MARIN

COATING EMISSIONS OF SEA SHIPPING FOR 2010

Netherlands Continental Shelf, Dutch port areas and OSPAR region II

Final Report

Report No. : 25334-1-MSCN-rev.1
Date : April 11, 2012

Signature Management:

MARIN
P.O. Box 28
6700 AA Wageningen
The Netherlands
T +31 317 47 99 11
F +31 317 49 32 45
E mscn@marin.nl
I www.marin.nl

COATING EMISSIONS OF SEA SHIPPING FOR 2010

Netherlands Continental Shelf, Dutch port areas and OSPAR region II

Ordered by : Deltares
Department of Waterquality and Ecosystems
Postbus 177
2600 MH Delft
The Netherlands

Revision no.	Status	Date	Author	Approval
0	Draft	March 12, 2012	A. Cotteleer	Y. Koldenhof
1	Final	April 11, 2012	A. Cotteleer	Y. Koldenhof

CONTENTS

Page

GLOSSARY OF DEFINITIONS AND ABBREVIATIONS

Definitions:

Voyage database	Database consisting of all voyages crossing the North Sea in 2008 collected by Lloyd's List Intelligence
SAMSON Traffic database	Database that contains the number of ship movements per year for each traffic link divided over ship type and size classes. It is based on the Lloyd's List Intelligence voyage database
Ship characteristics database	This database contains vessel characteristics of more than 116,000 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.

Abbreviations:

AIS	Automatic Identification System
Cu	Copper
EMS	Emissieregistratie en -Monitoring Scheepvaart (Emission Inventory and Monitoring for the Shipping Sector)
EU	European Union
GT	Gross Tonnage
kg	kg
IMO	International Maritime Organization
LLI	Lloyd's List Intelligence
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
SAMSON	Safety Assessment Model for Shipping and Offshore on the North Sea
TBT	Tributyltin
TNO	Netherlands Organisation for Applied Scientific Research
WSA	Wet Surface Area

1 INTRODUCTION

1.1 The Emission Register project

Biocidal antifoulants in marine ship coatings applied on the exterior of seagoing merchant vessels and fishing vessels are a source emissions. Coatings are designed to inhibit organisms attaching and growing on the exterior surface of the ships' hull, and to that end, most coatings release biocides continuously. The emissions in question are copper and co-biocides (also known as "boosters"). These co-biocides are components such as diuron and seanine, which reinforce the anti-fouling effect of the coating [5].

The emissions calculated in this project for the Netherlands Continental Shelf and the Dutch port areas are input to the Dutch Emission Register. Ref [1] explains the project, and the most important information has been copied into this introduction.

Since 1974 a number of organisations have been working closely together in the emission register project to collect and formally establish the yearly releases of pollutants to air, water and soil in the Netherlands. Goal of the project is to agree on one national data-set for emissions that meets the following criteria: transparent, complete, comparable, consistent and accurate.

Results of this project serve to underpin the national environmental policy. Furthermore, data is provided for numerous international environmental reports to the European Union and the United Nations, e.g. the National Inventory Report for the Kyoto Protocol.

The Emission Register (ER) contains data on the yearly releases of more than 350 pollutants to air, soil and water. The Emission Register project covers the whole process of collecting, processing and reporting of the emission data in the Netherlands. Emissions from individual point sources (companies or facilities) and diffuse emissions (calculated from national statistics by the so called task forces) are stored into one central database, from which all the national and international reporting is done.

The National Institute for Public Health and the Environment (RIVM) co-ordinates the Emission Register project on behalf of the Ministry of Infrastructure and Environment (I&M)

Collecting and processing national emissions for each emission source is done according to a standard protocol. Various emission experts from the participating organisations in the Task Forces calculate the national emissions from 1200 emission sources on the basis of these protocols.

The task force on transportation covers the emissions to soil, water and air from the transportation sector (aviation, shipping, rail and road transport). The following organisations are represented in this task force: RIVM, Netherlands Environmental Assessment Agency, (PBL), Statistics Netherlands (CBS) Centre for Water Management, Deltares and the Netherlands Organisation for Applied Scientific Research (TNO).

A formal agreement is drawn up by all the participating organisations. After close study, the national emissions are accepted by the project leader of the Emission Register and the data set is stored in the central database located at RIVM.

Together with national totals for each emission source, the ER website also shows maps with the emission given per community, water catchment area or on a 5 * 5 km grid cell. To allocate an emission spatially, the Emission Register has a spatial allocation available for each emission source. For example, traffic intensity (car kilometres) for the emissions from road traffic, land use (surface) for agricultural emissions and population density for the emissions from households. If an allocation per community is not available, the allocations on a 5*5 km grid are aggregated to the area of a community, taking the surface of each grid cell in that community into account.

1.2 OSPAR convention

OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. Since 1972 this Regional Convention has worked to identify threats to the marine environment and has organised, across its maritime area, programmes and measures to ensure effective national action to combat them. In doing so it has pioneered ways of ensuring monitoring and assessment of the quality status of the seas by setting internationally agreed goals and by checking that the participating Governments are delivering what is needed [3].

1.3 European Water Framework Directive

Water does not stick to national boundaries. EU member states have agreed therefore to the European Water Framework Directive (EWFD) [2]. The goal of this directive is to ensure that the quality of the surface water and groundwater in Europe reaches a high standard (‘good ecological status’) by the year 2015.

The EWFD is based on a river basin district approach to make sure that neighbouring member states assume joint responsibility for managing the rivers and other bodies of water they share. To meet the 2015 deadline, water authorities in each river basin district in Europe have set up a coherent programme of measures in 2009. Where a river basin district includes more than one member state, a trans-boundary management plan was drawn up. The Netherlands is involved in management plans for four trans-boundary river basin districts: Rhine, Meuse, Scheldt and Ems. The next trans-boundary management plans are planned for 2015.

1.4 Activities of MARIN

MARIN has performed a study to quantify the emissions of coatings and anodes by seagoing vessels in 2007. For the NCS the emissions were based on AIS data and for OSPAR region II they were based on the SAMSON traffic database [4].

In the present study MARIN has performed the same work regarding the emissions of coatings to sea water for 2010 as has been done in 2007. In the present study for 2010 also the emission of coatings by fishery is quantified as far as the data about this group was available.

1.5 Objective

This study aims to determine the emissions to water of seagoing vessels in 2010. Fishery will be included as far as data is available. The totals and the spatial distribution for the Netherlands Continental Shelf and the port areas Western Scheldt, Rotterdam, Amsterdam and the Ems are based on AIS data. In addition, the information contained in the AIS data for the NCS and the SAMSON traffic database for the whole of the North Sea are used to determine the emissions for 2010 in the OSPAR region II area at sea. A grid size of 5000 x 5000 m has been used.

The emissions for 2010 are determined for copper and the co-biocides Irgarol, Zineb, Diclofluanid, Zincpyrithione and Seanine. A distinction is made between ships that have an EU coating and ships that have a coating from the rest of the world.

1.6 Report Structure

Chapter 2 describes the emission databases that were delivered for 2010. Chapter 3 gives the percentage of ships that have a coating according to EU regulations. Chapter 4 describes the procedure that was used for the emission calculation based on AIS data. Chapter 5 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 6 summarises the wet surface area and emissions for 2010 for the NCS and the Dutch port areas. Chapter 7 describes the procedure used for the emission calculations based on the SAMSON traffic database. Chapter 8 summarises the 2010 wet surface area and emissions for OSPAR region II. Finally, Chapter 9 presents conclusions and recommendations.

2 2010 EMISSION DATABASES

This chapter contains information on the database that has been delivered for this study to Deltares, acting as coordinating party for the Ministry of Infrastructure and the Environment. It describes the basis of the traffic data that is used for the emission calculation. Furthermore, it defines the different areas for which emissions are reported by figures.

2.1 General information

The access database "Emissions_Coating_2010_MARIN.mdb" has been delivered and contains the calculated emissions to water from sea shipping for:

- the Netherlands Continental Shelf;
- the four Dutch port areas;
- OSPAR region II at sea.

All the columns in the delivered tables contain an explanation that can be read when opening the tables in "design view".

The tables that result from this study contain the average wet surface area in m^2 and the total emission per substance in kg on a grid cell basis, distinguished into:

- EMS ship type classes and ship size classes;
- sailing / non moving ships;
- region, for example within or outside the 12-mile zone;
- EU coating / non-EU coating.

The information can be used in studies for which a detailed spatial distribution of the emissions is necessary.

The aim of the EMS project (Emission Inventory and Monitoring for the Shipping Sector) was to (better) map out the different emission of sea shipping and inland shipping. The calculation methods are documented in protocols [5]. For this project, the seagoing ships are divided in 12 ship type classes and 8 ship size classes.

2.2 NCS and Dutch port areas

The emissions at the Netherlands Continental Shelf (NCS) and the four Dutch port areas are based on AIS data and have been reported in the tables:

- Emissions_Coatings_NCS_2010
- Emissions_Coatings_Ports_2010

The emissions have been calculated on a 5000 x 5000 m grid. The grids of the NCS and the port areas are chosen in such a way that they do not overlap each other.

The information is based on all vessels that both transmitted an AIS signal and could be connected with a vessel from the Lloyd's List Intelligence (LLI) ship characteristics database. As fishing vessels with a length under 45 m were not obliged to have an AIS system on board in 2010. The information of this ship type is incomplete in the size classes 0-100 GT and 100-1600 GT. Section 0 gives an estimate of the number of ships that is missing.

The NCS including port areas is presented in Figure 2-1 on an electronic sea chart. The purple lines are the traffic separations schemes. The different areas are indicated by plotting the centre points of the grid cells with different colours:

- The black points at sea are the cells outside the 12-mile zone;
- The pink points at sea are the cells within the 12-mile zone;
- The black points within the port areas are the cells that are included in the port database.

