Fulmar Litter EcoQO monitoring along Dutch and North Sea coasts
- Update 2010 and 2011

J.A. van Franeker & the SNS Fulmar Study Group

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Cover page photo:*

A 'double-light colour-phase' Fulmar flying along the cliffs of the Faroe Islands. This colourphase is virtually the only colour type in the temperate breeding populations of the North Atlantic. However, during winter, darker coloured fulmars that originate from arctic areas also enter the North Sea.

(*) All photographs in this report by Jan van Franeker, IMARES.

i. Summary Report

Fulmar Litter EcoQO monitoring along Dutch and North Sea coasts - *Update 2010 and 2011*

Marine debris has serious economic and ecological consequences. Economic impacts are most serious for coastal communities, tourism, shipping and fisheries. Marine wildlife suffers from entanglement and ingestion of debris, with microparticles potentially affecting marine food chains up to the level of human consumers. In the North Sea, marine litter problems were firmly recognized by bordering countries in 2002 when they assigned OSPAR the task to include marine plastic litter in the system of Ecological Quality Objectives (EcoQOs) (North Sea Ministerial Conference 2002). At that time, in the Netherlands, marine litter was already monitored by the abundance of plastic debris in stomachs of a seabird, the Northern Fulmar *(Fulmarus glacialis)*. Fulmars are purely offshore foragers that ingest all sorts of litter from the sea surface and do not regurgitate poorly degradable diet components like plastics. Initial size of ingested debris is usually in the range of millimetres to centimeters, but may be considerably larger for flexible items like threadlike or sheetlike materials. Items must gradually wear down in the muscular stomach to a size small enough for passage to the intestines. During this process, plastics accumulate in the stomach to a level that integrates litter levels encountered in their foraging area for a period of probably up to a few weeks (Van Franeker et al. 2011). The Dutch monitoring approach using beached fulmars was developed for international implementation by OSPAR as one of its EcoQOs for the North Sea (OSPAR 2008, 2009, 2010a,b) and the same approach is now also implemented as an indicator for 'Good Environmental Status (GES)' in the Marine Strategy Framework Directive (MSFD) (EC 2008, 2010; Galgani et al. 2010; MSFD GES Technical Subgroup on Marine Litter, 2011). OSPAR has set a preliminary target for acceptable ecological conditions in the North Sea as:

> *"There should be less than 10% of Northern fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years".*

OSPAR has set no date when this EcoQO target level should be reached. The European MSFD does have an overall target date for Good Environmental Status by the year 2020, and may therefore define its target differently. For marine areas where fulmars do not occur, other species are needed as ingestion indicators, for which methodology and targets are being developed.

The monitoring system uses fulmars found dead on beaches, or animals accidentaly killed as e.g. fisheries bycatch. In a pilot study it has been shown that the amount of plastic in stomachs of slowly starved beached animals is not different from that of healthy birds killed in instantaneous accidents. Standard procedures for dissection and stomach analyses have been documented in manuals and reports. Different categories of plastic are recorded, with as major types the industrial plastics (the raw granular feedstock for producers) as opposed to user plastics (from all sorts of consumer waste).
Information on abundance of plastics in fulmars may be expressed in different ways, such as by:

- **Incidence** – the percentage of birds having plastic in the stomach (cf. frequency of occurrence), irrespective of the quantity of plastic
- **Average ± se** –averages refer to straightforward arithmetic averages, often with standard errors. These are used for either number of particles or mass of plastic for all birds in a sample including the ones without any plastic ('population average').
- **Geometric mean** – Means refer to geometric means calculated using data transformation (natural logarithm) reducing influence of extreme outliers and facilitating comparison of smaller samples.
- **EcoQO performance** – the percentage of birds having more than 0.1 gram of plastic in the stomach, allowing direct comparison to the OSPAR target, which aims at having less than 10% of such birds
- **Pooled data** - In various graphs and tables in this report, these types of data are frequently pooled over 5 year periods to have a focus on reliable averages and consistent trends rather than on

incidental short term fluctuations. The 5 year data are not derived from annual averages or means, but are based on individual data from all birds sampled in these five years.

- **Statistics -** Statistical analyses investigating time related trends or regional differences are based on the mass of plastic. Tests for significance of trends over time are based on linear regressions of log-transformed data for the mass of plastics in individual birds against year of collection. A distinction is made between the 'long-term trend' over all years in the dataset (now 1979-2011 for the Netherlands) and the 'recent trend', which is defined as the trend over the past 10 years (now: 2002-2011). Regional differences are tested for significance by fitting individual log-transformed data in a generalized linear model and likelihood ratio test.
- **Graphs** often use pooled data for 5 years, but shifting one year by datapoint. Subsequent data points in the graph thus overlap for 4 years of data, and are only intended to visually illustrate trends over time or geographic patterns and have no statistical meaning, as statistical significance of trends or sample differences is only tested by above methods using data from individual birds.

Update of monitoring data for the Netherlands

This report adds new data for years 2010 and 2011 to earlier updates (Van Franeker & the SNS Fulmar Study Group, 2011). Beached Fulmar corpses were scarce in 2011, but an incidental lower sample size is not a problem for the monitoring system, as it only reduces certainty on the short term. Variability in abundance of live and dead Fulmars in a region is influenced by many factors, mainly in relation to food availability and weather conditions. Incidental years of low sample size are one of the reasons to recommend pooled 5-year data to consider the 'current' situation. Annual data and the most recent pooled 5-year details are summarized in *Table i.*

- **Current data for the Netherlands (years 2007 to 2011; 204 Fulmars) are that 95% of Fulmars have plastic in the stomach, with an average number of 36 particles and mass of 0.33 gram per bird. The critical EcoQO value of 0.1 gram plastic was exceeded by 60% of these birds.**

Table i ***Data summary for study years added to the existing monitoring series***

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2010	***36***	**46%**	**58%**	**10.7**	**0.23**	**94%**	**45.7**	**0.23**	**94%**	**56.4**	**0.46**	**64%**
2011	***19***	37%	**63%**	**6.6**	**0.15**	**95%**	**37.0**	**0.27**	**100%**	**43.6**	**0.43**	**79%**
2007-2011	*204*	43%	**59%**	**4.4**	**0.10**	**94%**	**31.1**	**0.24**	**95%**	**35.5**	**0.33**	**60%**

* Five-year data are arithmetic averages over all individual birds in the five year period (not from annual averages)

Long-term trend 1979-2011

Long term trends in the Netherlands are visualized for EcoQO performance in Fig.*i*, and for average mass in Fig.*ii.* Both graphs compare a single average for the 1980s to shifting 5-year data from 1995 onwards. The main message from the EcoQO graph is that since the 1980s ecological quality has consistently been nowhere close to the EcoQO target. EcoQO performance has varied between 57% and 67% whereas the target is that it should go down to 10%. From the mid-1990s until the early 2000's a 10% improvement was promising (Fig.*i* B), but more recently little change has been observed.

The graphs on average mass of plastics (Fig. *ii*) show more detail of changes. An initial strong increase in average plastic mass was observed from 1980s to mid-1990, followed by a period of rapid improvement until the early 2000s, but no further change since then. The current level for all plastics combined (Fig.*ii* A) is similar to the situation in the 1980s, but Fig.*ii* B shows that developments for industrial plastics have been very different than for consumer waste. User plastics were the main factor for the rise and fall seen in total plastics, but industrial granules approximately halved from the 1980s to mid 1990s and next tended to very slow continued decrease except for the exceptional last two datapoints.

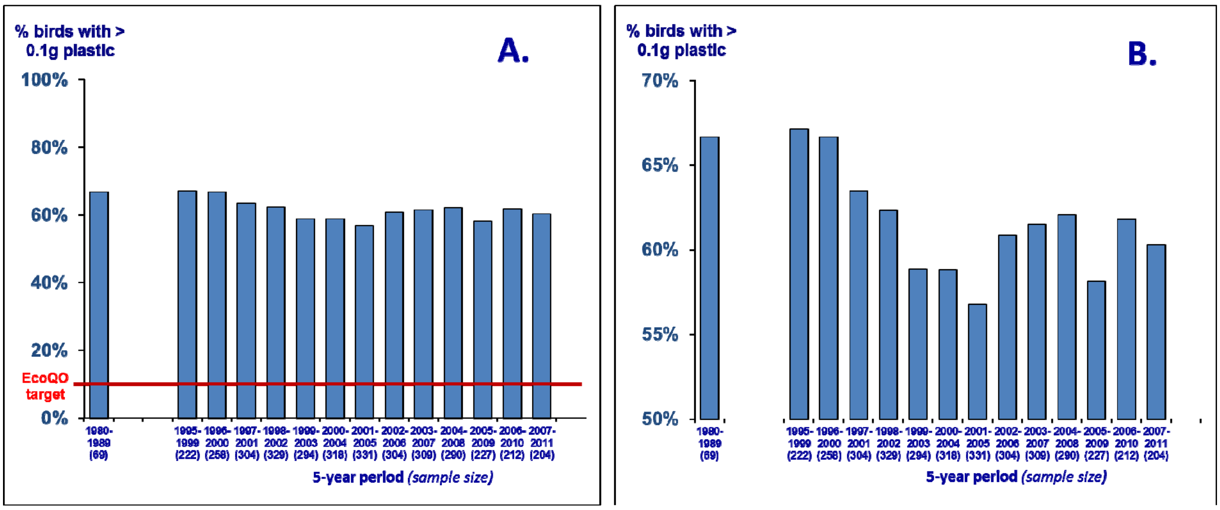

Figure i ***EcoQO performance by fulmars from the Netherlands 1980s-2011.*** *Figure A. shows data on a full 100% scale for the proportion of birds having more than 0.1 gram of plastic. This illustrates the distance to the 10% target for birds with more than 0.1 gram as defined by OSPAR. Fig.B shows the same data but has the y-axis restricted to the observed range, showing an almoste 10% improvement in the EcoQO around the turn of the century, but more or less stable and somewhat erratic performance since then. Data are shown by a single datapoint for the 1980s and annually updated 5 year performances after 1995 (i.e. data points shift one year ahead at a time).*

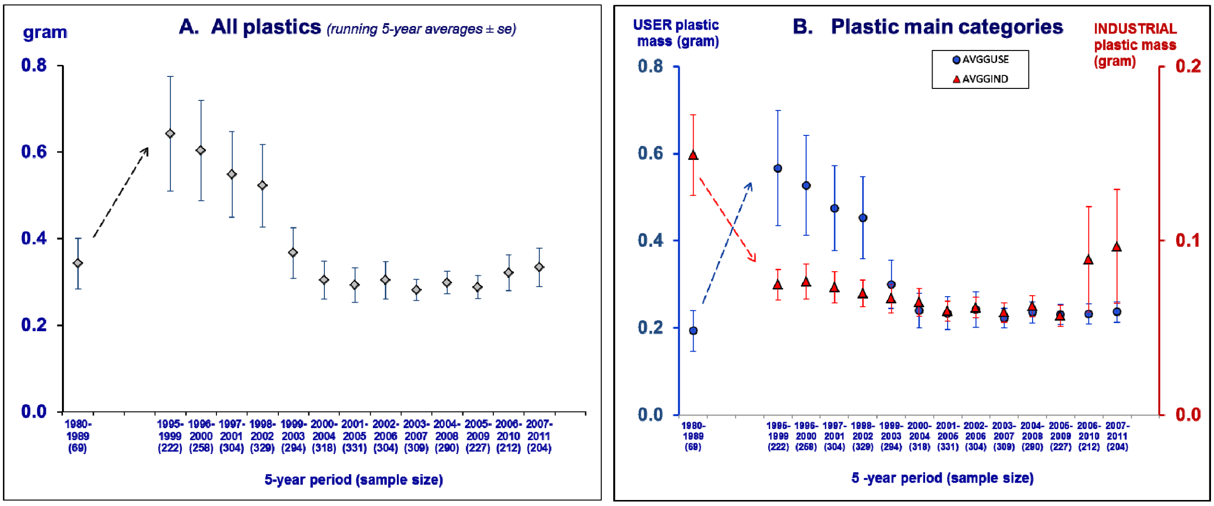

Figure ii ***Plastic mass in stomachs of Fulmars from the Netherlands 1980s-2011.*** *Figure A. shows data for all plastics combined; the figure on the right splits these data into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average ± standard error for mass in a single datapoint for the 1980s and running 5 year averages after 1995 (i.e. data points shift one year ahead at a time).*

Statistical tests for trends, illustrated in Fig.*iii* (and listed in detail in Report Table 4) are linear and thus ignore the long term rise and fall in overall plastics and user plastics before and after the mid 1990s. Industrial plastics on the other hand have strongly decreased since the early 1980s, resulting in a persistent highly significant long-term reduction ($p<0.001$) in spite of relative stability over the last decade and even increases in averages in the most recent 5-year periods. Recent data for average mass of industrial plastics are strongly influenced by just 2 birds, one in 2010 and one in 2011, having an exceptionally large number of industrial granules in the stomach (visible as uppermost individual datapoints for 2010 and 2011 in graphs of Fig.*iii; also see photo in Chpt.5).* Statistical tests based on ln transformed data are not really affected by the two outliers. As a consequence of this mix of long-term trends, the composition of plastic litter has strongly changed since the early 1980s, with nowadays a reduced proportion of industrial plastics (from about 50% to circa 20% of total mass) and an increased mass of user plastics. Decreases in industrial plastics have been observed in different parts of the world.

Recent 10-year trend 2002-2011

*R*egression analyses for 10-year trends showed significant decrease for the last time over the 1997-2006 period. Since then no significant trends have been observed in either industrial or user plastics. The 2002-2011 analyses suggest slowly continuing decreases for industrial plastic (negative t-values in Report Table 4B ; slope in Fig.*iii* B slightly downward) and slow increases for consumer plastics (positive t-values in Table 4B; slight upward slope in Fig.*iii* B). But none of these recent trends are statistically significant.

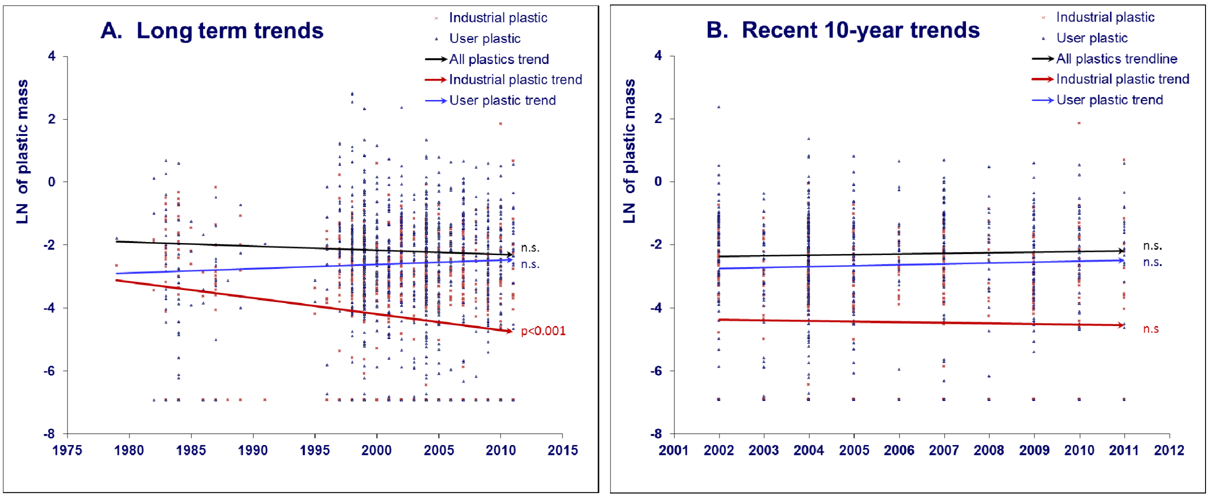

Figure iii ***Statistical trends in plastic mass in stomachs of Fulmars from the Netherlands 1980s-2011.*** *Graphs show ln transformed mass data for industrial plastic and user plastic in stomachs of individual Fulmars, plotted against year, and linear trendlines for industrial (lower, red line), user (middle blue line) and total plastics (top black line). Figure A. shows long term trends and B the recent trend over the past 10 years of data. Full details for results of statistical tests for trends are available in Table 4 of the report. N.s means that the test result is not significant.*

Monitoring data for the North Sea

Fulmar study areas in the North Sea are grouped into 5 regions, that is the Scottish Islands (Shetland and Orkney), East England (north- and southeast), Channel (Normandy and Pas de Calais), South-East North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast).

- **Current data for the whole North Sea (years 2007 to 2011; 796 Fulmars) are that 95% of Fulmars had plastic in the stomach , with an average number of 33 particles and mass of 0.38 gram per bird. The critical EcoQO value of 0.1 gram plastic was exceeded by 62% of these birds.**

Underlying this average for the recent 5 year period is a consistent regional pattern, in which highest plastic abundance is seen in Fulmars from the Channel, with decreasing levels further to the north both along western and eastern shores of the North Sea. From our earlier analyses of geographical patterns in fulmar stomach contents and studies of beached litter, our findings are considered to reflect concentrated shipping and fisheries activities in the south rather than coastal or riverine sources in that area. The regional differences are strong, but just not at a statistically significant level. Regional EcoQO percentages for 2007-2011 range from 55% to 86%, all far above the OSPAR target of 10% maximum (Fig. *iv; Report* Table *5*). In the North Atlantic stepwise decreases can be seen towards higher latitudes, with lowered levels visible in the Faroes and on Iceland, and the lowest levels in the Canadian Arctic. Only the Canadian Arctic approaches the OSPAR target for acceptable environmental quality.

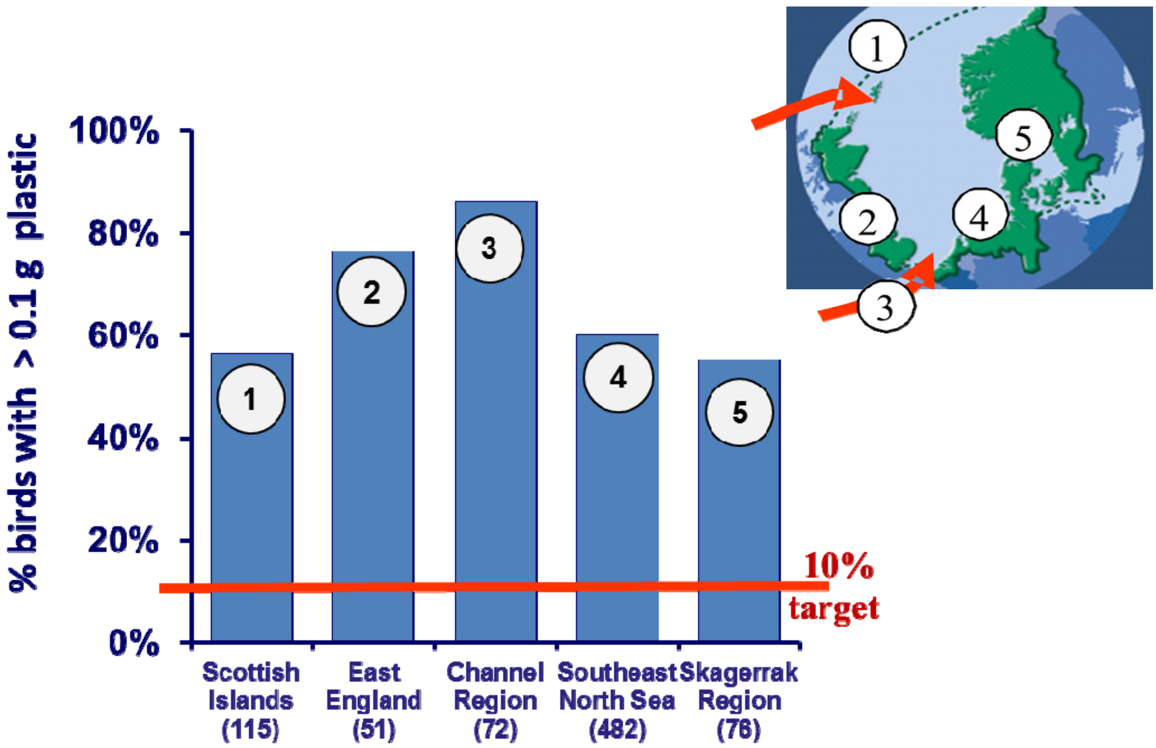

Figure iv ***EcoQO performance in North Sea regions 2007-2011*** *(see Report Table 5 for details)*.

Most regional datasets now span 10 years of data, a sufficiently long period to test for trends over time. Trends for Channel area, East England and Scottish Islands are upwards but not to a statistically significant level. Skagerrak and southeastern North Sea seem fairly stable. Location specific trends in the southeastern North Sea suggest decreasing levels in Belgium, stable levels in the Netherlands, and slightly increasing levels of ingested plastics in German Fulmars. It is tempting to speculate that harbour policies in the Rotterdam-Antwerp area are relatively successful, but none of the trends is significant and more factors could be involved.

The consistent large difference in pollution between the Channel area and the Scottish Islands indicates that a large proportion of North Sea marine litter is of local origin. If debris floating into Europe with Gulfstream waters was to blame, pollution to the north and south of UK would be much more similar. In addition, high levels of litter in Normandy, well before inflow of major river systems, suggest that litter in the North Sea is linked to sea-based activities, in particular shipping, rather than to riverine inputs. A detailed beach study on Texel, the Netherlands in 2005 confirmed that most debris had a North Sea origin and was primarily linked to merchant shipping and fisheries: among plastic wastes, 57% of mass were fishing nets and ropes and the major part of the remainder consisted of jerrycans, fishboxes, and other large items clearly linked to seabased activities. Using various other details of beached items, seabased sources were considered to be responsible for about 90% of the coastal debris found on Texel (Van Franeker 2005; Van Franeker & Meijboom 2006). The implementation of the EU Directive 2000/59/EC on Port Reception Facilities since 2004 has not resulted in significant improvement in Fulmar

EcoQO performance in the Dutch time series or the trends for other North Sea regions. However, considering strong increases in shipping traffic and the ever growing proportion of plastics in waste, the relative stability in ingested quantities of plastics in fulmar stomachs over the last decade (Fig.*v*) indicates that it is likely that the EC Directive on Port Reception Facilities has contributed to stabilizing marine debris input in the North Sea in particular in the southeastern sector.

