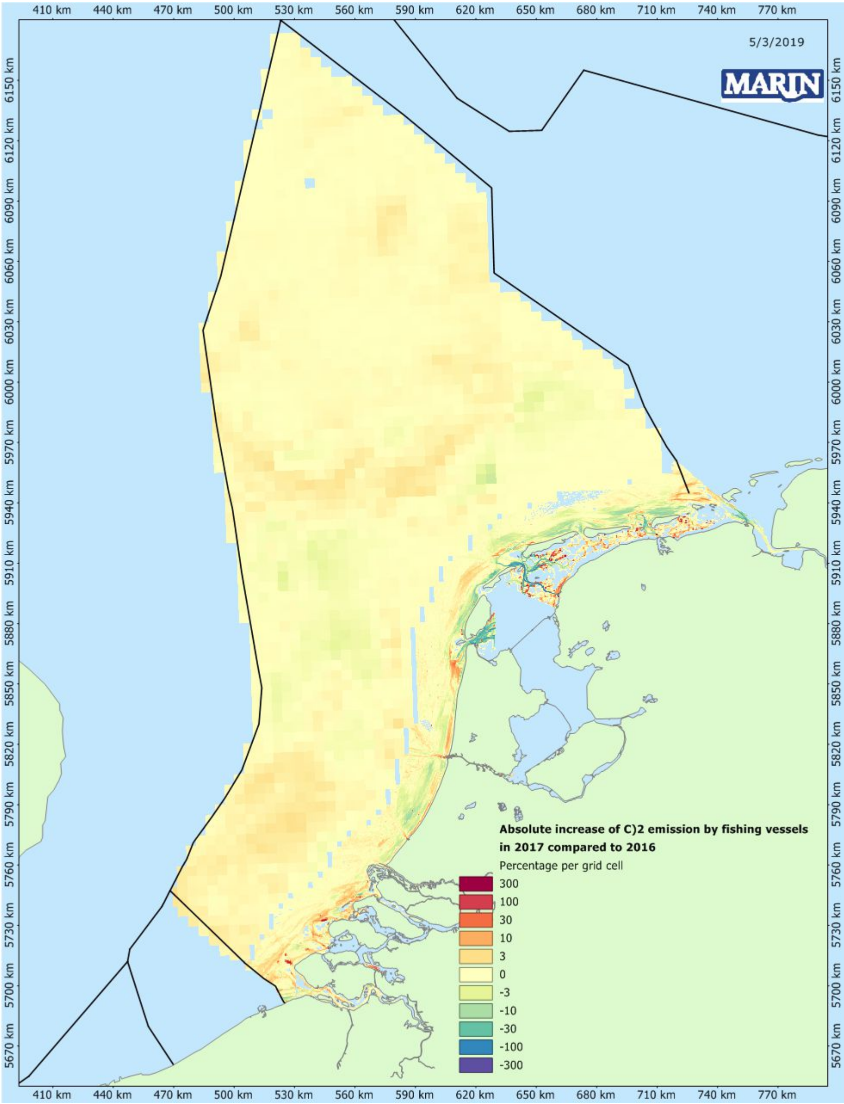

Figure 7-2 Absolute change in CO2 emission from 2016 to 2017 observed in the NCS, fishing vessels including trawlers.

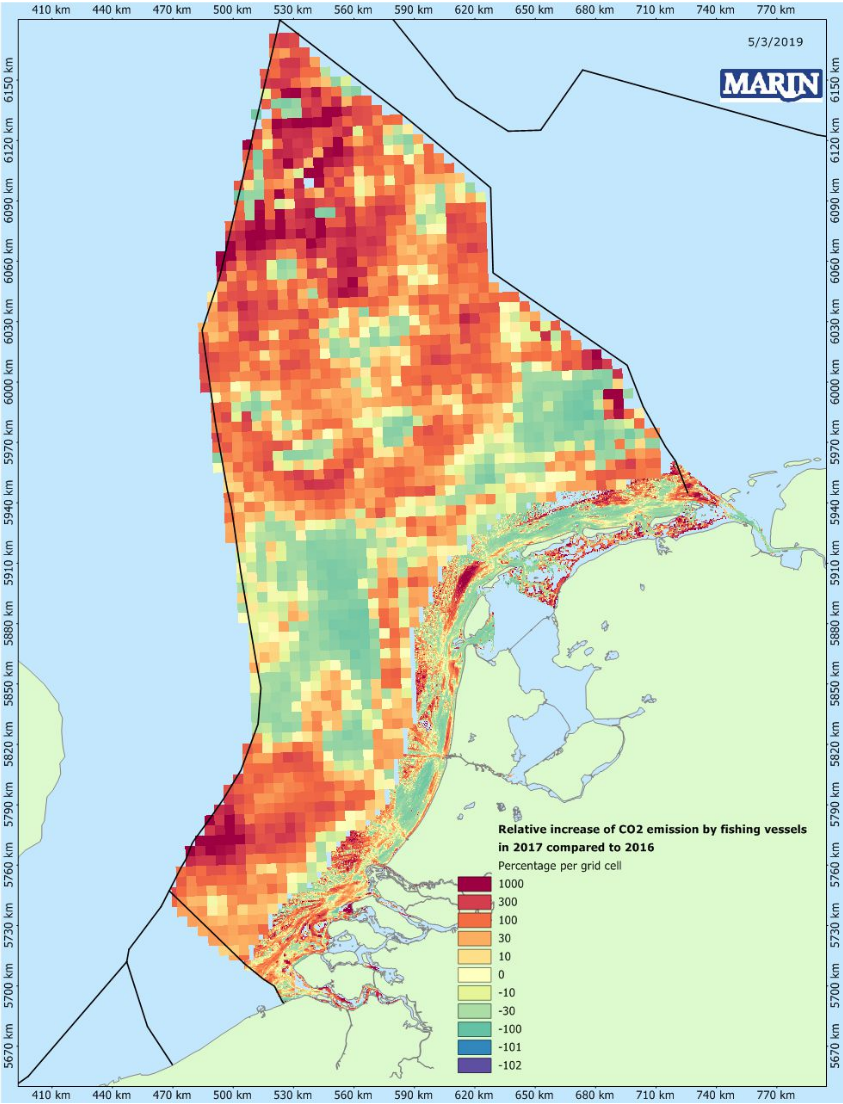

Figure 7-3 Relative change in CO2 emission from 2016 to 2017 observed in the NCS, fishing vessels including trawlers.

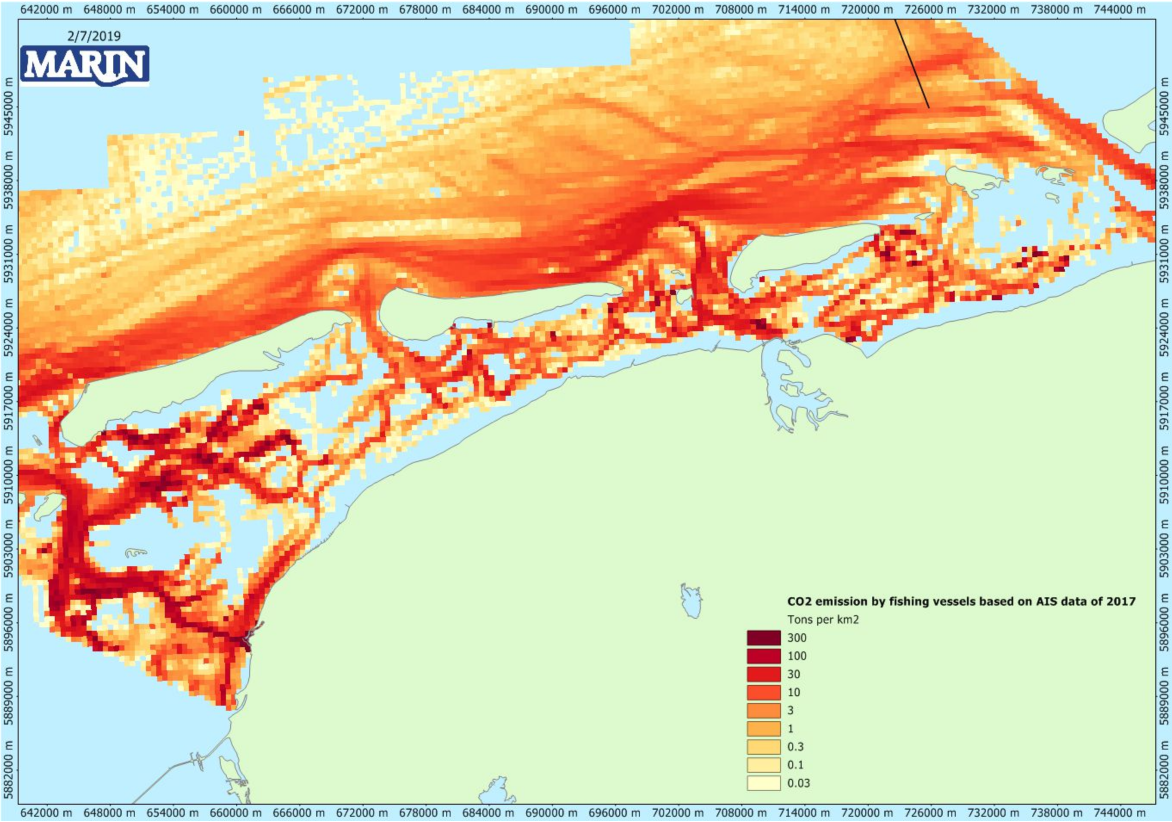

Figure 7-4 **CO_2 emission observed in the Dutch Wadden Sea, fishing vessels including trawlers, based on AIS data of 2017**