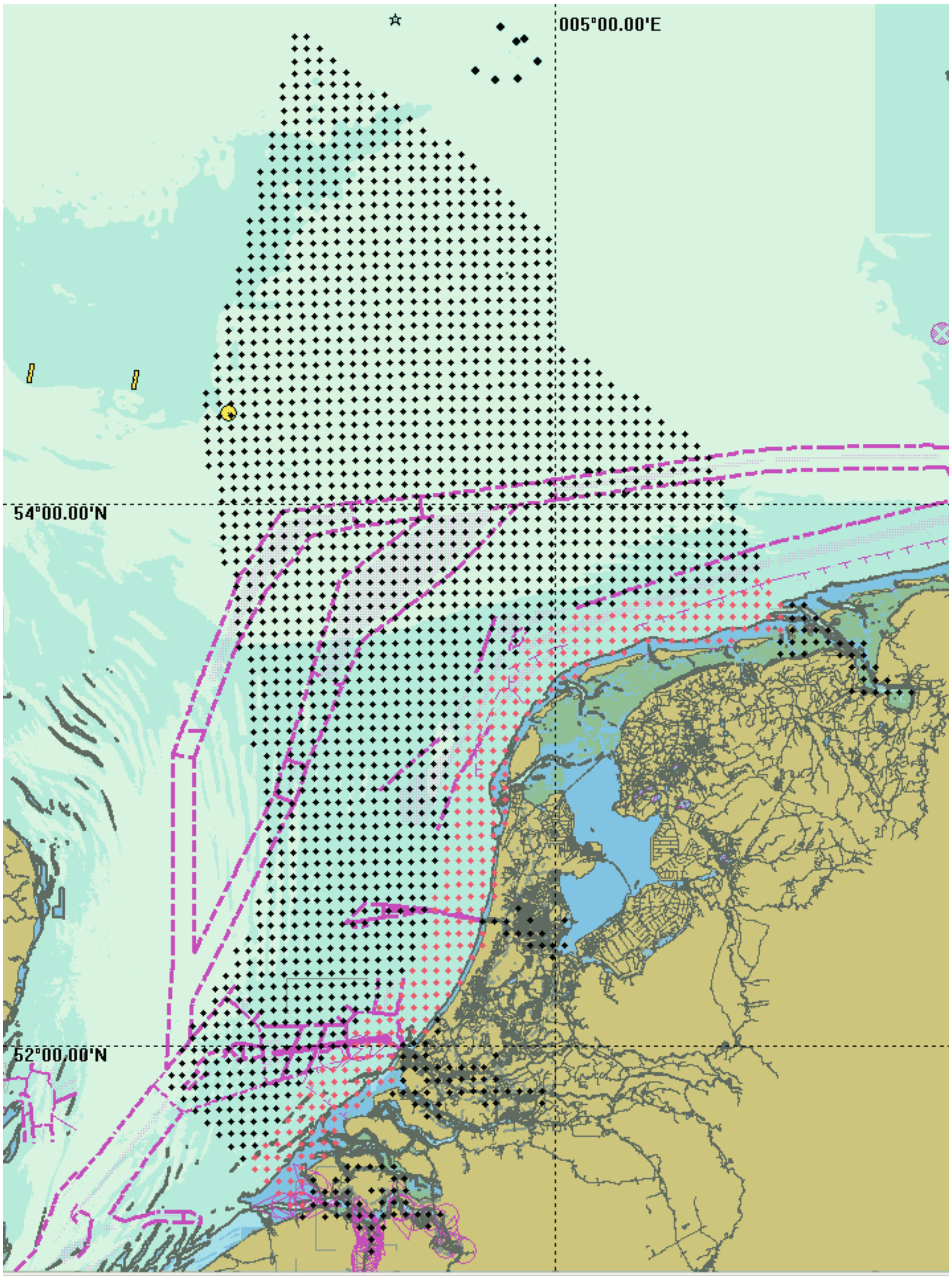

Figure 2-1 The Netherlands Continental Shelf with four port areas

2.3 OSPAR region II

The table "Emissions_Coatings_OSPAR_2010" contains the emissions in OSPAR region II at sea and is based on the SAMSON traffic database of 2008. The SAMSON traffic database contains the number of ship movements per year for each traffic link divided over ship types and ship size classes. It is based on the Lloyd's List Intelligence (LLI) voyage database. The calculated emissions have been corrected for the changes in the traffic volume and composition between 2008 and 2010.

This table in the database contains a specific field "Fishing" which tells the user whether the emission is from a fishing vessel or not. Only the few fishing vessels that are part of the LLI voyage database can be found here. These are mainly large fishing vessels that stay at sea for a long period of time.

The emissions have been calculated on a 5000 x 5000 m grid. Note that this grid is chosen independently of the NCS grid for the AIS based database. OSPAR region II has been divided in the following areas:

- the 12-mile zone of the NCS (in orange),
- the remainder of the NCS (in black),
- the North Sea as defined by IMO (with black line),
- OSPAR region II (with black dotted line).

They areas are indicated in Figure 2-2.

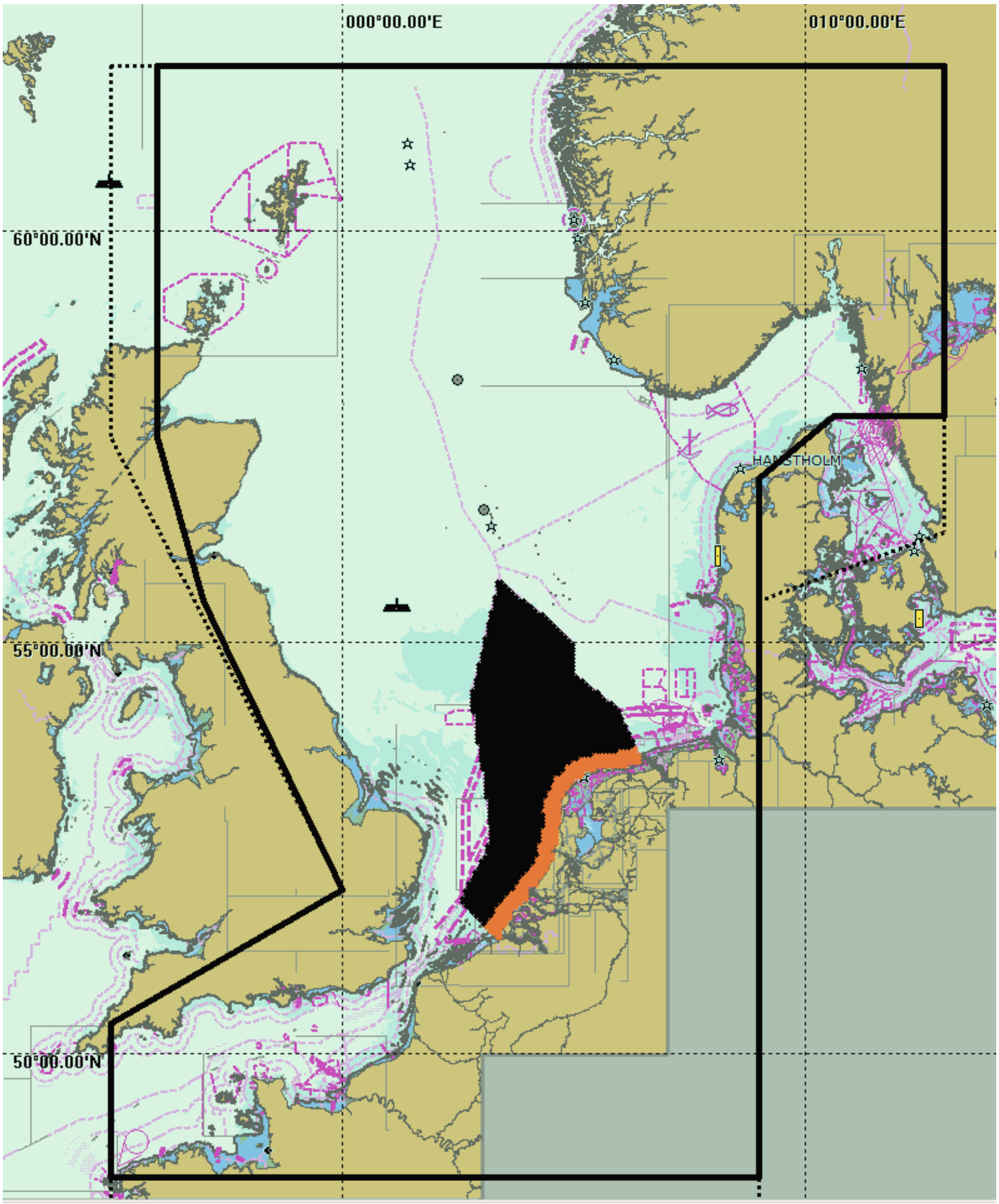

Figure 2-2 **Areas within OSPAR region II (dotted black line): North Sea according to IMO (black line), NCS outside 12-mile zone (black), NCS inside 12-mile zone (orange)**

3 PERCENTAGE OF SHIPS THAT HAVE A COATING ACCORDING TO EU REGULATIONS

Different countries allow different components for the antifouling coatings of ships. It is therefore interesting to know in which country a coatings is applied. Although there are also large differences between the substances that are allowed in antifouling coatings within the European Union (EU), the EU countries in general allow less substances then some countries outside the EU. Furthermore, labour is expensive in the EU. These are incentives for ship owners to have the antifouling coatings applied in countries outside the EU. Appendix A gives a list of countries that are expected to follow the EU rules for coatings and that are meant when mentioning “EU coatings” in this report.

In the databases, the resulting emissions are split up between EU coatings and non-EU coatings. The percentage of ships that have a coating from the EU is obtained from Table 3-1, which shows the percentage of ships that stayed within the EU per ship type and size class. This table is based on data of the LLI voyage database of 2008. It can be seen that a large percentage of ships in the smallest ship size classes stay within the EU, while the percentage in the largest ship size classes is very small.

The ship type class miscellaneous contains mainly work vessels such as pilot ships, research ships, crane ships, dredgers and patrol ships.

Table 3-1 Percentage of ships that stayed within the EU (per ship type and size class and totals per class, classes above 40% are marked green)

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		62.8	34.8	21.1	12.8	2.9	1.3	3.9	-	10.7
Chemical + Gas tanker		67.8	42.9	26.2	14.1	3.2	-	1.0	-	14.9
Bulk carrier		72.7	34.4	38.0	5.1	0.6	0.1	-	-	2.1
Container ship		-	31.6	24.7	21.3	2.9	-	-	-	5.7
General Dry Cargo	66.7	36.7	14.8	6.9	4.0	1.5	-			15.1
RoRo Cargo / Vehicle		88.5	43.5	26.7	34.5	40.2	3.2	-		25.8
Reefer		29.4	7.7	-	0.4	-				2.3
Passenger	100.0	80.4	57.6	57.4	64.4	58.4	58.1	5.7	-	61.2
Miscellaneous	91.3	75.7	58.2	41.3	37.2	27.3	4.8	66.7	100.0	60.7
Tug/Supply	85.2	59.7	54.3	66.0	47.1	50.0				60.0
Fishing	93.3	82.5	79.6	50.0	23.7	-				78.8
Non Merchant	53.8	46.6	20.0	-	37.5	-				44.4
Total	84.0	60.2	27.6	19.3	15.1	7.6	3.1	1.4	0.3	21.8

When taking all ships that are at a random moment at the NCS or in OSPAR region II, the percentage of ships within each ship type and size class that have a coating from the EU is probably larger than reported in Table 3-1 because of two reasons:

1. Some of the ships that travel to countries outside the EU will have a coating from an EU country;
2. The ships that stay within the EU spend a longer period of the year 'at the NCS'/' in OSPAR region II' than ships that travel to countries outside the EU. Therefore, their contribution to the wet surface area is larger than reported.

4 APPROACH: PROCEDURE FOR EMISSION CALCULATION BASED ON AIS DATA

This chapter describes the method for the emission calculation based on AIS data. This method has been used to calculate the emission for both NCS and the Dutch port areas. First, the input used for the calculations will be explained. Then, the procedure for combining the input to obtain emissions will be described.

4.1 Input

This section describes the input that is required for the emission calculation based on AIS data.

Emission in general can be calculated by the equation:

Emission = activity * emission factor

To calculate the emission of coatings to water, the activity is the coating area that is in contact with the water, this is called the wet surface area (WSA).

The input that has to be gathered for the emission calculation is:

- the wet surface area and
- the emission factor.

For the calculations based on AIS, the wet surface area is calculated based on:

- AIS data;
- ship characteristics database.

4.1.1 AIS data for 2010 at NCS and in Dutch port areas

Since 2005 all merchant vessels over 300 Gross Tonnage are equipped with an Automatic Identification System (AIS). These systems transmit information about the ship, its voyage and its current position, speed and course. Static information, such as name, IMO number, ship type, size, destination and draught, is transmitted every six minutes. Dynamic information such as position, speed and course is transmitted every 2 to 10 seconds. Information is not always complete and is occasionally entered incorrectly. The information on a ship's position is the most reliable as this is automatically transmitted via the navigation equipment installed onboard.

The AIS messages are received by base stations alongside the coast and on some offshore platforms. All the messages of Dutch base stations are sent to the Netherlands Coastguard in Den Helder. Once a month, all received AIS messages are copied to a tape that is sent to MARIN. MARIN is allowed to use this AIS data for research purposes, but may not supply individual ship data to third parties.

