Fulmar Litter EcoQO monitoring in the Netherlands - Update 2014

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*Cover page photo (clipped) *:*

For many years the E-Connection Group (www.e-connection.nl) has supported the systematic beach surveys conducted by Arnold Gronert (centre). E-Connection took care of all beach-permits and borrowed and paid all costs of their four-wheel-drive, that was used by Arnold to survey the coast of Noord-Holland. This included the collection of many beached wildlife specimens, seabirds, seals, porpoises and dolphins, for a range of scientific studies conducted by IMARES, NIOZ and universities and zoological museums. At incidental occasions, Arnold also assisted in other areas, such as (photo) during a wreck of fulmars in 2009 on the island of Texel. On the photo, Arnold is taking notes on an Eider Duck carcass handled by Kees Camphuysen. To our regret, in summer 2015 the 4-wheel-drive truly reached the end of its life-time, meaning the end of this project. Many studies, including the Fulmar monitoring project, loose an important surveyor and provider of beached animals. Thank you Arnold and E-Connection for fantastic support over many years, we regret to see you go!

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

i. Summary Report

Fulmar Litter EcoQO monitoring in the Netherlands - Update 2014.

Marine debris has serious economic and ecological consequences. Economic impacts are most severe 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 as for instance 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. 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; Van Franeker et al. 2011) 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 the preliminary target for acceptable ecological conditions in the North Sea as:

> *"There should be less than 10% of Northern fulmars (Fulmarus glacialis) having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different areas 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 different countries may therefore define an MSFD target for ingested plastics 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 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 was not statistically 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, with standard errors, 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** – geometric means of plastic mass are calculated using data transformation (natural logarithm) to reduce influence of extreme outliers and to facilitating comparison of smaller samples. To include zere values in the population means, the transformation includes addition of 1mg to each sample, later corrected for in back-calculation.
- **EcoQO performance** – The percentage of birds having more than 0.1 gram of plastic in the stomach (again including zero values), allowing direct comparison to the OSPAR target, which aims at having less than 10% of such birds

- **State assessment data pooling** - In this report, 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. **Graphs** often represent pooled data for 5 years, but shift one year by datapoint, i.e. running averages. 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 whatsoever.
- **Trend analysis 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 1979-2014 for the Netherlands) and the 'recent trend', which is defined as the trend over the past 10 years (now: 2005-2014). Regional differences are tested for significance by fitting individual log-transformed data in a generalized linear model and likelihood ratio test.

Update of monitoring data for the Netherlands

This report adds new data for year 2014 to earlier updates (Van Franeker et al. 2014). Beached fulmar corpses were very scarce in 2014. In spite of substantial effort in stimulating beach surveyors, we only obtained 12 fulmar corpses of which 11 had a stomach that could be used. A further two samples could be added to earlier years. Our program aims for an annual sample size of ±40 birds or more. 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. Years of low sample size are one of the reasons to recommend pooled 5-year data to consider the 'current' situation: our sample for the 5-year period 2010-2014 is 171 fulmars. Annual data and the most recent pooled 5-year details are summarized in *Table i.*

- Current data for the Netherlands (years 2010 to 2014; 171 fulmars) are that 93% of fulmars had plastic in the stomach. The average number of items per stomach was 32 particles with a mass of 0.34 gram. The critical EcoQO value of 0.1 gram plastic was exceeded by 57% of the birds.

Table i ***Data summary for study year added to the existing monitoring series*** *(the table presents year or period of sampling with sample size (n), and for each of main plastic categories and total plastic the incidence (%), the average number of particles (n) and the associated average mass per bird in gram (g). The final column gives EcoQO performance, that is the percentage of birds that exceeds 0.1 g of plastic mass in the stomach.*

		INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (ind+user)			
Year	*n*	%	n	**g**	%	n	**g**	%	n	**g**	EcoQO
2014	*11*	73%	2.4	**0.05**	100%	20.3	**0.33**	100%	22.6	**0.38**	82%
period 2010_14	*171*	61%	4.3	**0.10**	92%	27.4	**0.24**	93%	31.7	**0.34**	57%

Long-term trends 1979-2014

Long term trends in the Netherlands are visualized for EcoQO performance in ***Figure i*** and for average mass in ***Figure ii***. Both graphs show data as running 5-year averages (periods with 10 or less birds in the sample are not shown). The main message from the EcoQO graph is that throughout our period of observation, ecological quality has not been in compliance with the OSPAR EcoQO target. The EcoQO performance over 5-year periods has varied between 50% and 91%, whereas the target is that it should go below 10%. The most recent average of 57% of fulmars exceeding the critical 0.1 gram level is not as good as in two earlier periods. Measured over the long term data set, and using trend analysis, EcoQO performance is significantly improving (***Table ii***; p=0.012) but over the past 10 years the reduction is not significant.