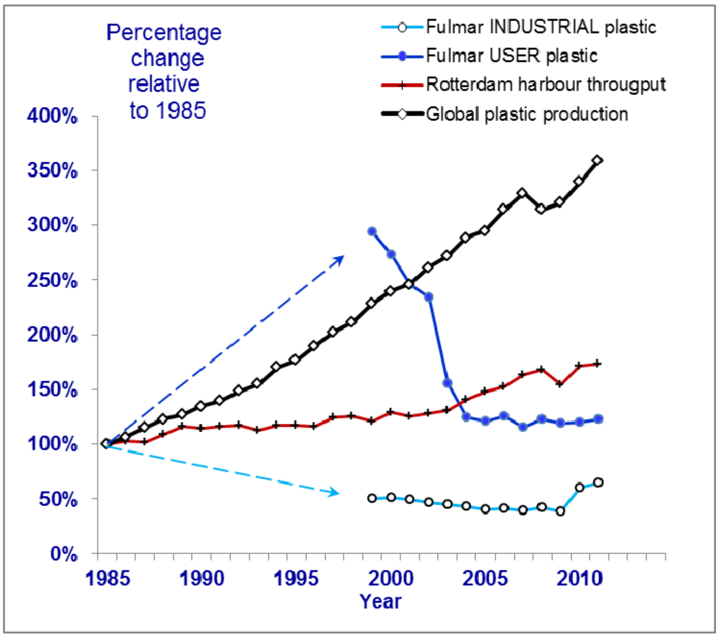

Figure v ***Comparative trends*** *in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars (5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985. (Recent high values for industrial plastic caused by outliers, not significant)*

CONCLUSIONS

1. North Sea governments aim at an Ecological Quality Objective (EcoQO) in which less than 10% of Fulmars exceed a critical level of 0.1 gram plastic in the stomach.
2. In the Netherlands, 60% of Fulmars exceed the 0.1 gram level (*204 fulmars 2007-20011: 95% contained plastic; on average 36 particles per stomach, weighing 0.33 gram).*
3. Long term data for the Netherlands show a sharp increase of marine plastic litter from the early 1980s to the mid-1990s, followed by a similar sharp decline but stabilization and lack of significant improvement during the recent decade.
4. The composition of ingested plastic has changed since the 1980s with a significantly reduced proportion of industrial plastic and increased proportion of consumer waste.
5. Over the whole North Sea, 62% of Fulmars exceed the 0.1g EcoQO level *(796* fulmars *2007-2011: 95% contained plastic; on average 33 particles per stomach, weighing 0.38 gram).*
6. Regional variation in the North Sea is consistent with highest pollution in the Channel (*86% of Fulmars exceed 0.1g EcoQO limit*) and less pollution further north (*to 55%*).
7. Shipping and fisheries continue to be considered the major source for marine litter in the North Sea.
8. In the North Sea, regional trends in amount of plastic in stomachs appear upward in the Channel, east England and the Scottish Islands, and relatively stable in the southeastern North Sea and Skagerrak. Within the southeastern North Sea, Belgian Fulmars suggest decreases, Dutch birds stability, and German Fulmars some increase. None of the trends reaches statistical significance.
9. Policy measures aimed at the shipping sector, such as implementation of the European Directive on Port Reception Facilities (Directive EC 2000/59/EC) probably have contributed to a stabilization in marine litter levels, but not yet to reduction.

Photo:

During a large scale beach litter study at Texel in 2005, 57% of the mass of plastic waste were ropes and nets, clearly related to shipping and fisheries. Much of remaining 43% of plastic mass consisted of jerrycans, fish boxes, crates and other large items clearly linked to seabased sources, rather than to tourism or coastal activity. Further pictures and report (dutch language) are available at : http://zeevogelgroep.nl/SchoonStrandTexel2005/

ii. Samenvatting

Stormvogel Zwerfvuil EcoQO monitoring langs Nederlandse en Noordzeekusten - bijwerking resultaten 2010 en 2011.

Zwerfvuil op zee veroorzaakt ernstige economische en ecologische schade. De economische gevolgen zijn het grootst voor kustgemeentes, toerisme, scheepvaart en visserij. Dieren komen om of lijden door verstrikking in, of het opeten van afval, waarbij microscopisch kleine stukjes mogelijk gevolgen hebben voor hele voedselketens tot het niveau van de menselijke consument. In het Noordzeegebied werd het probleem van zwerfvuil duidelijk erkend toen de aangrenzende landen in 2002 besloten om OSPAR de opdracht te geven zwerfaval op te nemen in het systeem van 'Ecologische Kwaliteits Doelstellingen (EcoQOs)(North Sea Ministerial Conference 2002). In die periode werd in Nederland al graadmeter onderzoek verricht om zwerfvuil op zee te monitoren aan de hand van de hoeveelheid plastic afval in magen van een zeevogel, de Noordse Stormvogel (*Fulmarus glacialis*). Stormvogels fourageren alleen op open zee, en eten allerlei soorten afval van het zeeoppervlak en spugen onverteerbare delen zoals plastic niet uit in de vorm van braakballen. De opgegeten opbjecten zijn veelal meerdere millimeters tot centimeters groot, maar kunnen nog aanzienlijk groter zijn als het flexibel draadvormige of velvormige materialen betreft. Zulke objecten moeten geleidelijk in de spiermaag worden afgesleten totdat ze klein genoeg zijn om door te stromen naar de darm. Gedurende dit slijtageproces hopen plastics zich op in de maag tot een niveau dat een geintegreerde afspiegeling vormt van de hoeveelheid afval die ze in hun fourageergebied zijn tegen gekomen over een periode van vermoedelijk enkele weken (Van Franeker et al. 2011). Deze Nederlandse graadmeter is voor internationaal gebruik door OSPAR als EcoQO verder ontwikkeld (OSPAR 2008, 2009, 20101,b) en dezelfde benadering wordt nu ook Europees toegepast als indicator voor een 'Goede Milieu Toestand' in de EU KaderRichtlijn Marien (KRM) (EC 2008, 2010; Galgani et al. 2010; MSFD GES Technical Subgroup on Marine Litter, 2011). OSPAR definieert de 'EcoQO doelwaarde voor aanvaardbare ecologische kwaliteit' in de Noordzee als de situatie waarin:

> *"minder dan 10% van de Noordse Stormvogels 0.1 gram of meer plastic in de maag heeft, in monsternames van 50 tot 100 aangespoelde vogels uit ieder van 5 verschillende Noordzee regio's gedurende een periode van tenminste 5 jaar"*

OSPAR kent geen vastgestelde datum waarop dit doel moet zijn bereikt. De Europese KRM heeft wel een datum voor het bereiken van de Goede Milieu Toestand, namelijk het jaar 2020, en lidstaten kunnen een daaraan aangepaste doelstelling formuleren. Voor gebieden waar geen Noordse Stormvogels voorkomen worden andere indicator soorten gezocht waarvoor methodes en doelstellingen worden ontwikkeld.

Het graadmeter onderzoek aan de Noordse Stormvogel gebruikt dood op kusten gevonden dieren of exemplaren die door ongelukken zijn omgekomen, zoals bijvangst uit visserij. In een verkennend onderzoek is aangetoond dat de hoeveelheid plastic in de maag van langzaam verhongerde exemplaren (de meeste strandvondsten) niet aantoonbaar verschilt van die in gezonde vogels die door een acuut ongeval zijn omgekomen. Standaard methodes voor dissecties van de vogels en het maagonderzoek zijn vastgelegd in handleiding en rapporten. Er wordt onderscheid gemaakt tussen verschillende categoriën plastic, waarbij het onderscheid tussen industrieel plastic (basis granulaat) en gebruiksplastics (afval van allerlei soorten produkten) het belangrijkst is. Informatie over het voorkomen van plastic in de magen van de stormvogels kan op verschillende manieren worden gepresenteerd

- **Frequentie van vóórkomen (Incidence**) – het percentage vogels dat plastic in de maag had, onafhankelijk van de hoeveelheid plastic
- **Gemiddelde ± standaardfout (Arithmetic Average ± se)** – het normaal berekende 'rekenkundig gemiddelde', veelal aangegeven inclusief de standaardfout. Dit kan worden

gebruikt voor zowel het aantal stukjes plastic als het gewicht, voor *alle* onderzochte magen uit een monster, dus inclusief die zonder plastic (populatie gemiddelde)

- **Geometrisch Gemiddelde (Geometric Mean) –** dit gemiddelde wordt berekend met een tussenstap van logaritmische transformatie (natuurlijk logaritme ln(x)) waarmee de verstorende invloed van extreme waardes op een gewoon gemiddelde die vooral optreedt bij kleinere monsters word voorkomen.
- **EcoQO Percentage (EcoQO Performance)** – het percentage van de onderzochte vogels dat meer dan 0.1 gram plastic in de maag heeft, hetgeen een directe vergelijking mogelijk maakt met de OSPAR doelstelling die stelt dat dit percentage lager moet zijn dan 10%.
- **Samengevoegde gegevens (pooled data)** – in veel grafieken en tabellen worden bovengenoemde gegevens gegroepeerd voor periodes van 5 jaar om korte termijn fluctuaties te vermijden en de nadruk te leggen op betrouwbare gemiddeldes en duidelijke trends. Dit soort getallen wordt niet afgeleid van jaarlijkse gemiddeldes, maar is gebaseerd op alle individuele waarnemingen uit de hele periode.
- **Statistiek (Statistics) –** Statistische analyses van trends in de tijd of verschillen tussen gebieden zijn alleen gebaseerd op plastic gewicht. Tijdsgebonden trends worden getest op significantie op basis van lineaire regressie van logaritmisch getransformeerde gegevens van plasticgewicht tegen het jaar van verzamelen voor alle individuele vogels. Daarbij wordt onderscheid gemaakt tussen de Lange-Termijn-Trend die naar een complete dataset kijkt (1979-2011 voor Nederland in dit rapport), en de Recente Trend die wordt berekend op basis van getallen over de afgelopen 10 jaar (2002-2011 in dit rapport). Verschillen tussen gebieden zijn getest op basis van logaritmisch getransformeerde gegevens in een zogenaamd Generalized Linear Model in combinatie met een 'Likelihood Ratio Test'.
- **Grafieken** maken veelvuldig gebruik van de samengevoegde 5-jaars gegevens, maar verschuiven per jaar, zodat opeenvolgende datapunten een overlap van 4 jaar gegevens hebben. Deze grafieken dienen alleen ter visuele ondersteuning van trends of geografische patronen en hebben zelf geen statistische betekenis, want die wordt alleen getest met de bovenvermelde methodes op basis van gegevens van individuele vogels.

Bijgewerkte Graadmetergegevens voor Nederland

Dit rapport voegt nieuwe gegevens toe voor de jaren 2010 en 2011 aan het voorgaande rapport (Van Franeker & the SNS Fulmar Study Group, 2011). In 2011 was slechts een beperkt aantal gestrande stormvogels beschikbaar, maar incidentele jaren van beperkte monstergrootte zijn geen probleem voor het monitoringsysteem, aangezien het alleen beperkingen oplegt aan korte termijn interpretaties. De wisselend aantallen levende en dode stormvogels in een gebied worden door vele factoren, vooral voedselbeschikbaarheid en weersomstandigheden, beinvloed. De zo nu en dan optredende jaren van schaarse gegevens vormen een van de redenen om samengevoegde gegevens over de afgelopen 5 jaar te beschouwen als de **'huidige situatie'.** Jaargegevens 2010 en 2011 en de huidige situatie 2007-2011 zijn samengevat in Tabel *i.*

- **De huidige graadmeter toestand voor Nederland (jaren 2007 t/m 2011; 204 stormvogelmagen) is dat 95% van de stormvogels plastic in de maag heeft, met een gemiddeld aantal van 36 stukjes en gewicht van 0.33 gram per vogel. De EcoQO grenswaarde van 0.1 gram plastic wordt door 60% van de Nederlanse vogels overschreden.**

Tabel i ***Samenvatting van gegevens die zijn toegevoegd aan de monitoring serie.***

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2010	***36***	**46%**	**58%**	**10.7**	**0.23**	**94%**	**45.7**	**0.23**	**94%**	**56.4**	**0.46**	**64%**
2011	***19***	**37%**	**63%**	**6.6**	**0.15**	**95%**	**37.0**	**0.27**	**100%**	**43.6**	**0.43**	**79%**
2007-2011	*204*	43%	**59%**	**4.4**	**0.10**	**94%**	**31.1**	**0.24**	**95%**	**35.5**	**0.33**	**60%**

* Five-year data are arithmetic averages over all individual birds in the five year period (not from annual averages)

Lange-termijn trend 1979-2011

De trends op de lange termijn voor Nederland zijn gevisualiseerd voor EcoQO Percentage in Fig. *i* en voor rekenkundig gemiddeld gewicht in Fig.*ii*. Beide figuren geven een totaal gemiddelde waarde voor de jaren ’80 en voor 5-jaars getallen vanaf 1995. Het overheersend beeld uit de EcoQO grafiek is dat al vanaf de jaren ’80, de feitelijke situate ver verwijderd is van de 10% doelstelling van OSPAR, en gefluctueerd heeft tussen de 57% en 67%. Een 10% verbetering van midden jaren ’90 tot de vroege jaren 2000 (Fig. *i* B) leek veelbelovend, maar meer recent wordt nauwelijks verandering waargenomen.
De grafieken voor plastic gewicht illustreren meer detail in de tijdsreeksen. Van het midden van de jaren ’80 naar midden jaren ’90 nam het plastic gewicht per maag zeer sterk toe, gevolgd door een vergelijkbaar snelle afname tot begin jaren 2000, maar nauwelijks verandering in de afgelopen decade. Het huidig niveau van alle plastic types tezamen (Fig.*ii* A) verschilt niet sterk van dat in de jaren ’80. De ontwikkelingen voor industrieel plastic waren echter totaal anders dan die voor gebruiksplastics (Fig. *ii* B). De gebruiksplastics domineren het beeld van de totale plastics, maar industrieel granulaat in de magen halveerde van de jaren ’80 tot midden jaren ’90 en hebben sindsdien voornamelijk een zwak doorgezette afname laten zien, met uitzondering van de opmerkelijke laatste twee datapunten. Statistiche toetsen van de trends zijn geillustreerd in Fig.*iii* (alle details in Rapport Tabel 4). Omdat de toetsmethode van rechtlijnige verbanden uitgaat, wordt de toe- en afname voor- en na midden jaren ’90 van gebruiksplastics en alle plastics samen niet weerspiegeld in deze trends. Industrieel plastic granulaat daarentegen nam sterk af vanaf de beginjaren en laat op grond daarvan een sterk significante afname zien op de lange termijn ($p<0.001$) ondanks een vrij stabiel beeld over de laatste decade en zelfs toenames in de rekenkundige gemiddeldes voor twee recentste 5-jaarsperiodes. Deze recente gegevens voor industrieel plastic gewicht worden sterk beinvloed door twee maaginhouden, één uit 2010 en één 2011, met zeer uitzonderlijke hoeveelheden industrieel plastic (zichtbaar als bovenste datapunten voor deze jaren in de dataplots in Fig. *iii*.; zie ook foto in Hfdst. 5). Statistische toetsen op basis van ln-getransformeerde gegevens worden door deze uitbijters niet duidelijk beinvloed. Als gevolg van de verschillende lange termijn trends is de samenstelling van het plastic afval sinds de jaren ’80 duidelijk veranderd met een afgenomen aandeel industrieel granulaat (van aanvankelijk ca. 50% op gewichtsbasis naar ca 20% nu) en een toegenomen aandeel gebruiksplastic. Afnames is industrieel granulaat zijn ook in andere delen van de wereld waargenomen.

Recente 10-jaar trend 2002-2011

De regressie analyses over de 10 jaar periodes waren voor het laatst significant voor de periode 1997-2006. Nadien werd geen significante trends meer gezien in zowel industriele als gebruiks-plastics. De meest recente trendlijnen voor de periode 2002-2011 (Fig. *iii* B; Rapport Tabel 4B) vertonen weinig verandering. Industrieel plastic lijkt over deze periode zeer zwak afgenomen (negatieve t-waarde in Tabel 4B en een zwak neerwaartse rode lijn in Fig. *iii* B) en gebruiksplastics nog iets te zijn toegenome (positieve t-waarde in Tabel 4B en zwakke stijging in de blauwe lijn in Fig. *iii* B). Maar geen van deze trends is statistisch significant.

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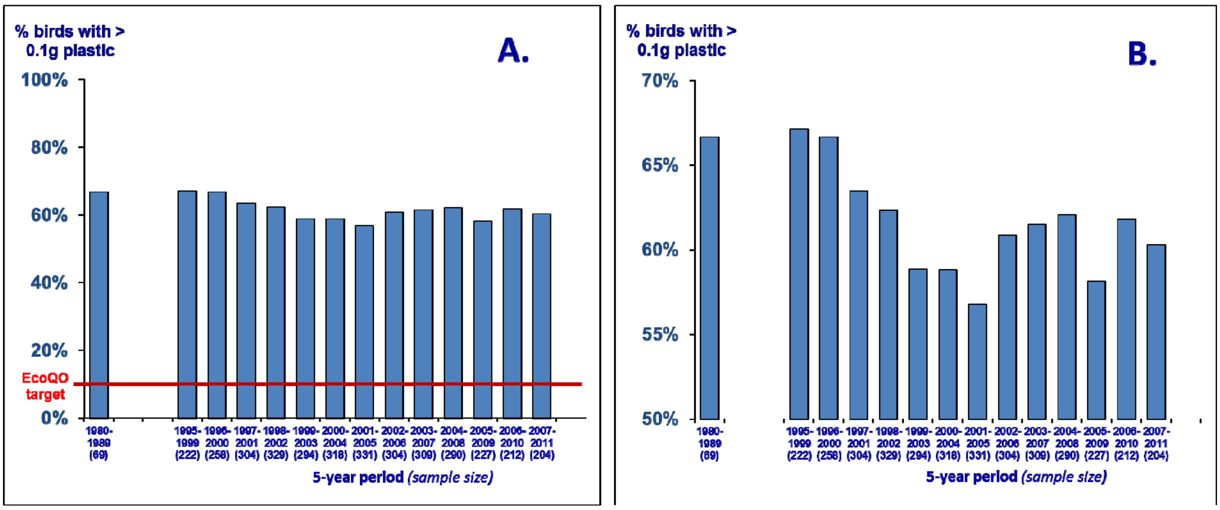
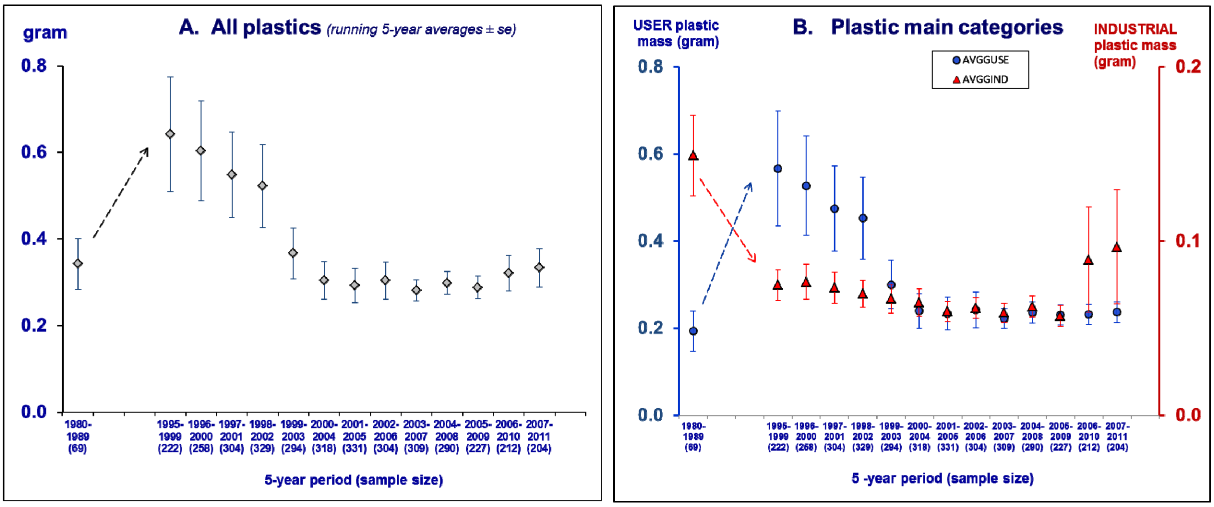


Figuur i ***EcoQO percentages van stormvogels uit Nederland 1980s-2011.*** *A: gegevens op een volle 100% schaal voor het aandeel van de vogels dat meer dan de 0.1 gram plastic uit de OSPAR norm bevat. B: zelfde gegevens, doch y-as beperkt tot de waargenomen percentages, die vanaf 1995 een stapsgewijze afname van 10% lieten zien, maar daarna geen gerichte verandering meer vertonen. Gegevens zijn weergegeven met een enkel getal voor de jaren 1980 en lopende 5-jaars gemiddeldes vanaf 1995.*



