SMED Report No 68 2005

Swedish Environmental Emissions Data

Emission factors, fuel consumption and emission estimates for Sweden's fishing fleet 1990-2004

David Cooper, Eje Flodström, IVL Swedish Environmental Research Institute;
Tomas Gustafsson and Mats Jernström, Statistics Sweden

Commissioned by the Swedish Environmental Protection Agency

Published at: www.smed.se
Publisher: Swedish Meteorological and Hydrological Institute
Address: SE-601 76 Norrköping, Sweden
Start year: 2006
ISSN: 1653-8102

SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. Through a long-term contract for the Swedish Environmental Protection Agency extending until 2014, SMED is heavily involved in all work related to Sweden's international reporting obligations on emissions to air and water, waste and hazardous substances. A central objective of the SMED collaboration is to develop and operate national emission databases and offer related services to clients such as national, regional and local governmental authorities, air and water quality management districts, as well as industry. For more information visit SMED's website www.smed.se.

Summary

Fuel consumption for the Swedish fishing fleet 1990-2004 has been estimated using statistics from the Swedish National Board of Fisheries on installed engine power. An additional estimation method was also described. Data on installed power was available for the years 1995-2004, and estimates 1990-1994 have been calculated by extrapolation. Thermal values and emission factors are based on a study conducted by SMED on behalf of the Swedish EPA in 2004. In order to fit the national fuel sales statistics, the diesel oil consumption was adjusted according to the national allocation model for international reporting. The adjusted fuel consumption accounted for about 68 700 – 93 900 m^3, corresponding to about 187 – 256 ktons CO_2.

Content

1 Fuel consumption estimate for 2003

Since no concrete data on fuel consumption for the Swedish fishing fleet is available in the statistics provided by the Swedish National Board of Fisheries[1], estimates can only be made based on rather rough assumptions. Two approaches have been considered here.

According to 2003 data from the Swedish National Board of Fisheries (Bengtsson et al., 2004), the fishing fleet consists of only 1 715 vessels with an installed machinery of ca. 221 002 kW. This total installed engine power and a typical specific fuel consumption value (205 g fuel/kWh) for medium speed engines can be used to provide a first approximation. In this case one also has to assume (very roughly) an average engine operating load (% of maximum) and an average value for the annual operating hours. Using estimates of 50 % and 3 000 hours respectively, the results indicate a total fuel consumption of 68 000 tons (or 80 800 m^3).

An alternative calculation can be based on cod fishing by the Swedish fleet. It is estimated that 55 861 kW (or 25.3%) of the 2003 machinery is installed on cod fishing boats (Bengtsson et al., 2004). Based on estimates from a Life Cycle Assessment for Swedish cod fishing for 1999 (Ziegler, 2001), a weighted CO_2 emission factor was assigned as 2.861 kg CO_2 /kg cod. Assuming a carbon fuel content of 86.7%, this corresponds to a fuel consumption of 0.90 kg fuel/kg cod. In year 1999, 19 656 ton of cod were caught which amounts to a fuel consumption for cod fishing of 17 690 ton fuel. In order to roughly estimate fuel consumption for 2003, two important assumptions need to be made. Firstly, the same methods are used in 1999 and 2003 for cod fishing, i.e. the same efficiency regarding cod caught and fuel used[2]. Secondly the ratio of installed machinery for cod fishing to the total fleet is equivalent to the corresponding ratio of the fuel consumption. On this basis, a rough estimate of the 2003 fuel consumption can be calculated as 17 690 / 0.253 = 70 000 tons fuel (ca. 83 000 m3).

These results (including the rough estimate presented in footnote 1 below) give indications on fuel consumption approximation, and we have chosen to use the first approach since it can be considered to be more stable and also easier to update.

2 Fuel consumption for other years

In order to estimate previous years fuel consumption, a direct correlation between total installed engine effect of the fleet can be used against a fixed (2003) where both the fuel consumption and installed effect is estimated. Data has been obtained from 1995 and onwards (Table 1) but before this no records are available (Bengtsson, 2005). Since the trend of decreasing installed effect is rather linear (see Figure 1), one could extrapolate back to the earlier years. Figure 2 shows the estimated fuel consumption for 1990-2004.

[1] A very rough, annual approximation has however been calculated for a period over 2000 – 2004. The result indicates 75 000 m3 fuel (Bengtsson, 2005).