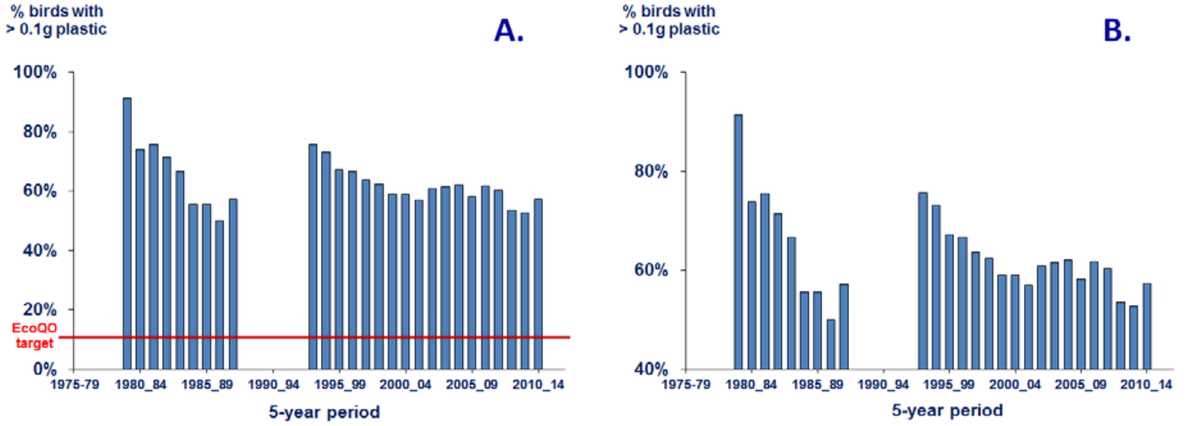


Figure i ***EcoQO performance among fulmars from the Netherlands 1979-2014.*** *A: data for the proportion of birds having more than 0.1 gram of plastic on a full 100% scale, illustrating the distance to the 10% target as defined by OSPAR; B: same data but y-axis restricted to the observed range,. Data are shown by annually updated 5 year performances (i.e. data points shift one year ahead at a time). Data for early 1990s not shown because of small sample size (<=10). These graphic visualizations do not represent a statistical trend analysis.*

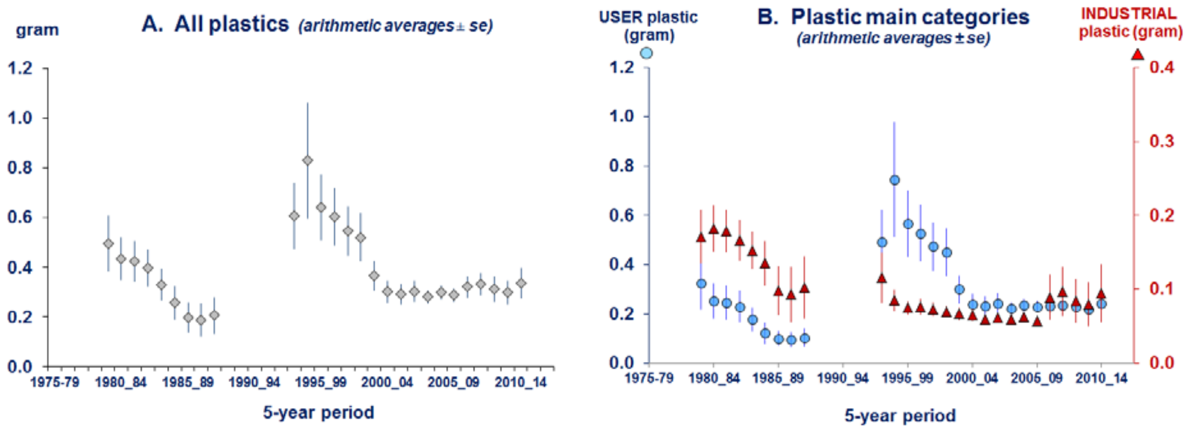


Figure ii ***Plastic mass in stomachs of fulmars from the Netherlands 1979-2014*** *A: all plastics combined (grey diamonds) and B: user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average ± standard error for mass for running 5 year averages (i.e. data points shift one year ahead at a time) where sample size was over 10 birds. These graphic visualizations do not represent a statistical trend analysis*