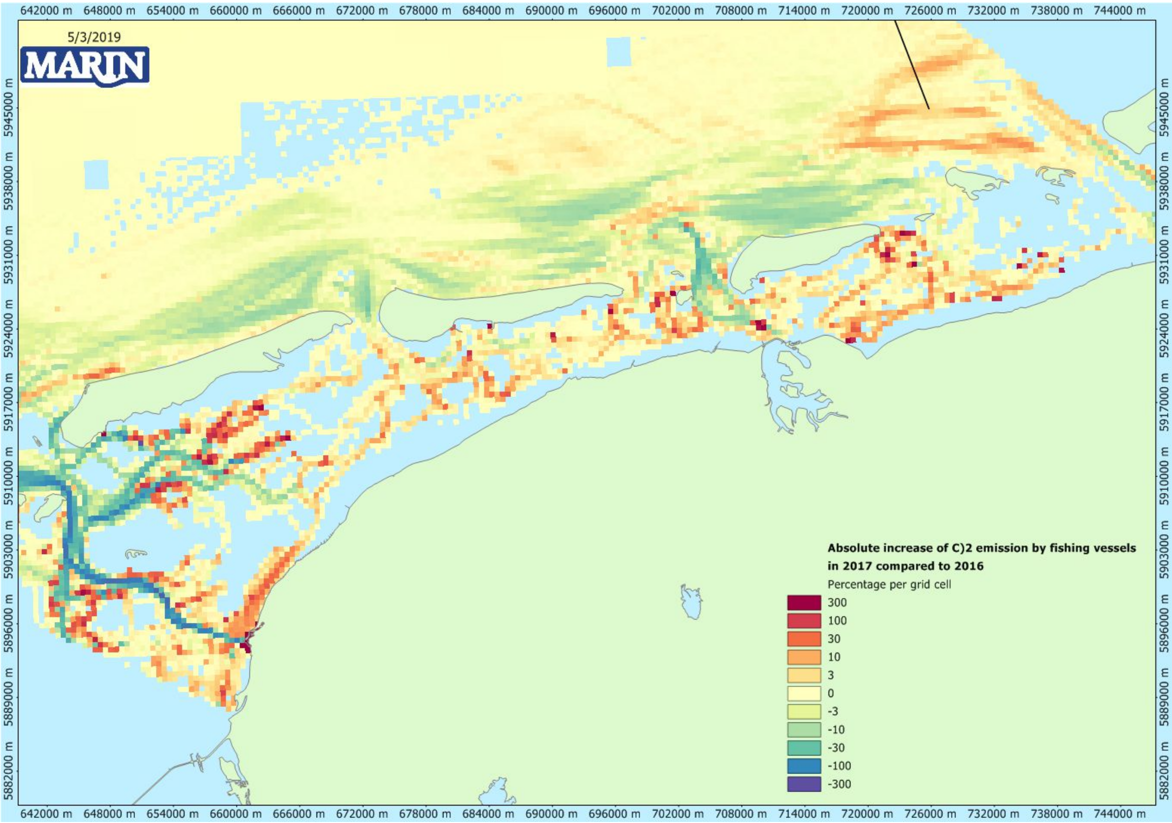

Figure 7-5 **Absolute change in CO2 emission from 2016 to 2017 in the Dutch Wadden Sea, fishing vessels including trawlers.**

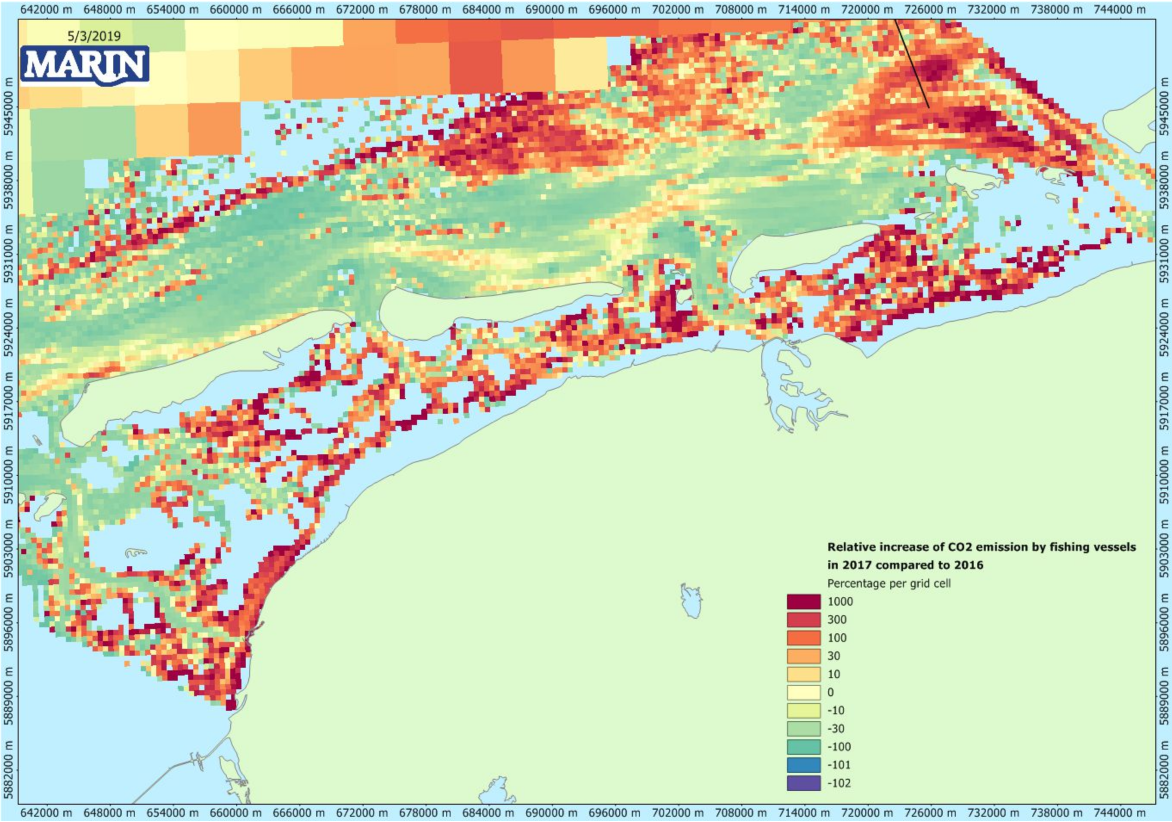

Figure 7-6 Relative change in CO2 emission from 2016 to 2017 in the Dutch Wadden Sea, fishing vessels including trawlers.

8 SUMMARY AND CONCLUSIONS

- **Deliveries**
  The main delivery of this study is a set of databases containing gridded emissions of seagoing ships, including fishing vessels, both at sea and in the Dutch port areas. These emissions are distinguished into ship type and size. Where applicable, the emissions are also distinguished into moving / not moving. These databases can be used in studies for which a detailed spatial distribution of the emissions is required.

- **Completeness of AIS data**
  The sum of periods missing which are larger than 10 minutes is approximately 1 day. To compensate for the missing period, the results are multiplied with a small correction factor: 365/364.

- **Activity data**
  Compared to the results presented in the previous study, most remarkable is the increase of berthed and moving ships in the port of Harlingen and the decrease of them in Den Helder. The increase for Harlingen is mainly due to an increase of the number of RoRo Cargo and Vehicle carriers. The decrease of berthed and moving ships in Den Helder might be due to the large dependency on the offshore industry. No distinctive differences are observed for moving ships in the NCP.