Although meant for improving safety at sea, dynamic AIS information offers great opportunities to gain insight into the spatial use of sea and waterways. Local traffic intensities and densities can, for example, be calculated very precisely. By linking the AIS data with a ship characteristics database, additional characteristics about the ship can be used, allowing for calculations of emissions.

In this study, AIS data of every second minute for 2010 for the NCS and the port areas Western Scheldt, Rotterdam, Amsterdam and the Ems has been used to calculate the emissions. Figure 4-1 gives an example of one week of AIS data, a dot was plotted to show the location of all vessels (ten minutes interval).

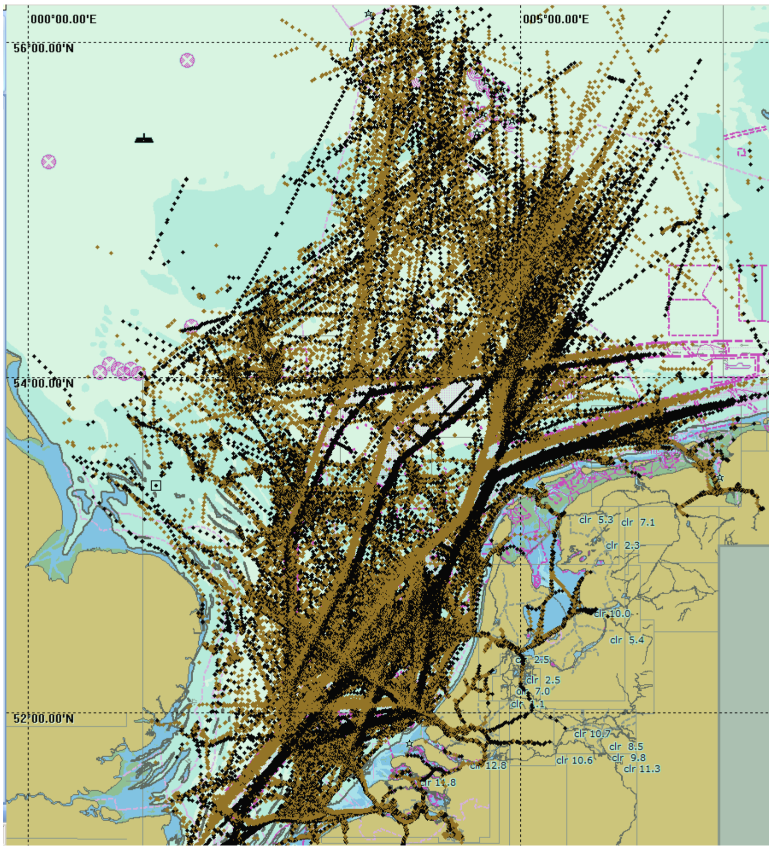

Figure 4-1 Example of one week of AIS data of route bound traffic. Every ten minutes a dot was plotted to show the location of all vessels. A brown dot indicates westwards travelling, a black dot indicates eastwards travelling.

4.1.2 Ship Identities

MARIN has made a ship Identity database in which as many as possible ships that were observed in the AIS data of 2010 are coupled with a ship in the ship characteristics database of Lloyd's List Intelligence (LLI) [10]. This is necessary to obtain information that is not part of the AIS data, eg. the EMS ship type, design draught, and Gross Tonnage.

For the calculations at the NCS all coupled ships are used. However, in the port areas, the coupled ships that are smaller than 135 m and that had no IMO number in the LLI database were not used. This was done because this selection mainly consists of inland ships that are not part of this study.

4.1.3 Emission factors

The calculation of release rates for anti-fouling products has long been a subject of contention and consumed considerable resources and man-hours from a range of experts. The most recent review of the available methods is given by Safinah Ltd and presented in document 463CCEP001R by the CEPE[1] Antifouling working group [9]. This review decides on the CEPE method and uses a correction factor, called the CEPE-CF approach. The approach is supported by IMO (International Maritime Organization) and can be applied to existing products and newer products.

The correction factor is based on a publication by Finnie [11]. In this paper, the relationship between the apparent copper release rate and the environmental release rate is established for a number of antifouling coating types using data from a variety of available laboratory, field and calculation methods. Using a conservative approach based on a realistic worst case and accounting for experimental uncertainty in the data that are currently available, Finnie proposes a correction factor for use with all paint types of 2.9 for the CEPE calculation method. Therefore the leach rate which is proposed in the Safinah document is 6 µg cm^{-2} day^{-1}. In the present study this rate is adapted. Arguments for this leach rate are also summarized in Willemsen (2012) [12].

Emission factors for sailing
In 2010 TBT-based coatings are all phased out. The leaching rates for copper-based coatings (Cu-based coatings) are obtained from [9] and based on international accepted standards. The other type of coating that is used is non-stick coating. Non-stick coatings are very slick so that biofouling has difficulty adhering to the ship's shell.

In correspondence with [9] it was assumed that 99% of the ships in most ship type and size classes use Cu-based coating and only 1% uses non-stick coatings. For large fast ships the percentage of non-stick coatings is 24% [5]. This category is defined as passenger and container ships with a Gross Tonnage of 60000 and larger. Table 4-1 and Table 4-2 summarize the emission factors that will be used for sailing. As long is the speed is above 1 knot, the emission factor is independent of the speed of sailing.

Table 4-1 Emission factors for sailing for most ships

Type of coating/component	% of WSA	Leaching rate in µg cm^{-2} day^{-1}
TBT-based coating	0	
Cu-based coating	99	
-Cu-holding substances		6
-Co-biocides		15% of 6 = 0.9
Non-stick coating	1	0

Table 4-2 Emission factors for sailing for large fast ships*

Type of coating/component	% of WSA	Leaching rate in µg cm^{-2} day^{-1}
TBT-based coating	0	
Cu-based coating	76	
-Cu-holding substances		6
-Co-biocides		0.9
Non-stick coating	24	0

* passenger and container ships with a gross tonnage of 60,000 and larger

[1] European Council of producers and importers of paints, printing inks and artists' colours. CEPE represents the interest of approximately 1000 members in the European Union, Norway and Switzerland.

The leaching rate for the sum of all co-biocides can be obtained from Table 4-1 and Table 4-2. Table 4-3 defines which co-biocide are taken into account in this study and the assumptions about use. Data on their use is rare. Some data is found: information from the allowed biocides in the UK [6], the Netherlands [7] and on actual measurements in Sweden [8]. However, the available data is not representative for all ships in the study area. Therefore we assume an equal use of all co-biocides.

Table 4-3 Co-biocides and the assumed equal use

CASno	Substance no	Co-biocide	%
28159-98-0	6030	Irgarol 1051/Cybutryne	20
12122-62-7	6136	Zineb	20
1085-98-9	8265	Diclofluanid	20
13463-41-7	9082	Zincpyrithione	20
64359-83	9083	Seanine 211N	20
		Total	100

Emission factors for non moving ships

The emission factors for non moving ships are 75% of those for sailing ships [5].

4.2 Procedure for combining the input to obtain emissions

The AIS messages contain detailed information about the location, identity and speed of the ships. This is the most important information for calculating the emissions to water. The main problem is how to organize the tremendous amount of data flows and keep the computing time manageable. Therefore, the work has been divided into a number of separate activities, delivering intermediate results. The final emission calculation uses these intermediate databases. Figure 4-2 visualizes the databases that are mentioned in the description of the procedure for the emission calculation in the remainder of this Section. The input files are the ones shown in blue in Figure 4-2 and they have been described in section 4.1.

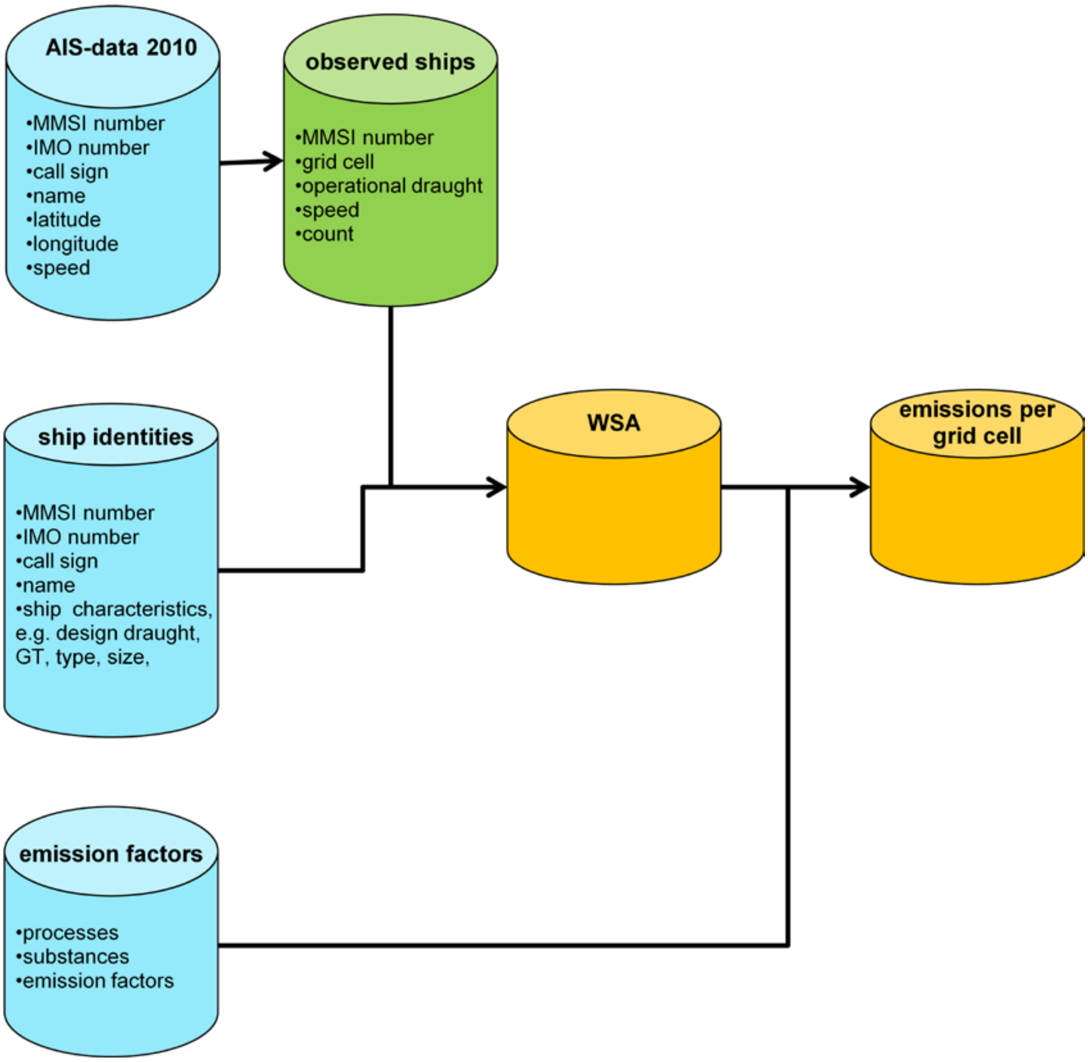

Figure 4-2 Databases with relations for emission calculation based on AIS data (blue = input, green is intermediate, orange = output

4.2.1 From "AIS data 2010" to "observed ships"

Each AIS data file contains the data of the ships in standard AIS format. That means that the file cannot be read with a text editor, but only by a program that converts the data into readable values. Therefore, an approach has been chosen in which every two minutes an observation is done to determine for the whole area which ships are in which grid cell with which speed. The essential parameters that have been collected during processing the AIS data files are:

- The MMSI numbers indicating the different ships;
- The position of each ship indicating the grid cell in which the ship has been observed;
- The speed, which has been converted to a speed class. A speed between 0 and 1 knots is processed as 0 knots because it is assumed that this means at berth or at anchor, a higher speeds is processed as sailing;
- The draught;
- The number of observations of this class (MMSI, grid cell, speed class).

