

# Supplementary material

## The role of the Belgian airborne sniffer measurements in the MARPOL Annex VI enforcement chain

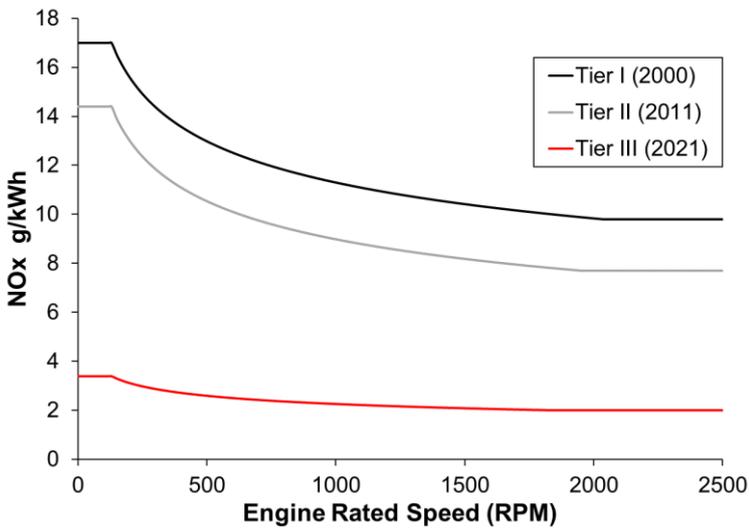
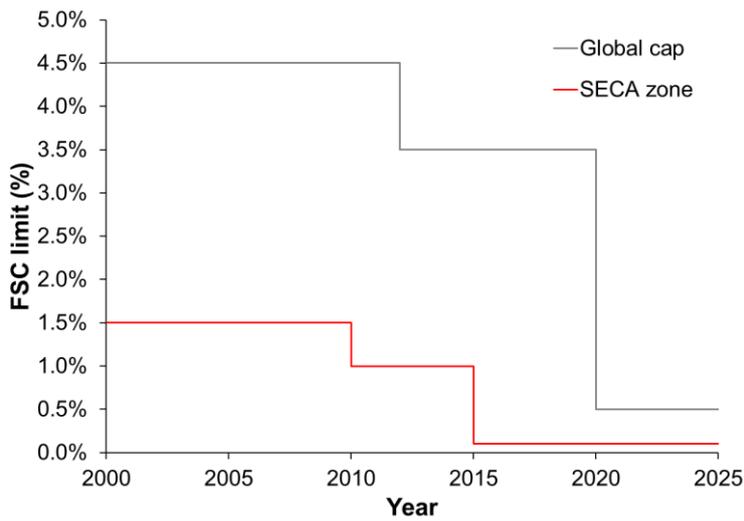