- **Emission results**
  Regarding the total emission for all port areas there is a clear decrease of emissions between 2016 and 2017, except for aerosols. For the emissions of CO_2 there is an overall reduction around 18 percent. Emissions in Harlingen and Ems have risen which is in line with a grow of activities in these ports.

  A decrease in SO_2, NO_x and CO_2 is clearly visible for the NCS and the 12-mile zone, approximately ten percent. The total average number of ships on the North Sea is of the same order of magnitude as compared to previous year.

  The difference between both calculation methods has no impact on the emissions for non moving ships. For moving ships we see an increase of emissions in tons around 10 percent when using method 1.

- **Emission results Fishery**
  Overall a clear decrease of emissions can be seen for fishing vessels. In all ports together around 18 percent and for the NCP and the 12-miles zone around 14 percent. This might be due to the ‘Masterplan Duurzame Visserij’ (MDV) since 2015 and the construction of new innovative fishing vessels with economic diesel engines or hybrid power systems.

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APPENDIX A: EMISSION FACTORS

Written by Jan Hulskotte of TNO

A1 SAILING AND MANOEUVRING

A1.1 Main Engines

During sailing and manoeuvring, the main engine(s) are used to propel/manoeuvre the ship. Their emission factors per ship, in g per kWh, were determined by TNO according to the EMS protocols [1, 2]. An English language report [5] is available, which covers the emission calculations in accordance with the EMS protocols. In the emission factor calculation, the nominal engine power and speed are used. For this study these parameters were taken from the LLI database of September 2016 as far as new valid data were available. In the case that only one single main engine is present, it is assumed that a vessel requires 85% of its maximum continuous rating power (MCR) to attain the design speed (its service speed). When multiple main engines are present some more assumptions have to be made in order to calculate the required power of the main engines. This is described in the next paragraph 0.

The following formula is used to calculate the emission factor per nautical mile.

Formula 1:

$$EF' = EF * CEF * \frac{P * fMCR}{V}$$

where:

EF’	Actual emission factor expressed as kg per nautical mile
EF	Basic engine emission factor expressed as kg per KWh (Table A-3/Table A-10)
CEF	Correction factors of basic engine emission factors (Table A-12/Table A-14))
P	Engine power [KiloWatts]
fMCR	Actual fraction of the MCR
V	Actual vessel speed [knots]

The correction factors of basic engine emission factors (CEF) reflect the phenomena that cause the emission factors to change when engines are active in sub-optimal power ranges.

Besides this change in emission factors, ships do not always sail at their designed speed. As such, the actual power use has to be corrected for the actual speed. The power requirements are approximately proportional to the ship’s speed to the power of three. For very low speeds this approximation would underestimate the required power, since manoeuvring in restricted waters increases the required power. Furthermore, engines are not capable of running below a certain load (minimal fuel consumption of 10% compared to full load). To account for this, the cubed relationship between speed and power is adjusted slightly to:

Formula 2:

$fMCR = CRScor * (1\text{-Sea margin}) = ([(V_{actual}/V_{design})^n + c] / (1+c)) * (1\text{-Sea margin})$

Following values are used in calculations that are reported:
Sea margin = 15%
n = 3.2 (value was 3.0 in previous reports)
c = 0.1 (value was 0.2 in previous reports)

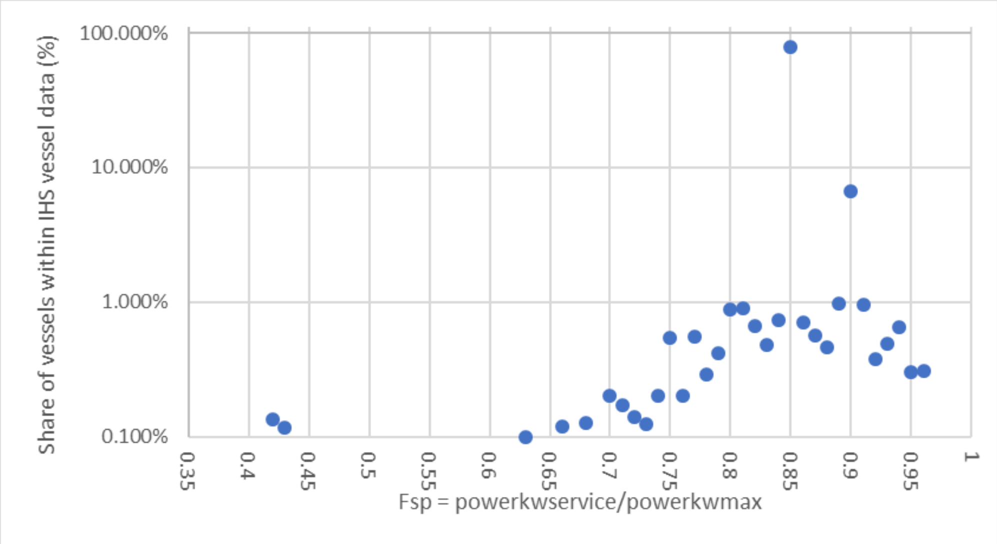

Figure A- 1 Statistics of the Sea-margin

Figure A-1 shows that of the majority of this vessels (about 80%) the power of reaching the service speed is exact 85% of the maximum rated power (Sea Margin = 15%) and for about 7% of the vessels the power of reaching the service speed is exact 90% of the maximum rated power (Sea margin = 10%). These data justify the application of 15% Sea margin within Formula 2.
Using data of sea trials MARIN (D.R. Schouten & T.W.F. Hasselaar [4]) has advised a value of 3.2 for n in Formula 2. Concerning the choice of a proper value of c no clear data were found in the literature. However it is obvious that the value of zero (used in many studies) will deliver far too low emission data in the low speed range. I a service letter concerning “low load operation” MAN diesel (Jensen and Jacobsen, 2009) show fuel usage of just below 20% of maximum usage around 55% of the service speed. The result of the parameters chosen in formula 2 confirm this number for the fuel usage around 55% of the service speed.
Note that the Correction Reduced Speed factor CRS_{cor} has to be capped at a maximum of 1.176, since this is the value for which 100% engine power is reached. In Figure A-2 the relationship is shown between the speed relative to the service speed and the power relative to the rated power of the ships single propulsion engine as implied in formula 2.

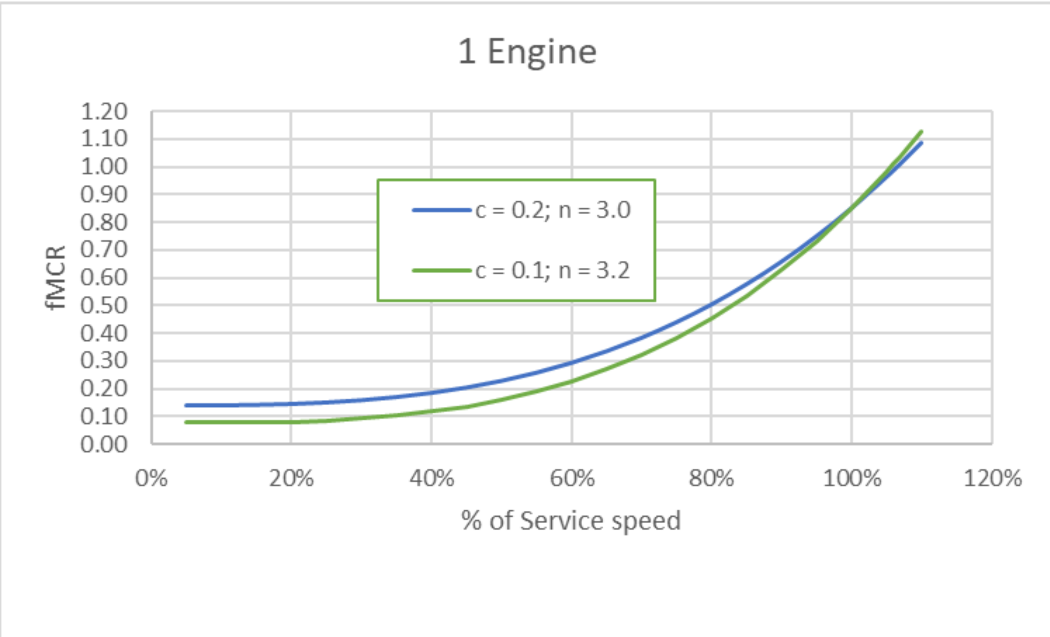

Figure A- 2 The relationship between service speed and fMCR at ships with one single propulsion engine used in emission calculations

A1.2 Multiple propulsion engines

When a ship has multiple main propulsion engines, probably not all of these engines will be used in all situations. For instance, many specialised ships have specialised installations that are only used when these ships are performing their specialised tasks (dredgers, supply ships, icebreakers, tugs etc.). Other ships may have redundant engine capacity for safety and other reasons (passenger ships, roro-ships). It is rather difficult to account for the usage of multiple engines within emission calculations, since many differences will exist between individual ship designs. All kinds of possible situations which are not known from the AIS-data may have different influence on emissions from different ships types. Nevertheless, ignoring the existence of multiple engines is not realistic. The presence of multiple engines on some ship types (i.e. passenger and roro-ships) could lead to serious underestimation of total emissions because only the power of the largest engine was taken into account until the emission calculation for 2010.