The graphs on average mass of plastics (***Figure ii***) show some more detail of changes. During the 1980s, there was a tendency for decreasing amounts of plastic (total plastic 1979-1989, n=70 p=0.034; similar trend in industrial and user plastic subcategories, but separately not significant). However, a sharp increase was seen towards the mid-1990s, which was completely due to increased user plastic debris. This peak for the mid-1990s was followed by a period of rapid reduction in ingested plastic mass until the early 2000s, but no further consistent change since then. The current level for all plastics combined (***Figure ii A***) is similar to the situation in the 1980s, but ***Figure 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 a very slow continued decrease except for slight abberations caused by exceptional outliers (recent 5-year data for average mass of industrial plastic were influenced by just 2 birds in 2010 and 2011 that had an exceptionally large number of industrial granules in the stomach).
In the EcoQO approach, statistical tests for trends only consider patterns of linear change. The rise and fall in overall plastics and user plastics before and after the mid 1990s in ***Figure ii*** is therefore not visible in their long term trendlines illustrated in ***Figure iii A*** and ***Table ii A.*** User plastics are virtually stable over the long term. 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 arithmetic averages in some of the most recent 5-year periods. 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 plastic mass) and an increased proportional mass of user plastics. The decrease in industrial plastics in the North Sea has also been observed in the North Pacific and South Atlantic oceans. Thanks to the long term decrease in industrial plastics, also the long term trendline for total plastic is significantly downwards (p=0.038). Note that although none of the recent trends is significant (***Table ii B.***), all indicators suggest that the direction of change (negative t values) is towards a cleaner environment.

Table ii ***Linear regression analysis of trends in plastic ingestion in Dutch fulmars for (A) long-term and (B) recent 10-year data series.*** *Trends in plastic mass evaluated by ln- transformed individual mass values against year. EcoQO performance by simple numerical score for above or below the critical 0.1 gram level (0 below; 1 above).*

A. **LONG TERM TRENDS 1979-2014**
for plastics in Fulmar stomachs, the Netherlands

	n	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	*1010*	84.1	-0.0441	0.0100	-4.41	<.001	- - - ↓
User plastics (lnGUSE)	*1010*	-12.8	0.0051	0.0086	0.59	0.556	*n.s.*↑
All plastics combined (lnGPLA)	*1010*	32.6	-0.0174	0.0084	-2.07	0.038	- ↓
EcoQO performance (birds with >0.1g)	*1010*	11.9	-0.0056	0.0022	-2.52	0.012	- ↓

B. **RECENT 10-YEAR TRENDS 2005-2014**
for plastics in Fulmar stomachs, the Netherlands

	n	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	*398*	41.2	-0.0227	0.0406	-0.56	0.576	*n.s.*↓
User plastics (lnGUSE)	*398*	48.8	-0.0256	0.0349	-0.73	0.463	*n.s.*↓
All plastics combined (lnGPLA)	*398*	51.4	-0.0268	0.0345	-0.78	0.438	*n.s.*↓
EcoQO performance (birds with >0.1g)	*398*	17.5	-0.0084	0.0093	-0.90	0.367	*n.s.*↓