Figuur ii ***Plastic gewicht in magen van stormvogels uit Nederland 1980s-2009.*** *A: alle plastics tezamen; B: dezelfde gegevens opgesplitst gebruiksplastics (blauwe cirkels, schaal op linker y-as) en industrieel plastic (rode driehoeken, rechter y-as) Gegevens zijn weergegeven als rekenkundige gemiddeldes ± standaardfout voor plastic gewicht, met een enkel gemiddelde voor de jaren 1980 en lopende 5-jaars gemiddeldes vanaf 1995.*

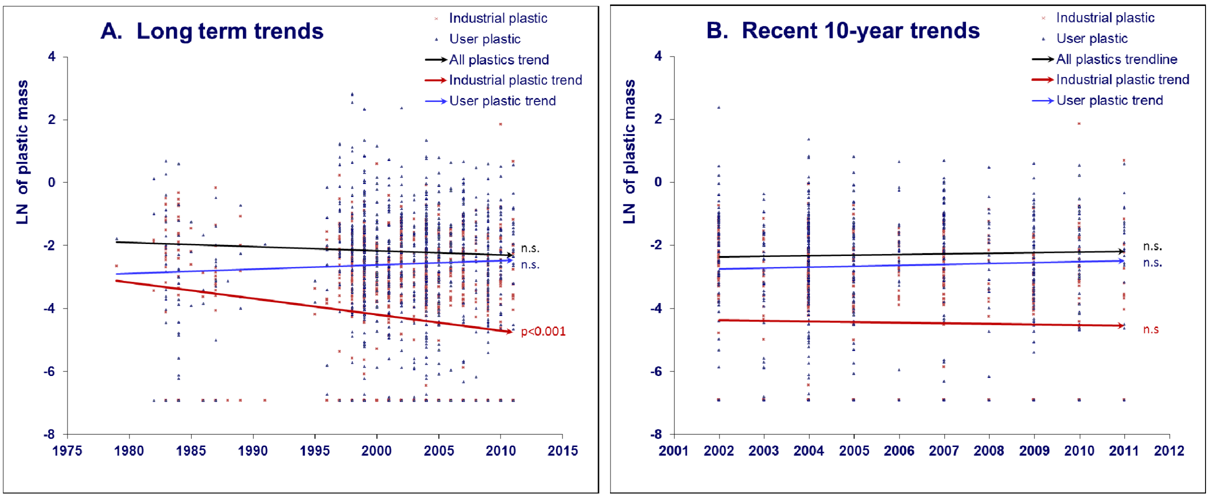


Figure iii ***Statistische trends in plastic gewicht in magen van stormvogels uit Nederland 1980s-2011.*** *A: Lange termijn trends; B: Recente 10 jaar trend. In de grafieken zijn de alle individuele datapunten geplot van de ln-getransformeerde gegevens voor industrieel plastic gewicht (rood) en gebruiksplastic gewicht (blauw). Lijnen geven de resultaten van statistische trendanalyses voor industrieel plastic (rood), gebruiksplastic (blauw) en alle plastics samen (zwart). Details van statische analyses zijn te vinden in Rapport Tabel 4. Bij significant toetsresultaat is de p waarde vermeld, n.s geeft aan dat de trendlijn geen significant verloop door de tijd liet zien.*

Monitoringsgegevens Noordzee

Onderzoekslocaties uit het stormvogel onderzoek rond de Noordzee zijn gegroepeerd in 5 regios, de Schotse Eilanden (Shetland en Orkney), Oost-Engeland (noordoost en zuidoost), Kanaalgebied (Pas de Calais en Normandië), zuidoostelijke Noordzee (België, Nederland, Duitsland) en het Skagerrak gebied (Skagen in Denemarken, Lista in Noorwegen, en Zweedse westkust).

- **De huidige graadmeter toestand voor gezamelijke Noordzee regios (jaren 2007 t/m 2011; 796 stormvogelmagen) is dat 95% van de stormvogels plastic in de maag heeft, met een gemiddeld aantal van 33 stukjes en gewicht van 0.38 gram per vogel. De EcoQO grenswaarde van 0.1 gram plastic wordt door 62% van de stormvogels uit de Noordzee overschreden.**

Onder dit totaalgemiddelde van de Noordzee is een blijvend regionaal patroon aanwezig, waarin het meeste plastic wordt aangetroffen in magen van stormvogels uit het Kanaal gebied, en de gehaltes naar het noorden toe geleidelijk afnemen, zowel langs de westelijk als oostelijke kust. Op basis van het eerder onderzoek naar geografische patronen, en de combinatie met onderzoek van strandafval, beschouwen we dit patroon als een afspiegeling van intensieve scheepvaart en visserij in de meer zuidelijke regios, en niet zozeer een afspiegeling van bronnen op de kust of vanuit rivieren. De regionale verschillen zijn aanzienlijk, maar bereiken niet echt een significant niveau. ECoQO percentages uit de periode 2007-2011 varieerden per regio dat 55% tot 86% van de onderzochte dieren meer dan 0.1 gram plastic in de maag had (Fig. *iv;* Rapport Tabel 5). Dus over de hele Noordzee zijn we nog ver verwijderd van de beoogde OSPAR norm dat maximaal 10% van de vogels zoveel plastic zou mogen bevatten. Noordelijk van de Noordzee in het Atlantisch gebied zijn trapsgewijs lagere niveaus waarneembaar in de Faroe Eilanden en IJsland. Pas in Arctisch Canada benaderen de maaginhouden de OSPAR norm voor acceptabele ecologische kwaliteit.

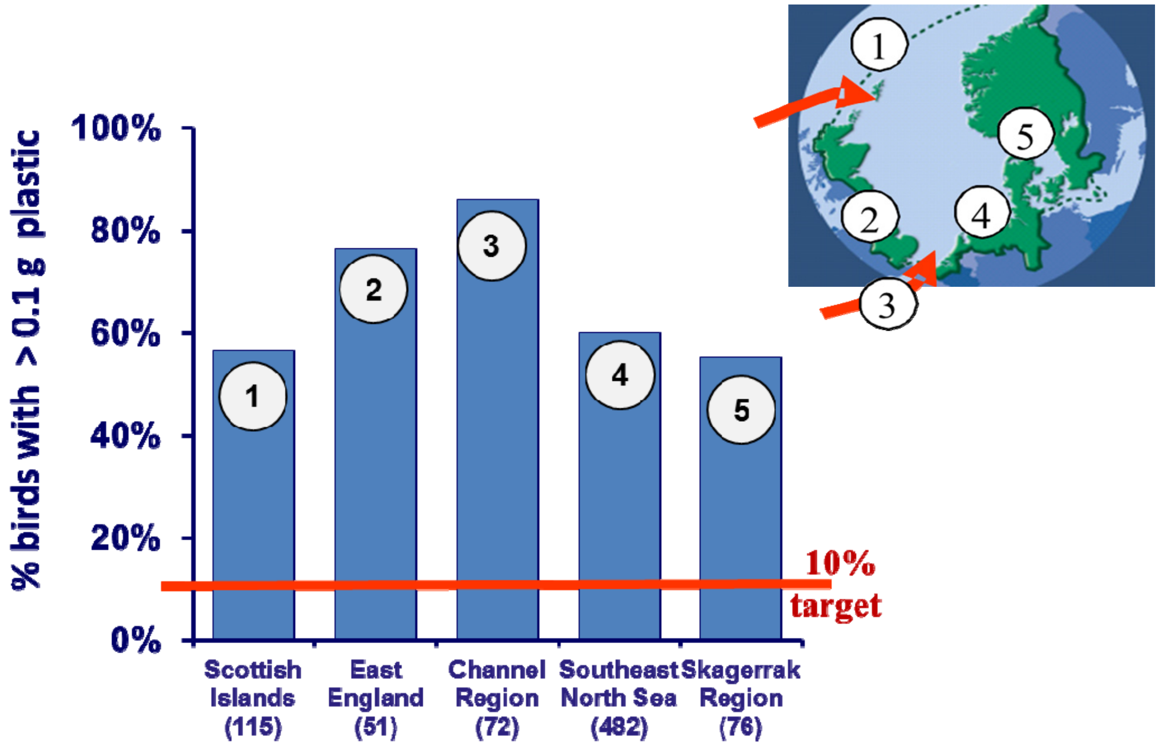


Figure iv ***EcoQO percentages in regios van de Noordzee 2007-2011*** *(see Rapport Tabel 5 voor details)****.***

Het merendeel van de regionale datasets begint nu een tijdreeks te bevatten van 10 jaar, een voldoende lange periode om tijdsgebonden trends te toetsen. Voor het Kanaalgebied, Oost Engeland en de Schotse Eilanden wijzen de trends op toenames in plastic, maar niet op een significant niveau. De niveaus in de zuidoostelijke Noordzee en het Skagerrak lijken stabiel. Trendanalyses voor de afzonderlijke locaties in de zuidoostelijke Noordzee regio, lijken te wijzen op afnames in Belgische vogels, stabiele gehaltes in Nederland, en lichte toenames in Duitsland. Het is verleidelijk om te speculeren dat het beleid ten aanzien van havenontvangstvoorzieningen in de Rotterdamse en Antwerpse havens naar verhouding succesvol zijn, doch geen van de trends is significant en ook andere factoren kunnen een rol spelen. Het aanzienlijk verschil in plastic belasting van stormvogels uit het Kanaalgebied en de Schotse eilanden vormt een aanwijzing dat veel van het zwerfvuil in de Noordzee van locale oorsprong is. Als met de Warme Golfstroom meegevoerd afval van elders de belangrijkste bron zou zijn, zouden de verschillen ten zuiden en noorden van de UK niet zo groot zijn. Daarnaast is het feit dat de hoogste vervuilings niveaus worden aangetroffen in de vogels van Normandië een aanwijzing dat bronnen op zee een vooral scheepvaart belangrijk zijn, omdat de grootste uitstroom van rivieren pas verder naar het noorden optreedt. Een gedetailleerd onderzoek aan zwerfvuil op Texel in 2005 bevestigde dat het meeste vuil uit de Noordzee zelf afkomstig was, en voornamelijk in verband kon worden gebracht met scheepvaart en visserij: ca. 57% van het gewicht aan plastic zwerfvuil was visnet en touwwerk, terwijl de bulk van het overige plastic gewicht ook bestond uit jerrycans, viskratten en andere grote objecten die duidelijk afkomstig waren van bronnen op zee. Ook gedetailleerde deelanalyses wezen in de richting van activiteiten op zee, en ondersteunden een schatting dat ca. 90% van het afvalgewicht op de Texelse kust afkomstig was van zeegebonden activiteiten (Van Franeker 2005; Van Franeker & Meijboom 2006).
De invoering van de EU Richtlijn 2000/59/EC voor Haven Ontvangst Voorzieningen vanaf 2004 heeft nog geen significante verbetering kunnen brengen in het Stormvogel EcoQO percentage in Nederland of elders in de Noordzee. Daarbij moet in aanmerking worden genomen dat de stabiliteit in plastics in stormvogelmagen in onze regio samenvalt met sterke toenames in scheepvaartverkeer en een steeds

groter aandeel van plastic in afvalstromen (Fig. *v*). In die zin is het aannemelijk dat de EU Havenrichtlijn heeft bijgedragen aan een stabilisatie van zwerfvuil in vooral de zuidoostelijke sector van de Noordzee.

Photo:

Bij een grootschalig zwerfvuilonderzoek op Texelse stranden in 2005, bleek 57% het gewicht aan plastic afval te bestaan uit touwen en netten, met een duidelijke relatie naar scheepvaart en visserij. Veel van de resterend 43% plastic gewicht bestond uit jerrycans, viskisten, manden en ander grote objected die duidelijk aan activiteit op zee waren te koppelen en veel minder aan touristen of kustbegonden activiteit. Verdere foto's om dit te illustreren en het rapport zijn te vinden op; http://zeevogelgroep.nl/SchoonStrandTexel2005/

CONCLUSIES

1. Noordzee landen streven naar een Ecologische Kwaliteitsdoelstelling (ECOQ) waarbij minder dan 10% van de Noordse Stormvogels een grenswaarde van 0.1 gram plastic in de maag overschrijdt.
2. In Nederland heeft momenteel 60% van de stormvogels meer dan 0.1 gram plastic in de maag *(204 stormvogels 2007-2011: 95% heeft plastic in de maag, gemiddeld 36 stukjes en 0.33g).*
3. Lange termijn gegevens voor Nederland tonen een sterke toename van zwerfvuil vanaf begin jaren 1980 tot midden jaren '90, gevolgd door een snelle afname tot kort na de eeuwwisseling maar daarna stabilisatie en geen significante verbeteringen in de afgelopen 10 jaar.
4. De samenstelling van door stormvogels ingeslikt plastic is sinds de jaren 1980 sterk veranderd met een significant afgenomen deel industrieel plastic en een toegenomen deel gebruiksplastics.
5. Gemeten over de hele Noordzee overschrijdt 62% van de stormvogels het 0.1g EcoQO niveau *(796 stormvogels 2007-2011: 95% heeft plastic in de maag, gemiddeld 33 stukjes en 0.38 g).*
6. Regionale variatie in de Noordzee vertoont een vast patroon met de hoogste vervuiling in het Kanaal (*86% van stormvogels boven de 0.1g EcoQO waarde*) en naar het noorden toe afnemende vervuiling (*tot 55%*)

7. Scheepvaart, inclusief visserij zijn nog steeds te beschouwen als de belangrijkste bron van zwerfvuil in de Noordzee.
8. Regionale trendanalyses suggereren toenames van plastic in stormvogelmagen in het Kanaal, Oost Engeland en de Schotse Eilanden en relatieve stabiliteit in de zuidoostelijke Noordzee en het Skagerrak. Locale patronen binnen de zuidoostlijke Noordzee suggereren afname in België, stabiliteit in Nederland en enige toename in Duitsland, maar geen van deze trends is significant.
9. Op scheepvaart gerichte maatregelen, zoals de invoering van de Europese Richtlijn voor HavenOntvangstVoorzieningen (Directive EC 2000/59/EC) hebben waarschijnlijk bijgedragen aan stabilisering van het vervuilingsniveau in de zuidelijke Noordzee, maar nog niet aan een afname.

1. Introduction

Marine litter, in particular plastic waste, represents an environmental problem in the North Sea and elsewhere, with considerable economic and ecological consequences. In 2005, a study on the island of Texel revealed that each day, on each km of beach, 7 to 8 kg of debris washed ashore (Van Franeker 2005): roughly half of the debris was wood, the other half synthetic materials, with relatively minor contributions from other materials such as glass and metals. On Texel, the main source of the debris, estimated up to 90% of mass, was related to activities at sea, i.e. shipping, fisheries, aquaculture and offshore industries.

The **economic consequences** of marine litter affect many stakeholders. Coastal municipalities are confronted with excessive costs for beach clean-ups. Tourism suffers damage because visitors avoid polluted beaches, especially when health-risks are involved. Fisheries are confronted with a substantial by-catch of marine litter which causes loss of time, damage to gear and tainted catch. Shipping suffers financial damage and -more importantly- safety-risks from fouled propellers or blocked water-intakes. Marine litter blowing inland can even seriously affect farming practices. The overall economic damage from marine litter is difficult to estimate, but detailed study in the Shetlands with additional surveys elsewhere indicate that even local costs may run into millions of Euros. (Hall 2000; Lozano and Mouat, 2009; Mouat et al., 2010).

The **ecological consequences** of marine litter are most obvious in the suffering and death of marine birds or mammals entangled in debris. Entangled whales are front page news and attract a lot of public attention. However, only a small proportion of entanglement mortality becomes visible among beached animals. Even less apparent are the consequences from the ingestion of plastics and other types of litter. Ingestion is extremely common among a wide range of marine organisms including many seabirds, marine mammals and sea-turtles. It can cause direct mortality but the major impact most likely occurs through reduced fitness of many individuals. Sub-lethal effects on animal populations remain largely invisible. In spite of spectacular examples of mortality from marine litter, the real impact on marine wildlife therefore remains difficult to estimate (Laist 1987, 1997; Derraik 2002). Plastics gradually break down to microscopically small particles, but these may pose an even more serious problem (Thompson *et al*. 2004). Concern about microplastics attracts more and more attention as evidence is growing that plastics in seawater strongly bind organic pollutants and microplastics may enter the base of the food-web by ingestion by filter-feeding marine organisms (Endo et al 2005; Teuten et al. 2007; Browne et al. 2008; Moore 2008; Arthur et al 2009; Thompson et al. 2009; Teuten et al. 2009). Thus, in addition to the toxic substances incorporated into plastics in the manufacturing process, plastics may concentrate much more pollutants from the environment and act as a pathway boosting their accumulation in marine organisms. Evidently, this same mechanism operates at all levels of organisms and sizes of ingested plastic material, from small zooplankton filter-feeders to large marine birds and mammals, but it is the microplastic issue and their ingestion by small filter-feeders that has emphasized the potential scale and urgency of the problem of marine plastic litter, as it may ultimately affect human food quality and safety as well. Accumulation of marine plastic litter, including a 'soup' of microplastics, in all major gyres of the oceans have emphasized the global scale of the marine litter problem (Moore 2008; Law et al. 2010; Maximenko et al. 2012).

Recognizing the negative impacts from marine debris, a variety of international policy measures has attempted to reduce input of litter. Examples of these are the London Dumping Convention 1972; Bathing Water Directive 1976; MARPOL 73/78 Annex V 1988; Special Area status North Sea MARPOL Annex V 1991; and the OSPAR Convention 1992. In the absence of significant improvements, political measures have been intensified by for example the EU-Directive 2000/59/EC on Port Reception Facilities (EC 2000), the Declaration from the North Sea Ministerial Conference (2002) in Bergen, and recently in the European Marine Strategy Framework Directive (EC 2008, EC 2010).

Policy initiatives have recognized the need to use quantifiable and measurable aims. Therefore, the North Sea Ministers in the 2002 Bergen Declaration decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQO's) (North Sea Ministerial Conference 2002). For example, the oil pollution situation in the North Sea is measured by the rate of oil-fouling among beached Guillemots

(*Uria aalge*) with an EcoQO target of less than 10% of beached Guillemots having oil on the plumage (OSPAR 2005). Similarly, as proposed by ICES Working Group on Seabird Ecology (ICES-WGSE, 2003), OSPAR decided to use the abundance of plastic in stomachs of seabirds, *in casu* the Northern Fulmar (*Fulmarus glacialis*) to measure quality objectives for marine litter (OSPAR 2008, 2009, 2010a, 2010b). The Fulmar EcoQO monitoring has been included as an indicator for marine litter in the approach for Good Environmental Status in the European Marine Strategy Framework Directive (Galgani et al. 2010, EC 2010, MSFD GES Technical Subgroup on Marine Litter, 2011).

Within the Netherlands, the Ministry of Infrastructure and the Environment (I&M) has a coordinating role in governmental issues related to the North Sea environment. As such, I&M is involved in the development of environmental monitoring systems ("graadmeters") for the Dutch continental shelf area. As a part of this activity, I&M has commissioned several earlier projects by IMARES working towards a Fulmar-Litter-EcoQO. The first pilot project for the North Sea Directorate considered stomach contents data of Dutch Fulmars up to the year 2000 and made a detailed evaluation of their suitability for monitoring purposes (Van Franeker & Meijboom 2002). A series of later reports commissioned by the Directorate-General for Civil Aviation and Maritime Affairs (DGLM) (see 'References') have provided annual updates on the Dutch time-series, paying special attention to shipping issues and EU Directive 2000/59/EC.

Internationally, as of 2002, the Dutch Fulmar research was expanded to all countries around the North Sea as a project under the ***Save the North Sea (SNS)*** program. SNS was co-funded by EU Interreg IIIB over period 2002-2004 and aimed to reduce littering in the North Sea area by increasing stakeholder awareness. The Fulmar acted as the symbol of the SNS campaign. The SNS Fulmar study was published as Van Franeker *et al*. 2005. Findings strongly supported the important role of shipping (incl. fisheries) in the marine litter issue. For further publications of the SNS Fulmar study see e.g. Save the North Sea 2004, Van Franeker 2004b and 2004c, Edwards 2005, Guse *et al* 2005, Olsen 2005. After completion of the European SNS project, the international work was continued through CSR awards from the NYK Group Europe Ltd and support from Chevron Upstream Europe. These funds contributed to further North Sea EcoQO updates, a peer reviewed scientific publication on the EcoQO methods with data up to 2007 (Van Franeker *et al. 2011*) and the forelast report with data to 2009 (Van Franeker & the SNS Fulmar Study Group 2011). These awards were used also to promote Fulmar work in other areas of the world such as the Faroe Islands (Van Franeker 2012), Iceland (Kühn and Van Franeker 2011), the Canadian Arctic (Mallory et al. 2006, Mallory, 2008, Provencher et al. 2009); and the Pacific (Nevins et al. 2011; Avery-Gomm et al. 2012), and to explore the potential use of other marine species for ingestion monitoring as intended in the European Marine Strategy Directive (Bravo-Rebolledo et al. 2012).