[2] This is clearly a weak assumption since in 2002 only 15 115 ton of cod were caught.

Table 1. Total installed machinery for years 1995 - 2004

Year	KW installed
1995	267 282
1996	257 001
1997	248 374
1998	239 853
1999	230 567
2000	239 438
2001	228 394
2002	224 601
2003	221 002
2004	217 089

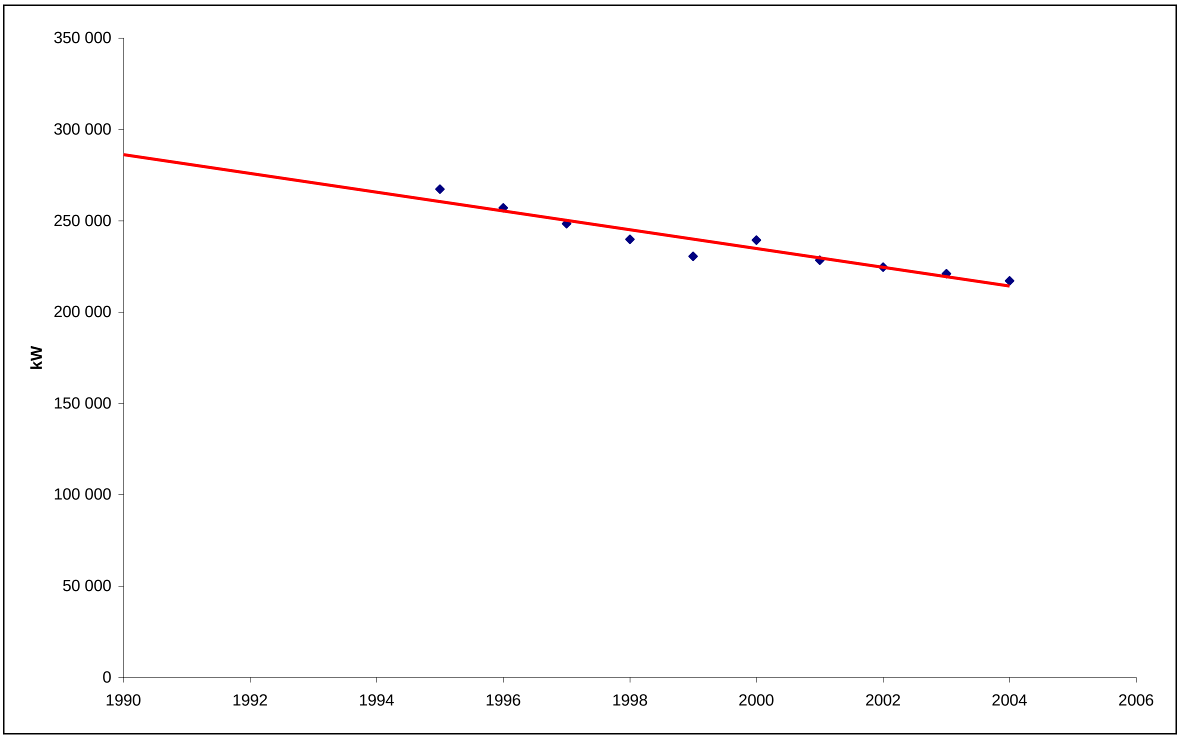

Figure 1. Total installed machinery for 1995 – 2004 and extrapolation 1990-1994.