At the end of the observation period, all observations consisting of MMSI number, grid cell, speed and draught with corresponding counts (number of similar observations) are written to the "observed ships" log file that has been used in the next steps.

Within the subsequent calculations it has been assumed that the emission for each ship in the next two minutes takes place in the observed grid cell.

4.2.2 From “observed ships” and “ship identities” to “WSA”

For each observed ship the wet surface area (WSA) of the ship is calculated according to the method described in [5]. The wet surface area for each ship is calculated from the Gross tonnage (GT) value with the formula:

$$WSA_{max} = C\ GT^{2/3}$$

The constant C gives the relation between the ship’s GT and its wet surface area. It is dependent on the ship shape. [5] has determined the values of C based on the Holtrop-Mennen method which is also described in the factsheet. This method is not based on GT, but on design draught, length between perpendiculars and width of the ship. Ship shapes don’t change rapidly over time, so the factor C that is used should be valid for some decades. The values of C per ship type are presented in Table 4-4.

Table 4-4 Factor for calculation of wet surface area

EMS ship type nr	Ship type	C (factor for $GT^{2/3}$)
1	Oil tankers	9.62
2	Chemical / LPG tankers	9.35
2a	LNG tankers	7.47
3	Bulk carriers	9.70
4	Container ships	8.57
5	General dry cargo	8.76
6	Ro/Ro Cargo/Vehicle	6.60
7	Reefers	10.20
8	Passenger ships and ferries	5.20
9,10,12	Other; supply ships; non-commercial ships	8.40
11	Fishing vessels	8.63

The table gives the factor for the calculation of the WSA for the maximal draught of the ship. However, most ships are not maximally loaded. The exposed WSA depends on the operational draught, which is sent out in the AIS-messages and stored in database of observed ships for the emission calculations. The real WSA, thus for the operational draught is derived with the relation given in [5]:

$$WSA = WSA_{max}\ (2\ \%T + 2.6)/4.6$$

In which %T is the operational draught divided by the maximum draught. The maximum draught is obtained from the ship identities database.

4.2.3 From “WSA” and “emission factors” to “emissions per grid cell”

The wet surface area and emission factor database are linked and the emissions are calculated based on all AIS messages every other minute for 2010. The emissions are calculated on a grid of 5x5 km.

4.3 Comparison with 2007 study

The previous study for the emission of coatings to water was performed for 2007 [4].

The calculation method used now is approximately similar to the one used for 2007. The wet surface area calculation has not been changed significantly and for non moving ships, the emission was also assumed to be 75% of the emission of moving ships.

However, the areas used for reporting and the emission factors used were different.

5 COMPLETENESS OF AIS DATA

This chapter informs on the completeness of AIS data. Both with respect to missing files and with respect to spots that are not fully covered by base stations. Also, an estimation is made of the number of fishing vessels that is missing. Finally, the influence of the completeness on the reported emissions is indicated.

5.1 Missing AIS minute files

Each AIS data file contains the AIS messages of all ships received in exactly one minute. The total collection of the AIS data of 2010 contains 523,992 files, which is 99.69% of the maximum number of 525,600 files (365 days times 24 hours times 60 minutes). Therefore, in total slightly more than one day is missing due to failures in the process.

However, 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. This approach has been followed to prevent incompleteness for larger distances from the coast where the reception of AIS messages by the base station decreases.

For 2010 a completion factor of 1.0017 has been used to correct for missing periods longer than 10 minutes, which add up to 15 hours. All emissions both at the NCS and in the Dutch port areas have been multiplied with this factor. For the previous study to the emission of coatings in 2007, data was available for only 350 days.

5.2 Bad AIS coverage in certain areas

5.2.1 Base stations

In the previous Section the completeness of the data has been described by the number of files received from the Netherlands Coastguard. There is, however, another type of completeness, namely, the area covered. This is illustrated in Figure 5-1, 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.

5.2.2 Known “weak” spots

In reality the coverage varies with the atmospheric conditions. Figure 5-1 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 at the NCS 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 spot above the Wadden on the border between the NCS and the German sector;
- the Western Scheldt close to the border with Belgium, and;
- the spot close to the border with the United Kingdom Continental Shelf and Belgium;

Especially this last location is a shortcoming because it is a very dense shipping traffic area. MARIN has noticed this also in other projects. In 2010, the coverage has changed over time. During some periods, the coverage was fine, but, unfortunately, the periods with bad coverage were longer. Good coverage has to do with favourable atmospheric conditions and occur more often during the summer than during the rest of the year. This weak spot has been discussed with the Netherlands Coastguard and improvements have been made. At the end of 2010 full coverage was realised. The effect is a minor underestimation of the calculated wet surface areas and emissions of coatings at the NCS.

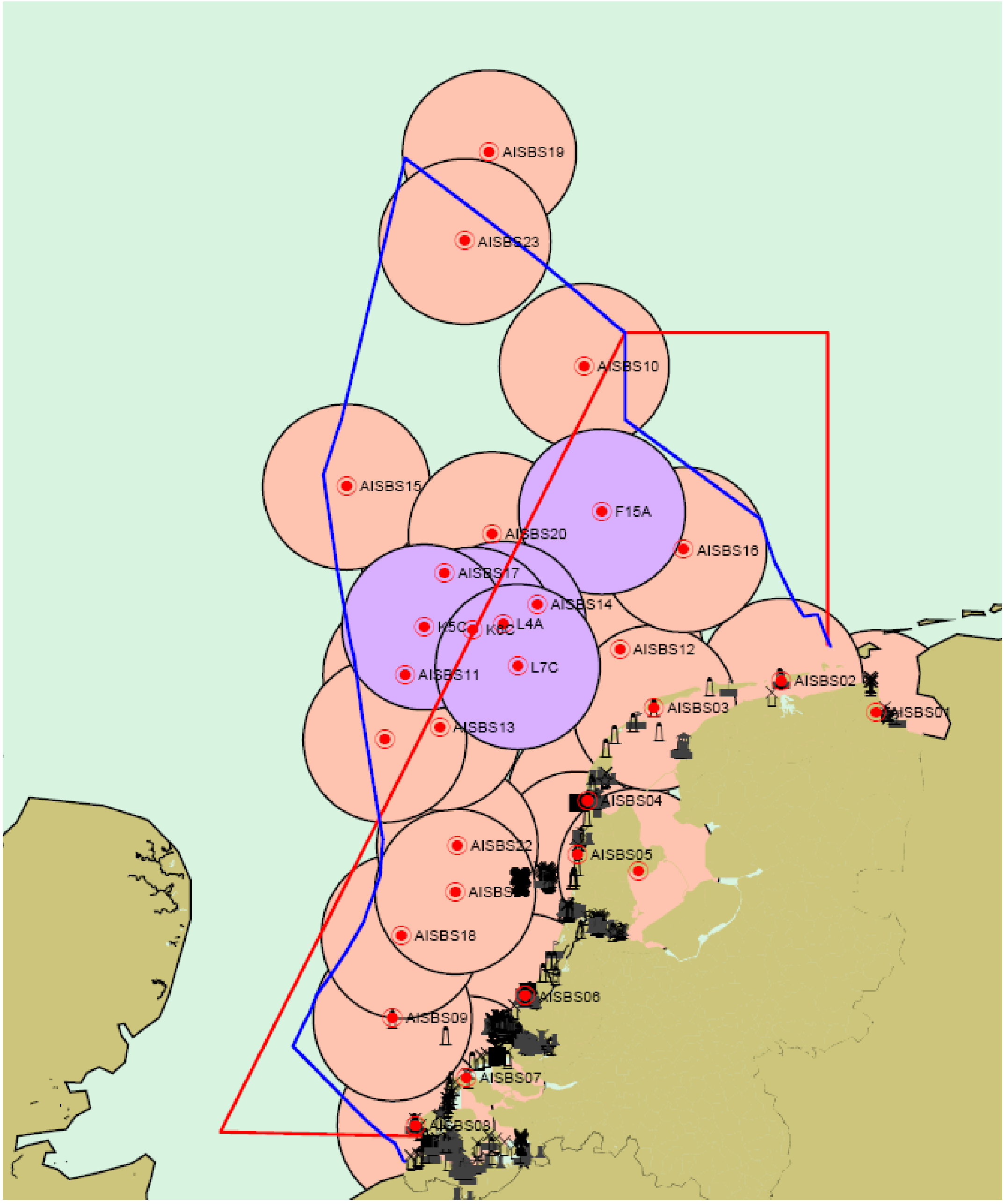

Figure 5-1 **AIS base stations delivering data to the Netherlands Coastguard, the blue line illustrates the NCS, the red line is not of interest for this study. The circles indicate the reach of the base stations, the purple circles indicate the newest base stations**

5.3 Number of fishing vessels included

Fishing vessels with a length over all of 45 m and larger are already obliged to have an AIS system on board. This means that all fishing vessels with a gross tonnage above 1600 are fully included in this study.

Starting in May 2012 AIS will be introduced stepwise on fishing vessels with a length below 45 m. For the current study it is interesting to know which percentage of this group was already equipped with an AIS system in 2010. When looking at the size classes used in this study, this means that we are interested in the percentage of fishing vessels with AIS in the class 100-1600 GT.

MARIN has some information about the number of fishing vessels at the NCS in 2009. In that year there were on average 59.4 fishing vessels with a gross tonnage between 100 and 1600 present at the NCS. This means that when taking a snap shot of the NCS at an arbitrary moment in 2009, approximately 60 fishing vessels will be observed. However, in the AIS data of 2010, the average number of fishing vessels at the NCS with a gross tonnage between 100 and 1600 is only 5.3. This means that approximately 9% of the fishing vessels in the size class 100-1600 GT had AIS in 2010.

Assuming that the average wet surface area of fishing vessels in this size class is similar for both data sets, a correction factor of 11 (59.4/5.3) should be applied to the wet surface area for fishing vessels of size class 100-1600 GT based on AIS data. Emissions scale linearly with the wet surface area, so the same factor can be used to calculate the corrected emission values.

6 RESULTS: WET SURFACE AREA AND EMISSION FOR 2010 FOR THE NCS AND THE DUTCH PORT AREAS

This chapter presents the wet surface area and emission that have been calculated for the NCS and the Dutch port areas for 2010. The calculations include all seagoing vessels that were observed in the AIS and that could be connected to a ship in the LLI ship characteristics database. As explained in Section 0, in 2010 only fishing vessels with a length over 45 m were obliged to have an AIS system on board. Smaller fishing vessels are therefore only partly included. The wet surface area of fishing vessels with a size of 100-1600 GT should be multiplied with 11 to obtain the results corrected for vessels without AIS system.

6.1 Wet surface area and emission at the NCS

This section first reports the wet surface area at the NCS per ship type and size class both for ships that are sailing and for non moving ships. Then, the emission from coatings to water for all substances are reported

6.1.1 Wet surface area at the NCS

Table 6-1 and Table 6-2 contain the average wet surface area at the NCS in 2010. This is the wet surface area that can be expected when looking at the NCS at any moment in the year. Table 6-1 contains the information about sailing ships and Table 6-2 about non moving ships. Ships with a speed below 1 knot are classified as non moving. 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).

It can be seen that the wet surface area of non moving ships is approximately 2/3 of the wet surface area of sailing ships. Container ships give the largest contribution to the wet surface area of sailing ships. Tankers give the largest contribution to the wet surface area of non moving ships. The wet surface area of non moving tankers is even larger than the wet surface area of sailing tankers.