The current assignment from the Dutch Ministry of Infrastructure and the Environment (I&M), through its section Rijkswaterstaat –Waterdienst (RWS-WD) included the following tasks:

- To update the Dutch time series on litter in stomach contents of Fulmars with the data from year 2010 and 2011 and to continue co-ordination of the beached bird sampling in the Netherlands
- As far as possible, to fill gaps in stomach analyses of fulmars from other North Sea countries for years 2010 and 2011 and integrate all data into a full North Sea EcoQO update up to 2011, giving special attention to details that could relate to the role of shipping

2. Shipping, marine litter and policy measures

In historic times, waste products from ships were discarded almost anywhere and at any time. The low intensity of shipping and degradable nature of wastes allowed such practice to continue for centuries without significant problems except inside harbours. However, exponential population growth and global industrialization has boosted marine transports by fast mechanically-powered ships with ever increasing quantities of poorly degradable and toxic wastes from fuel, cargo and household practises. Old habits are hard to change, particularly if such change involves costs in an extremely competitive international industry such as shipping. For example, the dramatic environmental consequences of oil discharges from ships were already known in the early 1900s (Camphuysen & Heubeck, 2001). More than a century later, under continuous public pressure and a continuous sequence of policy measures, the oil pollution problem is to some extent under control, but definitely not solved.

Compared to the problems from dumping of oil or toxic wastes, the issue of disposal of 'garbage' into the marine environment has long been considered of minor importance. It might still be considered that way if not for plastics. Plastics, although known since the early 1900s, started their real development only after 1960 (Andrady & Neal 2009). Since then, they have found their way into almost every application, replacing old materials in existing products, and creating a new and endless array of 'disposable' packaging products.

Unfortunately, the same factors that made plastics such a popular product have resulted in them becoming an environmental problem. Low production costs have promoted careless use and low degradability leads to accumulation in the environment. In 2011, the world production of plastics reached 280 million tons, over 40% of which is used for packaging; annual growth rates of between 5 to 10% were interrupted by the economic crisis in 2008, but this was a temporary interruption (PlasticsEurope, 2012).

At the same time, intensity of shipping has increased. At the end of 2011, the global fleet had grown to 55,000 vessels over over 100 gross tons, totalling to 983 million gross tons, or 1.47 billion tons deadweight, nearly double the tonnage of the global fleets at the start of the century (Department of Transport, 2012) . Increased shipping activity can also be seen in freight passing the port of Rotterdam (Fig. 14).

Marine litter originates from a variety of sources, including merchant shipping, fisheries, offshore industry, recreational boating, coastal tourism, influx from rivers or direct dumping of wastes along seashores. The relative importance of various sources differs strongly in different parts of the world, and is almost impossible to quantify. Dutch Coastwatch studies (e.g. Stichting de Noordzee 2003) score litter into categories 'from sea’ (shipping, fisheries, offshore); 'beach-tourism'; 'dumped from land'; and 'unknown'. In the Netherlands, the 'from sea' category consistently represents in the order of 40% of litter items recorded. The 'unknown' category scores a similar percentage. Considerable uncertainties are linked to this categorization. More specific information may come from the OSPAR initiative for monitoring litter on beaches in a somewhat more systematic approach. In a first German report (Fleet 2003), ten years of Coastwatch-like surveys, plus two years of the more detailed OSPAR pilot project, were evaluated. From both studies it is concluded that shipping, fisheries and offshore installations are the main sources of litter found on German North Sea beaches. The larger proportion of litter certainly originates from shipping, with a considerable proportion of this originating in the fisheries industry. In the Netherlands, data to this effect were collected in a large beach litter study on Texel (van Franeker 2005) suggesting that up to 90% of plastic litter originates from shipping and fisheries in the Dutch area. So, although there may be uncertainties in details, there is little doubt that waste disposal by ships is one of the important sources of marine litter worldwide, a fact also recognized by the International Maritime Organization (IMO) in a specific 'garbage-annex' to the MARPOL Convention.

The International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78) entered into force on 2nd October 1983 for Annexes I (oily wastes) and II (bulk liquid chemicals), but its Annex V, covering garbage, only achieved sufficient ratifications to enter into force on 31st December 1988. MARPOL Annex V contains the following main prohibitions for discharge of solid wastes:

- No discharge of plastics.
- No discharge of buoyant dunning, lining or packaging material within 25 nautical miles (nm).
- No discharge of garbage within 12 nm. Food waste may be discharged if ground to pieces smaller than one inch.
- No discharge of any solid waste, including food waste, within 3 nm.

Control of compliance with Annex V regulations on ships is difficult (OECD-MTC 2003; Rakestraw 2012).

In the European region, and especially the North Sea area, the sheer intensity of merchant shipping and fisheries makes them an undisputed source of marine litter. From that background, North Sea states promoted that the North Sea received the status of MARPOL Special Area for its annexes I (oil) and V (garbage). Amendments to that effect were made in 1989, and the Special Area status for the North Sea entered into force in February 1991. "Special Areas" under MARPOL Annex V have a more restrictive set of regulations for the discharge of garbage, with the main additions being:

- No discharge, not only of plastics, but also of any sort of metal, rags, packing material, paper or glass.
- Discharge of food wastes must occur as far as practicable from land, and never closer than 12 nm.

Recently, MARPOL Annex V was revised by the Marine Environment Protection Committee (MEPC 2011). Under the new regulations, entering into force on 1 January 2013, nearly all waste disposal is completely prohibited irrespective of distance to land. This now includes glass, metal and all packaging materials, so is similar to the Special Area Status that was already longer in force (1991) in the North Sea. Only food-wastes and 'non-harmful' cargo residues plus cleaning agents used in hold or on decks may be discharged under certain conditions such as distance to land.

Within the European Union, progress under worldwide MARPOL regulations was considered insufficient. High costs of proper disposal in combination with low risk of being fined for violations are a clear cause. Poor functioning of available reception facilities definitely plays a role as well. Compliance with MARPOL regulations is hard to enforce at sea, especially when many ships fall under jurisdiction of cheap flag-states with little concern for environmental issues. Compliance can only be promoted by measures that can be enforced when ships visit the harbour. From this perspective, the European Commission and parliament have installed the EU-Directive on Port Reception Facilities for ship-generated waste and cargo residues (Directive 2000/59/EC). Key elements of the Directive are:

- Obligatory disposal of all ship-generated waste to reception facilities before leaving port. Ship-generated waste includes operational oily residues, sewage, household and cargo-associated waste, but not residues from holds or tanks.
- Indirect financing, to a 'significant' degree, of the delivery of ship-generated waste. Finances for such 'free' waste reception should be derived from a fee system on all ships visiting the port. Delivery of cargo residues remains to be paid fully by the ship
- Ports need to develop and implement a 'harbour waste plan' that guarantees appropriate reception and handling of wastes

The term 'Significant' was later identified as meaning 'in the order of at least 30%'. Implementation date for the Directive was December 2002, but unfortunately suffered some delay in several countries. In the Netherlands, the Directive became implemented in late 2004, operating at or above the minimum level of indirect financing depending on the harbour. On an annual basis, results are evaluated by the Minister of Infrastructure and the Environment (I&M) in which also the results of the Fulmar-Litter-EcoQO monitoring are being used. This tool complements surveys of quantities of litter delivered in ports, or beach surveys for quantities of waste washing onto beaches. These approaches have their specific merits but do not measure residual levels of litter in the marine environment itself. The Fulmar-Litter-EcoQO does look at this marine environment and at the same time places such information in the context of ecological effects.

3. The Fulmar as an ecological monitor of marine litter

The interpretation of monitoring information presented in this report requires a summary of earlier findings.

Since the early days of plastic pollution of our oceans, the Northern Fulmar has been known as a species that readily ingests marine plastic debris (Bourne 1976; Baltz & Morejohn 1976; Day et al. 1985; Furness, 1985; Van Franeker 1985; Moser & Lee 1992; Robards et al. 1995; Blight & Burger 1997). But it took until the pilot study of Van Franeker & Meijboom (2002) to properly investigate the feasibility of using stomach contents of Northern Fulmars to monitor changes in marine litter abundance in an ecological context. Samples of Fulmars available for a feasibility study of monitoring in the Netherlands mainly originated from the periods 1982 to 1987 and 1996 to 2000, with smaller number of birds from the years in between.

Reasons for selection of the Fulmar out of a list of potential seabird monitoring species are of a practical nature:

- Fulmars are abundant in the North Sea area (and elsewhere) and are regularly found in beached bird surveys, which guarantees supply of an adequate number of bird corpses for research.
- Fulmars are known to consume a wide variety of marine litter items.
- Fulmars avoid inshore areas and forage exclusively at sea (never on land).
- Fulmars do not normally regurgitate indigestible items, but accumulate these in the stomach (digestive processes and mechanical grinding gradually wear down particles to sizes that are passed on to the gut and are excreted).
- Thus, stomach contents of Fulmars are representative for the wider offshore environment, averaging pollution levels over a foraging space and time span that avoids bias from local pollution incidents.
- Historical data are available in the form of a Dutch data series since 1982 (one earlier 1979 specimen); and literature is available on other locations and related species worldwide (Van Franeker 1985; Van Franeker & Bell 1988).
- Other North Sea species that ingest litter either do not accumulate plastics (they regurgitate indigestible remains); are coastal only and/or find part of their food on land (e.g. *Larus* gulls); ingest litter only incidentally (e.g. North Sea alcids) or are too infrequent in beached bird surveys for the required sample size or spatial coverage (e.g. other tubenoses or Kittiwake *Rissa tridactyla*).

Beached birds may have died for a variety of reasons. For some birds, plastic accumulation in the stomach is evidently the direct cause of death, e.g. by plastic sheets blocking food passage. But more often the effects of litter ingestion act at sub-lethal levels, except maybe in cases of ingestion of chemical substances. For other birds, fouling of the plumage with oil or other pollutants (Camphuysen 2012), collisions with ships or other structures, drowning in nets, extremely poor weather or food-shortage may have been direct or indirect causes of mortality.

At dissection of birds, their sex, age, origin, condition, likely cause of death and a range of other potentially relevant parameters are determined. Standardized dissection procedures for EcoQO monitoring have been described in detail in a manual (Van Franeker 2004b). Stomach contents are sorted into main categories of plastics (industrial and user-plastics), non-plastic rubbish, pollutants, natural food remains and natural non-food remains. Each of these categories has a number of subcategories of specific items. For each individual bird and litter category, data are recorded on presence or absence ("incidence"), the number of items, and the mass of subcategory (see methods). For efficiency/economy reasons, some of the details described in the manual and earlier reports were discontinued in the current research projects.

The pilot study undertook extensive analyses to check whether time-related changes in litter abundance were susceptible to error caused by bias from variables such as sex, age, origin, condition, cause of death, or season of death. If any of these would substantially affect quantities of ingested litter, changes in sample composition over the years could hamper or bias the detection of time-related trends.

A very important finding of the pilot study was that no statistical difference was found in litter in the stomach between birds that had slowly starved to death and 'healthy' birds that had died instantly (e.g. because of collision or drowning). This means that our results, which are largely based on beached starved birds, are representative for the 'average' healthy Fulmar living in the southern North Sea.

Only age was found to have an effect on average quantities of ingested litter, adults having less plastic in their stomachs than younger birds. Possibly, adults loose some of the plastics accumulated in their stomach when they feed chicks or spit stomach-oil during defence of nest-sites. Another factor could be that foraging experience may increase with age. Understanding of the observed age difference in plastic accumulation is poor. In search of better understanding of such issues, Chevron Upstream Europe has funded a cooperative project with the Faroese Fisheries Laboratory. Using Fulmars from the Faroe Islands, we investigate seasonal and age related variations in stomach contents. On the Faroe Islands, Fulmars are hunted for consumption and large numbers of samples are easily obtained. Additional samples have been obtained from fisheries by-catch in the area. Stomach contents are analysed for both normal diet (Faroese component in the study; Danielsen et al. 2010) and for accumulated litter (Dutch contribution to the study). General results were published in Van Franeker 2012, but detailed analyses of samples obtained from all months of the year during several years continue to be analysed.

Although age has been shown to affect absolute quantities of litter in stomach contents, changes over time follow the same pattern in adults or non-adults. As long as no directional change in age composition of samples is observed, trends may be analysed for the combined age groups. However, background information for the presentation of results and their interpretations always requires insight in age composition of samples.

Significant long term trends from 1982 to 2000 were detected in incidence, number of items and mass of industrial plastics, user plastics and suspected chemical pollutants (often paraffin-like substances). Over the 1982-2000 period, only industrial plastics decreased while user plastics significantly increased. When comparing averages in the 1980s to those in the 1990s, industrial plastics approximately halved from 6.8 granules per bird (77% incidence; 0.15g per bird) to 3.6 granules (64%; 0.08g). User-plastics almost tripled from 7.8 items per bird (84%; 0.19g) to 27.6 items (97%; 0.52g).

Analysis of variability in data and Power Analysis revealed that reliable figures for litter in stomachs in a particular region are obtained at a sample size of about 40 birds per year and that reliable conclusions on change or stability in ingested litter quantities can be made after periods of 4 to 8 years, depending on the category of litter. Lower annual sample sizes are no problem, but will lengthen the periods needed to draw conclusions on regional levels and trends.

Mass of litter, rather than incidence or number of items, should be considered the most useful unit of measurement in the long term. Mass is also the most representative unit in terms of ecological impact on organisms. Incidence loses its sensitivity as an indicator when virtually all birds are positive (as is the case in Fulmars). In regional or time-related analyses, mass of plastics is a more consistent measure than number of items, because the latter appears to vary with changes in plastic characteristics.

The pilot study concluded that stomach content analysis of beached Fulmars offers a reliable monitoring tool for (changes in) the abundance of marine litter off the Dutch coast. By its focus on small-sized litter in the offshore environment such monitoring has little overlap with, and high additional value to beach litter surveys of larger waste items. Furthermore, stomach contents of Fulmars reflect the potential ecological consequences of litter ingestion on a wide range of marine organisms and create public awareness of the fact that environmental problems from marine litter persist even when larger items are broken down to sizes below the range of normal human perception. As indicated there is an increasing awareness of the dangers from microplastics, but monitoring quantities and effects in these species is more difficult than that of intermediate sized plastics in seabirds.

The pilot study recommended that Dutch Fulmar-Litter monitoring should focus on mass of plastics (industrial plastic and user) and suspected chemical substance. Each of these represents different sources of pollution, and thus specific policy measures aimed at reduced inputs. Because no funding was obtained to work on suspected chemicals, this element has been dropped and plastics have become the main focus. However, data-recording procedures are such that at the raw data-level, various sub-categories of plastics, other rubbish and suspected chemicals continue to be recorded by number and mass, and can be extracted from databases, should the need arrive.

After publication of the pilot study, the Dutch monitoring has continued annually and has resulted in a series of reports (Van Franeker et al 2003 to 2010) that initially confirmed further decrease of industrial and especially user plastics but that later noted a halt to such trends and a lack of further change.

Internationally, the Fulmar Litter monitoring was boosted by the 'Save the North Sea (SNS)' campaign 2002-2004, which was co-funded by EU Interreg IIIB and aimed at increasing awareness among stakeholders so as to reduce littering behaviour. Expanding the Dutch Fulmar study to locations all around the North Sea was one of the project components. Co-operation was established with interested groups in all countries around the North Sea. The final project report (Van Franeker et al. 2005) showed that Fulmars from the southern North Sea had almost two times more plastic in the stomach than Fulmars from the Scottish Islands, and almost four times as much as that in a small sample from the Faroe Islands. Location differences and relative abundances of different types of litter suggested a major role of shipping, and showed that the bulk of the litter problem in the North Sea region is of local origin.

Also in 2002, North Sea Ministers in the Bergen Declaration, decided to start a system of '*Ecological Quality Objectives (EcoQO's) for the North Sea*'. One of the EcoQO's to be developed was for the issue of marine litter pollution, using stomach contents of a seabird, the Fulmar, to monitor developments, and to set a target for 'acceptable ecological quality'. OSPAR was requested to look after implementation of the ecological quality objectives. Since then, a number of steps have been taken, based on reports from the Dutch studies and the Save the North Sea project. The current wording of the EcoQO target level (OSPAR 2010b) is:

> *"There should be less than 10% of northern fulmars (Fulmarus glacialis) having more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".*

As recommended from the Dutch studies, the **mass** of plastics forms the basis of the EcoQO monitoring system. But rather than using average plastic mass for the target definition, a combination is used of frequency of occurrence of plastic masses above a certain critical mass level (10%; 0.1g). The background of such approach is that a few exceptional outliers can have a strong influence on the calculated average. The wording of the target level basically excludes influence of exceptional outlying values. A similar effect can be obtained by calculating mean values from logarithmically transformed data (Geometric means). The OSPAR Fulmar EcoQO has been published in a background document (OSPAR 2008) and its implementation was included in the OSPAR Quality Status Report (OSPAR 2010a and b).

As indicated in the introduction, the international work was continued and expanded after the SNS project. The EcoQO approach to marine litter is now an element for assessment of 'Good Environmental Status' in the European Marine Strategy Framework Directive (Galgani et al. 2010; EC 2010; MSFD GES Technical Subgroup on Marine Litter, 2011). Quality of the methodology has been established by publications in peer reviewed scientific articles (Ryan et al. 2009; Van Franeker et al. 2011; Kühn and Van Franeker 2012) and is used by researchers in the Canadian arctic and in the Pacific (Mallory, 2008; Provencher et al. 2009; Nevins et al. 2011; Avery-Gomm et al. 2012). In principle this monitoring can be implemented throughout the Fulmars Atlantic and Pacific breeding ranges (Hatch & Nettleship 1998).

The results of Fulmar studies were also used in the UNEP yearbook 2011, which devoted a chapter to the global problem of marine litter (Kershaw et al. 2011), ranking plastic pollution as one of the main global threats to the marine environment.

Photo:

Demonstration of Fulmar dissection for school teachers at the NIBI conference 12 Jan 2013

See: http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/imares/News-Calendar/Show/What-a-mess.htm

4. Materials and Methods

IMARES continues the collection of beached Fulmars from Dutch beaches with the assistance of the Dutch Seabird Group (Nederlandse Zeevogelgroep.- NZG) through its Working Group on Beached Bird Surveys (Nederlands Stookolieslachtofffer Onderzoek - NSO). Also several coastal bird rehabilitation centres support the collection program. Sampling effort for the Dutch fulmar study is spread over the full Dutch coastline, but hard to define in detail. Efforts for the Dutch beached bird surveys are given in Camphuysen 2012, but not every surveyor may be equally inclined to pick up birds. In general, most Fulmars in our study originate from the more northern part of the Netherlands, with next in line fulmars from the Zeeland area. The lower number of beached fulmars from the more central parts of the Dutch coast may be due to lower observer effort, but also to more rapid disappearance of corpses due to higher numbers of scavenging foxes or cleaning activities on the touristic beaches. Since the start of the ***Save the North Sea*** project in 2002, IMARES co-ordinates similar sampling projects at a range of locations in all countries around the North Sea. Organizations involved differ widely, and range from volunteer bird groups to governmental beach cleaning projects. Fig. 1 shows all locations involved in the North Sea monitoring program, and their regional grouping.

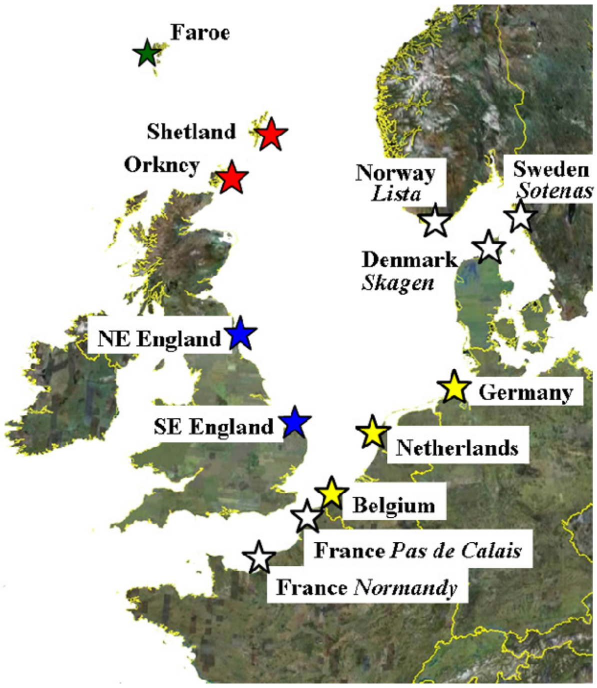


Fig. 1. ***Fulmar-Litter study sites in the Save the North Sea Project (SNS).*** *Colour of symbols indicates regional grouping into Scottish Islands (red), East England (blue), Channel area (white), Southeastern North Sea (yellow), and Skagerrak area (white). Not all locations are equally active. The Faroe Islands study area is considered as an external reference monitoring site for the North Sea. For further details see the online supplement of Van Franeker et al., (2011).*

Bird corpses are stored frozen until analysis. Standardized dissection methods for Fulmar corpses have been published in a dedicated manual (Van Franeker 2004b) and are internationally calibrated during annual workshops. Stomach content analyses and methods for data processing and presentation of results were described in full detail in Van Franeker & Meijboom (2002), further developed in consultation with ICES and OSPAR by updates in later reports and OSPAR documents (OSPAR 2008, 2010b). Scientific reliability of the methodology was established by its publication in the peer reviewed scientific literature (van Franeker et al. 2011)

For convenience, some of the methodological information is repeated here in a condensed form.

Dissection

At dissections, a full series of data is recorded that is of use to determine sex, age, breeding status, likely cause of death, origin, condition index and other issues. Age, the only variable found to influence litter quantities in stomach contents, is largely determined on the basis of development of sexual organs (size and shape) and presence of *Bursa of Fabricius* (a gland-like organ positioned near the end of the gut which is involved in immunity systems of young birds; it is well developed in chicks, but disappears within the first year of life or shortly after). Further details are provided in Van Franeker 2004b. In the near future, an updated version of the manual should be published to improve details and maximize efficiency of methods.