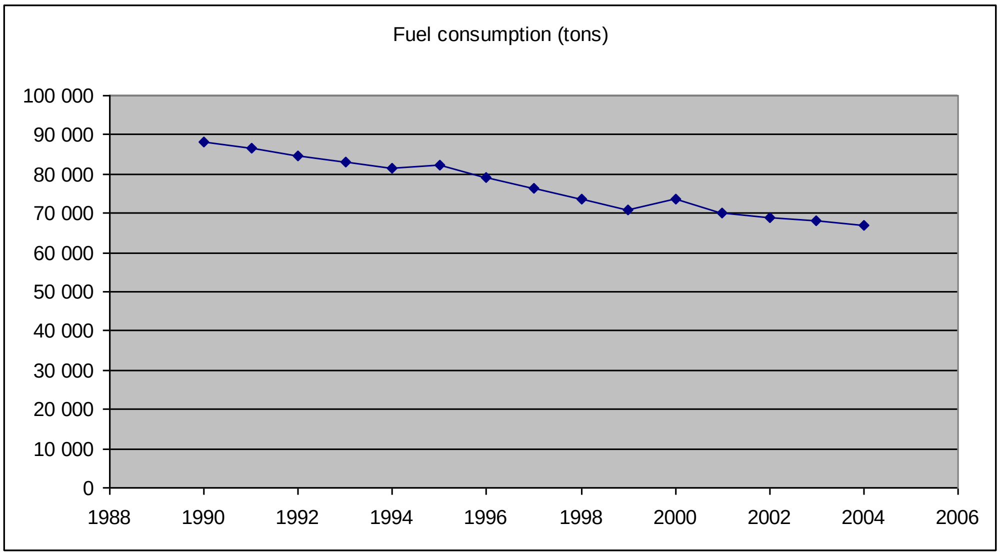

Figure 2. Estimated fuel consumption 1990-2004.

3 Emission factors

The fishing fleet is assumed to operate entirely using medium speed diesel engines running on marine distillate fuel[3]. In addition, the amount of emission abatement technologies used for the fleet (e.g. SCR for NOx reduction) is assumed to be negligible. Based on this and using the base emission factors from an earlier study conducted by SMED on behalf of the Swedish EPA (Cooper and Gustafsson, 2004), the emission factors in Table 2 can be applied for all years 1990-2004. The same thermal value for marine distillate has been used as presented in Cooper and Gustafsson, 2004, i.e. 36.64 Gj/m^3.

Table 2 Emission factors for fishing boats 1990-2004 (assumed as medium speed engines operating with marine distillate fuel).

Substance	g/ton fuel	Gg/TJ fuel supplied
NOx	64158	0.00150
CO	5366	0.00013
NMVOC	976	2.28E-05
SOx	8000	0.00019
NH3	15	3.43E-07
TSP	976	2.28E-05
PM10	976	2.28E-05
PM2,5	976	2.28E-05
Pb	0.15	3.51E-09
Cd	0.005	1.17E-10
Hg	0.00005	1.17E-12
As	0.03	7.03E-10
Cr	0.05	1.17E-09
Cu	1.7	3.98E-08
Ni	1	2.34E-08
Se	0.00005	1.17E-12
Zn	1	2.34E-08
PCB	0.000439	1.03E-11
Diox/Fur	1.46E-07	3.43E-15
Ben(a)pyr	0.0049	1.14E-10
Ben(b)flu	0.0098	2.28E-10
Ben(k)flu	0.0049	1.14E-10
Indenopyr	0.0098	2.28E-10
PAH-4	0.0293	6.85E-10
HCB	9.76E-05	2.28E-12
CO2	3179000	0.0744
CH4	19.5	4.57E-07
N2O	151	3.54E-06

[3] Some engines may also be of the high speed diesel category but their emission factors are very similar to those applied to medium speed engines.

4 Emission estimates for 1990-2004

Combining the emission factors and the estimated fuel consumption in chapter 2 and 3, result in emission levels for all substances as given in Appendix 1, Table I. Figure 3 shows emissions for CO_2 1990-2004.