When looking at the ship size classes, the largest contribution to the total wet surface area comes from ships between 10,000 and 30,000 gross tonnage.

Table 6-1 Average wet surface area in m^2 at the NCS of sailing ships in 2010 per ship type and size class

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		135	410	1,145	1,522	13,886	27,454	39,876	6,138	90,566
Chemical + Gas tanker		533	8,596	16,398	18,214	55,674	7,219	286	1,092	108,011
Bulk carrier		156	479	1,030	1,073	28,697	27,306	15,495	3,485	77,722
Container ship			1,391	1,428	18,379	29,540	36,109	48,905	20,466	156,217
General Dry Cargo	15	8,390	34,234	20,437	16,158	8,821	1,254			89,309
RoRo Cargo / Vehicle		1	186	105	5,860	29,149	24,997	6,427		66,724
Reefer		61	303	780	2,927	4,343				8,414
Passenger	1	21	21	53	85	2,658	6,747	3,416	670	13,672
Miscellaneous	44	4,198	3,071	2,379	6,752	13,282	551	160	458	30,894
Tug/Supply	17	4,959	7,832	906	387	103				14,204
Fishing	84	2,252	464	103	299	86				3,289
Non Merchant		103	41	6	49	10				209
Total	160	20,810	57,028	44,769	71,705	186,248	131,636	114,565	32,310	659,232

Table 6-2 Average wet surface area in m^2 at the NCS of non moving ships in 2010 per ship type and size class

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		7	235	1,782	2,170	27,119	57,034	46,848	20,787	155,981
Chemical + Gas tanker		496	5,933	15,325	27,398	97,180	14,083			160,416
Bulk carrier			4	275	230	10,121	12,428	18,772	6,189	48,018
Container ship			152	341	6,580	14,465	8,880	6,410	2,260	39,088
General Dry Cargo	17	942	4,226	3,481	2,869	1,589	119			13,243
RoRo Cargo / Vehicle			16	10	140	265	986	322		1,738
Reefer		4	45	115	769	793				1,725
Passenger	0	0	2	3		5	0	5	7	22
Miscellaneous	1	1,250	1,197	786	9,170	17,624	1,130	12	562	31,734
Tug/Supply	8	2,947	4,638	889	453	145				9,080
Fishing	10	389	7	1	7	4				418
Non Merchant		9	2							11
Total	36	6,043	16,457	23,009	49,786	169,309	94,660	72,368	29,805	461,474

6.1.2 Emission at the NCS

Table 6-3 summarises the calculated emissions for 2010, both for non moving and for sailing ships. The results have also been split up between emissions from ships with an EU coating and with a non-EU coating.
The emission from sailing ships is larger than the emission from non moving ships.

Table 6-3 Emission of sea shipping (in kg) at the NCS in 2010

Substance		Non moving			Sailing			Total
No.	Name	EU coating	non-EU coating	Total	EU coating	non-EU coating	Total	
5142	Copper	618	6,854	7,471	1,653	12,270	13,923	21,394
6030	Irgarol 1051/Cybutryne	19	206	224	50	368	418	642
6136	Zineb	19	206	224	50	368	418	642
8265	Diclofluanid	19	206	224	50	368	418	642
9082	Zincpyrithione	19	206	224	50	368	418	642
9083	Seanine 211N	19	206	224	50	368	418	642

6.2 Wet surface area and emission in Dutch port areas

6.2.1 Wet surface area in Dutch port areas

Table 6-4 gives a summary of the total average wet surface area in 2010 for the four Dutch port areas. Appendix B contains tables with the average wet surface area per ship type and size class for each Dutch port area, both for sailing and non moving ships.

Rotterdam is the largest Dutch port area and the average wet surface area for this area is obviously larger than for the other Dutch port areas. In the Western Scheldt, the average wet surface area of sailing ships is almost identical to the average wet surface area of non moving ships. This is because lots of ships have to sail a long distance to Antwerp and the wet surface area of non moving ships in the port of Antwerp is not included in this report.

Table 6-4 Average wet surface area in m^2 in the Dutch port areas in 2010

Area	non moving	sailing
Western Scheldt	86,766	68,811
Rotterdam	539,639	58,025
Ems	25,425	6,639
Amsterdam	163,159	14,357

6.2.2 Emission in Dutch port areas

Table 6-5 contains the emission in the Dutch port areas. The trends are the same as observed for the wet surface area in Section 6.2.1.

Table 6-5 Emission of sea shipping (in kg) in Dutch port areas in 2010, fishing vessels included as far as possible

Substance			Coating	Western Scheldt	Rotterdam	Ems	Amsterdam	Total
5142	Copper	Non moving	EU	259	975	104	278	1,615
			non-EU	1,152	7,510	307	2,372	11,340
		Sailing	EU	149	181	39	44	414
			non-EU	1,305	1,041	104	265	2,715
		Total non moving		1,411	8,485	410	2,649	12,956
		Total sailing		1,454	1,222	144	310	3,129
		Total		2,865	9,707	554	2,959	16,084
6030	Irgarol	Non moving	EU	8	29	3	8	48
			non-EU	35	225	9	71	340
		Sailing	EU	4	5	1	1	12
			non-EU	39	31	3	8	81
		Total non moving		42	255	12	79	389
		Total sailing		44	37	4	9	94
		Total		86	291	17	89	483
6136	Zineb	Non moving	EU	8	29	3	8	48
			non-EU	35	225	9	71	340
		Sailing	EU	4	5	1	1	12
			non-EU	39	31	3	8	81
		Total non moving		42	255	12	79	389
		Total sailing		44	37	4	9	94
		Total		86	291	17	89	483
8265	Dichlofluanid	Non moving	EU	8	29	3	8	48
			non-EU	35	225	9	71	340
		Sailing	EU	4	5	1	1	12
			non-EU	39	31	3	8	81
		Total non moving		42	255	12	79	389
		Total sailing		44	37	4	9	94
		Total		86	291	17	89	483
9082	Zincpyrithione	Non moving	EU	8	29	3	8	48
			non-EU	35	225	9	71	340
		Sailing	EU	4	5	1	1	12
			non-EU	39	31	3	8	81
		Total non moving		42	255	12	79	389
		Total sailing		44	37	4	9	94
		Total		86	291	17	89	483
9083	Seanine	Non moving	EU	8	29	3	8	48
			non-EU	35	225	9	71	340
		Sailing	EU	4	5	1	1	12
			non-EU	39	31	3	8	81
		Total non moving		42	255	12	79	389
		Total sailing		44	37	4	9	94
		Total		86	291	17	89	483

6.3 Spatial distribution of the emissions

All substances show the same spatial distribution because all emissions depend on the wet surface area. Therefore, only the spatial distribution of copper is presented for the NCS and the four Dutch port areas in Figure 6-1.

The highest emissions of coating per km^2 are found in the port areas, in the approaches to the port areas and in anchorage areas. The emission in the traffic lanes is somewhat lower. Some single grid cells in other areas also have relatively high emission. This is due to activities at sea, for example activities around offshore platforms.

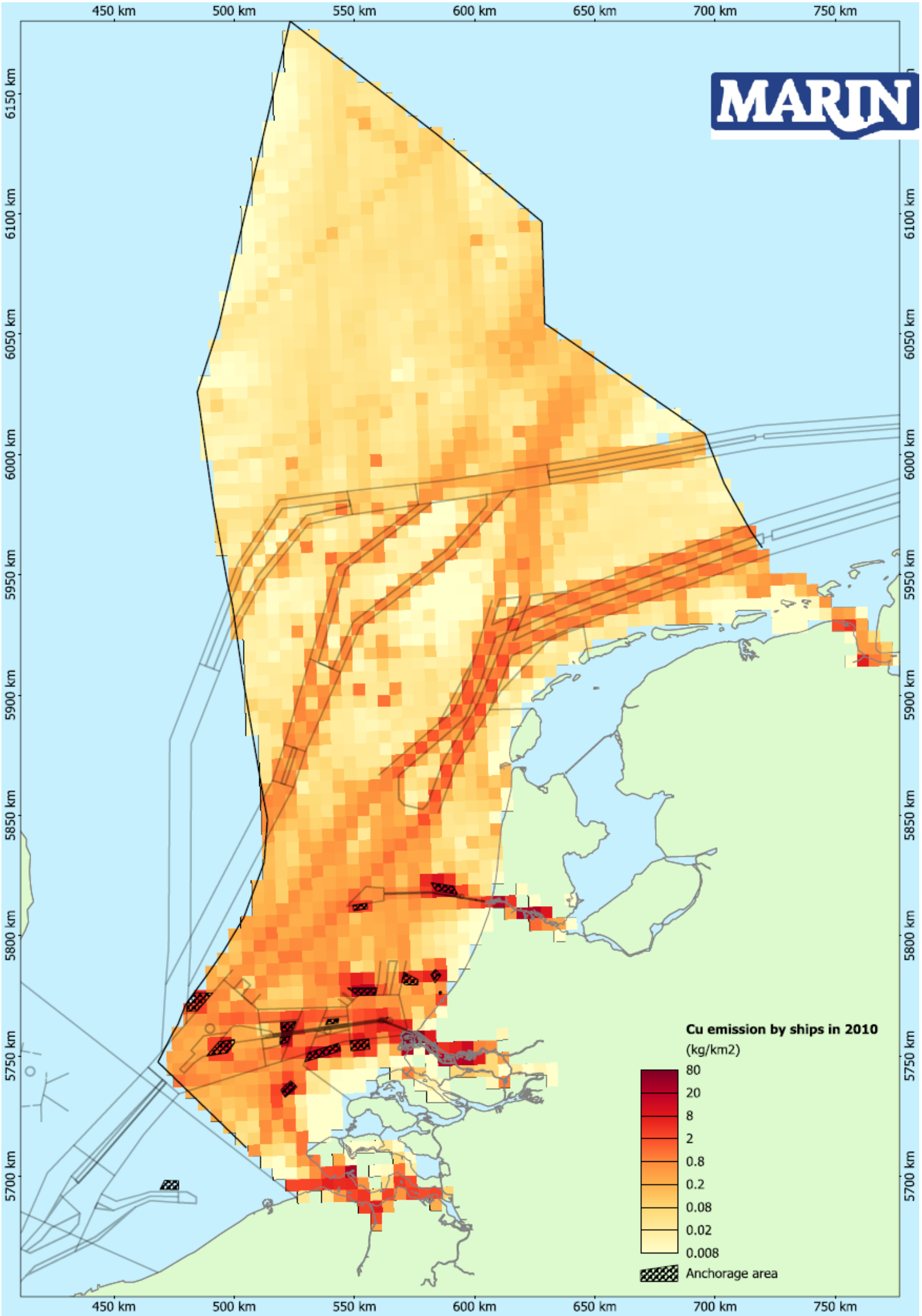

Figure 6-1 Copper emission at the NCS and Dutch port areas by ships with AIS in 2010

7 APPROACH: PROCEDURE FOR EMISSION CALCULATION BASED ON SAMSON TRAFFIC DATABASE

This chapter explains the procedure that has been used to perform the emission calculations based on the SAMSON traffic database. This method has been used to calculate the emission for OSPAR region II. Figure 7-1 visualizes the databases that are referred to in the description of the procedure. The input files are the ones shown in blue. A description of AIS data and emission factors can be found in Section 4.1. This section starts with a description of the SAMSON traffic database for 2008 and continues with the procedure for calculation of the wet surface area and emission.