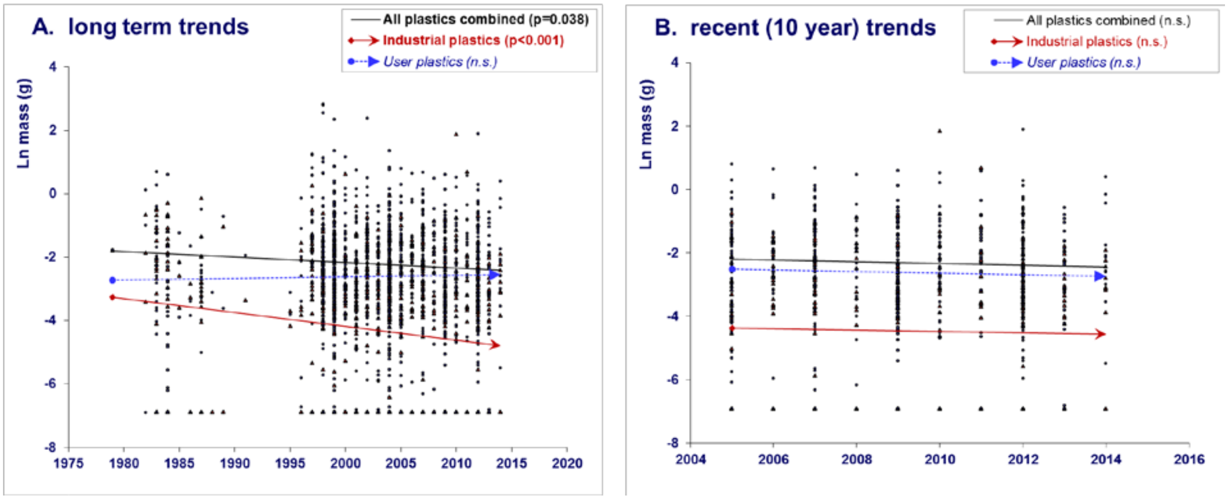


Figure iii ***Trends in plastic mass in stomachs of fulmars from the Netherlands 1979-2014, for (A) long-term and (B) recent 10-year data series.*** *Graphs show ln transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for industrial (lower, red line), user (middle blue line) and total plastics (top black line). N.s means that the test result is not significant.*

Recent 10-year trends 2005-2014

Regression analyses for 10-year trends (***Table ii B***; ***Figure iii B***) showed no significant change over the 2005-2014 period. Decreases were seen for the last time over the 1997-2006 period. Since then, no significant trends can be detected for either industrial or user plastics, nor for their combined total Negative t-values for all tested categories in ***Table ii B*** may indicate a very slow tendency to improvement.

It is unclear which factors triggered the strong increase in consumer plastics and decrease in industrial plastics from the 1980's to the 1990s, nor can we pinpoint a clear background for the subsequent decrease in user debris or the stability in the past decade. As for user plastics, a detailed beach study on Texel in the Netherlands in 2005 showed that most debris along the Dutch coast had its origin in or near the North Sea itself 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 mass coastal debris found on Texel. However, 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. On the other hand, the relative stability in ingested quantities of plastics in fulmar stomachs over the last decade should be viewed in the light of strong increases in shipping traffic and the ever growing proportion of plastics in waste (***Figure iv***). Under these conditions, various policies including the EC Directive on Port Reception Facilities are likely to have contributed to stabilization of marine debris input in our part of the North Sea. As yet, it is too early to expect statistically significant changes in relation to more recent developments. Public and stakeholder awareness has strongly increased in recent years following media attention for plastic soup and gyral garbage patches in the open ocean. International legislation for waste disposal by ships (MARPOL Annex V) has strongly changed and improved starting 2013. Developments are underway for implementation of the European Marine Strategy Directive (2008/56/EC) and its requirements towards Good Environmental Status. The plastic ingestion data for fulmars over year 2014 are less positive than those for 2012 and 2013, but represents only a small sample not affecting overall conclusion of little change or at best extremely slow improvement.

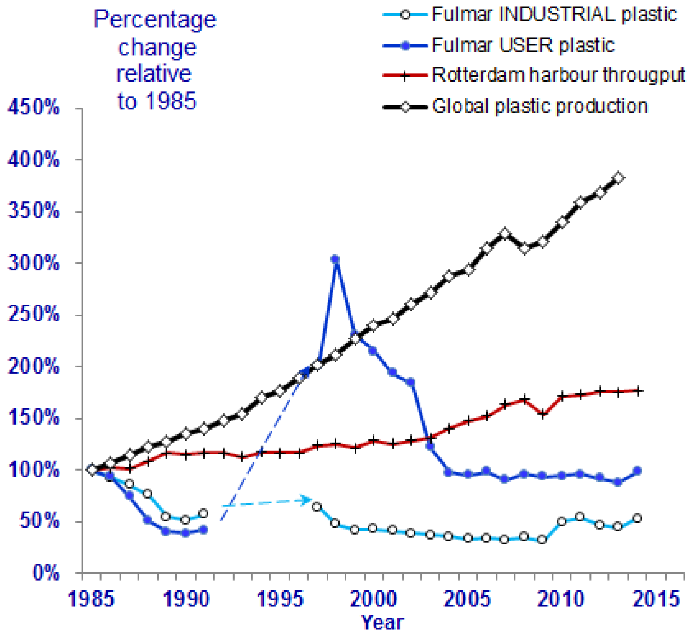


Figure iv ***Comparative trends in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars*** *(5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985.*