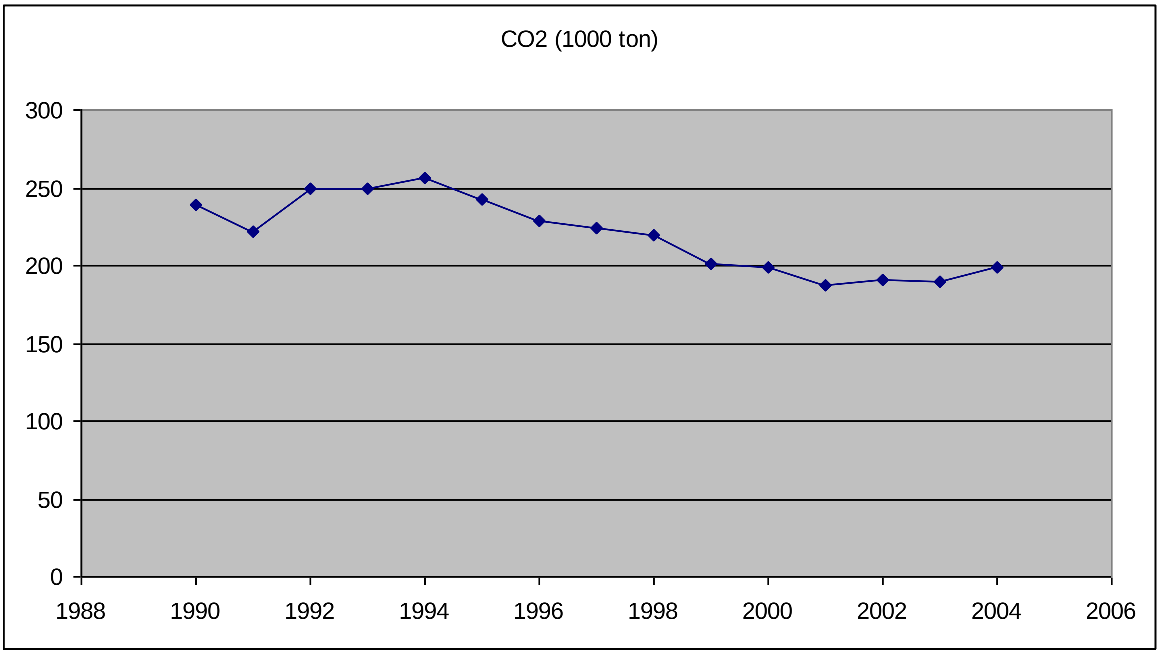

Figure 3. Emissions of CO_2 1990-2004 (in 1000 ton).

Note that the fuel consumption has been adjusted to fit the national fuel sales statistics according to the national model for diesel oil allocation for international reporting to the UNFCCC[4] (Figure 4). Due to the dependency to diesel consumption in some other sub-sectors, the consumption for fisheries may be further adjusted before reported to the Swedish Submission 2006 to the UNFCCC.