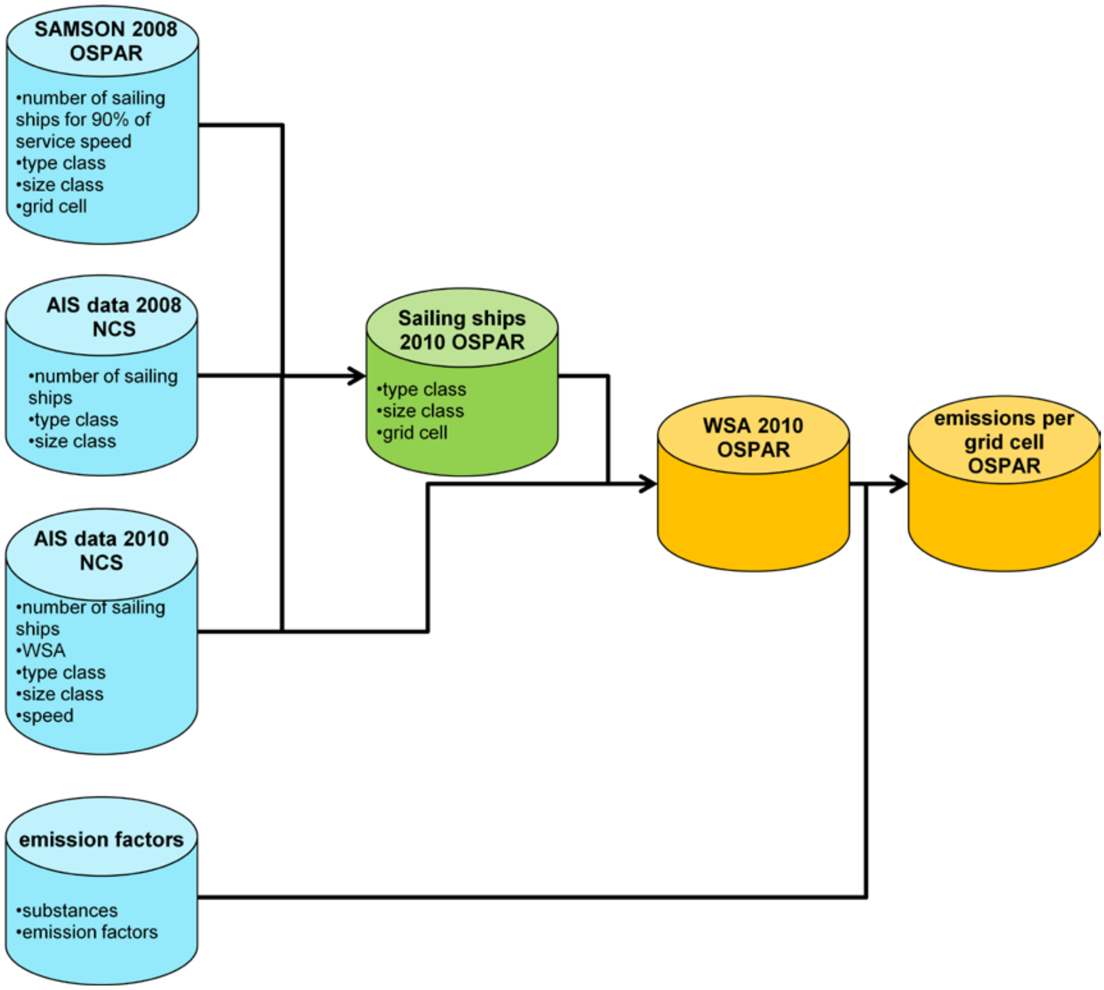

Figure 7-1 Databases with relations for emission calculation based on SAMSON (blue = input, green is intermediate, orange = output

7.1 Input "SAMSON 2008 OSPAR"

MARIN has no access to AIS data for the whole OSPAR region II. For the estimation of the emissions in this area the number of ships in each type and size class have been obtained from the SAMSON traffic database. The basis for this traffic database are all voyages crossing the North Sea in 2008 collected by Lloyd's List Intelligence.. Figure 7-2 shows all traffic links in the 2008 SAMSON traffic database.

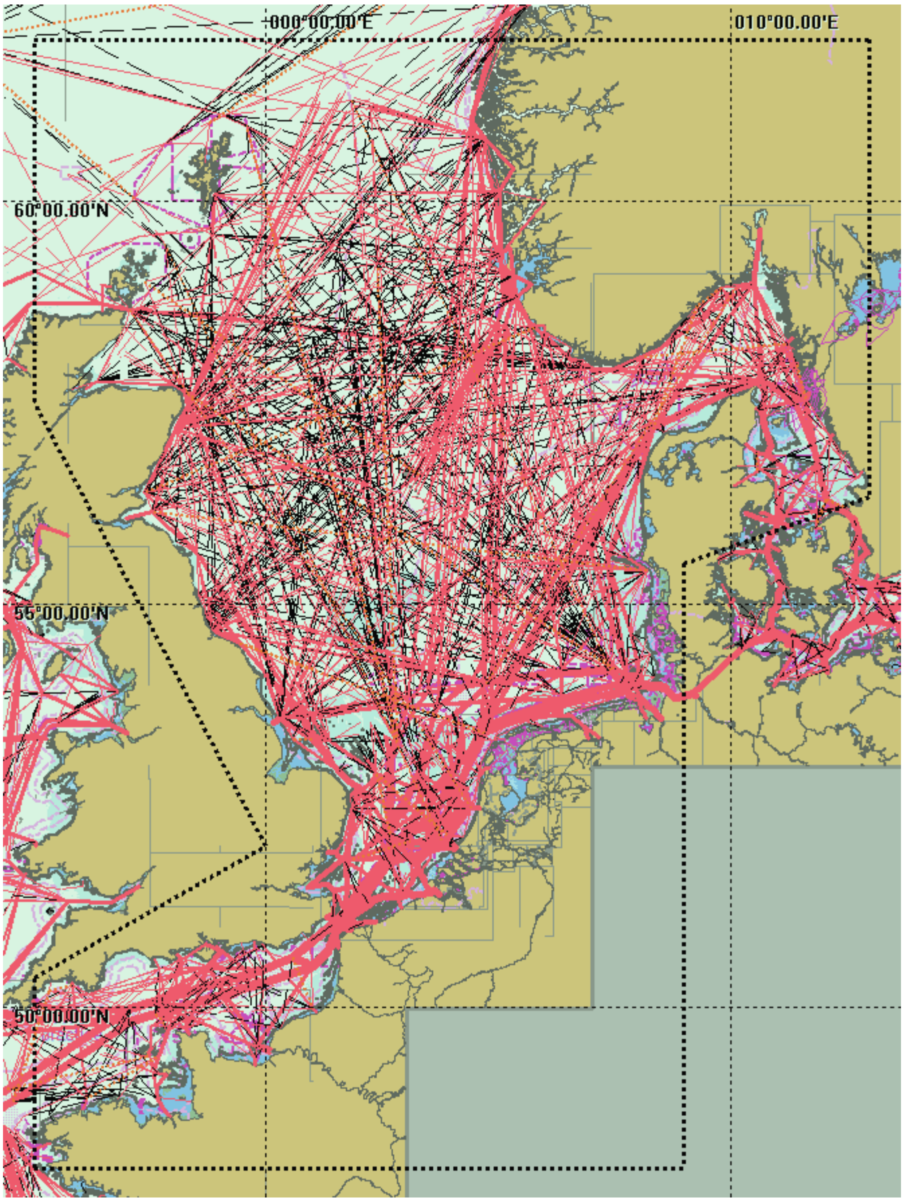

Figure 7-2 Traffic links in OSPAR region II, the width indicates the intensity of ships on the link, red links represent a higher intensity than black links

The black lines represent links with less than one movement per month. The red lines describe the traffic links with more movements. The width indicates, on a non linear scale, the number of movements per year. The traffic links in Dover Strait represent about 40,000 movements in one direction per year.

The SAMSON traffic database contains the number of ship movements per year for each traffic link divided over 36 ship types and 8 ship size classes. Only a few fishing vessels are part of this database. These are mainly large fishing vessels that stay at sea for a long period of time.

7.2 Procedure for combining the input to obtain emissions

This Section describes the steps that have been taken to calculate the emissions for OSPAR region II based on the SAMSON traffic database. The steps are visualized in Figure 7-1.

7.2.1 Combining "SAMSON 2008 OSPAR", "AIS data 2008 NCS" and "AIS data 2010 NCS" to obtain "Sailing ships 2010 OSPAR"

The main input to calculate the average number of ships sailing in OSPAR region II for 2010 is the SAMSON traffic database for 2008. There are two corrections that have been made:

1. The average number of ships per ship type and size class in each grid cell that is obtained from SAMSON, has been calculated by assuming an average speed of 90% of the service speed. Based on the AIS data for 2010, the actual average speed at the NCS has been determined per ship type and size class. Based on this actual speed the calculated average number of ship has been corrected. So the average number of ships is now based on the actual speed from AIS.
2. The average number of ships in OSPAR region II per ship type and size class in each grid cell for 2008 based on the actual speed of AIS has been multiplied with a factor $F_{ij}^{traffic}$ to calculate the average number of ships for 2010.

$$ships_{cij}^{OSPAR} = F_{ij}^{traffic} \cdot ships_{cij}^{OSPAR,2008}$$

In which:
c = grid cell
i = ship type class
j = ship size class

$$F_{ij}^{traffic} = \frac{ships_{ij}^{2010,AIS}}{ships_{ij}^{2008,AIS}}$$

The factor $F_{ij}^{traffic}$is based on the AIS data of 2008 and 2010 at the NCS, assuming that the changes at the NCS are also representative for the total OSPAR region II.

7.2.2 Combining "AIS data 2010 NCS" and "Sailing ships 2010 OSPAR" to obtain "WSA 2010 OSPAR"

The average wet surface area per ship in 2010 has been calculated for all ship type and size classes for the NCS. It is assumed that this average wet surface area is similar in OSPAR region II. The wet surface area in OSPAR region II per grid cell is obtained by multiplying the average number of sailing ships per grid cell in OSPAR region II with the average wet surface area per ship from the NCS.

$$WSA_{cij} = ships_{cij}^{OSPAR} \cdot WSA_{ij}^{NCS,AIS}$$

7.2.3 Combining "WSA 2010 OSPAR" and "emission factors" to obtain "emissions per grid cell OSPAR"

The emissions and wet surface areas were linked in the same way as for the emissions calculated based on AIS data.

8 RESULTS: WET SURFACE AREA AND EMISSIONS FOR OSPAR REGION II IN 2010

This chapter presents the wet surface area and emission that have been calculated for OSPAR region II for 2010. The calculations include all seagoing vessels that are included in the SAMSON traffic database. Most fishing vessel have a non route-bound character, while this is a database containing route bound traffic only. A large percentage of the fishing vessels is therefore missing.

8.1 Wet surface area

This Section reports the wet surface area that is calculated based on SAMSON. First The wet surface area for the NCS is reported and compared with the values calculated based on AIS data. Then, the wet surface area for OSPAR region II is reported.

8.1.1 Wet surface area at NCS based on SAMSON

Table 8-1 summarises the average wet surface area at the NCS for sailing ships in 2010 based on SAMSON. Table 8-2 makes a comparison with the average wet surface area that is calculated based on AIS data. The wet surface area of fishing vessels, tug/supply and miscellaneous calculated based on SAMSON is much lower than calculated based on AIS data. This is because only the information of route bound ships in SAMSON is used, while these ships mainly have a non route-bound behaviour.

The overall average wet surface area at the NCS is 3% higher by the calculation based on the SAMSON traffic database than based on AIS data.