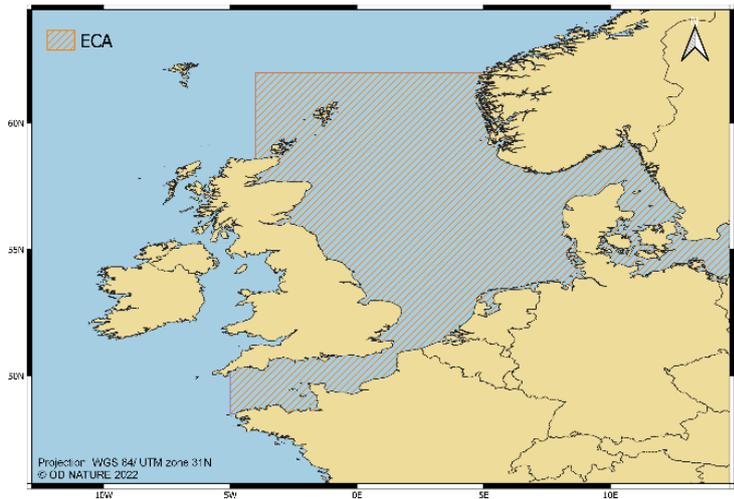
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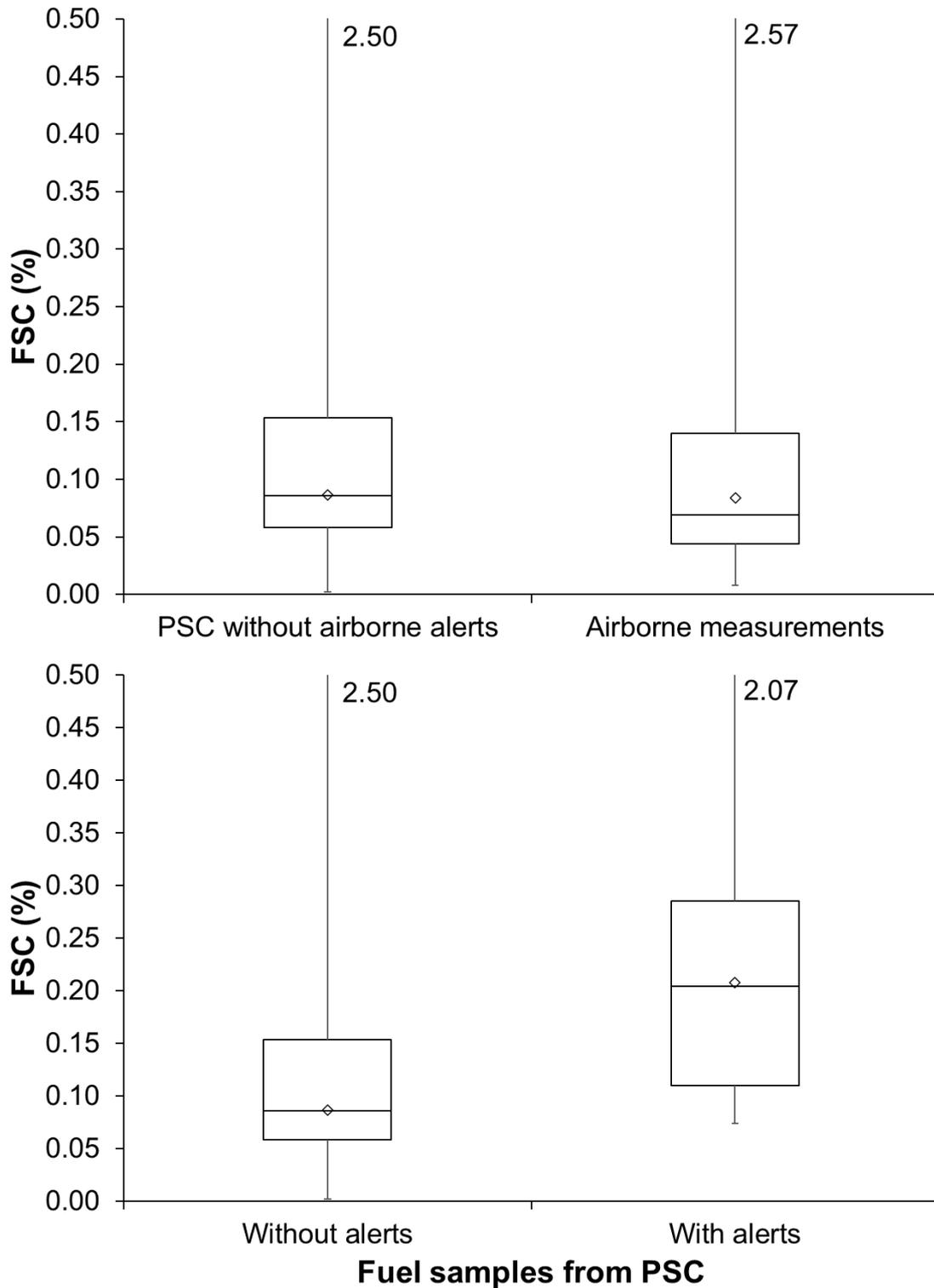
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### 1. Additional figures

