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TNO report

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Revised calculation of emissions of fisheries on the Netherlands territory

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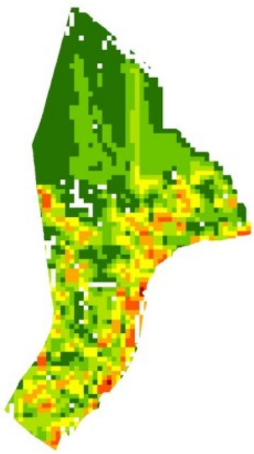
Summary

This report describes the outcome of a project wherein the emissions of fishery vessels on the Dutch territorial waters were reassessed using a novel method based on the application of AIS-data as activity data.
In a preparation of the method that is presented in this report, average fuel consumption of fishery vessels was determined by Wageningen Economic Research. Within this preparation the fleet of fishing vessels was divided in 15 segments having different fuel usage patterns in dependence of prevalent activities (fishing or sailing) characterised by speed ranges that were indicated. In most cases the highest fuel rate is found during fishing activities which are most often indicated by lower speed ranges. After having studied the type of engines that are installed on Dutch fishery cutters it was decided that engines used are very similar to engines used in inland waterway transport. By consequence the conclusion was drawn that emission factors applied on inland ships are probably most suitable to model emissions from fishery vessels. Future emission factors however will be governed by Regulation 13 of Annex VI of MARPOL. This means that new fishery ships require marine diesel engines to comply with the Tier III NOX emission limit when installed on ships constructed on or after 1 January 2021.
Emission factors were attributed to individual vessels based on the year of build of the engine. Results of emission calculations are presented per segment of fishing vessels and as a new map containing spatial allocation of fishery emissions. The new map of fishing emissions is considered to be of superior quality compared to the map that was used before within the national Emission Inventory. The resulting implied emission factors for air pollutants can also be used to derive national emission totals for emission reporting under the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) and the EU National Emission Ceilings Directive. According to international guidelines, national emission totals have to be reported based on the amount of fuel sold to fisheries within the country.

Contents

1 Introduction

The assessment of fishery emissions within the Dutch emission inventory has got very limited attention until now. The emission factors currently used, are from an outdated report about seagoing vessels which was based on literature concerning seagoing ships (Hulskotte and Koch, 2000). Fleet renewal was not covered in emission factors until now.
Annual emissions were calculated using the fuel sales to fishery sectors and the outdated emission factors.
Figure 1 shows the spatial distribution of fishery emissions, which was based on density of traffic by fishing vessels per grid cell (The NCP is divided in a square mesh of nautical miles/ 5*5km) in the year 2005 obtained by AIS[1]-data (Koldenhof, 2006). Only fishing vessels having IMO-numbers were covered in this report.



*Example map 20c: fishing vessels, nautical miles 5*5km. Orange and red colours indicate higher numbers of nautical miles per grid cell.*

Institutes involved
RIVM
MARIN
TNO

Currency of distribution basis data
2014 (non-fishing vessels), 2004 (fishing vessels)

Background documents
Sea shipping emissions 2014: Netherlands continental shelf, 12-mile-zone,port areas and OSPAR region II
MARIN Report no. 28771-1-MSCN-rev.2
MARIN,Wageningen, 2016

Fisheries (in Dutch)
Koldenhof, Y.
Afgelegde zeemijlen op het NCP in 2004
MARIN rapportnr 20894.620/1
MARIN, Wageningen, 2006

Figure 1 Previous spatial distribution of fishery emissions on the Netherlands territory

Both the renewal of emission factors and the renewal of the spatial distribution are included in the revision of emission calculation as reported here.

[1] The automatic identification system (AIS) is an automatic tracking system used for collision avoidance on ships and by vessel traffic services (VTS).

2 Results

2.1 Approach

The basic approach for calculating emissions of fisheries comprises two subsequent steps (Klein et al., 2016). In the first step the fuel consumption of different types of fishing ships is estimated. The second step is the multiplication of fuel consumption with engine emission factors.
In this revision the fuel consumption estimation is much more refined than before and the emission factors were made dependent on the year of build of the engine.