Table 8-1 Average wet surface area in m^2 at the NCS of sailing ships in 2010 based on SAMSON

Ship Type	EMS Gross Tonnage classes								Total
	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker	144	1,201	697	1,502	15,936	29,929	44,127	7,021	100,558
Chemical + Gas tanker	619	13,461	10,618	20,024	58,629	6,436	156	2,407	112,349
Bulk carrier	195	994	636	1,225	30,820	28,846	14,826	2,981	80,523
Container ship	0	2,019	931	18,539	32,453	40,592	53,193	21,575	169,303
General Dry Cargo	9,195	36,821	23,986	18,530	8,821	1,348	0		98,701
RoRo Cargo / Vehicle	2	357	95	6,485	30,260	26,913	7,345		71,458
Reefer	27	800	402	3,024	3,952				8,206
Passenger	78	37	58	102	2,952	6,746	2,444	823	13,239
Miscellaneous	1,143	1,310	1,152	3,745	10,053	695	80	918	19,096
Tug/Supply	1,875	345	354	330					2,905
Fishing	560	255	225	863	667				2,570
Total	13,839	57,600	39,154	74,369	194,545	141,505	122,171	35,725	678,908

Table 8-2 Average wet surface area in m^2 at the NCS of sailing ships in 2010 based on SAMSON as percentage of wet surface area based on AIS

Ship Type	EMS Gross Tonnage classes								Total
	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker	107%	293%	61%	99%	115%	109%	111%	114%	111%
Chemical + Gas tanker	116%	157%	65%	110%	105%	89%	55%	220%	104%
Bulk carrier	125%	207%	62%	114%	107%	106%	96%	86%	104%
Container ship		145%	65%	101%	110%	112%	109%	105%	108%
General Dry Cargo	110%	108%	117%	115%	100%	107%			111%
RoRo Cargo / Vehicle	337%	192%	91%	111%	104%	108%	114%		107%
Reefer	45%	264%	51%	103%	91%				98%
Passenger	365%	177%	110%	119%	111%	100%	72%	123%	97%
Miscellaneous	27%	43%	48%	55%	76%	126%	50%	200%	62%
Tug/Supply	38%	4%	39%	85%					20%
Fishing	25%	55%	217%	289%	774%				78%
Total	67%	101%	87%	104%	104%	107%	107%	111%	103%

8.1.2 Wet surface area in OSPAR region II

Table 8-3 contains the average wet surface area of sailing ships in OSPAR region II in 2010.

The average wet surface area in OSPAR region II is 5.7 times higher than the average wet surface area at the NCS. A more detailed comparison on ship type level learns that container and RoRo ships are over represented at the NCS and that oil tankers and passenger ships are under represented at the NCS.

When looking at the ship size classes, the largest wet surface area comes from ships between 10,000 and 30,000 gross tonnage. This is the same size class as at the NCS.

Table 8-3 Average wet surface area in m^2 in OSPAR region II of sailing ships in 2010

Ship Type	EMS Gross Tonnage classes								Total
	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker	1,662	14,086	9,787	23,062	86,009	218,402	341,026	52,791	746,825
Chemical + Gas tanker	5,237	68,034	54,064	100,150	307,511	40,938	7,995	27,090	611,018
Bulk carrier	1,220	7,678	4,910	8,254	185,090	186,062	114,510	16,275	523,999
Container ship	0	11,549	5,327	122,057	159,120	173,951	202,109	81,269	755,382
General Dry Cargo	57,213	185,586	120,749	93,086	51,957	6,904	0		515,495
RoRo Cargo / Vehicle	21	3,533	932	41,876	150,822	123,808	33,712		354,705
Reefer	141	7,087	3,558	17,051	24,438				52,274
Passenger	1,454	725	1,214	1,279	17,643	40,984	34,660	7,562	105,520
Miscellaneous	8,623	11,474	10,101	25,867	74,196	3,815	693	4,700	139,469
Tug/Supply	10,343	3,911	4,010	12,091					30,354
Fishing	6,665	2,188	1,929	2,999	5,239				19,019
Total	92,578	315,850	216,581	447,773	1,062,024	794,864	734,705	189,686	3,854,061

8.2 Emission in OSPAR region II

Table 8-4 summarises the emission in OSPAR region II in 2010.

Table 8-4 Emission (in kg) in OSPAR region II in 2010

Substance		Sailing		
No.	Name	EU coating	non-EU coating	Total
5142	Copper	8,753	73,167	81,920
6030	Irgarol 1051/Cybutryne	263	2,195	2,458
6136	Zineb	263	2,195	2,458
8265	Diclofluanid	263	2,195	2,458
9082	Zincpyrithione	263	2,195	2,458
9083	Seanine 211N	263	2,195	2,458

Figure 8-1 contains the spatial distribution of copper emission in OSPAR region II. By comparing the emission at the NCS in Figure 8-1 which is based on the SAMSON traffic database with the emission at the NCS Figure 6-1 which is based on AIS data, one sees that the emissions based on the SAMSON traffic database are more concentrated on the traffic lanes. This is because in the calculations for OSPAR region II it was assumed that all ships sail over the centre line of each shipping route. Furthermore, the emissions based on AIS data contain non moving ships and more ships sailing outside the main routes, such as supply vessels and other work vessels.

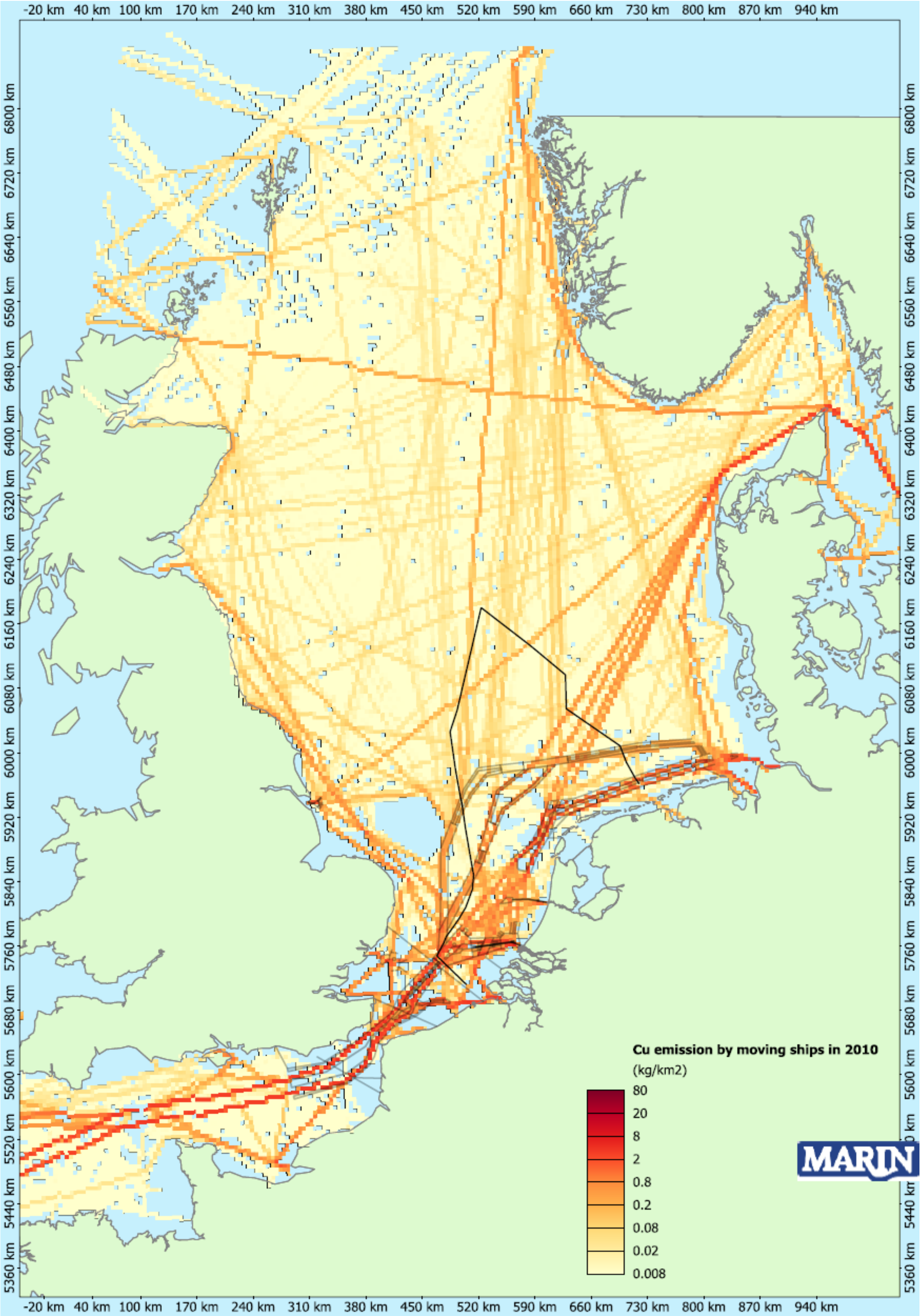

Figure 8-1 **Copper emission in OSPAR region II at sea in 2010 of route bound ships that are sailing**

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The emission of coating to water of seagoing vessels in 2010 has been determined for the NCS, the Dutch port areas and OSPAR region II, including fishery as far as possible. The following substances have been taken into account: copper and the co-biocides Irgarol, Zineb, Diclofluanid, Zincpyrithione and Seanine. The following distinctions were made:

- EMS ship type classes and ship size classes;
- sailing / non moving ships;
- region, for example within or outside the 12-mile zone;
- EU coating / non-EU coating.

A grid size of 5000 x 5000 m has been used. Results have been delivered in a database and the wet surface area has also been reported.

The calculations for the NCS and the Dutch port areas are based on AIS data for 2010, the calculations for OSPAR region II are based on the SAMSON traffic database for 2008. For OSPAR region II a correction was made for the change in traffic between 2008 and 2010 obtained from AIS data.

It is difficult to make a comparison with the results from the study for 2007 [4]. In that study, the wet surface area was not reported and different emission factors were used resulting in different emissions. The area definition was also different. For the current study the same area definition is used as for the emission to air [10].

An estimate was made on how many of the ships have a coating from the EU per ship type and size class. It appeared that on average 22% of the ships stay within the EU. Smaller vessels stay more often in the EU and larger vessels almost always travel to countries outside the EU. It has been assumed that ships that travel outside the EU have a non-EU-coating. The emission from EU-coatings is a lower bound value.

Fishing vessels with a length over all below 45 m are not yet obliged to have an AIS system on board. The results for fishing vessels in the size class 100-1600 GT has to be multiplied with 11 to obtain the values corrected for ships without AIS.

The average wet surface area at the NCS calculated based on the SAMSON traffic database is very similar to that based on AIS data; the difference is only 3%.

The calculated emissions from coatings at the NCS and in OSPAR region II for 2010 are summarized in Table 9-1.

Table 9-1 Summary of emission at the NCS and in OSPAR region II in 2010 in kg

Substance		NCS			OSPAR region II
No.	Name	Non moving	Sailing	Total	Sailing
5142	Copper	7,471	13,923	21,394	81,920
6030	Irgarol 1051/Cybutryne	224	418	642	2,458
6136	Zineb	224	418	642	2,458
8265	Diclofluanid	224	418	642	2,458
9082	Zincpyrithione	224	418	642	2,458
9083	Seanine 211N	224	418	642	2,458

9.2 Recommendations

Improvement of the coverage of AIS or an increase of the number of ships sailing with AIS can result in a growth of the reported emissions that cannot be assigned to the actual changes in emissions of ships. Therefore, the AIS coverage should remain a point of attention in the future to prevent drawing wrong conclusions.

The recommended update frequency depends on the expected changes in the emission from coatings to water in the future. Changes in the reported emission can be caused by changes in:

- traffic;
- completeness of AIS data;
- coatings used;
- emission factors.