Before going into an analysis of the usage of main engines when multiple engines are present, it is interesting to analyse which number of engines occurs so often that it has a significant influence on total emissions. In table A-1 it is shown that at ships with multiple engines, only ships with 2 and 4 engines contribute significantly to the total installed power of the whole seagoing fleet. The same conclusion will probably hold with respect to the contribution to total emissions. Therefore, it can be justified to concentrate the analysis on ships with 2 and 4 propulsion engines.

Table A- 1 World seagoing fleet with number of installed main engines and their total installed power and average installed power per ship

Main Engine count	Ships count	Total power installed MW	Average power installed per ship MW	% of total power installed
1	109,489	534,901	4.9	80.9%
2	24,011	87,343	3.6	13.2%
3	926	4,459	4.8	0.7%
4	1,912	25,822	13.5	3.9%
5	89	1,551	17.4	0.23%
6	177	5,992	33.9	0.91%
7	4	139	34.8	0.02%
8	31	1,017	32.8	0.15%
9	6	261	43.5	0.04%
10	1	3.0	3.0	0.00%
12	2	15.6	7.8	0.00%
	136,648	661,504	4.8	100.0%

As a data source for daily fuel usage the ship characteristic database-item FUEL_CONSUMPTION of the LLI database was analysed. Daily fuel consumption is given for only about 10.000 ships. By far, most of these 10.000 ships are ships with a single main engine. In order to perform a check on the emission calculation, a check on the fuel consumption serves as a very good proxy. When fuel consumption is modelled properly, emission calculation probably will give results with comparable accuracy.

To estimate the daily fuel consumption of a ship (ton/day) we applied a very simple formula:

FC = Active_Engines * MCRss * Power * SFOC * 24/1000.

FC	: Daily fuel oil consumption (ton/day)
Active_Engines	: number of active engines involved in normal propulsion (-)
MCRss	: fraction of power to reach service speed (0.85 for single engine ships, for more engines see table **A-2**)
Power	: power of a single engine (MW)
SFOC	: specific fuel oil consumption (kg/MWh)
24/1000	: 24 hours/day;1000 kg/ton

Note that the calculation of fuel consumptions is completely parallel to the calculation of emissions. Instead of EF, approximate values of the SFOC are used. Because (in the LLI database) the service speed is assumed, the values of CEF in the calculation can be ignored because the values will be very close to 1.

The SFOC (specific fuel oil consumption) applied is 0.175 (kg/kWh) for engines above 3 MW and 0.200 (kg/kWh) for engines equal to and below 3 MW. As a reference for these values, see for instance the tables A-3 to A-6.

As a reference for ships with multiple engines, the fuel consumption of ships with 1 main engine is shown. So far, a power setting of 85% MCR is assumed in modelling ship's emissions. It can be seen in Figure A2 that this assumption gives rather accurate results for the majority of ships (but not all ships) with one main engine. The 7918 ships of which data on fuel consumption was available had an average *calculated* fuel consumption of 24.8 ton/day by the main engine while the average *specified* fuel consumption was 26.1 ton/day. This implies that calculated fuel consumption (on average) on the service speed seems to be 5% lower than the specified fuel consumption. Given the number of possible uncertainties this does not seem to be a major difference.

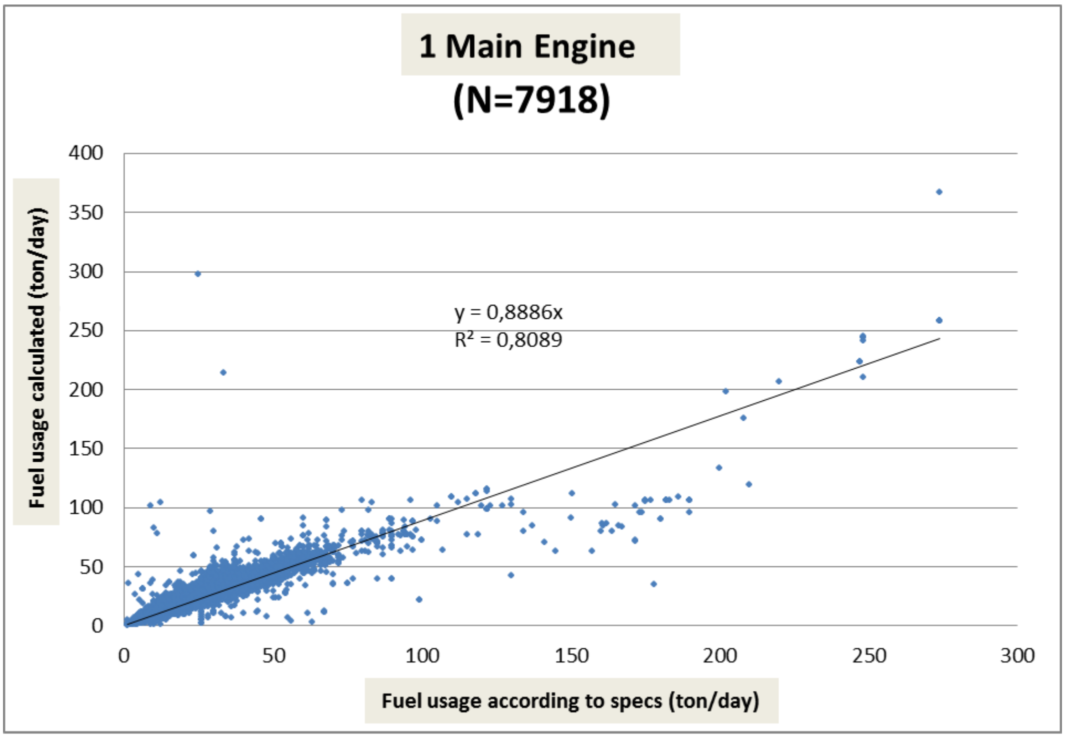

Figure A- 3 Calculated daily fuel usage of one engine ships compared with specifications

For ships with two main engines two active engines were assumed and 75% MCR (instead of the standard of 85% [13]) to reach the service speed. It can be seen in Figure A-3 that these assumptions give rather accurate results for the majority of ships with two main engines. The 546 ships of which data on fuel consumption are available show an average calculated fuel consumption of 35.7 ton/day while the average specified fuel consumption is 35.6 ton/day.