2.2 Fuel consumption

In the preparation of this project the fuel consumption was determined by Wageningen Economic Research (Turenhout et al., 2016). In this project 15 categories of fishing gear and propulsion power were defined. For each category the hourly fuel consumption was determined in two speed categories.
The method first described Poos et al., 2013 is as follows. For each of the 15 categories speed frequency plots were produced based on VMS-data[2] from the year 2014. Each peak within the frequency plots (see Figure 2) is considered representative for one of the activities that are discerned: resting, fishing and steaming.

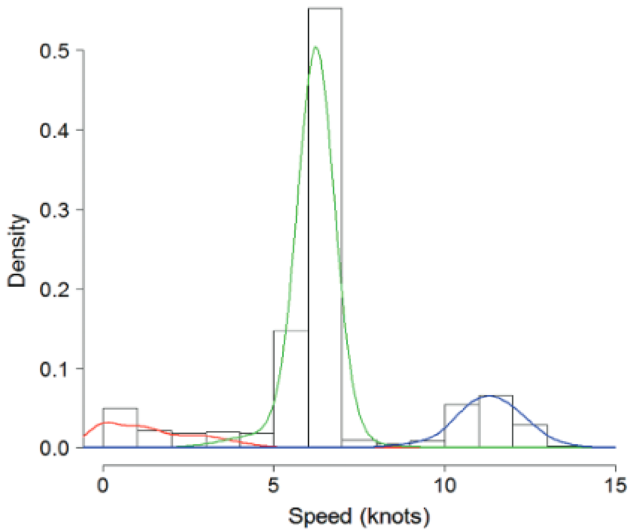


Figure 2 Frequency distribution of observed vessel speeds and the component density functions showing the activity modes during resting (red), fishing (green), and steaming (blue), source: Poos et al., 2013

The lower speed category with higher engine power and hourly fuel consumption is considered representative for actual fishing.
The higher speed category with lower engine power and hourly fuel consumption is considered representative for travelling ("steaming").

[2] The vessel monitoring system (VMS) is a satellite-based monitoring system which at regular intervals provides data to the fisheries authorities on the location, course and speed of vessels.

The application of speed categories in the emission calculations is possible due to the availability of AIS-data that has been collected for many years to determine emissions of marine transport.
However, usage of this data for fishing vessels was withheld because fishing vessels in most cases show inverse relations between speed and fuel consumption.

Table 1 Speed categories associated with fishing activities, (knots)

Power range	Gear/Catch	Rest	Fishing	Steaming
<= 300 Hp	Shrimps	<= 2	2 - 5	>5
	Bottomtrawl/Sumwing	<= 2	2 - 7	>7
	Pulsewing	<= 2	2 - 6	>6
	Twinrig/Quadrig	<= 2	2 - 5	>5
	Flyshoot	-	0 - 7	>7
	Standing rigging	-	0 - 2	>2
	Shellfishery	-	0 - 2	>2
	Trapfishery	-	0 - 2	>2
301-2000 Hp	Bottomtrawl/Sumwing	<= 2	2 - 8	>8
	Pulsewing	<= 2	2 - 8	>8
	Twinrig/Quadrig	<= 2	2 - 4	>4
	Flyshoot	-	0 - 6	>6
	Standing rigging	-	0 - 2	>2
	Shellfishery	-	0 - 2	>2
>2000 Hp	Twinrig/Quadrig	<= 2	2 - 5	>5

The hourly fuel consumption was translated to hourly energy consumption (Table 2) associated with individual fishing ships by assuming that an average specific fuel consumption is applicable.

Table 2 Fuel consumption/energy consumption in connection with fishing activities, Litre/hour, kWh/hour between brackets

Fishery Segment	Power range	Gear/Catch	Fishing	Steaming
1	<= 300 Hp	Shrimps[1]	44 (180)	39 (158)
2		Bottomtrawl/Sumwing[1]	86 (354)	39 (158)
3		Pulsewing[1]	77 (316)	39 (158)
4		Twinrig/Quadrig[1]	85 (347)	39 (158)
5		Flyshoot[1]	65 (250)	39 (147)
6	301-2000 Hp	Bottomtrawl/Sumwing[1]	269 (1129)	138 (578)
7		Pulsewing[1]	168 (688)	138 (563)
8		Flyshoot[1]	77 (316)	110 (451)
9		Twinrig/Quadrig[1]	185 (756)	138 (563)
11		Trapfishery[2]		85 (348)
12	<= 300 Hp	Shellfishery[2]		12 (49)
13	301-2000 Hp	Shellfishery[2]		90 (369)
14	<= 300 Hp	Standing rigging[2]		17 (70)
15	301-2000 Hp	Standing rigging[2]		85 (348)
16	>2000 Hp	Twinrig/Quadrig[2]	700 (2868)	500 (2049)