Traffic
Large changes in traffic at the NCS can be expected due to changes in the infrastructure of Dutch ports. The biggest change is Maasvlakte 2, which is an extension of the port of Rotterdam for the largest ships in the world. The first containers will be processed in 2013. This will result in an increase in wet surface area.

Completeness of AIS data
One of the reasons for improved correctness of AIS data, is the extension of the AIS user group. Smaller fishing vessels will be obliged to have an AIS system on board in the coming years. The introduction scheme of AIS systems on fishing vessels is as follows:
May 31, 2012: between 24 and 45 m
May 31, 2013: between 18 and 24 m
May 31, 2014: between 15 and 18 m.

The majority of fishing vessels at the NCS has a length between 26 and 46 m. This means that the completeness of fishing vessels in the AIS data will be much larger in 2013 than it was in 2010. This will result in an increase in calculated wet surface area. Therefore, the first new study is recommended for 2013.

Coatings
January 1, 2013 the EU directive on Biocidal Product Regulation is scheduled to come into force. This will result in a change in the coatings used. It will take some time before the effect is visible, but large changes are expected in 2015. Therefore, the second new study is recommended for 2015.

Emission factors
The uncertainty about the correctness of the emission factors that are used in this study is large. Therefore, it is recommended to perform a study to determine new emission factors before performing a new study to determine the emissions.

REFERENCES

[1] www.emissieregistratie.nl

[2] www.helpdeskwater.nl/

[3] www.ospar.org/

[4] C. van der Tak
Emissions of coatings and anodes by shipping in the greater North Sea (OSPAR region II), based on AIS data
MARIN, no: 22776.620/2, November 4, 2008

[5] Netherlands National Water Board – Water Unit in cooperation with Deltares and TNO
Antifoulants in marine coatings, merchant shipping and fisheries
Version dated June 2008
http://www.emissieregistratie.nl/ERPUBLIEK/documenten/Water/Factsheets/English/Coatings,%20merchant%20shipping.pdf

[6] Health and Safety Executive
http://webcommunities.hse.gov.uk/connect.ti/pesticides/viewdatastore?dsid=2308&adv=S&search=&searchcolNo=&showAllColumns=N&SEARCH_0=1&sortCol1=Col%5F0&sortDir1=asc&showNum=100&dir=asc&sort=Col_0&trim=Y&startRow=301

[7] CTGB – College voor toelating van gewasbeschermingsmiddelen en biociden
www.ctgb.nl

[8] KEMI - kemikalieinspektionen
Sold quantities of pesticides - 2010

[9] Rakat
Active Ingredient Releases from Anti-fouling coatings into European Waters from Commercial and Yachts / Pleasure Craft Movements
Safinah, document number 463CCEP001R, 15 December 2010

[10] A. Cotteleer and J.H.J. Hulskotte
Sea shipping emissions 2010: Netherlands Continental Shelf, port areas and OSPAR region II
MARIN, no. 25185-1-MSCN-rev. 4, February 9, 2012

[11] A. A. Finnie
Improved estimates of environmental copper release rates from antifouling products
2006 Biofouling, page 1-13

[12] A. C. Willemsen
Emission factor related to antifoulant products used in marine coatings, merchant shipping and fisheries
ICOMIA

APPENDIX A

COUNTRIES THAT ARE EXPECTED TO FOLLOW THE EU RULES FOR COATINGS

Albania
Aland Islands
Andorra
Austria
Azores
Belgium
Bulgaria
Bosnia Hercegovina
Switzerland
Canary Islands
Czechoslovakia
Cyprus
Czech Republic
German Democratic Republic
Germany
Danish International Register
Denmark
Spain
Republic of Estonia
Finland
France
United Kingdom
Gibraltar
Guadeloupe
Greece
Greenland
French Guiana
Republic of Croatia
Hungary
Republic of Ireland
Iceland
Italy
Liechtenstein
Republic of Lithuania
Luxembourg
Republic of Latvia
Monaco
Republic of Macedonia
Malta
Montenegro
Martinique
Norwegian International Register
Netherlands
Norway
Madeira
Poland
Portugal
Reunion
French International Register
Romania
Svalbard & Jan Mayen Islands
San Marino
Slovakia
Republic of Slovenia
Sweden
Vatican City
Yugoslavia

APPENDIX B

WET SURFACE AREA PER SHIP TYPE AND SIZE CLASS FOR THE DUTCH PORT AREAS

Table B - 1 Average wet surface area in m² in the Dutch part of the Western Scheldt of sailing ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		2	111	129	92	609	1,212	1,049	31	3,235
Chemical + Gas tanker		53	1,308	2,633	2,094	4,077	620		4	10,789
Bulk carrier			19	65	42	2,986	2,492	223	28	5,855
Container ship			122	118	1,642	6,396	8,975	5,490	2,040	24,783
General Dry Cargo		676	2,667	1,370	1,695	1,969	438			8,815
RoRo Cargo / Vehicle		0	33	8	141	1,731	5,312	975		8,200
Reefer				34	112	1,232				1,377
Passenger		135	1	3		13	8	47		207
Miscellaneous	31	636	961	758	936	1,833	23			5,178
Tug/Supply	2	286	12	53	3					356
Fishing	0	2	0		8					11
Non Merchant		5								5
Total	33	1,796	5,235	5,170	6,764	20,846	19,079	7,785	2,104	68,811

Table B - 2 Average wet surface area in m² in the Dutch part of the Western Scheldt of non moving ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		3	169	15	108	866	1,464	1,867	147	4,638
Chemical + Gas tanker		21	1,131	2,553	2,560	7,409	1,659		14	15,348
Bulk carrier			34	119	60	7,081	5,601	1,178	16	14,088
Container ship			74	68	922	777	565	12	15	2,434
General Dry Cargo		970	4,505	3,347	3,216	4,937	3,873			20,848
RoRo Cargo / Vehicle		4	124	22	531	5,630	1,277	41		7,630
Reefer				454	1,803	1,311				3,568
Passenger		267	12	71		1	9	0		360
Miscellaneous	61	4,504	2,890	2,332	2,659	2,043	285			14,774
Tug/Supply	14	2,075	121	219	10					2,440
Fishing	0	8	1		476					485
Non Merchant		156								156
Total	76	8,009	9,061	9,198	12,345	30,055	14,732	3,097	192	86,766

Table B - 3 Average wet surface area in m² in Rotterdam port area of sailing ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		10	43	116	107	904	1,884	2,975	1,444	7,483
Chemical + Gas tanker		46	856	1,504	1,648	4,720	421			9,196
Bulk carrier			11	23	51	1,046	1,371	1,382	661	4,545
Container ship			474	386	5,615	3,593	3,204	4,864	1,939	20,075
General Dry Cargo		658	1,885	976	1,083	606	58			5,265
RoRo Cargo / Vehicle			5	2	260	3,945	224	103		4,539
Reefer			1	8	160	219				388
Passenger		1	1			244	741	404	46	1,436
Miscellaneous	30	225	286	1,023	369	1,044	53	17	35	3,082
Tug/Supply	2	1,871	62	23	29	2				1,990
Fishing	3	11	4		3					21
Non Merchant		4	3							7
Total	35	2,826	3,632	4,061	9,325	16,323	7,956	9,744	4,125	58,025

Table B - 4 Average wet surface area in m² in Rotterdam port area of non moving ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		4	195	336	484	8,139	24,320	36,659	23,807	93,945
Chemical + Gas tanker		223	3,259	6,719	8,800	38,487	7,024			64,512
Bulk carrier			1	69	244	14,960	30,787	45,692	23,419	115,173
Container ship			1,337	2,235	28,115	19,759	18,700	52,140	22,430	144,715
General Dry Cargo		1,191	8,281	5,768	7,848	7,782	964			31,835
RoRo Cargo / Vehicle			21	91	1,559	16,611	890	427		19,598
Reefer			1	86	1,350	838				2,275
Passenger		3	2			2,948	6,254	2,068	82	11,356
Miscellaneous	201	1,571	3,321	2,254	2,802	20,913	2,007	778	9,647	43,493
Tug/Supply	11	8,436	930	437	205	25				10,044
Fishing	51	1,332	745		535					2,663
Non Merchant		17	11							28
Total	263	12,777	18,104	17,995	51,943	130,462	90,945	137,764	79,385	539,639

Table B - 5 Average wet surface area in m^2 in Amsterdam port area of sailing ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		4	19	68	22	607	595	178		1,493
Chemical + Gas tanker		8	103	180	620	2,180	386			3,477
Bulk carrier		0	1	37	13	705	1,698	1,266	16	3,738
Container ship			8	3	0	94	31	31	0	168
General Dry Cargo		246	823	187	164	87	11			1,517
RoRo Cargo / Vehicle		1	2	1	342	103	506	121		1,076
Reefer		6	25	40	49	27				147
Passenger		3	0	2	5	31	444	277		761
Miscellaneous	0	121	136	189	320	201				967
Tug/Supply	2	809	66	15		1				893
Fishing	0	11	15	21	45	9				102
Non Merchant		14	3							17
Total	2	1,222	1,202	744	1,581	4,046	3,672	1,873	16	14,357

Table B - 6 Average wet surface area in m^2 in Amsterdam port area of non moving ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		1	138	243	82	5,308	5,904	2,618		14,293
Chemical + Gas tanker		13	354	855	3,330	17,128	4,860			26,540
Bulk carrier		3	5	207	65	11,976	28,903	26,816	377	68,352
Container ship			109	27	14	1,211	848	237	0	2,447
General Dry Cargo		1,861	7,721	2,541	3,026	1,370	69			16,587
RoRo Cargo / Vehicle		32	25	1	1,335	545	3,825	550		6,315
Reefer		279	1,061	701	1,241	811				4,094
Passenger		12	1	4	26	571	1,602	764		2,979
Miscellaneous	0	1,277	856	1,670	1,352	3,227				8,383
Tug/Supply	15	5,883	1,202	419		10				7,530
Fishing	0	578	945	1,151	1,941	520				5,135
Non Merchant		402	101							504
Total	15	10,344	12,518	7,820	12,412	42,677	46,011	30,984	377	163,159

Table B - 7 Average wet surface area in m^2 in the Dutch part of the Ems area of sailing ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		13	16		4	8				41
Chemical + Gas tanker		46	64	97	157	51	23			437
Bulk carrier				33	116	106	12		5	272
Container ship			7	21	5	20	10			62
General Dry Cargo		160	578	352	283	89	45			1,507
RoRo Cargo / Vehicle		0	349		477	332	813	155		2,127
Reefer		2	24	14						39
Passenger		63	53					26	37	179
Miscellaneous	0	218	195	52	1,207					1,672
Tug/Supply	0	160	67	34	29					292
Fishing	0	7	2							9
Non Merchant		1		1						2
Total	1	671	1,355	604	2,278	606	903	181	42	6,639

Table B - 8 Average wet surface area in m^2 in the Dutch part of the Ems area of non moving ships in 2010

Ship Type	EMS Gross Tonnage classes									Total
	0 100	100 1600	1600 3000	3000 5000	5000 10000	10000 30000	30000 60000	60000 100000	>100000	
Oil tanker		14	6		36	2				58
Chemical + Gas tanker		55	184	289	347	25				900
Bulk carrier				20	614	818	245		206	1,902
Container ship			58	93	3,112					3,263
General Dry Cargo		772	3,157	2,051	2,969	316				9,266
RoRo Cargo / Vehicle			425		1,913	186	13			2,537
Reefer		33	294	101						428
Passenger		18	121					512	284	934
Miscellaneous	0	386	726	1,137	873					3,121
Tug/Supply	5	2,434	239	21	237					2,936
Fishing	4	40	34							78
Non Merchant										
Total	9	3,752	5,245	3,713	10,100	1,347	258	512	489	25,425