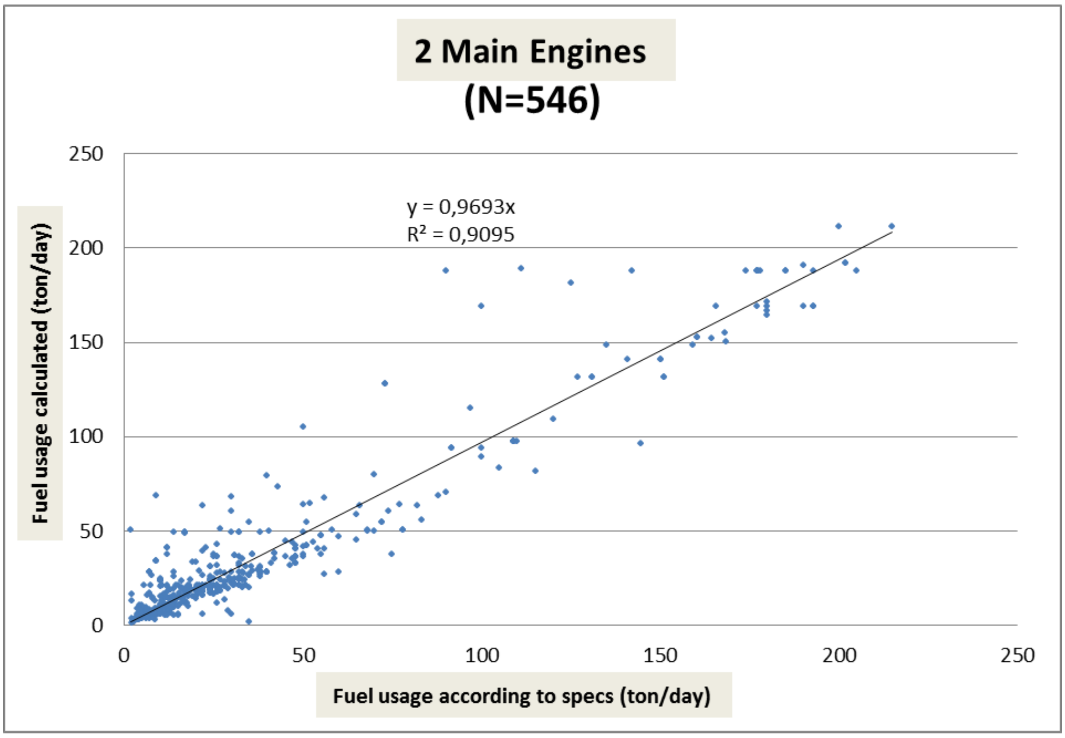

Figure A- 4 Calculated daily fuel usage of two engine ships compared with specifications

For ships with four main engines four active engines were assumed and also 75% MCR (instead of the standard of 85%) to reach the service speed. As can be seen in Figure A-4 much less data is available for four engine ships which causes more scatter in the data. The 29 ships of which data are available show an average *calculated* fuel consumption of 39.2 ton/day while the average *specified* fuel consumption is 32.8 ton/day.

It has to be mentioned that some data filtering was applied to four engine ships. Excluded in the analysis are special cases such as high speed ferries, supply and service vessels, tugs and fishing ships and one ship mainly propelled by LNG.

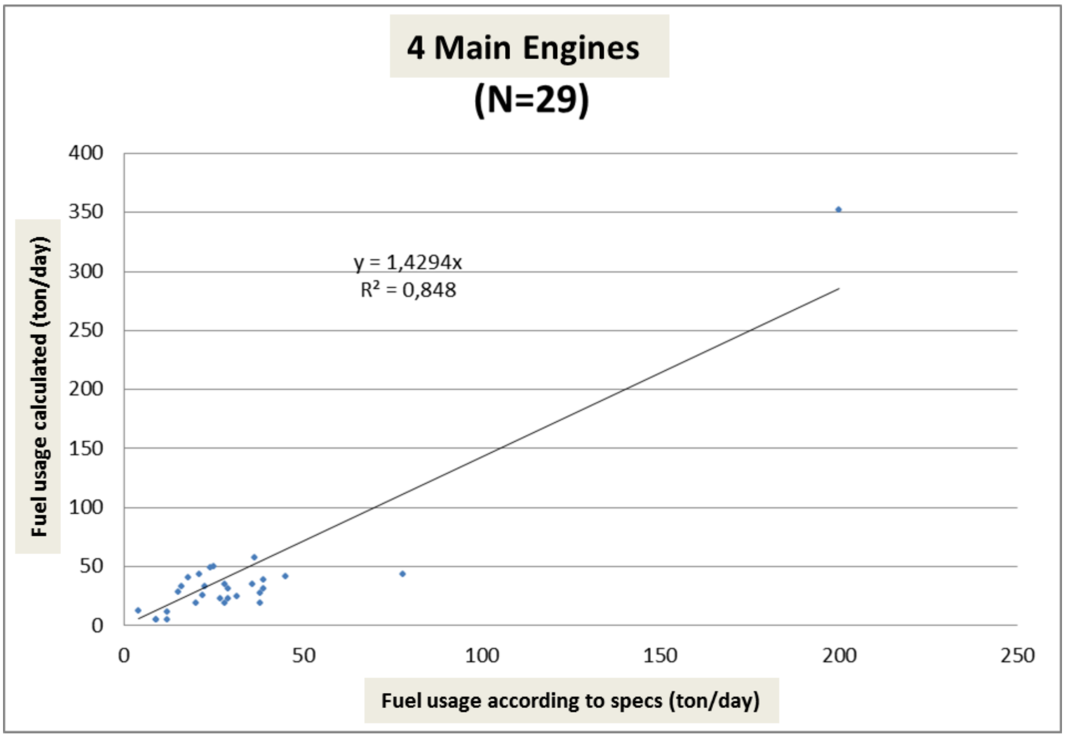

Figure A- 5 Calculated daily fuel usage of four engine ships compared with specifications

It can be argued that energy consumption of four engine ships seems to be overestimated by the assumptions that are applied, but with such a small dataset it is hard to determine whether the assumptions on ships with four main engines are correct or not. Even if there is an overestimation, this will probably not lead to big differences in total emissions, since the contribution of four engine ships in total installed power is below 4% (Table A- 1).

For ships with other numbers of main engines the available data did not allow any check of possible assumptions on the fuel consumption.

Apart from the check of fuel consumption of two and four engine ships as presented above, for ships with three or five to twelve engines additional assumptions had to made in order to enable calculation of emissions of these ships. These assumptions are shown in Table A-2 and are rather uncertain. However, the total installed power is only 2% and therefore, the influence on total emissions will be minimal.

Table A- 2 Maximum number of engines assumed to be operational for propulsion with multiple engines present and the fraction of MCR assumed (MCR_{ss}) to attain the service speed

Ship type	Engines Present → / Engines Operational ↓	2	3	4	5	6	7	8	9	10	12
Oil tanker	2	0.75	0.85								
	4			0.75							
Chemical/LNG/LPG tanker	2	0.75	0.85								
	4			0.75		0.75					
	6								0.75		
Bulk carrier	2	0.75	0.85								
	4			0.75	0.75	0.75					
Container ship	2	0.75	0.85								
	4			0.75	0.75	0.75	0.75	0.75			
	6								0.75	0.75	
General Dry Cargo	2	0.75	0.85								
	4			0.75	0.75	0.75		0.75			
RoRo Cargo / Vehicle	2	0.75	0.85								
	4			0.75	0.75	0.75		0.75			
Reefer	2	0.75	0.85								
	4			0.75	0.75						
Passenger	2	0.75	0.85	0.75		0.75			0.75		
Miscellaneous	2	0.75									
	4			0.75							
Tug/Supply	2	0.65	0.85	0.8	0.75	0.85	0.75	0.75	0.75		0.75
Fishing	2	0.75	0.85								
Non Merchant	2	0.5	0.85	0.75	0.75	0.75	0.75	0.75			0.75

The calculation of emissions with multiple engines becomes more complicated because the number of active engines has to be calculated separately. For this reason the calculation of EF' is slightly different from formula 1.

Formula 3:

$$EF' = EF * CEF * \frac{NoEA * P * fMCR}{V}$$

EF' Actual emission factor expressed as kg per nautical mile
EF Basic engine emission factor expressed as kg per KWh (Table A-3/Table A-10)
CEF Correction factors of basic engine emission factors (Table A12/Table A-14)
NoEA Number of active engines (engines that actually are working on a certain moment)
P Engine power of one single engine [Watts]
*f*MCR Actual fraction the MCR of active engines
V Actual vessel speed [knots]

Formula 4:

NoEA =
minimum (Engines Operational, round (CRS_{cor} * Engines Operational * MCR_{ss})+1)

(Note that the Number of active engines depends on the level of CRScor, which depends on the ships speed, and that the maximum number of active engines is equal to Engines Operational).

Formula 5:

*f*MCR= [Engines Operational]/NoEA * CRScor * MCRss

The *f*MCR for individual ship engines is linear inversely related to the Number of active engines (more engines active give lighter work for individual engines). In essence Formula 3 is the same as Formula 1 except the accounting of Engines Active in the available total Engine power and the application of modified *f*MCR in the selection of the CEF-values (Formula 5).

A1.3 Auxiliary Engines and Equipment

Aside from the main engines, most vessels have auxiliary engines and equipment that provide (electrical) power to the ship's systems. There is very little information available on the use of auxiliary engines. Perhaps the best estimate to date has been made in the *Updated 2000 Study on Greenhouse Gas Emissions from Ships* report (Buhaug et al., 2008, [3]), to which many ship experts contributed. The percentage of the auxiliary power compared to the main engine power as presented in Table 14 of the Buhaug et al report [3] was used in this study. The percentage taken from Buhaug was multiplied with the main power of each individual ship of which no details of auxiliary power are included in the LLI-database. For those ships of which the auxiliary power was included in the LLI-database, the loadfactor of auxiliary engines given by Buhaug specified per ship type was applied on the biggest auxiliary engine of the individual ship as inferred from the LLI-database.