[4] United Nations Framework Convention on Climate Change

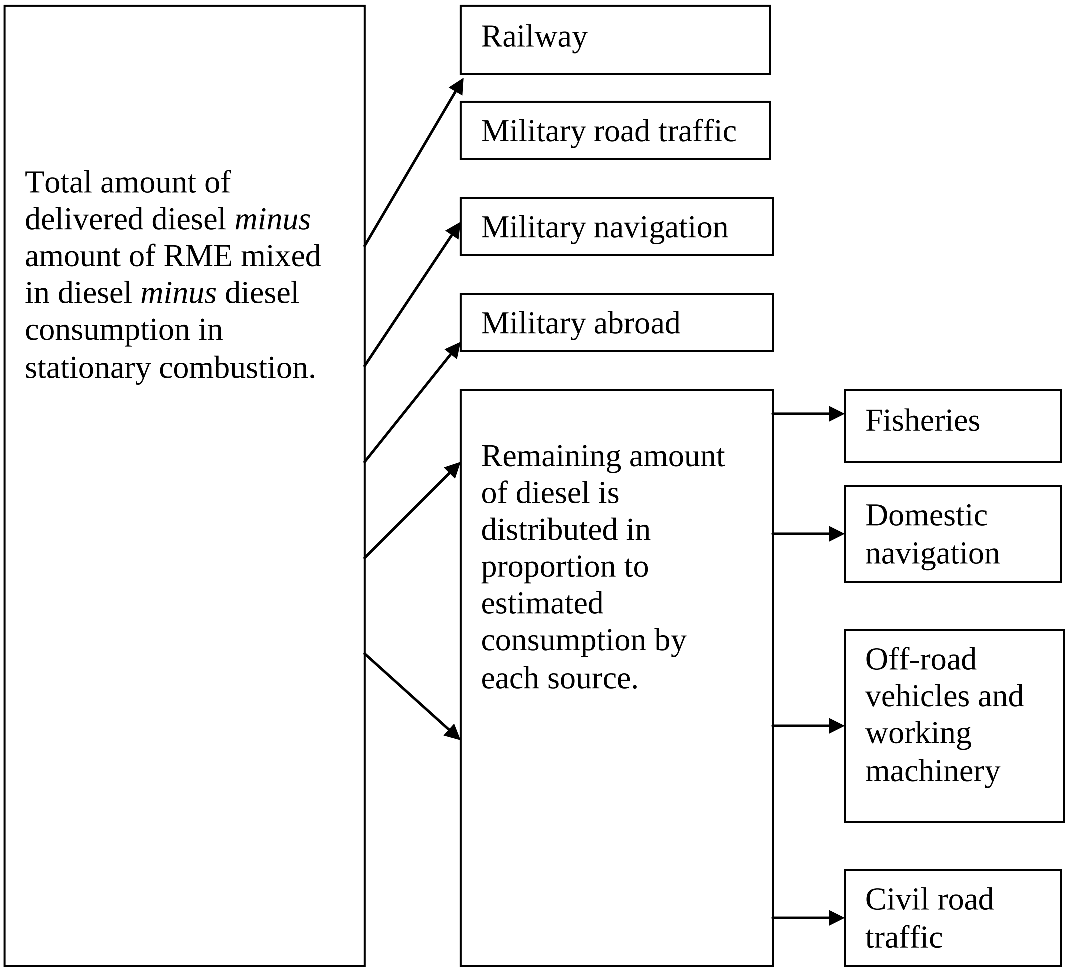

Figure 4. National model for diesel oil allocation for international reporting.

References

Bengtsson, I., 2005. Personal communication 27th April, 2005. Swedish National Board of Fisheries, Gothenburg. Tel. 031-7430316.

Bengtsson, I., Bernhardsson, M-A., Hellsten, M., 2004. Statistics of fishing industry and fishing fleet 2003.(in Swedish). ISSN 1404-8590. Swedish National Board of Fisheries, Gothenburg.

Cooper, D.A., Gustafsson, T., 2004. Methodology for calculating emissions from ships – 1. Update of emission factors.SMED report No. 4. IVL Swedish Environmental Research Institute, Gothenburg.

Swedish EPA (2005): Sweden's National Inventory Report 2005. Submitted under the Monitoring Mechanism of Community greenhouse gas emissions. Swedish Environmental Protection Agency, Stockholm.

Ziegler, F., 2001. Environmental Assessment of seafood with a life-cycle perspective. MSc thesis. Department of Marine Ecology, University of Gothenburg.

Appendix 1. Fuel consumption and emission estimates for the fishing fleet in Sweden 1990-2004

Table I. Fuel consumption and emissions estimates for the fishing fleet in Sweden 1990-2004

	Adjusted fuel consumption		Emissions, 1000 ton, Gg								ton, Mg		
Year	m3	TJ	CO2	SO2	NOX	NMVOC	CH4	CO	N2O	NH3	TSP	PM10	PM2,5
1990	87499	3206	239	0.60	4.82	0.073	0.0015	0.40	0.0114	0.0011	73.25	73.25	73.25
1991	81169	2974	221	0.56	4.47	0.068	0.0014	0.37	0.0105	0.0010	67.95	67.95	67.95
1992	91397	3349	249	0.63	5.03	0.077	0.0015	0.42	0.0119	0.0011	76.51	76.51	76.51
1993	91397	3349	249	0.63	5.03	0.077	0.0015	0.42	0.0119	0.0011	76.51	76.51	76.51
1994	93864	3439	256	0.64	5.17	0.079	0.0016	0.43	0.0122	0.0012	78.58	78.58	78.58
1995	88828	3255	242	0.61	4.89	0.074	0.0015	0.41	0.0115	0.0011	74.36	74.36	74.36
1996	83777	3070	229	0.58	4.61	0.070	0.0014	0.39	0.0109	0.0011	70.13	70.13	70.13
1997	82244	3013	224	0.56	4.53	0.069	0.0014	0.38	0.0107	0.0010	68.85	68.85	68.85
1998	80445	2948	219	0.55	4.43	0.067	0.0013	0.37	0.0104	0.0010	67.34	67.34	67.34
1999	73868	2707	202	0.51	4.07	0.062	0.0012	0.34	0.0096	0.0009	61.84	61.84	61.84
2000	72756	2666	198	0.50	4.01	0.061	0.0012	0.33	0.0094	0.0009	60.91	60.91	60.91
2001	68734	2518	187	0.47	3.78	0.058	0.0012	0.32	0.0089	0.0009	57.54	57.54	57.54
2002	69861	2560	191	0.48	3.85	0.058	0.0012	0.32	0.0091	0.0009	58.48	58.48	58.48
2003	69577	2549	190	0.48	3.83	0.058	0.0012	0.32	0.0090	0.0009	58.25	58.25	58.25
2004	72810	2668	199	0.50	4.01	0.061	0.0012	0.34	0.0094	0.0009	60.95	60.95	60.95