Stomach procedure

After dissection, stomachs of birds are opened for analysis. Stomachs of Fulmars have two 'units': initially food is stored and starts to digest in a large glandular stomach (the *proventriculus*) after which it passes into a small muscular stomach (the *gizzard*) where harder prey remains can be processed through mechanical grinding. In early phases of the project, data for the two individual stomachs were recorded separately, but for the purpose of reduction in monitoring costs, the contents of proventriculus and gizzard are now combined.

Stomach, contents are carefully rinsed in a sieve with a 1mm mesh and then transferred to a petri dish for sorting under a binocular microscope. The 1 mm mesh is used because smaller meshes become clogged with mucus from the stomach wall and with food-remains. Analyses using smaller meshes were found to be extremely time consuming and particles smaller than 1 mm seemed rare in the stomachs, and when present contribute little to plastic mass.

If oil or chemical types of pollutants are present, these may be sub-sampled and weighed before rinsing the remainder of stomach content. Although this was a standard component at the start of our studies, requirements for the Dutch "graadmeter" and international EcoQO have a focus on plastic or at best MARPOL Annex V litter types. Thus, for financial efficiency, potential chemical pollutants in the stomachs are no longer part of the project. If sticky substances hamper further processing of the litter objects, hot water and detergents are used to rinse the material clean as needed for further sorting and counting under a binocular microscope.

Categorization of debris in stomach contents

The following categorization is used for plastics and other rubbish found in the stomachs, with acronyms between parentheses:

1. **PLASTICS (PLA)**
    - 1.1. **Industrial plastic pellets (IND).** These are small, often cylindrically-shaped granules of ± 4 mm diameter, but also disc and rectangular shapes occur. Various names are used, such as pellets, beads or granules. They can be considered as "raw" plastic or a half-product in the form of which, plastics are usually first produced (mostly from mineral oil). The raw industrial plastics are then usually transported to manufacturers that melt the granules and mix them with a variety of additives (fillers, stabilizers, colorants, anti-oxidants, softeners, biocides, etc.) that depend on the user product to be made. For the time being, included in this category are a relatively small number of very small, usually transparent spherical granules, also considered to be a raw industrial product.
    - 1.2. **User plastics (USE)** (all non-industrial remains of plastic objects) differentiated in the following subcategories:
        - 1.2.1. **sheetlike user plastics (she)**, as in plastic bags, foils etc., usually broken up in smaller pieces;
        - 1.2.2. **threadlike user plastics (thr)** as in (remains of) ropes, nets, nylon line, packaging straps etc. Sometimes 'balls' of threads and fibres form in the gizzard;
        - 1.2.3. **foamed user plastics (foa)**, as in foamed polystyrene cups or packaging or foamed polyurethane in matrasses or construction foams;
        - 1.2.4. **fragments (fra)** of more or less hard plastic items as used in a huge number of applications (bottles, boxes, toys, tools, equipment housing, toothbrushes, lighters etc.);

1.2.5. **other (oth)**, for example cigarette filters, rubber, elastics etc., so items that are 'plastic-like' or do not fit into a clear category.

2. **RUBBISH (RUB)** other than plastic:
   2.1. **paper (pap)** which besides normal paper includes silver paper, aluminium foil etc., so various types of non-plastic packaging material;
   2.2. **kitchenfood (kit)** for human food wastes such as fried meat, chips, vegetables, onions etc., probably mostly originating from ships' galley refuse;
   2.3. **various rubbish (rva)** is used for e.g. pieces of timber (manufactured wood); paint chips, pieces of metals etc.;
   2.4. **fish hook (hoo)** from either sport-fishing or long-lining.

Further optional categories of stomach contents (not included this study)

3. POLLUTANTS (POL)

3.1.1. for items indicating industrial or chemical waste remains such as slags (the remains of burning ovens, e.g. remains of coal or ore after melting out the metals); tar-lumps (remains of mineral oil); chemical (lumps or 'mud' of paraffin-like materials or sticky substances arbitrarily judged to be unnatural and of chemical origin) and feather-lumps (indicating excessive preening by the bird of feathers sticky with oil or chemical pollutants).

4. NATURAL FOOD REMAINS (FOO)

4.1.1. Numbers of specific items may be recorded in separate subcategories (fish otoliths, eye-lenses, squid-jaws, crustacean remains, jelly-type prey remains, scavenged tissues incl. feathers, insects, other).

5. NATURAL NON-FOOD REMAINS (NFO)

5.1.1. Numbers of subcategories e.g. plant-remains, seaweed, pumice, stone and other may be recorded.

Non-plastic or debris categories

To be able to sort out items of categories 1 and 2, all other materials in the stomachs described in categories 3 to 5, have to be cleaned out. However in these latter categories, further identification, categorization, counting, weighing and data-processing is not essential for the EcoQO. Whether details are recorded depends of the interest of the participating research group and their reasons to collect beached Fulmars.

Acronyms

In addition to the acronyms used for (sub)categories as above, further acronyms may be used to describe datasets. Logarithmic transformed data are initiated by 'ln' (natural logarithm); mass data are characterized by capital G (gram) and numerical data by N (number). For example lnGIND refers to the dataset that uses ln-transformed data for the mass of industrial plastics in the stomachs; acronym NUSE refers to a dataset based on the number of items of user plastics.

Particle counts and category weights

For the main categories 1 (plastic) and 2 (rubbish) we record for each bird and each (sub)category:

- The number of particles (N=count of number of items in each (sub)category)
- mass (W=weight in grams) using Sartorius electronic weighing scale after at least a two day period of air drying at laboratory temperatures. For marine litter (categories 1 to 3 above), this is done separately for all subcategories. In the early Fulmar study we also weighed the natural-food and natural-non-food categories as a whole, but this was discontinued in 2006 to reduce costs. Weights are recorded in grams accurate to the 4th decimal (= tenth of milligram).

On the basis of these records, data can be presented in different formats.

Incidence

The most simple form of data presentation is by presence or absence. Incidence (Frequency of occurrence) gives the percentage of investigated stomachs that contained the category of debris discussed. The quantity of debris in a stomach is irrelevant in this respect.

Arithmetic Average
Data for numbers or mass are frequently shown as averages with standard errors (se) calculated for a specific type of debris by location and specified time period. Averages are calculated over all available stomachs in a sample, so including the ones that contained no plastic ('population averages'). Especially when sample sizes are smaller, arithmetic averages may be influenced by short term or local variations or extreme outliers. An option then is to pool data over a larger area or longer time period. An alternative to reduce influence of outliers is by logarithmic transformation of data

Geometric Mean
Sample sizes may not be large enough to average out the impact of occasional extreme outliers. Therefore data are often additionally presented as geometric means, calculated from logarithmic data values. Logarithmic transformation reduces the role of the higher values, but as a consequence the geometric mean is usually considerably lower than the arithmetic mean for the same data. In mass data for plastics in the Fulmar stomachs, geometric means are only about one third to half of the arithmetic averages. Geometric means thus do not properly reflect absolute values, but are useful for comparative purposes between smaller sample sizes, for example when looking at annual data rather than at 5-year-periods. Logarithmic transformation cannot deal with the value zero, and thus the common approach chosen is to add a small value (e.g. 0.001g in mass data) to all datapoints, and then substracting this again when the mean of log values is back-calculated to normal value. This however implies that geometric means become less reliable with an increasing number of zero values in a data-set. The natural logarithm (ln) is used to run calculations for geometric means.

EcoQO performance
For early Dutch reports, the analyses focused on trends in average or mean mass data for different categories. However, OSPAR (2010b) words its Ecological Quality Objective (EcoQO) for levels of litter (plastic) in stomachs of fulmars (the '*Fulmar-Litter-EcoQO*') as:

> *"There should be less than 10% of northern fulmars (Fulmarus glacialis) having more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".*

Thus, the information requested for OSPAR and the EcoQO focuses on the category of 'total plastic' and pooled data for 5-year periods over larger areas, and a simple decision rule for each stomach if the plastics in ite weigh more than 0.1 gram or less, including zero.
EcoQO compliance or performance is defined as the percentage of birds in a sample that has 0.1 g or more plastic mass in the stomach. The OSPAR target is thus to reduce that percentage to under 10%. The EcoQO format is a highly simplified form of data-presentation but through that simplicity escapes the problems faced by more sophisticated procedures as a consequence of excessive outliers or a large proportion of zero values in a data set. In the background however, details of various subcategories of litter continue to play an important role for correct interpretation of the EcoQO metric.

Data pooling
To avoid that short term variations cause erratic information on the level of ingested plastics, data are frequently pooled into 5-year periods. Such pooled data for 5-year periods are ***not*** derived from the annual averages, but are calculated from all individual birds over the full 5 year period. For data presentation, the ***Current Situation*** of plastic ingestion is defined as the figures for incidence and number or mass abundance for the most recent 5 year period, not the figures for the recent single year! Time related changes are illustrated in graphs by running 5-year averages, each time shifting one year and thus overlapping for four years.
For pooling study locations in the North Sea, the OSPAR EcoQO target definition has triggered a grouping into five areas or regions (Fig. 1): the Scottish Islands (Shetland and Orkney), East England (northeast and southeast England), the Channel (Normandy and Pas de Calais), South-Eastern North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast)

Statistical tests

Data from dissections and stomach content analysis are recorded in Excel spreadsheets and next stored in Oracle relational database. GENSTAT 15 is used for statistical tests. As concluded in the pilot study (Van Franeker & Meijboom 2002) and later reports, statistical trend analysis is conducted using mass-data. Tests for trends over time are based on linear regressions fitting ln-transformed plastic mass values for individual birds on the year of collection. Logarithmic transformation is needed because the original data are strongly skewed and need to be normalized for the statistical procedures. The natural logarithm (Ln) is used. Tests for **'long term' trends** use the full data set; **'recent' trends** only use the past ten years of data. This 10 year period was derived from the pilot study (Van Franeker & Meijboom 2002) which found that in the Dutch situation a series of about eight years was needed to have the potential to detect significant change. To be on the safe side in our approach, this period was arbitrarily increased to a standard period of 10 years for tests of current time related trends.
Statistical tests of regional differences are conducted in GENSTAT 15th edition, using data from individual birds. Differences in plastic weight were evaluated by fitting a negative binominal generalized linear model with and without region included as a factor and differences between those two models were tested using a likelihood ratio test (Venables and Ripley, 2002; van Franeker et al. 2011).

Summary of data presentation and analysis:

- **Incidence** – Incidence represents the percentage of birds having plastic in the stomach
- **Average ± se** – Averages these refer to straightforward arithmetic averages from all available samples (population average), usually given with standard errors.
- **Geometric mean** – Means refer to geometric means calculated using data transformation (natural logarithm) reducing influence of extreme outliers.
- **EcoQO performance** – The % of birds having more than 0.1 gram of plastic in the stomach.
- **Pooled data** - Data are mostly presented as pooled over 5 year periods to avoid incidental short term fluctuations. The **'Current level of plastic ingestion'** is defined by pooled data for the most recent 5 years, not by an annual figure. **Graphs** often use the pooled data for 5 years, but shifting one year by datapoint. These only intend to visually illustrate trends over time or geographic patterns and have no statistical relevance.
- **Statistics** - Statistical analyses are solely based on the mass of plastic using ln transformed data of individual birds. Tests for significance of trends over time are based on linear regressions of ln-transformed against year of collection. The **long term trend** is derived from the full dataset, the **Recent trend** from only the most recent 10 years of data. Regional differences are tested in a generalized linear model and likelihood ratio test.

Photo *IMARES annually hosts a 3 to 5 day Fulmar study workshop on Texel with the purpose to provide training and calibration of dissection methods to participants and others interested in the study. Foreign project partners bring their bird samples to Texel to dissect them with the group under guidance of experienced members. One day is dedicated to data discussions, presentations and future planning of the project.*

5. Results & Discussion

5.1. Monitoring in the Netherlands 1979-2011 and trends

In 2010, with 36 stomachs examined, sample size was close to the desired annual sample size of 40 stomachs. However, in 2011, beached Fulmar corpses were scarce, not just in the Netherlands but also in surrounding countries of the southern North Sea. In spite of considerable effort no more than 19 samples were obtained from the Dutch coastline in all of year 2011. A incidental lower sample size is not a problem for the monitoring system, as it only reduces certainty on events on the very short term. For that reason, as advised before, 5-year periods are the best basic unit to consider the 'current' situation.
In both 2010 and 2011, plastic abundance in the Fulmar stomachs was relatively high, with around 44-56 particles per stomach and average plastic mass 0.43 to 0.46 gram (Tables 1 and 2). Figures were especially elevated in comparison to 2009, when an unusual low level of plastic pollution was present, attributed to a high proportion of relatively 'clean' arctic birds that died in a sudden influx and mass mortality of northern birds (Van Franeker. & the SNS Fulmar Study Group 2011).
In terms of EcoQO performance, annual percentages of birds having over 0.1 gram of plastic in the stomach were also high in recent years, that is they ranged from 64% in 2010 to 79% in 2011.

Current levels for the Netherlands (2007-2011)
Because of occasional years of low sample size and incidental variability, it is strongly recommended to describe the 'current pollution level' on the basis of average stomach contents over the most recent 5 years. The 5-year period is also a standard element in the description of the OSPAR EcoQO (see below).

- **Current 5 year data for the 2007-2011 period (Table 1d), are that 95% of our sample of 204 Fulmars from the Dutch coastline has plastic debris in the stomach, in an average number of 36 particles and mass of 0.33 gram. The critical EcoQO value of 0.1 gram plastic is currently exceeded by 60% of the birds (Table 2)** so still at great distance from the target of less than 10% of birds exceeding the 0.1 g level.

Industrial plastic granules as well as consumer waste contributed to a pattern of small increases in total plastic abundance over recent 5-year periods (Table 3, Fig. 2A), although viewed over a longer period especially the increase in industrial plastic in 2010 and 2011 was noticeable (Fig.2B). Whether the recent data for industrial plastics initiate a true change is hard to decide: standard errors for the recent periods are much higher than before and indicate the influence of incidental odd outliers.

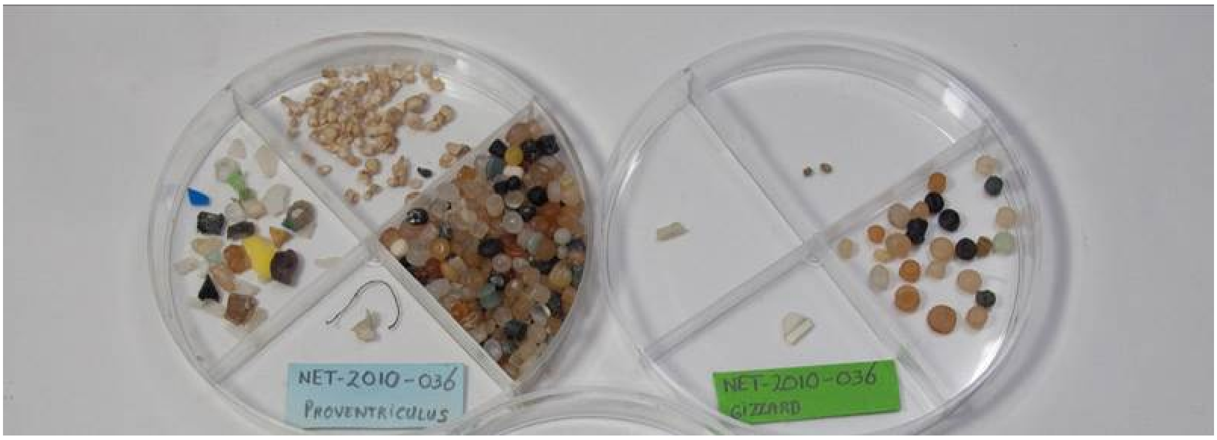


Photo *Incidental 'outliers' may affect calculations of averages of number or mass of plastics. In exceptional cases this will even affect the recommended 5-year averages (see Fig. 2). Fulmar number NET-2010-036 was such a bird, as it had 278 industrial pellets in the stomach (253 in proventriculus; 25 in gizzard). EcoQO figures (simple split in under or above 0.1 gram), or statistical tests (using log transformed data suppressing influence of outliers) are not seriously affected by such extremes.*

Table 1 *Summary of sample characteristics and stomach contents of Fulmars collected for Dutch marine litter monitoring in the years a) 2010 and c) 2011 including data tabulated for 5-year periods in b) 2006-2010 and d) 2007-2011. The top line in each sub-table shows sample composition in terms of age, sex, origin (by colourphase; darker phases are of distant Arctic origin), death cause oil, and the average condition-index (which ranges from emaciated condition=0 to very good condition=9). Although only age is currently relevant in the Dutch dataset, this is not necessarily true in later international comparisons. For each litter-(sub)category the table lists: Incidence, representing the proportion of birds with one or more items of the litter category present; average number of plastic items per bird stomach ± standard error; average mass of plastic ± standard error per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-transformed values as used in trend-analyses.*

a) Year 2010

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2010	**36**	**46%**	**56%**	**97%**	**0%**	**2.9**	
		incidence	**average number of items**	**(n/bird) ± se**	**average mass of litter**	**(g/bird) ± se**	**max. mass recorded**	**geometric mean mass (g/bird)**
1	**ALL PLASTICS**	**94%**	**56.4**	**± 16.319**	**0.462**	**± 0.197**	**6.9**	**0.1120**
1.1	**INDUSTRIAL PLASTIC**	**58%**	**10.7**	**± 7.685**	**0.233**	**± 0.175**	**6.3**	**0.0120**
1.2	**USER PLASTIC**	**94%**	**45.7**	**± 12.501**	**0.229**	**± 0.057**	**1.7**	**0.0837**
1.2.1	sheets	64%	6.3	± 1.637	0.011	± 0.004	0.1	0.0032
1.2.2	threads	67%	2.5	± 0.513	0.020	± 0.009	0.3	0.0037
1.2.3	foamed	64%	10.7	± 4.258	0.041	± 0.030	1.1	0.0034
1.2.4	fragments	92%	25.1	± 8.746	0.123	± 0.026	0.6	0.0434
1.2.5	other plastic	25%	1.0	± 0.597	0.033	± 0.019	0.6	0.0017
2	**OTHER RUBBISH**	**36%**	**1.4**	**± 0.507**	**0.012**	**± 0.005**	**0.2**	**0.0017**
2.1	paper	3%	0.1	± 0.111	0.000	± 0.000	0.0	0.0001
2.2	kitchenwaste (food)	19%	1.1	± 0.507	0.010	± 0.005	0.2	0.0008
2.3	rubbish various	14%	0.2	± 0.087	0.002	± 0.001	0.0	0.0004
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

b) 5-year period 2006-2010

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2006-2010	**212**	**46%**	**49%**	**82%**	**3%**	**1.5**	
		incidence	**average number of items**	**(n/bird) ± se**	**average mass of litter**	**(g/bird) ± se**	**max. mass recorded**	**geometric mean mass (g/bird)**
1.0	**ALL PLASTICS**	**94%**	**34.5**	**± 3.811**	**0.321**	**± 0.041**	**6.9**	**0.1074**
1.1	**INDUSTRIAL PLASTIC**	**61%**	**4.1**	**± 1.332**	**0.089**	**± 0.030**	**6.3**	**0.0119**
1.2	**USER PLASTIC**	**93%**	**30.5**	**± 3.224**	**0.232**	**± 0.023**	**2.0**	**0.0796**
1.2.1	sheets	57%	3.7	± 0.459	0.014	± 0.004	0.8	0.0025
1.2.2	threads	47%	1.6	± 0.228	0.024	± 0.007	1.1	0.0020
1.2.3	foamed	67%	6.8	± 1.043	0.021	± 0.005	1.1	0.0036
1.2.4	fragments	87%	17.7	± 2.192	0.154	± 0.017	1.9	0.0440
1.2.5	other plastic	21%	0.7	± 0.200	0.019	± 0.004	0.6	0.0012
2.0	**OTHER RUBBISH**	**35%**	**1.9**	**± 0.363**	**0.068**	**± 0.023**	**4.0**	**0.0026**
2.1	paper	2%	0.0	± 0.021	0.004	± 0.003	0.7	0.0001
2.2	kitchenwaste (food)	27%	1.7	± 0.363	0.057	± 0.023	4.0	0.0017
2.3	rubbish various	8%	0.1	± 0.034	0.007	± 0.003	0.5	0.0003
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