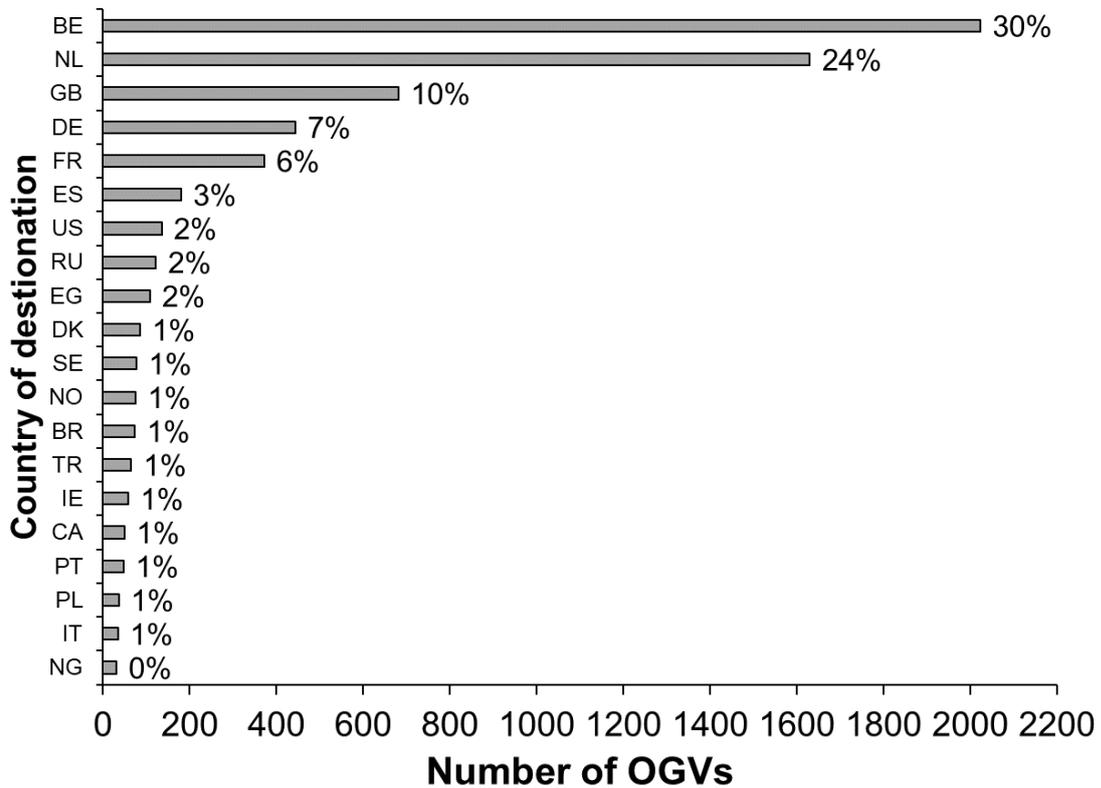
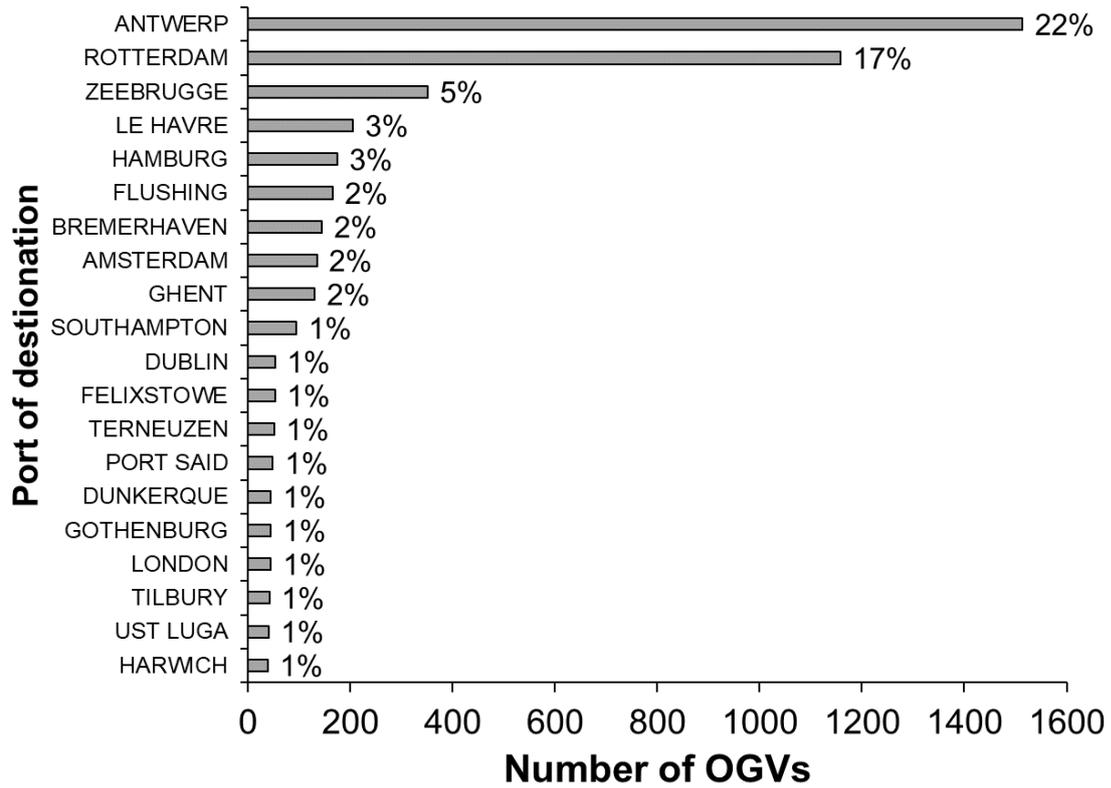
### 2. Additional tables