A1.4 Engine Emission Factors

Table A-3 to Table A-10 show the engine emission factors [1], [2] per engine type and fuel type expressed in grams per unit of mechanical energy delivered by ships engines (g/kWh). Partial implementation of the SECA according to the MARPOL Annex VI in 2016 has been assumed. The reason behind this decision is that very little response by national government(s) in Europe has been observed on the Trident Alliance initiative (a group of important stakeholders demanding proper enforcement). As a consequence, the sulphur percentage in heavy fuel oil is set on 0.5% and the sulphur percentage in marine diesel oil is assumed to be 0.25% in the NCP part of the SECA. In the harbour areas, however, full implementation is assumed (all fuels set on 0.1% m/m sulphur).
Linear relations exist between SFOC and SO2 and CO2 depending on fuel quality. SFOC values as such are not used in emission calculations.
PM-reduction is associated with sulphur reduction because a certain fraction of oxidised sulphur is emitted as sulphuric acid which easily condenses to sulphuric acid particles (PM) in exhaust gases. Based on the sulphur reductions, additional PM reductions were estimated applying a linear relationship between sulphur and PM as demonstrated in [12].

Table A- 3 Emission factors and specific fuel oil consumption (SFOC) applied on slow speed engines (SP) operated on heavy fuel oil (HFO), (g/kWh)

Year of build	NO_x	PM-HFO NCP[1]	PM-HFO Other[2]	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 – 1973	16	0.47	0.43	0.84	0.42	0.6	0.75	666	210
1974 – 1979	18	0.46	0.43	0.80	0.40	0.6	0.75	635	200
1980 – 1984	19	0.46	0.43	0.76	0.38	0.6	0.75	603	190

1 NCP: Dutch Continental Shelf
2 Other areas: Include harbours areas

1985 – 1989	20	0.46	0.43	0.72	0.36	0.6	0.63	571	180
1990 – 1994	18	0.46	0.43	0.70	0.35	0.5	0.5	555	175
1995 – 1999	15	0.35	0.33	0.68	0.34	0.4	0.5	539	170
2000 – 2010	~rpm[3]	0.35	0.33	0.67	0.34	0.3	0.5	533	168
2011 – 2016		0.25	0.23	0.66	0.33	0.3	0.5	524	165

Table A- 4 Emission factors and specific fuel oil consumption (SFOC) applied on slow speed engines (SP) operated on marine diesel oil (MDO), (g/kWh)

Year of build	NO_x	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 - 1973	16	0.37	0.33	0.84	0.42	0.6	0.75	666	210
1974 - 1979	18	0.36	0.33	0.80	0.40	0.6	0.75	635	200
1980 - 1984	19	0.36	0.33	0.76	0.38	0.6	0.75	603	190
1985 – 1989	20	0.36	0.33	0.72	0.36	0.6	0.63	571	180
1990 – 1994	18	0.36	0.33	0.70	0.35	0.5	0.5	555	175
1995 – 1999	15	0.25	0.23	0.68	0.34	0.4	0.5	539	170
2000 – 2010	~rpm[1]	0.25	0.23	0.67	0.34	0.3	0.5	533	168
2011 – 2016		0.25	0.23	0.66	0.33	0.3	0.5	523	165

Table A- 5 Emission factors and specific fuel oil consumption (SFOC) applied on medium/high speed engines (MS) operated on Heavy fuel oil (HFO), (g/kWh)

Year of build	NO_x	PM-HFO NCP	PM-HFO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 – 1973	12	0.67	0.64	0.90	0.45	0.6	0.75	714	225
1974 – 1979	14	0.67	0.63	0.86	0.43	0.6	0.75	682	215
1980 – 1984	15	0.67	0.63	0.82	0.41	0.6	0.75	651	205
1985 – 1989	16	0.66	0.63	0.78	0.39	0.6	0.63	619	195
1990 – 1994	14	0.66	0.63	0.76	0.38	0.5	0.5	603	190
1995 – 1999	11	0.56	0.53	0.74	0.37	0.4	0.5	587	185
2000 – 2010	~rpm[1] 9[2]	0.56	0.53	0.73	0.37	0.3	0.5	581	183
2011 - 2016	~rpm 7[2]	0.56	0.53	0.90	0.36	0.3	0.5	571	180

[2] applied on auxiliary engines only

[3] Dependant on revolutions per minute (Table A-8)

Table A- 6 Emission factors and specific fuel oil consumption (SFOC) applied on medium/high speed engines (MS) operated on marine diesel oil (MDO), (g/kWh)

Year of build	NO_X	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
1900 - 1973	12	0.37	0.33	0.90	0.45	0.6	0.75	714	225
1974 - 1979	14	0.37	0.33	0.86	0.43	0.6	0.75	682	215
1980 - 1984	15	0.37	0.33	0.82	0.41	0.6	0.75	650	205
1985 - 1989	16	0.36	0.33	0.78	0.39	0.6	0.63	619	195
1990 - 1994	14	0.31	0.33	0.76	0.38	0.5	0.5	603	190
1995 - 1999	11	0.26	0.23	0.74	0.37	0.4	0.5	587	185
2000 - 2010	~rpm[1] 9[2]	0.26	0.23	0.73	0.37	0.3	0.5	581	183
2011 - 2016	~rpm[1] 7[2]	0.26	0.23	0.72	0.36	0.3	0.5	571	180

[2] applied on auxiliary engines only

Emission factors of CO were reduced by a factor of 4 according to [16]. Emission factors of PM and SO2 at NCP were lowered based on observations of Chalmers University in commission of the Danish Ministry of Environment and Food concerning the enforcement of IMO SECA [17] .

Table A- 7 Emission factors of NO_X dependant on engines RPM

Year of build	RPM range	IMO-limits (g/kWh)	Emission factor NO_X (g/kWh)
2000 – 2010 (Tier I)	< 130 RPM	17.0	0.87 x 17.0
	Between 130 and 2000 RPM	$45 \times n^{-0.2}$	$0.87 \times 45 \times n^{-0.2}$
	> 2000 RPM	9.8	0.87 x 9.8
2011 – 2016 (Tier II)	< 130 RPM	14.4	0.93 x 17.0
	Between 130 and 2000 RPM	$44 \times n^{-0.23}$	$0.93 \times 44 \times n^{-0.23}$
	> 2000 RPM	7.7	0.93 x 7.7

The reduction factor for Tier II engines was adjusted from 0.85 to 0.93 and the reduction factor for Tier I engines was adjusted from 0.85 to 0.87. The information was based on IAPP-certificate engine data obtained in a project for the Port of London Authority (report still in preparation).

Table A- 8 Emission factors and specific fuel oil consumption (SFOC) of gas turbines (TB) operated on marine diesel oil (MDO), (g/kWh)

Fuel	NO_X	PM-MDO NCP	PM-MDO Other	SO_2 NCP	SO_2 Other	VOC	CO	CO_2	SFOC
MDO	5.7	0.140	0.065	1.55	0.62	0.1	0.32	984	310

Emission factors of steam turbines were partially adjusted according to Cooper [9].

Table A- 9 Emission factors and specific fuel oil consumption (SFOC) of steam turbines (ST) operated on LNG, HFO or MDO

Fuel	NO_X	PM NCP	PM Other	SO_2 NCP	SO_2 Other	CH4	VOC	CO	CO_2	SFOC
LNG	1.94	0.01	0.01	0.0	0.0	0.045		0.06	688	250
HFO	2.0	0.495	0.300	3.06	0.61		0.1	0.15	971	306
MDO	2.0	0.490	0.295	1.45	0.58		0.1	0.15	923	291

Emissions of more modern LNG tanker propelled mostly propelled by medium speed diesel engines fuelled by LNG were calculated by means of emission factors as shown in the table below.

Table A- 10 Emission factors and specific fuel oil consumption (SFOC) of medium speed engines (MS) operated on LNG, (g/kWh)

Fuel	NO_X	PM	SO_2	CH4	CO	CO_2	SFOC
LNG	2.0	0.02	0.0	2.43	0.2	450	162

The change-over from fuels at LNG-tankers in the model calculations is assumed dependent on the speed of the ships expressed as CRScor. Below a value of CRScor of 0.2 LNG-tankers switch from gaseous LNG to liquid fuel used by main engines according to the scheme presented in the table below. The fuels assumed to be used by auxiliary engines are also presented in the same table A-11.