Table 1 ***Continued**: Summary of sample characteristics and stomach contents of Fulmars collected for Dutch marine litter monitoring.*

c) YEAR 2011

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2011	**19**	**37%**	**47%**	**76%**	**0%**	**1.9**	

		incidence	average number of items (n/bird) ± se		average mass of litter (g/bird) ± se		max. mass recorded	geometric mean mass (g/bird)
1	**ALL PLASTICS**	**100%**	**43.6**	**± 13.103**	**0.425**	**± 0.188**	**3.7**	**0.1826**
1.1	**INDUSTRIAL PLASTIC**	**63%**	**6.6**	**± 4.140**	**0.151**	**± 0.102**	**2.0**	**0.0142**
1.2	**USER PLASTIC**	**95%**	**37.0**	**± 10.373**	**0.274**	**± 0.092**	**1.8**	**0.1106**
1.2.1	sheets	58%	7.3	± 3.412	0.037	± 0.033	0.6	0.0023
1.2.2	threads	42%	1.2	± 0.509	0.005	± 0.004	0.1	0.0010
1.2.3	foamed	63%	10.0	± 6.149	0.040	± 0.024	0.4	0.0059
1.2.4	fragments	89%	18.4	± 4.182	0.181	± 0.057	1.1	0.0645
1.2.5	other plastic	21%	0.2	± 0.096	0.010	± 0.007	0.1	0.0010
2	**OTHER RUBBISH**	**21%**	**2.1**	**± 1.321**	**0.036**	**± 0.017**	**0.2**	**0.0019**
2.1	paper	11%	0.5	± 0.474	0.013	± 0.009	0.2	0.0007
2.2	kitchenwaste (food)	5%	1.3	± 1.263	0.007	± 0.007	0.1	0.0003
2.3	rubbish various	11%	0.3	± 0.214	0.016	± 0.013	0.2	0.0007
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

d) current 5-year period 2007-2011

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2007-2011 (204)	**204**	**43%**	**50%**	**81%**	**2%**	**1.6**	

		incidence	average number of items (n/bird) ± se		average mass of litter (g/bird) ± se		max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**95%**	**35.5**	**± 4.020**	**0.333**	**± 0.045**	**6.9**	**0.1100**
1.1	**INDUSTRIAL PLASTIC**	**59%**	**4.4**	**± 1.432**	**0.097**	**± 0.033**	**6.3**	**0.0108**
1.2	**USER PLASTIC**	**94%**	**31.1**	**± 3.354**	**0.237**	**± 0.024**	**2.0**	**0.0812**
1.2.1	sheets	57%	4.1	± 0.560	0.018	± 0.005	0.8	0.0026
1.2.2	threads	47%	1.4	± 0.176	0.024	± 0.007	1.1	0.0019
1.2.3	foamed	67%	7.5	± 1.207	0.024	± 0.006	1.1	0.0040
1.2.4	fragments	88%	17.4	± 2.202	0.152	± 0.016	1.7	0.0449
1.2.5	other plastic	20%	0.6	± 0.203	0.019	± 0.004	0.6	0.0011
2.0	**OTHER RUBBISH**	**36%**	**2.1**	**± 0.393**	**0.072**	**± 0.024**	**4.0**	**0.0029**
2.1	paper	2%	0.1	± 0.049	0.005	± 0.004	0.7	0.0001
2.2	kitchenwaste (food)	27%	1.9	± 0.392	0.060	± 0.024	4.0	0.0018
2.3	rubbish various	8%	0.1	± 0.038	0.007	± 0.003	0.5	0.0003
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

Table 2 ***Annual details for plastic abundance in Fulmars from the Netherlands.*** *For separate and combined plastic categories, incidence (%) represents the proportion of birds with one or more items of that litter present; number (n) abundance by average number of items per bird; and mass (g) abundance by average mass per bird in grams. The column on the far right indicates level of performance in relation to the OSPAR EcoQO, viz. the percentage of birds having more than the critical level of 0.1 gram of plastic in the stomach. The bottom line of the table shows the 'current' situation as the average over the past 5 years. Note sample sizes (n) to be very low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures. Also note erratic variability in age proportions of birds in samples, where age is known to influence amount of litter in the stomach.*

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	n	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
1979	1	0%	100%	2.0	0.07	100%	3.0	0.17	100%	5.0	0.24	100%
1980												
1981												
1982	3	0%	100%	5.0	0.11	67%	6.0	0.50	100%	11.0	0.61	100%
1983	19	41%	84%	8.8	0.19	89%	7.2	0.31	100%	16.0	0.49	89%
1984	20	40%	70%	9.6	0.19	90%	8.4	0.17	90%	17.9	0.35	55%
1985	3	33%	100%	5.3	0.14	100%	5.0	0.14	100%	10.3	0.28	100%
1986	4	25%	50%	0.8	0.02	75%	4.8	0.06	75%	5.5	0.08	25%
1987	15	67%	80%	3.9	0.11	67%	8.9	0.09	80%	12.7	0.20	53%
1988	1	0%	0%	0.0	0.00	100%	2.0	0.04	100%	2.0	0.04	0%
1989	4	50%	75%	5.3	0.14	100%	11.0	0.16	100%	16.3	0.29	75%
1990												
1991	1	0%	0%	0.0	0.00	100%	11.0	0.14	100%	11.0	0.14	100%
1992												
1993												
1994												
1995	2	50%	100%	1.5	0.02	100%	3.5	0.03	100%	5.0	0.06	0%
1996	8	62%	75%	2.9	0.07	100%	24.5	0.19	100%	27.4	0.26	63%
1997	31	16%	74%	5.9	0.13	97%	29.8	0.60	97%	35.8	0.73	84%
1998	74	45%	69%	3.1	0.07	95%	25.9	0.88	96%	29.0	0.95	72%
1999	107	70%	58%	3.4	0.06	97%	31.8	0.38	98%	35.3	0.44	61%
2000	38	58%	61%	3.4	0.08	100%	18.6	0.27	100%	22.0	0.35	61%
2001	54	38%	63%	2.6	0.06	96%	20.4	0.18	96%	22.9	0.24	48%
2002	56	54%	68%	4.6	0.09	96%	47.2	0.41	98%	51.8	0.50	68%
2003	39	56%	51%	2.3	0.05	92%	26.3	0.12	95%	28.5	0.17	54%
2004	131	80%	54%	2.6	0.06	91%	20.8	0.22	91%	23.4	0.27	60%
2005	51	68%	53%	2.0	0.05	96%	15.8	0.22	98%	17.8	0.27	47%
2006	27	62%	78%	3.5	0.08	93%	30.4	0.23	93%	33.9	0.30	85%
2007	61	42%	70%	3.1	0.07	90%	32.5	0.30	92%	35.6	0.37	70%
2008	20	58%	65%	3.8	0.08	95%	40.8	0.23	95%	44.5	0.31	55%
2009	68	40%	46%	1.7	0.04	96%	17.6	0.18	97%	19.3	0.22	46%
2010	36	46%	58%	10.7	0.23	94%	45.7	0.23	94%	56.4	0.46	64%
2011	19	37%	63%	6.6	0.15	95%	37.0	0.27	100%	43.6	0.43	79%
2006-2010	212	46%	61%	4.1	0.09	93%	30.5	0.23	94%	34.5	0.32	62%
2007-2011	204	43%	59%	4.4	0.10	94%	31.1	0.24	95%	35.5	0.33	60%

* Five-year data were averaged over all individual birds in the five year period (so not from annual averages)

Table 3 ***Incidence, number of particles and mass of plastics in stomachs of fulmars beached in the Netherlands in the 1980's and 'running' 5-year periods since 1995****. Mass data are also shown as geometric mean mass, and as percentage of stomachs with more than 0.1 gram of plastic (EcoQO performance).*

ALL AGES								
5-year	***sample***	**Incidence**	**average number**		**average mass**		**geometric**	**Over 0.1 g**
period	***n***	**%**	**n**	**± se**	**g**	**± se**	**mean mass (g)**	**EcoQO %**
1980s	*69*	91%	14.6	± 2.0	0.34	± 0.06	0.11	67%
1995-1999	*222*	97%	32.7	± 3.7	0.64	± 0.13	0.15	67%
1996-2000	*258*	98%	31.3	± 3.2	0.60	± 0.12	0.15	67%
1997-2001	*304*	97%	29.9	± 2.8	0.55	± 0.10	0.14	63%
1998-2002	*329*	98%	33.1	± 3.3	0.52	± 0.10	0.13	62%
1999-2003	*294*	98%	33.5	± 3.6	0.37	± 0.06	0.11	59%
2000-2004	*318*	95%	28.8	± 2.9	0.30	± 0.04	0.09	59%
2001-2005	*331*	95%	27.9	± 2.7	0.29	± 0.04	0.09	57%
2002-2006	*304*	94%	29.3	± 3.0	0.30	± 0.04	0.09	61%
2003-2007	*309*	93%	26.5	± 2.1	0.28	± 0.02	0.09	61%
2004-2008	*290*	93%	27.4	± 2.2	0.30	± 0.03	0.10	62%
2005-2009	*227*	95%	27.3	± 2.5	0.29	± 0.03	0.10	58%
2006-2010	*212*	94%	34.5	± 3.8	0.32	± 0.04	0.11	62%
2007-2011	*204*	95%	35.5	± 4.0	0.33	± 0.04	0.11	60%

Trends in the Netherlands

Trends focus on the mass of plastics in stomachs, rather than on incidence or number of plastic particles. In trend discussions, a distinction is made between:

- **'recent trend'** defined as trend over the past 10 years (now: 2002-2011)

The changes over the past 10 years represent no significant recent trend for industrial plastics or consumer plastics or all plastics combined (Fig. 3B; Table 4B). Absence of detectable change is characteristic for the period since about 2003, which followed a period of significant increase from the 1980s to 1990s and significant decrease from 1995 to c. 2003.

- **'long-term trend'** defined as the trend over all years in the dataset (now 1979-2011)

Long term trends are influenced by the fact that in initial years, trends for industrial and user plastics were opposite (Fig. 2B, Fig. 3A, Table 4A), when industrial plastics halved from early 1980s to mid 1990s during a period when user plastics near tripled. Measured over the full period of over 30 years of data for the Netherlands, the initial decrease of industrial plastics still makes the long term trend significantly downward, in spite of the lack of noticeable change over the last decade and even increase in the two most recent years (Tabel 2). The decreased abundance of industrial plastics in the marine environment was signalled before and has been observed in various oceanographic regions (Van Franeker & Meijboom 2002, Vlietstra & Parga 2002, Ryan 2008, Van Franeker et al. 2011). For user-plastics, the initial increase from the 1980s to mid 1990s was largely 'compensated' by a rapid decrease from late 1990s to around 2003, without significant long-term trend for all birds combined. The 'sign' of long term change is still up for user plastics (positive t values in Table 4A) but only slightly significant for the non-adult age group, and not for adults nor all ages combined.

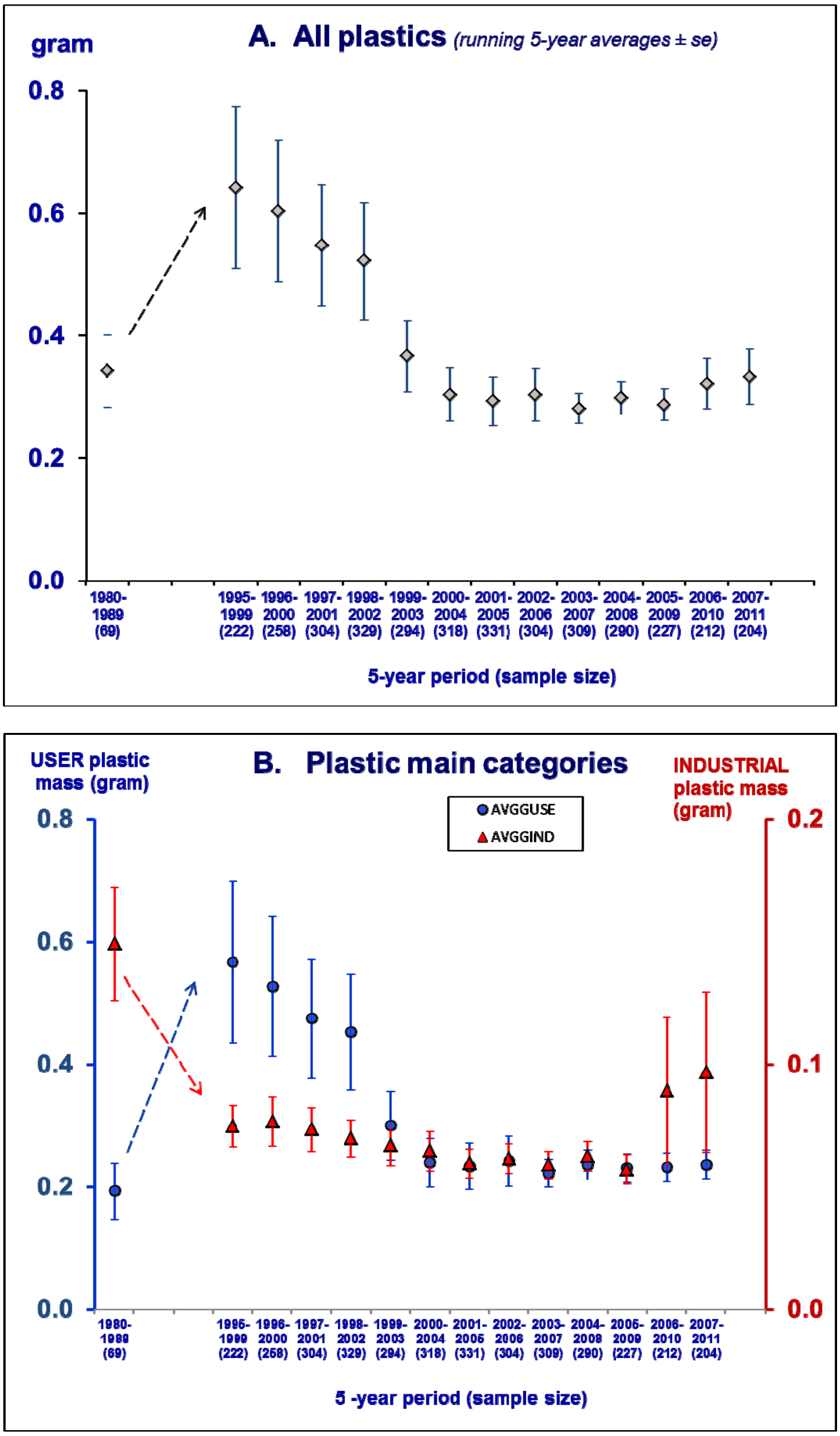


Figure 2 ***Plastic mass in stomachs of Fulmars from the Netherlands 1980s-2011.*** *A: Data for all plastics combined; B: same data but split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average ± standard error for mass in a single datapoint for the 1980s and running 5 year averages after 1995 (i.e. data points shift one year ahead at a time).*

Table 4 ***Details of linear regression analyses for time related trends in plastic abundance in stomachs of fulmars in the Netherlands*** *. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over the full time period 1979-2011 (Table 4A) and the most recent 10 years of data (Table 4B). The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x. When the t-value of a regression is negative it indicates a decreasing trend in the tested litter-category; a positive t-value indicates increase. A trend is considered significant when the probability (p) of misjudgement of data is less than 5% (p<0.05). Significant trends in the table have been labelled with positive signs in case of increase (+) or negative signs in case of decrease (-). Significance at the 5% level (p<0.05) is labelled as - or + ; at the 1% level (p<0.01) as -- or ++; and at the 0.1% level (p<0.001) as --- or +++.*

A.	LONG TERM TRENDS 1979-2011						
	for plastics in Fulmar stomachs, the Netherlands						
INDUSTRIAL PLASTIC (lnGIND)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*893*	99.0	-0.0516	0.0117	-4.42	<.001	- - -
adults	*479*	73.9	-0.0392	0.0180	-2.18	0.030	-
non adults	*400*	103.3	-0.0536	0.0153	-3.50	<.001	- - -
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*893*	-29.7	0.0136	0.0099	1.37	0.170	*n.s.*
adults	*479*	-10.9	0.0041	0.0160	0.25	0.801	*n.s.*
non adults	*400*	-55.4	0.0265	0.0122	2.18	0.030	+
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*893*	24.0	-0.0131	0.0096	-1.36	0.173	*n.s.*
adults	*479*	15.6	-0.0090	0.0158	-0.57	0.569	*n.s.*
non adults	*400*	16.9	-0.0094	0.0113	-0.83	0.409	*n.s.*

B.	RECENT 10-year TRENDS (2002-2011)						
	for plastics in Fulmar stomachs, the Netherlands						
INDUSTRIAL PLASTIC (lnGIND)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*508*	30.7	-0.0175	0.0370	-0.47	0.636	*n.s.*
adults	*300*	68.0	-0.0361	0.0524	-0.69	0.492	*n.s.*
non adults	*208*	77.0	-0.0406	0.0542	-0.75	0.454	*n.s.*
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*508*	-61.0	0.0291	0.0308	0.94	0.346	*n.s.*
adults	*300*	-13.3	0.0052	0.0480	0.11	0.914	*n.s.*
non adults	*208*	-26.3	0.0120	0.0381	0.31	0.754	*n.s.*
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*508*	-37.9	0.0178	0.0305	0.58	0.561	*n.s.*
adults	*300*	-3.6	0.0005	0.0474	0.01	0.991	*n.s.*
non adults	*208*	9.7	-0.0058	0.0378	-0.15	0.878	*n.s.*

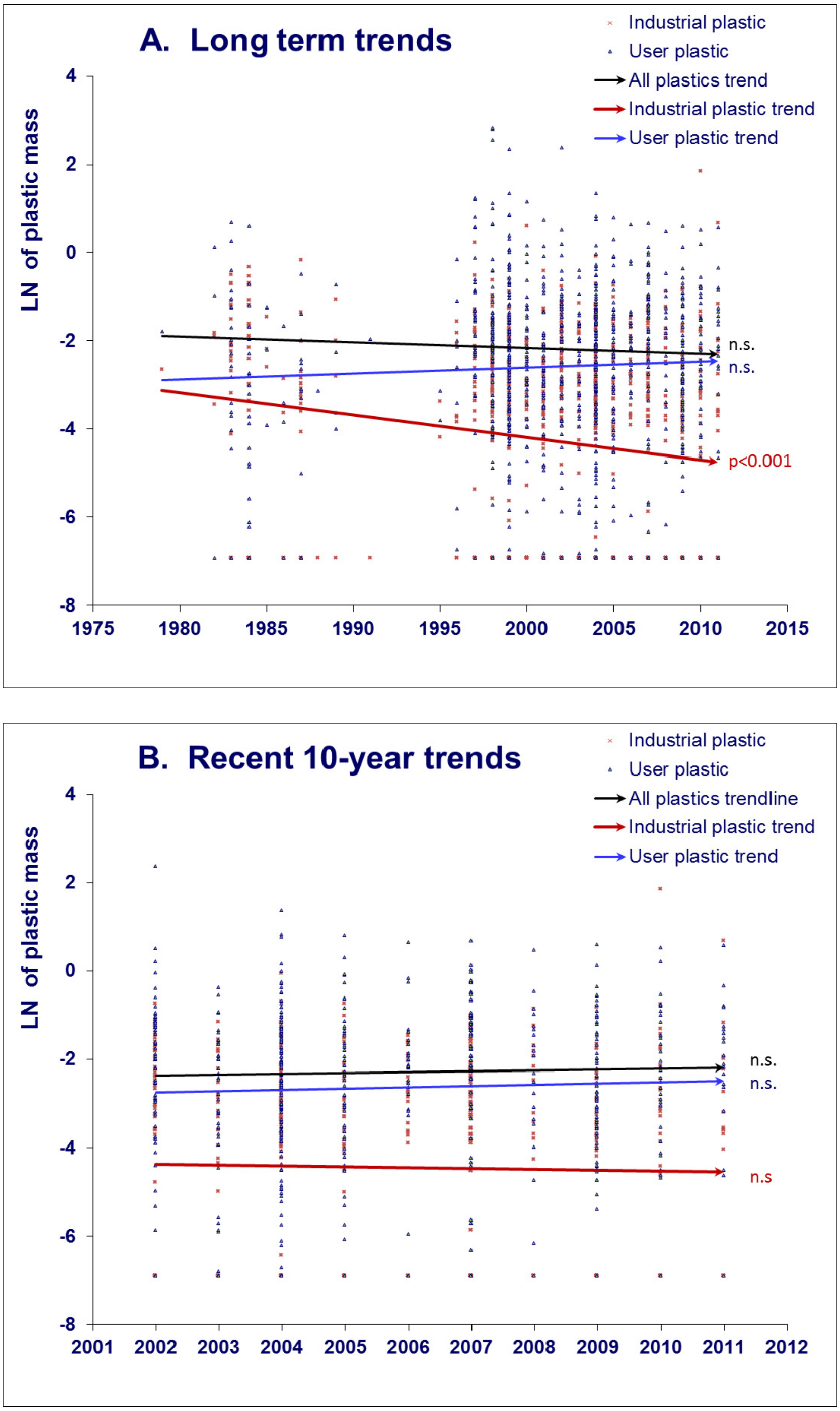


Figure 3 ***Statistical trends in plastic mass in stomachs of Fulmars from the Netherlands 1980s-2011.*** *Graphs show plotted ln-transformed mass data for industrial plastic and user plastic in stomachs of individual Fulmars, plotted against year, and linear trendlines for industrial (lower, red line), user (middle blue line) and total plastics (top black line). Figure A. shows long term trends and B the recent trend over the past 10 years of data. Full details for results of statistical tests for trends are available in Table 4. N.s means that the test result is not significant.*

Younger birds (the 'non-adult' category which represents not just first year juveniles, but includes immatures up to several years of age), have consistently higher levels of ingested plastics than adult birds. In presentations of results of our monitoring efforts, all age groups are usually combined assuming that in the long term, there will be no major directional change in the age-composition of beached birds. However shorter term variations may occur, and in fact years 2009, 2010 and 2011 had relatively low proportions of adult birds (Table 2) which might influence overall data. Fig. 4 provides some impression of age related variations. In geometric means, the always present difference between adults and non-adults is very clear: both age groups follow the same pattern through the years, but at a fairly consistent different level. On a more detailed level, the all-age graph shows an slow increase in recent years, which is not as clearly visible in the separate age groups, and likely indicates an on average relatively high proportion of younger birds in the samples. However, as shown by test results in table 4B, none of these changes reaches significance.