**Figure S.1.** Emission Control Area (ECA) as defined by MARPOL Annex VI (**Upper**). Limits on the Fuel Sulfur Content of marine fuels according to the MARPOL Annex VI regulation 14 (**Middle**). NOx emission limits according to MARPOL Annex VI Regulation 13 (**Lower**).



**Figure S.2.** Boxplot comparison of results of fuel samples executed without airborne alerts and the results of the airborne measurements, with minimum, maximum median, average (♦), 25 and 75 percentiles (**Upper**). Comparison of results of fuel sample analysis executed by Belgian port inspection authorities initiated without and with the use of airborne alerts (**Lower**).



**Figure S.3.** Number OGVs and relative amount of 20 most observed ports of destination (**Upper**) and country of destination (**Lower**).

**Table S.1.** Emission ratios for EGCS systems (MEPC, 2015).

<b>Fuel oil sulfur content (% m/m)</b>	<b>Ratio emission SO2(ppm)/CO2(% v/v)</b>
4.5	195
3.5	151.7
1.5	65
1	43.3
0.5	21.7
0.1	4.3

**Table S.2.** Test cycles and weighting factors according to the NO<sub>x</sub> Technical code (MEPC, 2008b).

	Speed	100%	100%	100%	100%
<b>E2</b>	Power	100%	75%	50%	25%
	WF	0.2	0.5	0.15	0.15
	Speed	100%	91%	80%	63%
<b>E3</b>	Power	100%	75%	50%	25%
	WF	0.2	0.5	0.15	0.15