Table A- 11 Fuel switch scheme of LNG-tankers in dependence of operational speed

Engine type	Main engines		Auxiliary engines	
	0.2 <= CRScor < 1.2	0 <= CRScor < 0.2	0.2 <= CRScor < 1.2	0 <= CRScor < 0.2
MS	LNG	MDO	MDO	MDO
MS	LNG	HFO	HFO	MDO
ST	LNG	MDO	MDO	MDO
ST	LNG	HFO	HFO	MDO

A1.5 Correction factors of engine Emission Factors

At speeds around the design speed, the emissions are directly proportional to the engine's energy consumption. However, in light load conditions, the engine runs less efficiently. This phenomenon leads to a relative increase in emissions compared to the normal operating conditions. Depending on the engine load, correction factors specified per substance can be adopted according to the EMS protocols. The correction factors were extended by distinction of different engine types in order to get more accurate calculations. Three engine groups were discerned: reciprocating engines, steam turbines and gas turbines.
The correction factors used are shown in Table A-12 to Table A-14 The list was extended by some values provided in the documentation of the EXTREMIS model [4].

Table A- 12 Correction factors for reciprocating diesel engines

Power % of MCR	CO_2, SO_2 SP	CO_2, SO_2 MS	NO_X	PM-HFO/ PM-MDO	VOC, CH4	CO
10	1.2	1.21	1.34	1.63	4.46	5.22
15	1.15	1.18	1.17	1.32	2.74	3.51
20	1.1	1.15	1.1	1.19	2.02	2.66
25	1.07	1.13	1.06	1.12	1.65	2.14
30	1.06	1.11	1.04	1.08	1.42	1.8
35	1.05	1.09	1.03	1.05	1.27	1.56
40	1.045	1.07	1.02	1.03	1.16	1.38
45	1.035	1.05	1.01	1.01	1.09	1.23
50	1.03	1.04	1.00	1.01	1.03	1.12
55	1.025	1.03	1.00	1.00	1.00	1.06
60	1.015	1.02	0.99	1.00	0.98	1.00
65	1.01	1.01	0.99	0.99	0.95	0.94
70	1.00	1.01	0.98	0.99	0.92	0.88
75	1.00	1.00	0.98	0.98	0.89	0.82
80	1.01	1.00	0.97	0.98	0.87	0.76
85	1.02	1.00	0.97	0.97	0.84	0.7
90	1.03	1.01	0.97	0.97	0.85	0.7
95	1.04	1.02	0.97	0.97	0.86	0.7
100	1.05	1.02	0.97	0.97	0.87	0.7

The correction factors for CO_2 en SO_2 are assumed to be equal. These newly added factors for CO_2 and SO_2 were derived from two recent publications [10] and [11] by taking interpolated values. A distinction was made for Slow-speed engines (referred as SP) and Medium and high-speed engines (referred as MS). Although correction factors for other substances may differ by engine type also, a numerical distinction was not possible so far.

Since steam turbines are predominantly used by LNG-carriers two types of fuels were assumed to be consumed: LNG and HFO. It was assumed that at lower engine loads (up to CRScor = 0.2) steam turbines are operated by HFO. On higher loads (from CRScor = 0.2) usage of LNG (boil-off gas) is assumed. The source of the correction factors of steam turbines was taken from the EXTREMIS model [4].

Table A- 13 Correction factors for steam turbines

Power % of MCR	CO_2	SO_2	NO_X	PM-HFO	VOC, CH4	CO
10	1.4	3.04	0.3	3	5.44	11.65
15	1.4	3.04	0.34	2.8	5.11	10.83
20	1.4	3.04	0.37	2.8	4.72	9.96
25	1.4	3.04	0.41	2.8	4.39	9.09
30	1.2	2.02	0.44	1.5	4.00	8.26
35	1.00	1.00	0.47	1.00	3.61	7.39
40	1.00	1.00	0.51	1.00	3.28	6.57
45	1.00	1.00	0.54	1.00	2.89	5.7
50	1.00	1.00	0.57	1.00	2.56	4.83
55	1.00	1.00	0.61	1.00	2.17	4
60	1.00	1.00	0.64	1.00	1.83	3.13
65	1.00	1.00	0.68	1.00	1.44	2.26
70	1.00	1.00	0.76	1.00	1.33	1.96
75	1.00	1.00	0.84	1.00	1.22	1.65
80	1.00	1.00	0.92	1.00	1.11	1.30
85	1.00	1.00	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00	1.00	1.00
95	1.00	1.00	1.00	1.00	1.00	1.00
100	1.00	1.00	1.00	1.00	1.00	1.00

Correction factors for gas turbines were estimated with data from the ICAO Aircraft Engine Emissions Databank [7]. The emission behaviour of the GE CF6-6D (marine derivative: GE LM2500) and the Allison 501 (AN 501) was taken as representative for the two most occurring gas turbines in marine applications. CEF values in low power ranges have been changed since the 2011 calculation because an adapted interpolation scheme has been applied.

Table A- 14 Correction factors for gas turbines

Power % of MCR	CO_2, SO_2	NO_X	PM-MDO	VOC	CO
10	1.26	0.23	0.98	48.71	64.4
15	1.17	0.3	0.95	37.73	51.15
20	1.04	0.41	0.9	22.35	32.6
25	0.96	0.48	0.88	13.02	21.34
30	0.87	0.55	0.85	2.58	8.75
35	0.88	0.58	0.84	2.46	7.98
40	0.89	0.61	0.84	2.33	7.2
45	0.91	0.64	0.83	2.21	6.42
50	0.92	0.67	0.82	2.08	5.65
55	0.93	0.7	0.81	1.96	4.88
60	0.94	0.74	0.8	1.83	4.1
65	0.95	0.77	0.8	1.71	3.32
70	0.96	0.8	0.79	1.58	2.55
75	0.97	0.83	0.78	1.46	1.77
80	0.98	0.86	0.78	1.33	1
85	0.99	0.93	0.89	1.17	1
90	0.99	0.95	0.92	1.1	1
95	1	0.98	0.96	1.05	1
100	1	1	1	1	1

A2 EMISSIONS OF SHIPS AT BERTH

When a ship is berthed, in most cases the main engines are stopped. The auxiliary engines and equipment will be kept in service to provide (electrical) power to the ship's systems, on board cargo handling systems and accommodations.

The procedure for the calculation of emissions from ships at berth is derived from the EMS protocol with some minor modifications. The methodology was published in Atmospheric Environment [8]. In the EMS modelling system, a fixed value is assumed for the length of time at berth, for each ship type. In this study, the length of time at berth was derived for each individual event for each ship on the basis of AIS data. Ships with speeds below 1 knot were considered as ships at berth. Since the year of build of each ship was known, emission factors per amount of fuel dependant on the classification of year of build were applied. The amount of fuel used was calculated from the length of time at berth, ship type and volume in gross tonnage. The amount of fuel used at berth is more accurately determined in two reports on behalf of the CNSS project [14] , [15].

Table A- 15 Fuel rate of ships at berth, (kg/1000 GT.hour)

Ship type	Fuel rate
Bulk carrier	2.4
Container ship	6
General Cargo	6.1
Passenger <=30000 GT	8.9
Passenger > 30000 GT	32.4
RoRo Cargo	6.1
Oil Tanker	19.3
Other Tanker	14.5
Reefer	19.6
Other	9.2
Tug/Supply	15.6

Since January 1st 2010 the sulphur content of marine fuels used for ships at berth is regulated to a maximum of 0.1 percent. This implies that only marine gas oil with a sulphur content below 0.1 percent is allowed in harbours. The specification of fuel types at berth is adapted according to this new regulation (Table A- 16).

Table A- 16 Specification of fuel types of ships at berth per ship type (%)

Ship type	HFO	MDO	MGO/ULMF
Bulk carrier	0	0	100
Container ship	0	0	100
General Cargo	0	0	100
Passenger	0	0	100
RoRo Cargo	0	0	100
Oil Tanker	0	0	100
Other Tanker	0	0	100
Fishing	0	0	100
Reefer	0	0	100
Other	0	0	100
Tug/Supply	0	0	100

Table A-17 gives figures about allocation of fuel amount over engine types and apparatus during berth.

Table A- 17 Allocation of fuels usage in engine types and apparatus per ship type (%)

Ship type	Power (MS)	Boiler
Bulk carrier	90	10
Container ship	70	30
General Cargo	90	10
Passenger	70	30
RoRo Cargo	70	30
Oil Tanker	20	80
Other Tanker	50	50
Reefer	90	10
Other	100	0
Tug/Supply	100	0

In following Table A-18 to Table A- 21, the emission factors used for emissions at berth are presented.