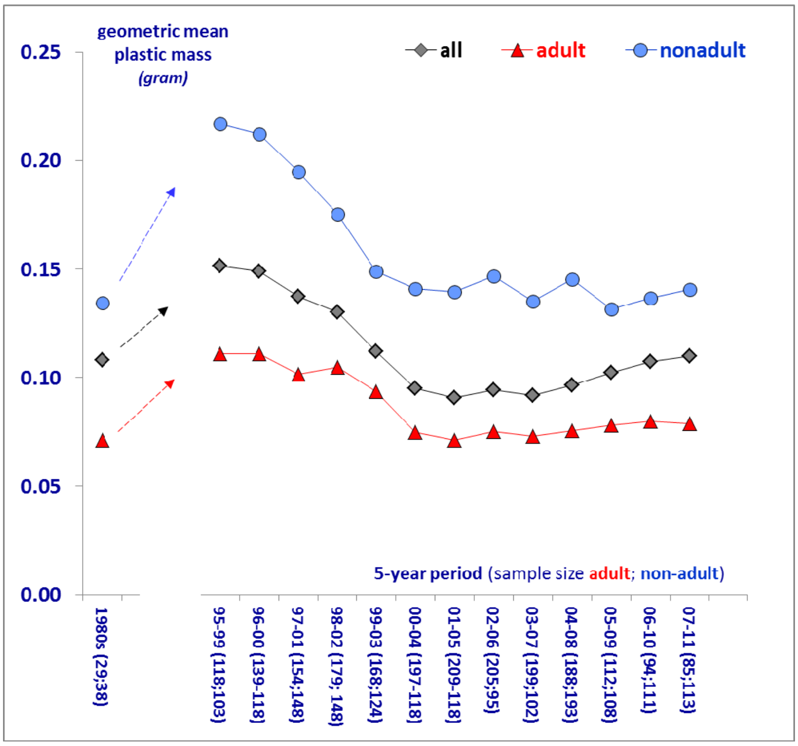


Figure 4 ***Geometric means for mass of plastics in stomachs of beached Fulmars*** *from the Netherlands 1982-2011 for all age groups combined (including birds of unknown age), adult birds and non-adults, with sample sizes in brackets in the x-axis labels. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trend-line in the summary.*

Dutch data in terms of the OSPAR EcoQO metric

ICES working groups (eg ICES-WGSE, 2001, 2003), followed by OSPAR (2008, 2009), have initiated the approach in which the EcoQO metric for marine litter is expressed in terms of a percentage of birds exceeding a critical value of plastic in the stomach. At first sight, one might argue that it would be easier to use an EcoQO definition based on for example only the average mass of plastics. However, whether intentional or not, the 'percentage above critical value' definition represents a sort of simplified procedure that avoids the mathematical problems caused by a few excessive stomach contents distorting comparative analyses. In the testing procedures and calculations of geometric means, such problems are overcome by logarithmic transformation of data. And although this is a standard statistical procedure, it is not always easily conveyed to the general public, and differences between means (arithmetic versus geometric) can be confusing. The EcoQO metric avoids such problems by using classes of birds in which the exceptional stomach contents lose their influence. Currently, the target for acceptable ecological quality has been defined as the situation in which *"less than 10% of northern fulmars (Fulmarus glacialis) have more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".*

So in such a definition an excessive stomach content of e.g. 10 gram of plastic does not change the metric compared to the situation in which that bird would have had for example only 0.2 g in its stomach.

Using the same data as in earlier sections of this report, Fig. 5 shows the time trends in the 5-year average EcoQO performance of Fulmars found in the Netherlands. With the Y-axis scaled to a 100% range (Fig. 5A), the distance from the 10% EcoQO target set by OSPAR is strongly visualised and emphasizes the need for further improvement. At this axis scale the graph insufficiently shows the changes since the mid 1990's. The same data at a finer scale can be seen in Fig. 5B showing gradual improvements in EcoQO performance from 67% down to 57% exceeding 0.1g level in the 2001-2005 period. Small increases in the following periods were of concern, but geometric means and current EcoQO data, in combination with the 10-year trend tested in Table 4B, do indicate decreases, albeit at extremely slow and insignificant rate. The low 46% EcoQO figure for just year 2009 (Table 2) is expected to be biased because of the January wreck of recently arrived northern birds. Over the integrated recent 5-year period 2007-2011, 60% of Dutch Fulmars exceeds the 0.1g critical EcoQO level, which is still far off the 10% target.

***Photo**: Fulmar EcoQO Monitoring around the North Sea is based on beached fulmars collected by volunteers. Numbers found may vary strongly. Incidental years of low sample size are not a problem, but may somewhat delay detection of significance in tests for changes over time or spatial differences.*

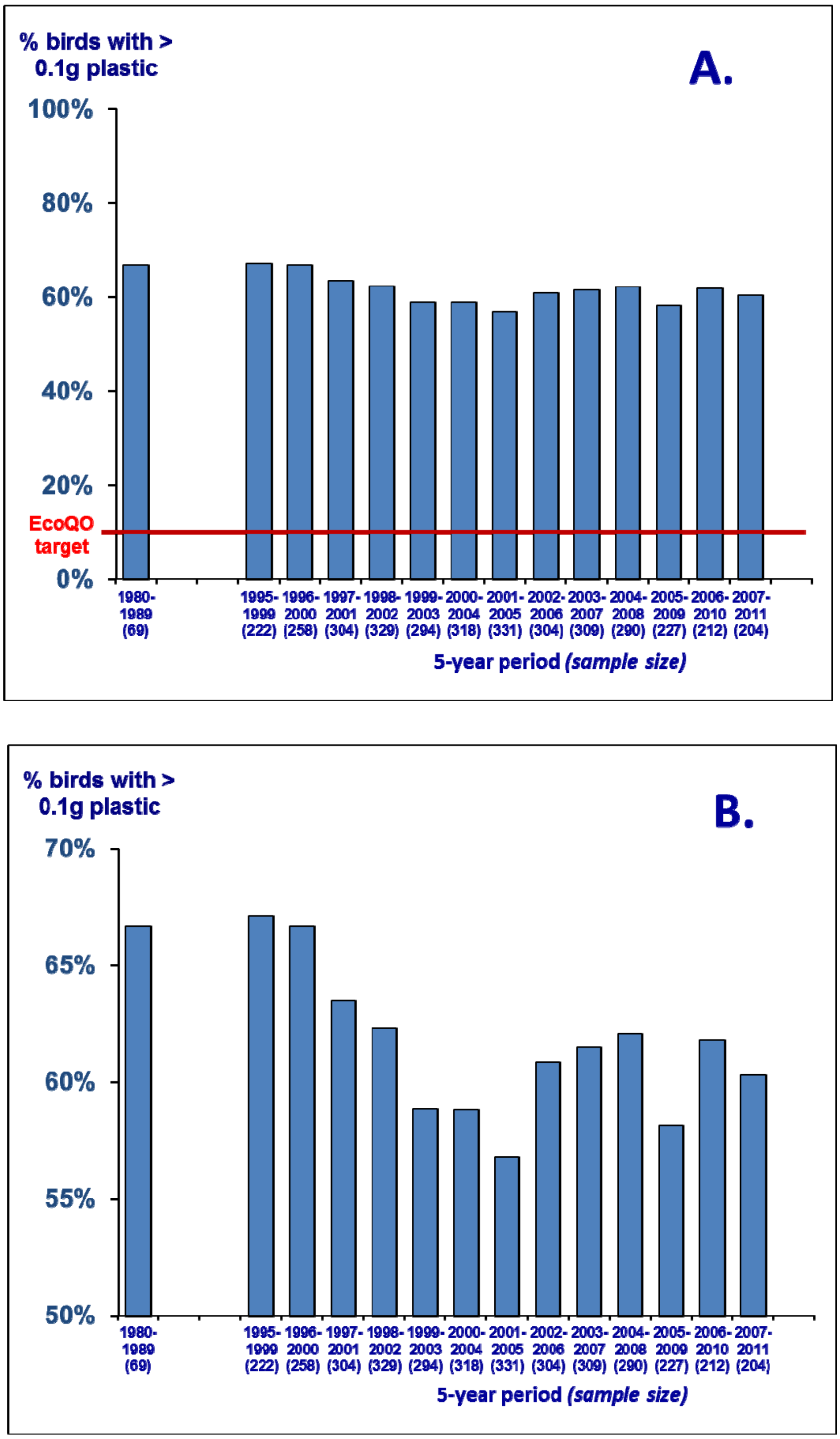


Figure 5 ***EcoQO performance of fulmars in the Netherlands*** *over running 5-year periods (single average for 1980s); graphs A and B show the same data. Fig A illustrates the distance from the OSPAR EcoQO target to reduce the percentage of birds with more than 0.1g of plastic in the stomach to below 10%. Fig B. provides finer scaling of the y axis, to illustrate trends over time.*

5.2. Monitoring data in the North Sea

As convened in OSPAR (2008), study areas in the North Sea are grouped into 5 regions, that is the Scottish Islands (Shetland and Orkney), East England (north- and southeast), Channel (Normandy and Pas de Calais), South-Eastern North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast).

Earlier integrated North Sea wide EcoQO reports discussed the periods 2002-2004 (Van Franeker et al. 2005) later extended up to 2007 (Van Franeker et al. *2011*) and to 2009 (Van Franeker and the SNS Fulmar Study Group, 2011). In addition to the Dutch monitoring program, parts of the international data collections were co-funded by EU Interreg IIIB, the NYK Group Europe Ltd., Chevron Upstream Europe, German, Norwegian and UK governments. The current update up to year 2011 became possible because of funding by the Dutch and UK authorities and data contributions from Germany.

The regional pattern within the North Sea documented in our earlier studies persists with minor variations. Highest plastic abundance continues to be present in Fulmars from the English-French Channel area, with gradually decreasing levels further to the north both along western and eastern shores of the North Sea. During 2007-2011 (Table 5, Fig. 6), as in the first SNS report, there is a strong difference in the geometric mean mass of plastics in Fulmars in the Channel area (0.28g) and that in birds from the Faroe Islands (0.05g). This means that by geometric means, the Channel shows a more than 5 times higher pollution than the Faroe Islands, our first reference area outside of the North Sea. This represents an increase compared to the 4 times difference (0.27 versus 0.6 g) observed before 2009. Regional differences within the North Sea seem slightly less pronounced than before, in which Fulmar stomachs from East England appear to become more polluted and the birds from the SE North Sea somewhat less polluted than in earlier periods. However, details are not fully consistent when data are looked at as arithmetic average mass, geometric mean mass or EcoQO% (Table 5).
Relatively low annual sample sizes in some of the North Sea regions may somewhat reduce the power of statistical tests analysing regional differences or trends over time. As for regional differences (cf geometric means in table 5) Channel data for the recent 2007-2011 period are significantly higher than those from the Faroe Islands or Iceland ($p<0.001$), but within the North Sea they only differ significantly from the large sample of Fulmars from the nearby SE North Sea ($p=0.026$), but just not from Skagerrak ($p=0.052$), Scottish Islands ($p=0.071$) and East England ($p=0.147$)
Fig. 7 visualizes trends in 5 year running averages for EcoQO performance in the different North Sea regions since 2002. Tendencies seen in the graphs suggest stability for e.g. SE-North Sea and Faroe Islands to slowly increasing pollution in several of the other regions. Hoewever, for none of the regions tests over 10 years of data reach significance. Only the pattern seen in the Channel approaches significance ($p=0.066$).
Whatever the details on regional differences and trends, it is clear that nowhere in the North Sea the OSPAR EcoQO target of a maximum of 10% of birds exceeding 0.1g plastic in the stomach, is reached. During 2007-2011, EcoQO performance within the North Sea ranged from 55% (Skagerrak) to 86% (Channel). When moving out of the North Sea, fulmar stomachs are cleaner at the Faroe Islands (40% EcoQO performance), and Iceland (28% in a single year sample 2011) and only approach the target in the Canadian Arctic (Fig. 8, Canadian data compiled from Mallory et al. 2006, Mallory, 2008, and Provencher et al. 2009 and personal information from the authors). Probably the situation within the Canadian arctic does comply with the OSPAR EcoQO target for the North Sea, but the measured level is somewhat biased by birds that had recently migrated into the area returning from more polluted wintering areas (Van Franeker *et al. 2011)*.

Table 5 Incidence, number of particles and mass of plastics in stomachs of fulmars beached in different North Sea regions during the 5-year period 2007-2011. *Mass data also shown as geometric mean mass, and as percentage of stomachs with more than 0.1 gram of plastic (EcoQO performance)*

Region	*sample n*	Incidence %	average number n ± se	average mass g ± se	geometric mean mass (g)	EcoQO % (over 0.1g)
Scottish Islands	*115*	90%	21.9 ± 3.1	0.36 ± 0.07	0.09	57%
Northeast England	*51*	98%	46.4 ± 6.7	0.35 ± 0.07	0.15	76%
Channel Region	*72*	99%	51.7 ± 9.3	0.54 ± 0.08	0.28	86%
Southeast North Sea	*482*	95%	28.2 ± 2.1	0.37 ± 0.05	0.11	60%
Skagerrak Region	*76*	93%	54.2 ± 16.1	0.32 ± 0.05	0.11	55%
North Sea total	***796***	**95%**	**33.1 ± 2.3**	**0.38 ± 0.03**	**0.12**	**62%**
Faroe Islands	*699*	91%	11.3 ± 0.6	0.15 ± 0.01	0.05	40%
Iceland 2011	*58*	79%	6.0 ± 1.0	0.13 ± 0.04	0.02	28%

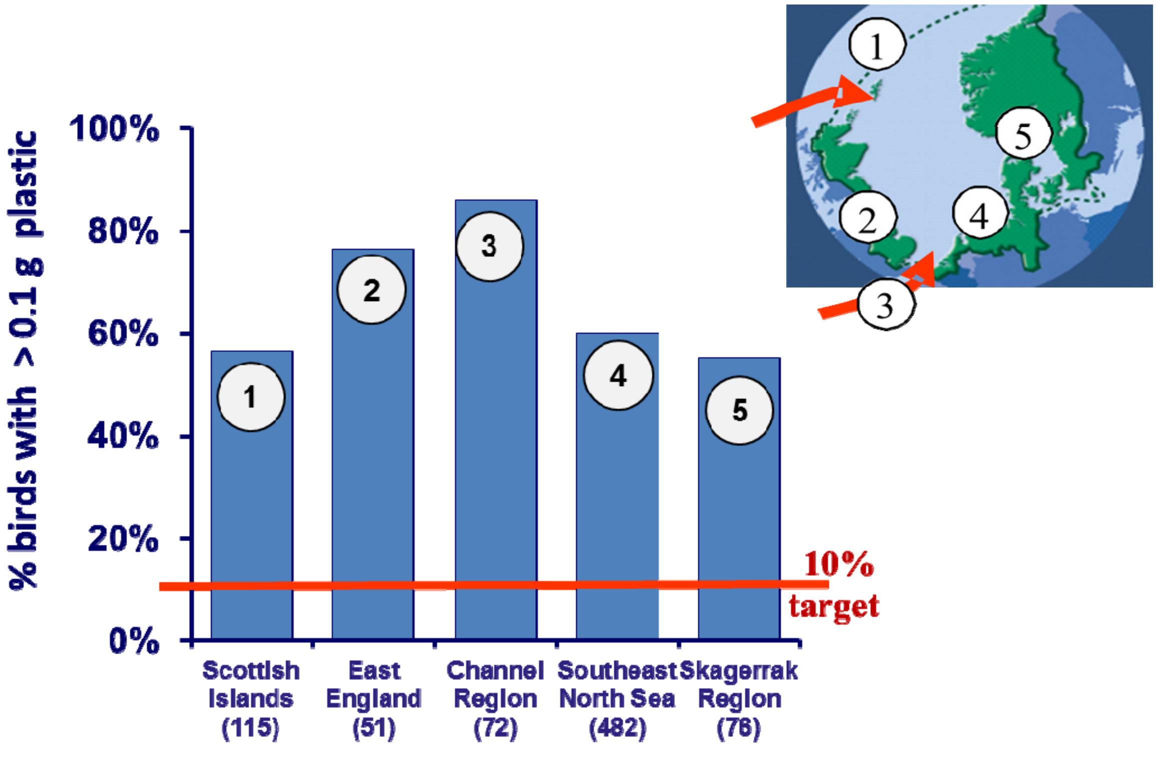


Figure 6 Regional variation in average plastic mass in fulmar stomachs in the North Sea regions 2007-2011, *by EcoQO performance (% of birds with > 0.1g plastic).*

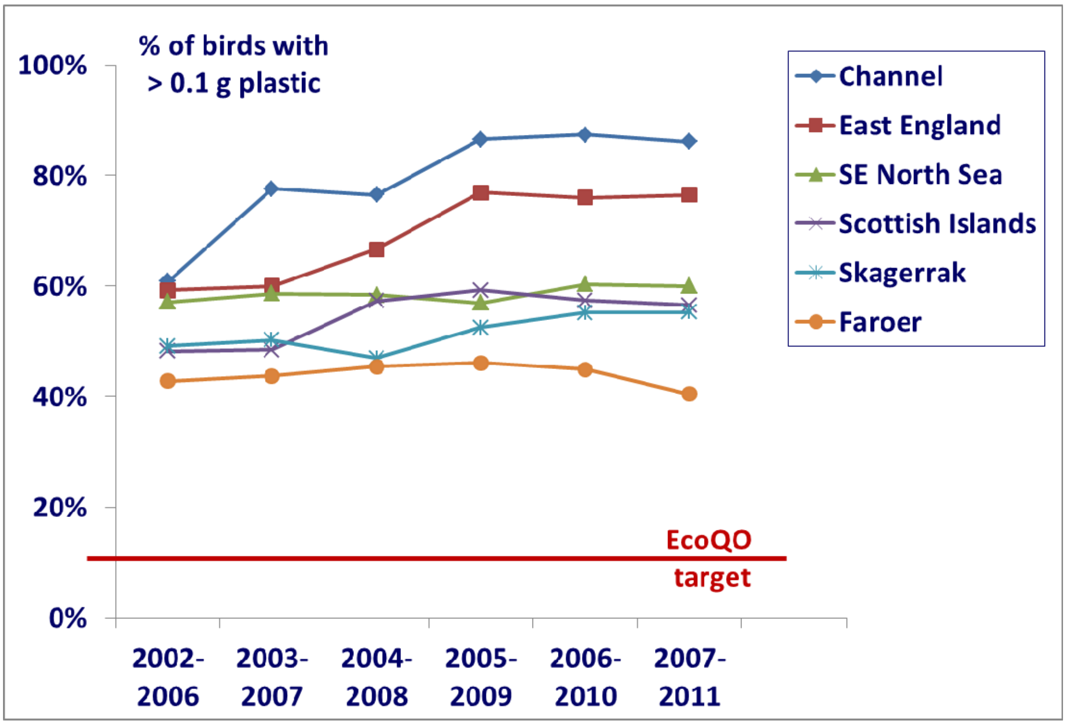


Figure 7 ***Trends in EcoQO performance in different regions of the North Sea since 2002*** *(by running 5-year average data).*

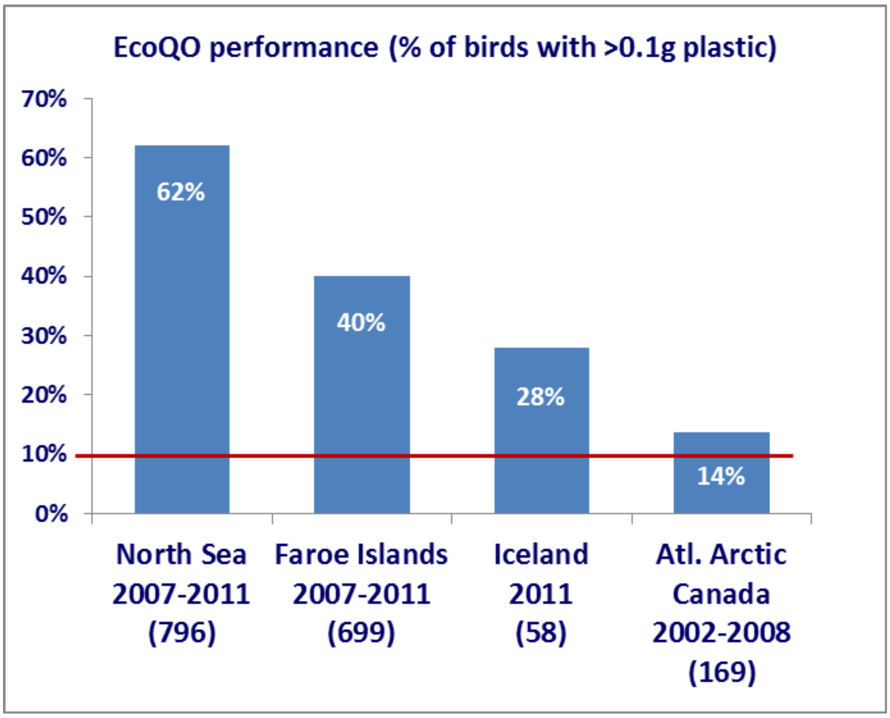


Figure 8 ***North Sea EcoQO performance (2007-2011), compared to more northern areas.***

5.3. Exploring details in North Sea data: patterns and sources

Van Franeker et al. (2005) surveyed data from the 2002-2004 SNS study for details beyond the basic plastic monitoring required for the OSPAR EcoQO. Splitting up data for separate locations and subcategories of materials reduces statistical robustness because of smaller samples and local variations, but can nevertheless be indicative for certain important elements. The earlier analyses provided more insight into patterns and sources of marine debris in the North Sea, in particular on the potential role of shipping.