[1] Consumption data based on statistical data; [2] Consumption data based on expert judgement; Consumption during “resting” assumed 15% of steaming

The reason for the conversion from fuel usage to energy consumption is that the emission factors are expressed in gram/kWh instead of g/kg fuel.

2.3 Emission factors

Individual data of ((Dutch and former Dutch) fishing ships were purchased from Shipdata (http://www.shipdata.nl) to help estimate the emission factors. 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 FIGIS-database managed by FAO. In this merged dataset it was discovered that the engine models used in most fishing ships are very similar to engines applied in inland shipping. However, on average the engines used in Dutch fisheries seem to be older than engines applied in inland waterway vessels.

Table 3 Age and power distribution of fishing fleet on Dutch waters in 2015

Emission factor grouping	Engine year of build From	Till	Ships number	Average power kW
1	1959	1973	8	948
2	1975	1979	15	426
3	1980	1984	22	576
4	1985	1989	79	826
5	1990	1994	94	681
6	1995	2001	266	750
7	2002	2007	102	828
8	2008	2014	93	1025
9	2015	2016	16	868

Both the average and median engine age of the fishing fleet in 2015 seen in the Dutch waters is 18 years. During a project in 2009 on Dutch waterways, 146 inland waterway vessels were investigated. In this sample the median age of engines was 9 years while the average age was 15 years. So it may be concluded that fishing ships have older engines than vessels used in inland waterway transport.
The emission factors for fishing vessels were derived from the emission factors of inland waterway vessels (Hulskotte et al., 2012) taking into account the age of the engine. Basically the emission regulation of fishery ships is regulated by Regulation 13 of Annex VI of MARPOL. This means that new fishery ships require marine diesel engines to comply with the Tier III NOX emission limit when installed on ships constructed on or after 1 January 2021 when operating in the North Sea and the Baltic Sea. Diesel engines operating on inland waterways however have to comply with the stage V standards of the EU NRMM directive by 1 January 2020. The limit values for NOx set by the respective standards are almost equal. Annex VI of MARPOL however does not regulate PM emissions.

Table 4 Emission factors and specific fuel consumption applied on fishing vessels, (g/kWh)

Emission factor group	VOC	NOx	CO	PM	Fuel
1	1.2	10.8	4.5	0.6	235
2	0.8	10.6	3.7	0.6	230
3	0.7	10.4	3.1	0.6	225
4	0.6	10.1	2.6	0.5	220
5	0.5	10.1	2.2	0.4	220
6	0.4	9.4	1.8	0.3	205
7	0.3	9.2	1.5	0.3	200
8	0.2	6	1.3	0.2	200
9	0.2	6	1.3	0.2	195

Emission factors for individual fishing ships were derived by combination of fishery segment (combination of engine power and gear/catch) with engine age.
Table 5 shows an example of the calculation procedure for the NOx-emission factor per activity using the fuel consumption of a ship in fishery segment 1 and NOx-emission factor per kWh of group 5.

Table 5 Example of calculation procedure of emission factors per activity in g/hour

Activity	Speed range	Formula (g/hour)
Fishing	2 - 5	180 * 10.1 = 1818
Steaming	>5	158 * 10.1 = 1596
Resting	<= 2	158 * 0.15 * 10.1 =239.4

2.4 Emissions

Emissions have been calculated for the year 2015 based on AIS-messages received from the Dutch Coastguard by MARIN. For 98% (691 fishery vessels) of the fishery vessels the information was complete enough to determine the emission factors. The vessels were registered in various countries as can be seen in Table 6.