Table I (continued)

Year	Adjusted fuel consumption m3	TJ	Pb (ton, Mg)	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCB (kg)	Diox/Fur (g)
1990	87499	3206	0.0113	0.0004	0.0000038	0.0023	0.0038	0.13	0.075	0.0000038	0.075	0.033	0.0110
1991	81169	2974	0.0104	0.0003	0.0000035	0.0021	0.0035	0.12	0.070	0.0000035	0.070	0.031	0.0102
1992	91397	3349	0.0118	0.0004	0.0000039	0.0024	0.0039	0.13	0.078	0.0000039	0.078	0.034	0.0115
1993	91397	3349	0.0118	0.0004	0.0000039	0.0024	0.0039	0.13	0.078	0.0000039	0.078	0.034	0.0115
1994	93864	3439	0.0121	0.0004	0.0000040	0.0024	0.0040	0.14	0.081	0.0000040	0.081	0.035	0.0118
1995	88828	3255	0.0114	0.0004	0.0000038	0.0023	0.0038	0.13	0.076	0.0000038	0.076	0.033	0.0112
1996	83777	3070	0.0108	0.0004	0.0000036	0.0022	0.0036	0.12	0.072	0.0000036	0.072	0.032	0.0105
1997	82244	3013	0.0106	0.0004	0.0000035	0.0021	0.0035	0.12	0.071	0.0000035	0.071	0.031	0.0103
1998	80445	2948	0.0104	0.0003	0.0000035	0.0021	0.0035	0.12	0.069	0.0000035	0.069	0.030	0.0101
1999	73868	2707	0.0095	0.0003	0.0000032	0.0019	0.0032	0.11	0.063	0.0000032	0.063	0.028	0.0093
2000	72756	2666	0.0094	0.0003	0.0000031	0.0019	0.0031	0.11	0.062	0.0000031	0.062	0.027	0.0091
2001	68734	2518	0.0088	0.0003	0.0000029	0.0018	0.0029	0.10	0.059	0.0000029	0.059	0.026	0.0086
2002	69861	2560	0.0090	0.0003	0.0000030	0.0018	0.0030	0.10	0.060	0.0000030	0.060	0.026	0.0088
2003	69577	2549	0.0090	0.0003	0.0000030	0.0018	0.0030	0.10	0.060	0.0000030	0.060	0.026	0.0087
2004	72810	2668	0.0094	0.0003	0.0000031	0.0019	0.0031	0.11	0.062	0.0000031	0.062	0.027	0.0091

Table I (continued)

	Adjusted fuel consumption		Mg, ton					kg
Year	m3	TJ	Ben(a)pyr	Ben(b)flu	Ben(k)flu	Indenopyr	PAH-4	HCB
1990	87499	3206	0.0004	0.0007	0.0004	0.0007	0.0022	0.0073
1991	81169	2974	0.0003	0.0007	0.0003	0.0007	0.0020	0.0068
1992	91397	3349	0.0004	0.0008	0.0004	0.0008	0.0023	0.0077
1993	91397	3349	0.0004	0.0008	0.0004	0.0008	0.0023	0.0077
1994	93864	3439	0.0004	0.0008	0.0004	0.0008	0.0024	0.0079
1995	88828	3255	0.0004	0.0007	0.0004	0.0007	0.0022	0.0074
1996	83777	3070	0.0004	0.0007	0.0004	0.0007	0.0021	0.0070
1997	82244	3013	0.0003	0.0007	0.0003	0.0007	0.0021	0.0069
1998	80445	2948	0.0003	0.0007	0.0003	0.0007	0.0020	0.0067
1999	73868	2707	0.0003	0.0006	0.0003	0.0006	0.0019	0.0062
2000	72756	2666	0.0003	0.0006	0.0003	0.0006	0.0018	0.0061
2001	68734	2518	0.0003	0.0006	0.0003	0.0006	0.0017	0.0058
2002	69861	2560	0.0003	0.0006	0.0003	0.0006	0.0018	0.0058
2003	69577	2549	0.0003	0.0006	0.0003	0.0006	0.0017	0.0058
2004	72810	2668	0.0003	0.0006	0.0003	0.0006	0.0018	0.0061