Table A- 18 Emission factors of medium/high speed engines (MS) at berth, (g/kg fuel)

Year of build	NO_X	PM-MDO	VOC	CO
Fuel	all	MGO/ULMF	all	all
1900 – 1973	53	1.4	2.7	13
1974 – 1979	65	1.5	2.8	14
1980 – 1984	73	1.6	2.9	15
1985 – 1989	82	1.8	3.1	13
1990 – 1994	74	1.3	2.6	11
1995 – 1999	59	0.8	2.2	11
2000 – 2010	49	0.8	1.6	11
2011 – 2016	39	0.8	1.6	11

At berth usage of medium speed engines was assumed.

Table A- 19 Emission factors of boilers of boilers at berth, (g/kg fuel)

Fuel	NO_X	PM-MDO	VOC	CO
MGO/ULMF	3.5	0.7	0.8	1.6

Table A- 20 Emission factors of all engines and apparatus, (g/kg fuel)

Fuel	SO_2	CO_2
MGO/ULMF	4	3150

In tanker ships a reduction factor for boilers (50% for PM and 90% for SO_2) is applied to the emission factors, because gas scrubbers are often applied in order to protect ship internal spaces for corrosion by inert gases produced by boilers.

A3 FISHERIES

Fisheries source category covers emissions from fishing activities in the Netherlands, including inland fishing, coastal fishing and deep-sea fishing. Diesel engines are used to propel fishing vessels such as deep-sea trawlers and cutters, and to generate electrical power on-board fishing vessels. These diesel engines can be fuelled with either diesel oil (distillate) or residual fuel oil. The combustion process that takes place in these diesel engines causes emissions of greenhouse gases and air pollutants.

A3.1 Activity data

Two methodologies based on AIS-data are applied from 2016 onwards. For deep-sea trawlers the same AIS-based methodology as used for maritime navigation is applied (see A1 and 0) because essentially no fishing activities are performed on Dutch national territory, including the Dutch Continental Shelf. This means that these vessels essentially are only sailing towards and from remote fishing grounds. For the other fishing vessel categories (rather small vessels mostly cutters) another AIS-based methodology is described in detail by Hulskotte and ter Brake, 2017 [18]. This is essentially an energy based method whereby energy-rates of fishing vessels are split up by activity (sailing and fishing) with a distinction in available power of propulsion engine(s). For each fishery segment (combination of gear or catch method combined with power category) a fuel rate (kilogram/hour) for sailing or fishing was assessed by Turenhout et al., 2016 [19]. The distinction for each fishery segment between sailing and fishing is based on the actual speed of the fishing vessels as taken from AIS-data.

A3.2 Emission factors

The emission factors of small vessels (other than deep-sea trawlers) are assumed to be equal to emission factors of inland navigation because the engine types that are applied in these vessels are essentially the same.

Table A- 21 Emission factors and specific fuel consumption applied on fishing vessels, (g/kWh)

Engine year of build		VOC	NOx	CO	PM	SFOC
From	Till					
1959	1973	1.2	10.8	4.5	0.6	235
1975	1979	0.8	10.6	3.7	0.6	230
1980	1984	0.7	10.4	3.1	0.6	225
1985	1989	0.6	10.1	2.6	0.5	220
1990	1994	0.5	10.1	2.2	0.4	220
1995	2001	0.4	9.4	1.8	0.3	205
2002	2007	0.3	9.2	1.5	0.3	200
2008	2014	0.2	7	1.3	0.2	200
2015	2016	0.2	7	1.3	0.2	195

The year of build of the engines of (Dutch and former Dutch) fishing ships were initially purchased from Shipdata (http://www.shipdata.nl) in order to select the emission factors from table A-21. Part of this data concerned the engine type and model and the year of build. Data were enriched with engine changes when indicated on the website http://www.kotterfoto.nl and data of foreign fishing ships (including installing data of new engines) were added from the combined European fishing registers or the FIGIS-database managed by FAO.
As a fuel ultra low sulphur diesel fuel compliant with EN-590 specification was assumed to be used by the small fishery cutters.

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APPENDIX B: EMISSION RESULTS OF METHOD 1

Table B - 1 Total emissions in ton in each port area for 2017, excluding Fishing vessels, EMS-type 11

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	2	1	0	6	17	0	28
	Total	2	1	0	6	17	0	28
1237 VOC	Berthed	46	166	49	10	7	3	280
	Sailing	271	192	30	28	4	9	534
	Total	316	358	79	38	11	13	814
4001 SO_2	Berthed	87	323	92	21	14	7	544
	Sailing	243	155	23	25	4	7	458
	Total	330	478	115	47	18	14	1002
4013 NO_x	Berthed	1148	3688	1145	255	191	104	6531
	Sailing	9263	5235	778	870	148	257	16550
	Total	10411	8923	1924	1125	339	361	23082
4031 CO	Berthed	73	294	84	16	10	5	483
	Sailing	496	363	56	46	9	12	981
	Total	569	657	139	62	19	17	1464
4032 CO_2	Berthed	98817	411837	117578	20304	13084	6523	668143
	Sailing	409341	264387	39936	46297	11549	13076	784587
	Total	508158	676224	157514	66601	24633	19599	1452729
6601 Aerosols MDO	Berthed	21	79	23	4	3	2	131
	Sailing	33	28	7	8	1	3	80
	Total	54	107	29	12	4	5	211
6602 Aerosols HFO	Berthed	0	0	1	0	0	0	2
	Sailing	195	133	16	19	3	4	370
	Total	196	133	17	19	4	4	372

Table B - 2 Emissions in each port area (including the total Western Scheldt area) for 2017 as percentage of the emissions in 2016, excluding Fishing vessels, EMS-type 11. The percentages in grey are based on very low absolute numbers, and not very reliable

Substance	Source	Western Scheldt	Rotter-dam	Amster-dam	Ems	Den Helder	Harlingen	Total
1011 Methane	Berthed							
	Sailing	125%	292%	244%	106%	835%		
	Total	125%	292%	244%	106%	835%		
1237 VOC	Berthed	82%	72%	59%	129%	87%	106%	73%
	Sailing	93%	104%	93%	89%	62%	268%	98%
	Total	91%	87%	69%	97%	75%	189%	87%
4001 SO_2	Berthed	82%	71%	63%	138%	88%	106%	73%
	Sailing	91%	101%	94%	89%	61%	270%	95%
	Total	88%	78%	67%	106%	80%	155%	82%
4013 NO_x	Berthed	85%	71%	63%	133%	92%	119%	74%
	Sailing	96%	107%	99%	97%	80%	301%	100%
	Total	95%	88%	74%	103%	86%	209%	91%
4031 CO	Berthed	82%	74%	61%	137%	88%	108%	74%
	Sailing	98%	109%	96%	95%	75%	245%	102%
	Total	95%	90%	71%	103%	82%	177%	91%
4032 CO_2	Berthed	85%	78%	62%	146%	96%	118%	77%
	Sailing	96%	109%	103%	98%	105%	292%	102%
	Total	94%	88%	69%	109%	100%	196%	89%
6601 Aerosols MDO	Berthed	98%	138%	63%	233%	101%	127%	109%
	Sailing	90%	99%	110%	107%	87%	217%	98%
	Total	93%	125%	69%	133%	96%	175%	105%
6602 Aerosols HFO	Berthed	8%	0%	16%	13%	36%	2%	3%
	Sailing	91%	102%	86%	79%	50%	530%	94%
	Total	89%	72%	73%	74%	48%	384%	80%

Table B - 3 Emissions of ships in ton in the Netherlands sea area for 2017 compared with 2016, excluding Fishing vessels, EMS-type 11

Nr	Substance	Emission in ton in 2017			Emission in '17 as percentage of '16		
		Not moving	Moving	Total	Not moving	Moving	Total
1011	Methane	-	36	36	-	109%	109%
1237	VOC	89	2182	2270	86%	95%	95%
4001	SO_2	209	4357	4566	88%	95%	94%
4013	NO_x	2714	79957	82671	89%	97%	97%
4031	CO	143	3828	3971	88%	99%	99%
4032	CO_2	168327	3582452	3750779	90%	98%	97%
6601	Aerosols MDO	70	232	303	93%	94%	94%
6602	Aerosols HFO	4	2066	2070	19%	93%	92%
Number of Ships		85	158	243	87%	102%	96%