**Table S.3.** Cost breakdown of the Belgian Sniffer program 2016-2022.

Cost Category	Year							Total
	2016	2017	2018	2019	2020	2021	2022	
<b>Instrumentation</b>								
Sensor and installation	€ 233,010.00	€ 1,624.00	€ -	€ 63,479.49	€ 23,587.77	€ 51,263.64	€ 15,542.19	€ 388,507.09
Calibration and gases	€ 9,509.97	€ 4,651.87	€ 7,829.61	€ 9,913.42	€ 6,966.36	€ 12,676.03	€ 9,800.25	€ 61,347.51
General Equipment	€ 2,614.76	€ -	€ 639.83	€ 1,809.47	€ 1,167.47	€ -	€ 744.93	€ 6,976.46
Software	€ 23,000.00	€ -	€ -	€ 501.83	€ -	€ -	€ 1,689.16	€ 25,190.99
Hardware	€ 20,790.04	€ 1,007.65	€ 561.74	€ 717.35	€ -	€ 6,795.52	€ 162.87	€ 30,035.17
<b>Total Instrumentation cost</b>	<b>€ 288,924.77</b>	<b>€ 7,283.52</b>	<b>€ 9,031.18</b>	<b>€ 76,421.56</b>	<b>€ 31,721.60</b>	<b>€ 70,735.19</b>	<b>€ 27,939.40</b>	<b>€ 512,057.22</b>
<b>Platform</b>								
Fuel for sniffer Flight Hours (FH)	€ 31,219.67	€ 17,167.05	€ 20,301.17	€ 68,753.38	€ 7,751.34	€ 23,005.80	€ 28,771.99	€ 196,970.40
Regular Maintenance	€ 98,915.52	€ 99,792.92	€ 78,709.51	€ 89,076.17	€ 78,210.00	€ 74,301.00	€ 87,656.54	
Part Regular Maintenance for sniffer FH	€ 39,199.93	€ 27,497.48	€ 23,774.49	€ 27,221.00	€ 12,583.22	€ 23,147.09	€ 25,810.64	€ 179,233.85
Major Maintenance (unit cost per flight hour)								
Engine overhaul (2800 EH)		€ 48.70						
Propeller overhaul (2800 EH)					€ 3.93			
Repaint (2800 EH)		€ 15.04						
500 (EH) maintenance	€ 56.61			€ 30.61				
1000 (EH) maintenance			€ 27.25			€ 33.62		
Other unscheduled major parts (2800 EH)		€ 4.97	€ 14.53		€ 9.73		€ 7.04	
Part Major Maintenance for sniffer FH	€ 7,693.62	€ 5,496.73	€ 3,687.30	€ 2,941.12	€ 502.20	€ 3,323.24	€ 638.26	€ 24,282.47
<b>Total Platform cost</b>	<b>€ 78,113.22</b>	<b>€ 50,161.25</b>	<b>€ 47,762.96</b>	<b>€ 98,915.50</b>	<b>€ 20,836.76</b>	<b>€ 49,476.14</b>	<b>€ 55,220.89</b>	<b>€ 400,486.72</b>
<b>Labour</b>								
Operator cost for sniffer FH	€ 10,552.95	€ 5,356.83	€ 7,096.89	€ 7,627.37	€ 2,219.92	€ 8,739.20	€ 8,197.59	€ 49,790.76
Part Mission cost for sniffer FH	€ 1,641.67	€ 979.87	€ 1,080.92	€ 1,215.30	€ 475.24	€ 1,278.08	€ 1,338.40	€ 8,009.48
Pilot cost for sniffer FH	€ 1,090.34	€ 1,403.61	€ 2,253.68	€ 2,305.11	€ 725.62	€ 1,783.25	€ 1,942.41	€ 11,504.02
<b>Total Labour cost</b>	<b>€ 13,284.95</b>	<b>€ 7,740.32</b>	<b>€ 10,431.49</b>	<b>€ 11,147.78</b>	<b>€ 3,420.78</b>	<b>€ 11,800.53</b>	<b>€ 11,478.41</b>	<b>€ 69,304.26</b>
<b>Total</b>	<b>€ 380,322.94</b>	<b>€ 65,185.09</b>	<b>€ 67,225.63</b>	<b>€ 186,484.84</b>	<b>€ 55,979.14</b>	<b>€ 132,011.86</b>	<b>€ 94,638.70</b>	<b>€ 981,848.20</b>
<b>Total/flight hour</b>	<b>€ 2,798.21</b>	<b>€ 814.81</b>	<b>€ 761.76</b>	<b>€ 1,940.87</b>	<b>€ 1,523.24</b>	<b>€ 1,335.70</b>	<b>€ 1,043.81</b>	<b>€ 1,567.20</b>
Number of measurements	1219	887	1138	1232	405	1015	965	6975
<b>Total/measurement</b>	<b>€ 312.00</b>	<b>€ 73.49</b>	<b>€ 59.07</b>	<b>€ 151.37</b>	<b>€ 138.22</b>	<b>€ 130.06</b>	<b>€ 98.07</b>	<b>€ 140.77</b>