The regional pattern of marine litter that was shown in Fig. 6 is repeated for the separate study locations during the 2007-2011 period in Fig. 9 and compared to the data for the same locations in the preceding 2002-2006 5-year period. Locations SE England, Pas de Calais and Sweden are not incorporated in these data because at those locations no samples were available for the 2007-11 period. The recent results support the conclusion on high pollution in the Channel area, gradually decreasing to the north. Belgian and Dutch pollution levels appear relatively low compared to the Channel and other areas. To some extent this was already the case in the early period, but whereas pollution levels apparently increased in all directly surrounding areas, Belgium improved EcoQO performance in comparison to the early period and the Netherlands remaind stable (Table 4B). Tests for trends for individual locations over period 2002-2011 show that Belgian birds indeed display a near-significant downward trend ($p=0.06$) in mass of plastics in their stomach. The combination with a virtually stable situation in the Netherlands, and slight increase in Germany results in the overall stability suggested for the combination of the 3 countries into the southeastern North Sea region in Fig. 7. It is tempting to suggest that the Rotterdam-Antwerp harbour policies could be relatively successful for ships approaching or leaving those ports. However, as indicated, at this stage none of the trends is significant and other factors than shipping may be involved.

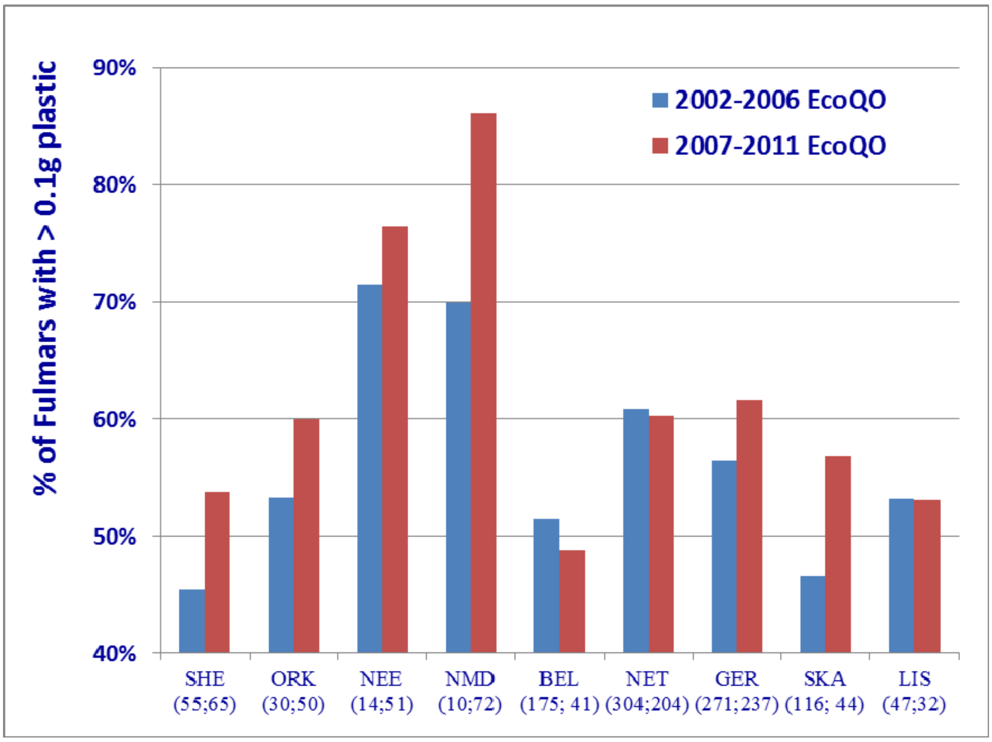


Figure 9 ***EcoQO performances 2002-2006 and 2007-2011 for all separate Fulmar study locations in the North Sea.***

The residual currents in the European Atlantic are northwards through the Channel and around the UK mainland into the North Sea. The large difference in pollution between the Channel and Scottish Islands shows that a large proportion of North Sea marine litter is of local origin. If debris floating into Europe with Gulfstream waters was to blame, pollution to the north and south of UK would be much more similar. In addition, high levels of litter in Normandy, well before inflow of major river systems, suggest that that litter in the North Sea is linked to sea-based activities, in particular shipping, rather than to riverine inputs.
Compared to Fulmars from the Shetland Islands, Fulmars from the Orkney Islands have an elevated level of debris in their stomachs (in the 2007-2011 dataset 0.31 ± 0.08g and 0.42 ± 0.08g respectively). This pattern is consistent with observations in earlier reports and is considered to indicate shipping as a source of marine litter. Both areas receive similar input of Gulfstream water and have relatively low levels of population and economic activity. But shipping density around Orkney is about double that around the Shetlands. It must be noted that in both island groups, marine litter seems to be increasing: in the earlier 2002-2006 period, Shetland birds averaged at 0.18±0.04g of plastic and the Orkney birds 0.28±0.07g. The increase in plastic load in birds from Shetland over the 2002-2011 period approaches significance ($p=0.07$). Major shipping activities in the European area are shown in Fig. 10.
A large detailed beach study on Texel, the Netherlands, in 2005 confirmed both conclusions i.e. that in the North Sea most debris has its origin within the region and is mainly linked to merchant shipping and fisheries (Van Franeker 2005; Van Franeker & Meijboom 2006).

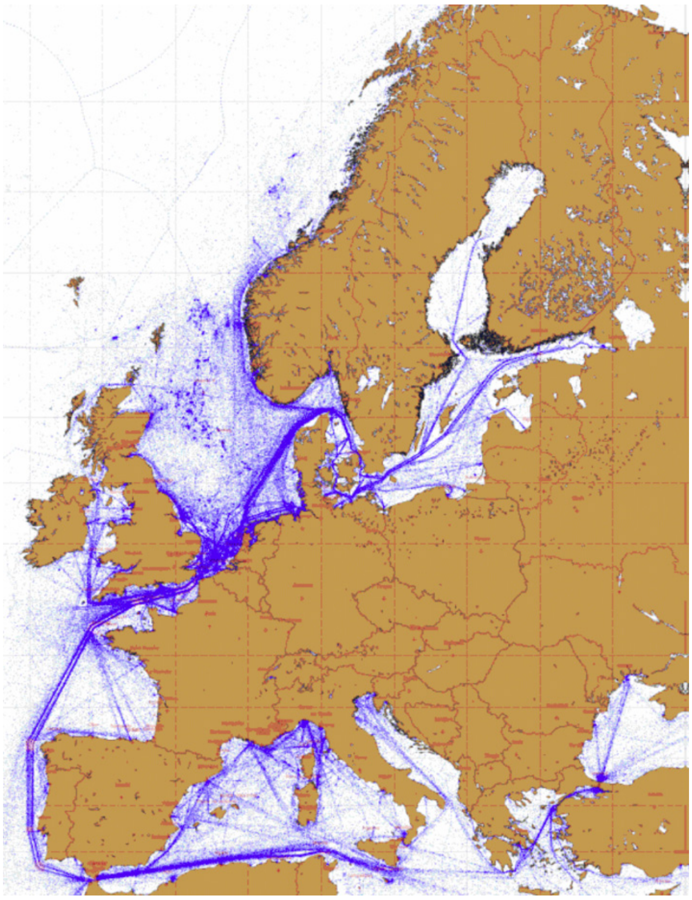


Figure 10 ***Shipping density in European waters (2002-2009),*** *by CLS, powered by SARTool, ENVISAT ASAR Products, European Space Agency ESA www.esa.int/esaEO/SEMBDI0OWUF_index_0.html*

There are additional approaches to assess the role of shipping, and it may be of use to look at other litter types or plastic subcategories that could be indicative. Our category of 'non-plastic rubbish' is dominated by galley type food-remains which can be discharged legally by ships. Considering rates of degradation and likely sinking of materials, a land-based origin of such food-remains in fulmar stomachs must usually be considered unlikely. We consider presence of non-plastic rubbish in fulmar stomachs to be an indicator of foraging on ships wastes. Similarly we consider elevated abundance of foamed plastics to be indicative for immediate nearby sources at sea. Because of their extreme buoyancy, wind and waves will quickly displace foamed plastics, most pieces beaching rapidly onto shores. Fig. 11 explores these two indicators for the different locations. Foamed plastics largely confirm earlier conclusions on peak densities of litter in the Channel and gradual reductions further north, indicating shipping as an important source of debris. The reduced level in all types of plastics seen in the Belgian Fulmars in Fig. 9 is evident also in foamed plastics and non-plastic rubbish (Fig 11A and B). Not fitting the pattern of highest shipping indicators in the Channel area is the abundance of non-plastic debris for our 2007-2011 data: both by incidence and geometric mean mass non-plastic rubbish does not match the foamed plastic levels (Figs. 11 A and B), for which we lack an explanation. In NE England high presences of foamed plastics and non-plastic rubbish support a major role of sea based sources of pollution.

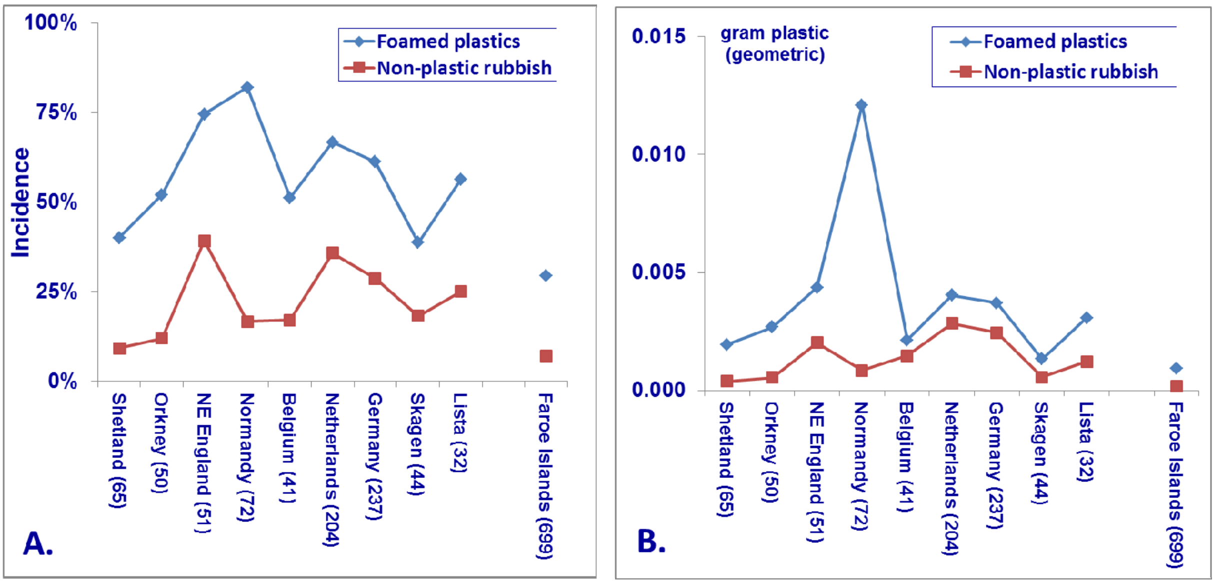


Figure 11. Incidence and geometric mean mass of foamed plastics and non-plastic rubbish in fulmar stomachs 2007-2011.

Differences in patterns for industrial and user plastics in Van Franeker et al. (2005; Fig 14 in that report) suggested then that industrial plastics could be more from riverine sources, because the French sample at the time showed lower abundance of industrial plastics than samples from north of major river outflows into the North Sea, a pattern opposite that of user plastics. However, as already indicated in Van Franeker, J.A. & the SNS Fulmar Study Group (2011) such a conclusion cannot be confirmed with the current data. Re-analyis of the early data showed that it had to rely on only a sample of fulmars from France in the 2004 wreck. When now comparing data for Normandy for both the early period and current situation (Fig. 12), it appears that abundance of industrial plastic peaks in the Normandy area and also in NE England. Thus there is no indication for a link with major riverine inflow in general. This does not mean that coastal sources should be excluded, as the geographical pattern is also not quite the same as for all plastics (cf Fig. 9). The Normandy and northeast England are so different from other locations (in both time frames), that localised sources may be suspected.

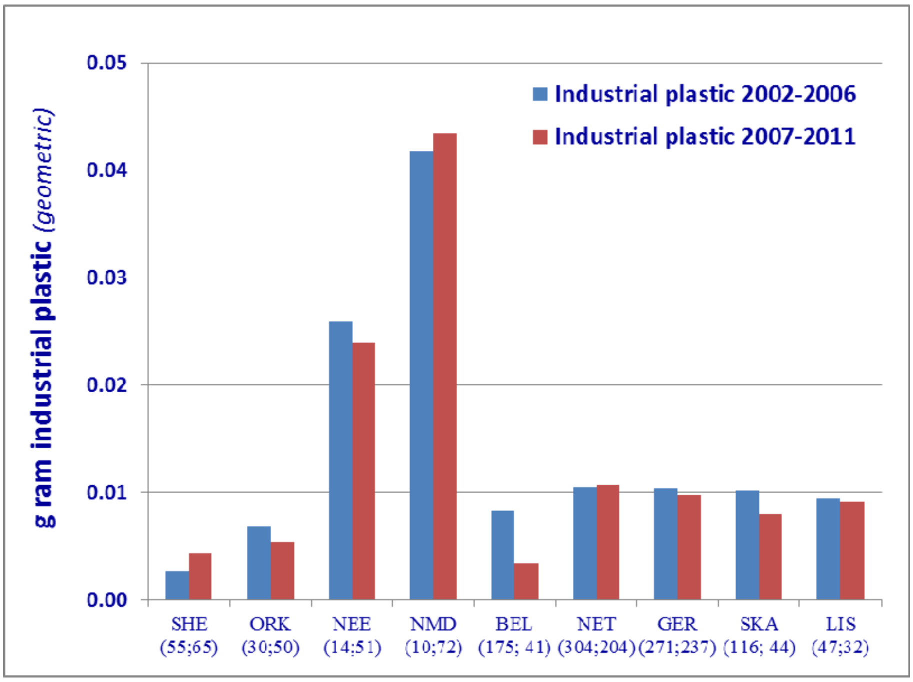


Figure 12 ***Geometric mean mass of industrial plastics 2002-2006 and 2007-2011 for all separate Fulmar study locations in the North Sea.***

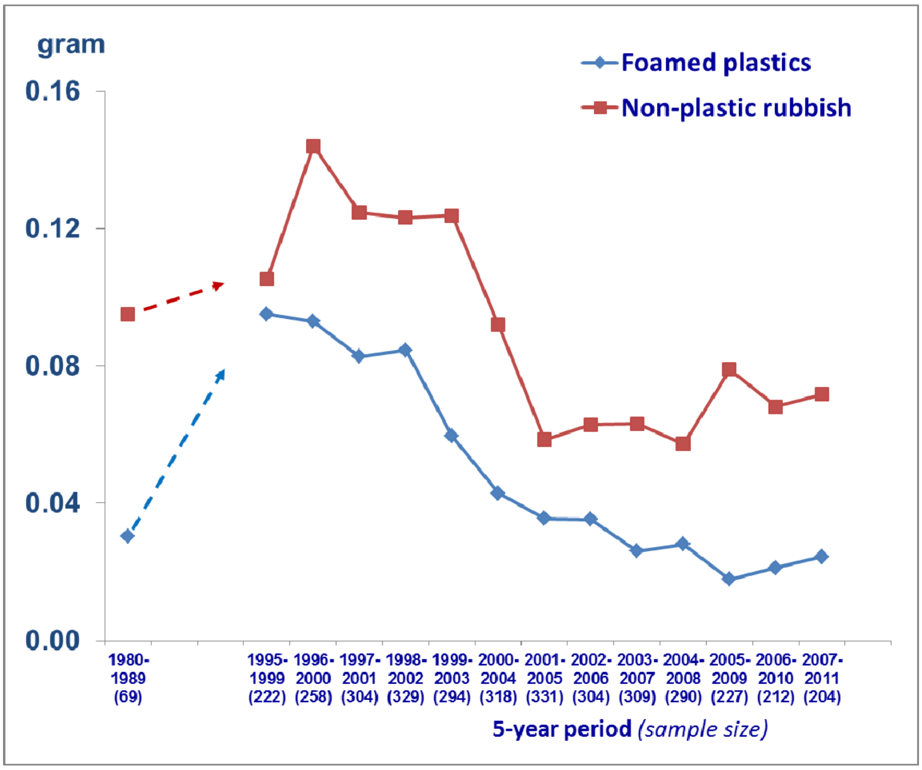


Figure 13 ***Trends in abundance (5-year average mass) of foamed plastics and non-plastic rubbish in Fulmars from the Netherlands, 1980-2011.***

Only for the Dutch data, a time trend in what we consider to be indicators for shipping as a source of marine debris can be looked at. Unlike the pattern for overall plastic mass in stomachs (Fig. 2) in which decreases from the late 1990s halted in more recent years, the analysis for foamed plastics suggests continued decrease, which may suggest a decreasing role of shipping in/near the area, which could explain a relatively good performance (e.g. Fig. 9 and Fig. 11) of fulmars from Belgium and the Netherlands. This could be a careful sign of the Directive on Port Reception Facilities and a reduced role of ships in litter abundance. This is not necessarily contradicted by fact that non-plastic rubbish, mainly galley wastes, is not showing a similar continued decrease.

At the detailed level of differences between locations and subcategories of litter, statistical significant conclusions are often hard to reach. Nevertheless, these detailed analyses do have a useful role in linking pollution to potential sources and thereby can contribute to appropriate management policies. So even when the OSPAR approach only requires regionally pooled data and a single plastic category, it will be useful to continue the current sampling scheme and detail of data recording as described in Chapter 4.

Even if there are some weak indications that the situation off the Belgian coasts is improving and stable for the Netherlands, the EU Directive on Port Reception facilities has clearly not yet triggered the intended significant reduction in marine litter after its implementation in 2004. For unknown reasons, substantial improvement was achieved in years prior to the Directive. However, it must be taken into account that shipping and the use of plastic materials have strongly increased. Fig. 14 shows trends in plastic production, shipping activity and the abundance of industrial and user plastics in stomachs of fulmars. It clearly shows that abundance of industrial plastics has been reduced while production and transport strongly increased. Ingested user plastics initially showed strong increases in line with shipping intensity and usage of plastic, improved considerably around the turn of the century and since then have stabilized in a period of continued growth of shipping and plastic production (except the 2008-09 crisis period). Even though the graphs in Fig. 14 should not be viewed proportionally, they do indicate that lack of improvement not necessarily means that policy measures like various MARPOL regulations and the EU Directive on Port Reception Facilities have been without effect (Trouwborst 2011).

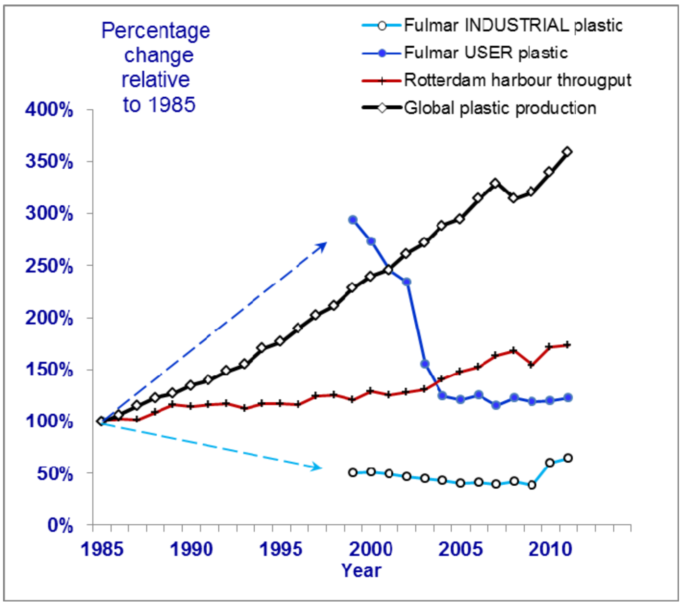


Figure 14 ***Comparative Trends*** *in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars(5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985.*

5.4. Conclusion

Stomach contents of Fulmars in the Netherlands indicate that the marine litter situation off the Dutch coast over the last decade is stable. This appears to be the case for the combined SE North Sea region in general, which combines Belgian (decrease), Dutch (stable) and German Fulmars (light increase). Data for other North Sea regions indicate lightly increasing trends. However, all local and regional changes at the moment occur at insignificant rates. Shipping including fisheries is considered the major source of marine debris in our area. Policy measures aimed at the shipping sector, such as implementation of the European Directive on Port Reception Facilities, probably have contributed to a stabilization in marine litter levels in a period where potential sources of debris have increased.

Photo *A dark colourphase Fulmar (colour indicating arctic origin) feeding on tiny particles of fatty fish remains in wastewater discharged by a fish factory on the Faroe Islands. In this type of feeding direct ingestion of small plastic particles can easily occur.*

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The SNS Fulmar Study Group consists of (with apologies to those not specifically named) Christine Blaize, Elisa Bravo Rebolledo, Kees Camphuysen, Wouter Courtens, Maria Dam, Johannes Danielsen, Keith Fairclough, David Fleet, Jane Gollan, Gilles and Damien Le Guillou, Nils Guse, Poul-Lindhard Hansen, Martin Heubeck, Jens-Kjeld Jensen, Susanne Kühn, Eric Meek, André Meijboom, Mick Mellor, Bergur Olsen, Kare-Olav Olsen, John Pedersen, Helle Schulz, Eric Stienen, Dan Turner, Hilbran Verstraete, Marc van de Walle and Stefan Weiel. Beached fulmars are mainly collected by volunteers, far too many to be named individually, but without whom a project such as this is totally impossible. We are extremely grateful for their long-lasting support.

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Relevant websites

www.wageningenur.nl/plastics-fulmars

www.zeevogelgroep.nl *click on downloads – Fulmar-Litter-Study*

8. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

9. Justification

Report C076/13
Project Number: 430.61205.01

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved : E.M. Foekema
Research scientist

Signature:

Date: 24 May 2013

Approved: J. Asjes
Head of Department

Signature:
Date: 24 May 2013