Table 6 Nationality of registries of fishing vessels in Dutch coastal waters

Country	Count of ships
Netherlands	477
Belgium	16
Germany	44
Denmark	57
United Kingdom	40
France	38
Norway	7
Sweden	9
Ireland	2
Lithuania	1
Total	**691**

Table 7 shows the total emissions per pollutant of the fishery segments in Dutch coastal waters, derived from the findings in this project.
The pulsewing segment is found to have the highest emission contributions, followed by the pelagic segment. Vessels in the shrimp segment show substantial emissions too. The distribution amongst the fishery segments probably has changed substantially because fishery techniques have changed drastically during the last decade.

Table 7 Emissions in 2015 from fishing ships in Dutch coastal waters based on AIS-data, (metric ton)

Power range	Gear/Catch	CO2	NOx	PM	SOx	VOC	CO
<= 300 Hp	Shrimps	27816	384	14.0	0.17	17.4	80
	Bottomtrawl/ Sumwing	453	7	0.2	0.00	0.3	1
	Pulsewing	7796	112	3.8	0.05	4.6	21
	Twinrig/ Quadrig	5018	72	2.3	0.03	2.7	14
	Flyshoot	259	4	0.2	0.00	0.3	1
	Standing rigging	839	11	0.5	0.01	0.6	3
	Shellfishery	23	0	0.0	0.00	0.0	0
	Trapfishery	262	3	0.1	0.00	0.1	1
301-2000 Hp	Bottomtrawl/ Sumwing	16496	229	8.5	0.11	10.2	47
	Pulsewing	39405	554	20.8	0.25	24.4	113
	Twinrig/ Quadrig	3646	49	1.7	0.02	2.1	10
	Flyshoot	9889	133	5.2	0.06	6.1	29
	Standing rigging	370	5	0.2	0.00	0.2	1
	Shellfishery	11384	156	5.5	0.07	6.6	31
>2000 Hp	Twinrig/ Quadrig	4280	57	2.4	0.03	2.1	11
	Pelagic	36826	732	26.6	75.26	28.1	144
Totals		164763	2510	92	76	106	507

Comparison with national emissions
Emission data in Table 7 are not comparable to emission data as presented in the PRTR because of a difference in definition. Data in Table 7 only represents the emission of fishery vessels in Dutch waters and the Dutch part of the continental shelf (NCP). Data in the PRTR are based on fuel sales to fishery vessels combined with emission factors derived in 2000 (Hulskotte and Koch, 2000). According to a LEI publication (2015) an amount of 86 million litres of diesel was used by Dutch cutter fisheries in 2015. The amount of CO_2 equivalent to this amount of diesel is 272,62 tonnes (applying an emission factor of 3.17 kg/kg). The amount of CO2 in Table 7 except pelagic fishery is 127,939 tonnes.
The share of CO2 covered by the calculation is127,937/272,62 = 47%.

There are a number of realistic explanations for this incomplete coverage:

a. Dutch fishery cutters are fishing outside the Dutch part of Dutch continental shelf;
b. In the Waddenzee there are fishery areas of which no AIS messages were accounted in the AIS-calculations;
c. There are quite a number of small fishery ships that don't have an AIS-transponder;
d. There are still some vessel types (MMSI-numbers) missing in the database;

Proposal for new emission factors
Current fishery emissions are calculated by fuel consumption in combination with general emission factors from (Hulskotte and Koch, 2000) as shown in Klein et al. (2016). The methodology used in this report delivers a new set of implied emission factors that can be applied to fuel usage reported for fishery cutters (MGO) and for trawlers using HFO. By using the new emission factors for each individual ship dependant on the engine age and the change of engine technologies is included. Besides this, more representative averages have been obtained. Also, by using the new calculation methodology the annual updating of average emission factors is made possible. It may be expected that estimation of emissions by the new method will be more accurate. The combination of technology based emission factors applied on individual vessels and activity data based on AIS-messages will allow rather accurate monitoring of emissions. The method applied before just only relied on monitoring of total fuel usage. Further future improvements in the methodology could be prepared by doing measurement on most important types of fishery vessels during various activity modes.