Foto: Industrial plastic pellets from a Dutch beach

Industrial plastic granules or 'pellets' are the virgin materials in which plastics are first produced, usually from mineral oil. The granules are transported to factories that melt them and add a wide range of additives to give the final plastic products the characteristics that we desire. The pellets may be lost during production or processing in factories and during transports. With a diameter of around 4 a 5 mm they are categorized as micro-plastics, and are regularly ingested by marine birds.

CONCLUSIONS

1. North Sea governments aim at the OSPAR Ecological Quality Objective (EcoQO) in which less than 10% of fulmars exceed a critical level of 0.1 gram plastic in the stomach.

2. Currently, in the Netherlands, 57% of fulmars exceed the 0.1 gram level (*171 fulmars 2010-2014: 93% contained plastic, on average 32 particles per stomach, weighing 0.34 gram).*

3. Long term data for the Netherlands showed an increase of marine plastic litter from the 1980s to the mid-1990s, followed first by a near similar decline but then gradual stabilization.

4. Over the most recent decade (2005-2014) analyses show no trend with statistical significance.

5. The composition of ingested plastic has changed since the 1980s with a significantly reduced proportion of industrial plastic and increased proportion of consumer waste.

6. Shipping and fisheries continue to be considered the major source for marine litter in the North Sea. Against the trends of increased marine activities and use of plastics, dedicated policy measures such as the European Directive on Port Reception Facilities (2000/59/EC) probably have contributed to a stabilization in marine litter levels, but not to reduction. It may be expected that recently increased awareness, improved MARPOL regulations for ship wastes, and policies towards implementation of the European Marine Strategy Framework Directive (MSFD 2008/56/EC) will all have a positive result, but as yet can not be demonstrated.

Photo: fulmar flock feeding

A dense group of fulmars feedingon small fish bits and fat droplets at the outlet of a fish factory. When small food items are abundant enough,also in natural frontal systems, even a larger bird such as the fulmar can forage efficiently on very small prey. Likely this behaviour implies a risk for microplastics accumulating in similar situations of waste effluents or marine fronts.

Foto: Groep fouragerende Noordse Stormvogels

Een dicht opeengepakte groep Noordse Stormvogels etend van kleine stukjes visweefsel en vetdruppels bij de afvoerpijp van een visfabriek. Als stukjes voedsel maar in voldoende dichtheid aanwezig zijn, ook in natuurlijke fronten, kan ook een groter dier zoals de Noordse Stormvogel efficient fourageren op zeer kleine prooien. Zulk gedrag betekent waarschijnlijk een risico op het eten van microplastics die zich in vergelijkbare situaties van afvalwater of stroomnaden kunnen ophopen.

ii. Samenvattend rapport

Stormvogel Zwerfvuil EcoQO monitoring langs Nederlandse kust - bijwerking resultaten 2012 en 2013.

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 objecten 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. Deze Nederlandse graadmeter is voor internationaal gebruik door OSPAR als EcoQO verder ontwikkeld (OSPAR 2008, 2009, 2010a,b; Van Franeker et al. 2011)) 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 deelgebieden van de Noordzee 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 een handleiding en rapporten. Er wordt onderscheid gemaakt tussen verschillende categorieën plastic, waarbij het onderscheid tussen industrieel plastic (basis granulaat) en gebruiksplastics (afval van allerlei soorten producten) 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', inclusief de standaardfout voor aantallen stukjes of gewicht van plastics in een monster, inclusief de vogels zonder plastic (populatie gemiddelde).
- **Geometrisch Gemiddelde (Geometric Mean) –** voor plastic gewichten berekenen we ook het geometrisch gemiddelde dat een tussenstap gebruikt van logaritmische transformatie (natuurlijk logaritme ln(x)) waarmee de verstorende invloed van extreme waardes wordt gereduceerd. Om

ook hier nulwaardes te kunnen betrekken voor de berekening van het populatie gemiddelde, wordt voor de transformatie 1mg gewicht bij iedere waarde opgeteld, waarvoor in de latere terugrekening weer wordt gecorrigeerd.