Table 8 New implied emission factors for fishery cutters, (g/kg fuel)

Substance	Current Emission factors	Proposed Emission Factors MGO	Proposed Emission Factors HFO
CO	8.0	9.0	12.4
VOC	2.7	1.9	2.4
NO_x	59	44.1	63.1
PM_{10}	1.4	1.6	2.3

2.5 Spatial allocation

Spatial allocation of fishery emissions is recalculated by means of almost complete AIS-data within this project. The applied AIS-data selection contained 1 message per fishing vessel every 2 minutes and the geographical position. Using this data, emissions per grid cell for each individual fishing vessel were calculated by summing the amount of messages per grid cell and dividing by 30 and multiply this number by the applicable emission factors (depending on speed) of the individual fishing vessel. By taking the sum of the emissions of individual vessels the total emissions per grid cell were obtained.

$$Emission_s = \sum (M_{g,i} \times Ef_{i,s})/30$$

Emission = emission of substance (s) within 1 grid cell, (kg/year)
$M_{g,i}$ = number of AIS-messages per 2 minutes in grid cell (g) of vessel (i), #
$Ef_{i,s}$ = emission factor of substance (s) of individual vessel (i), kg/hour

In this calculation the appropriate emission factors depending on the fishery segment (gear and catch) in combination with the actual speed are applied.

The results of this calculation is shown in Figure 3.

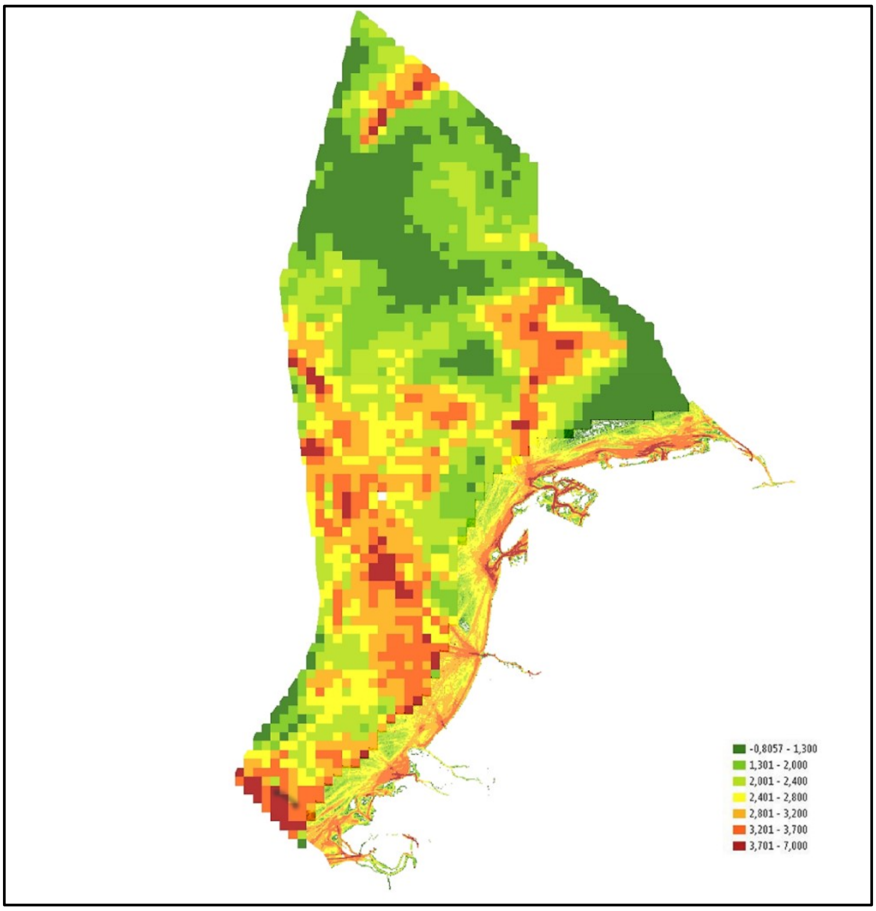


Figure 3 Relative density of CO2-emissions of fishery ships in the Netherlands territory

When comparing the new spatial pattern with the original pattern it becomes clear that intensive fishing in coastal zones is much better represented in the new map. It was known before that fishing in coastal zones is a common practice. The new observation is mainly caused by taking into account most of the small fishing ships without an IMO-number. In the old map only a minority of bigger fishing ships with an IMO-number were represented. On the new map it is possible to discern fishing ships spreading over the wider North Sea area while leaving from fishery harbours like Katwijk, IJmuiden, Den Helder and Harlingen. Some white areas on the Waddenzee are not included in the MARIN-grid. This will be improved in the next update.

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