- **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%.
- **Samenvoeging gegevens voor toestands bepaling (State assessment)** – in dit rapport worden bovengenoemde gegevens vaak gegroepeerd in periodes van 5 jaar om verwarrende 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. **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 geen enkele statistische betekenis.
- **Trend analyse statistiek –** 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 (1979-2014 voor Nederland in dit rapport), en de Recente Trend die wordt berekend op basis van getallen over de afgelopen 10 jaar (2005-2014 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'.

Bijgewerkte Graadmetergegevens voor Nederland

Dit rapport voegt nieuwe gegevens toe voor het jaar 2014 aan het voorgaande rapport (Van Franeker et al. 2014). Gestrande stormvogels waren zeer schaars in 2014. Ondanks veel tijdbesteding aan het stimuleren van de vrijwillige medewerkers op de stranden, konden slechts 12 kadavers worden verzameld, waarvan er 11 een bruikbare maag hadden. Daarnaast werden aan eerdere jaren nog twee nagekomen samples toegevoegd. Er wordt gestreefd naar een jaarlijkse monstername van ± 40 of meer vogels. 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 één van de redenen om samengevoegde gegevens over de voorgaande 5 jaar te beschouwen als de 'huidige situatie'. Jaargegevens en de meest recente 5 jaars gemiddeldes zijn samengevat in ***Tabel i***.

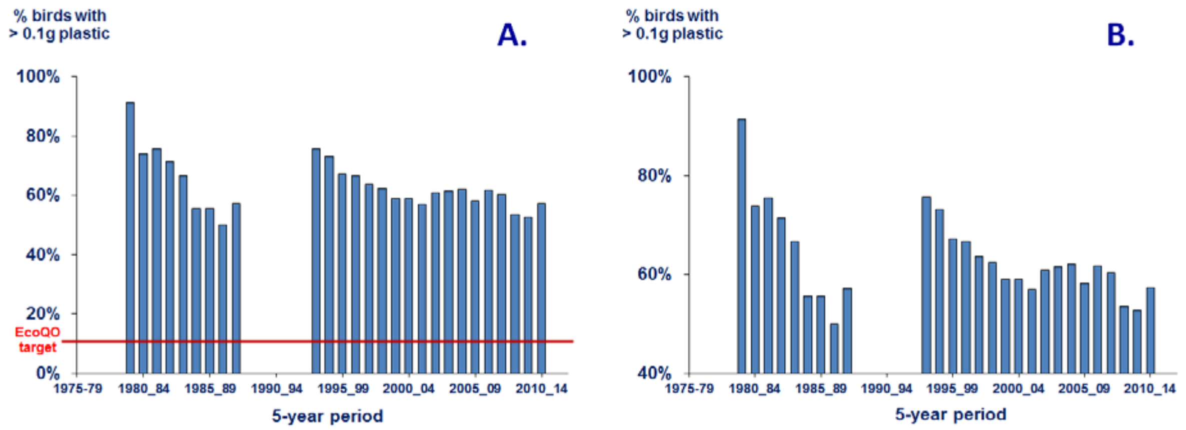
- De huidige toestand voor Nederland (jaren 2010 t/m 2014; 171 stormvogels) is dat 93% van de stormvogels plastic in de maag had, met een gemiddeld aantal van 32 stukjes en gewicht van 0.34 gram per vogel. De EcoQO grenswaarde van 0.1 gram plastic werd overschreden door 57% van de stormvogels.

Tabel i ***Samenvatting van gegevens die zijn toegevoegd aan de monitoring serie.*** (de tabel toont het jaar of periode van verzamelen met het aantal onderzochte magen (*n*), en vervolgens voor ieder van de hoofdtypes plastic en het totaal, de frequentie van voorkomen (%), het gemiddeld aantal stukjes plastic (n) en het daarbij behorende gewicht in gram (g). De laaste kolom toont het EcoQO percentage van vogels die meer dan de grenswaarde van 0.1 gram plastic in de maag hebben.

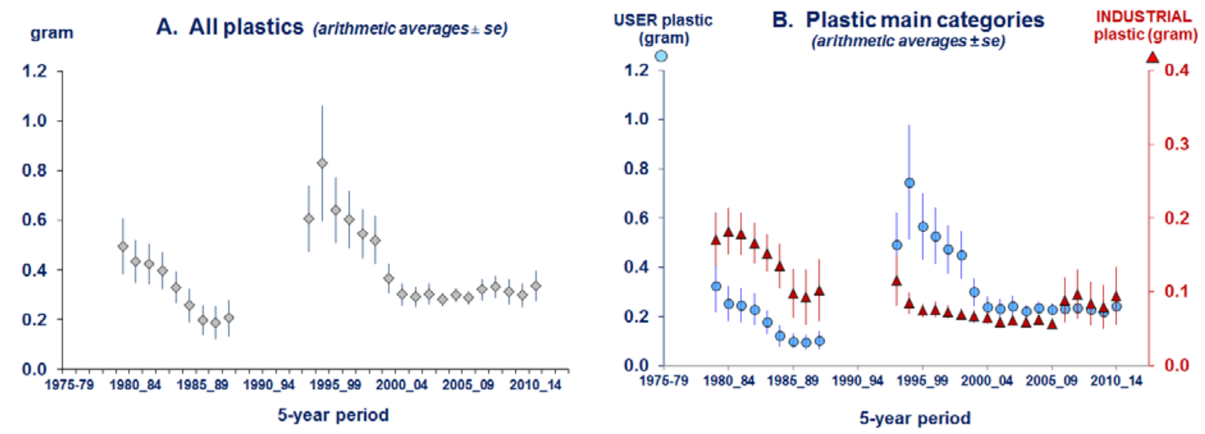
		INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (ind+user)			
Year	*n*	%	n	**g**	%	n	**g**	%	n	**g**	EcoQO
2014	*11*	73%	2.4	**0.05**	100%	20.3	**0.33**	100%	22.6	**0.38**	82%
period 2010_14	*171*	61%	4.3	**0.10**	92%	27.4	**0.24**	93%	31.7	**0.34**	57%

Lange-termijn trends 1979-2014

De trends op de lange termijn voor Nederland zijn gevisualiseerd voor EcoQO Percentage in ***Figuur i*** en voor rekenkundig gemiddeld gewicht in ***Figuur ii***. Beide figuren tonen lopende 5-jaars gemiddeldes, waarbij 5-jaarsperiodes met een monstergrootte van 10 of minder vogels niet zijn weergegeven. Het overheersend beeld uit de EcoQO grafiek is dat al vanaf de jaren ’80, de feitelijke situatie ver verwijderd is van de ecologische doelstelling van OSPAR. Het percentage vogels met meer dan 0.1 gram plastic in de maag heeft gefluctueerd tussen 50% en 91%, terwijl OSPAR beoogt dit percentage tot onder de 10% te brengen. Het meest recente gemiddelde EcoQO percentage waarbij 57% van de vogels meer dan 0.1 gram plastic in de maag heeft is minder goed als in de 2 voorgaande periodes. Gemeten over de lange termijn wijst trendanalyse op significante verbetering (***Tabel ii*** ;p=0.005), maar over de recente 10 jaar is de trend niet significant.



Figuur i ***EcoQO percentages van stormvogels uit Nederland 1979-2014.*** *A: gegevens voor het aandeel van de vogels met meer dan 0.1 gram plastic in de maag op een volle 100% schaal, als illustratie voor de afstand tot de 10% doelstelling van OSPAR. B: zelfde gegevens, doch y-as beperkt tot bandbreedte van waargenomen percentages. Gegevens zijn getoond als lopend 5-jaarsgemiddelde (telkens één jaar opschuivend). Voor begin jaren 1990 zijn geen getallen getoond vanwege te kleine aantallen vogels (<=10). Deze visualisatie van gegevens vertegenwoordigt geen statistische trend analyse.*



Figuur ii ***Plastic gewicht in magen van stormvogels uit Nederland 1979-2014.*** *A: alle plastics tezamen (grijze ruiten); 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 over lopende 5-jaars gemiddeldes. Deze visualisatie van gegevens vertegenwoordigt geen statistische trend analyse.*

De grafieken voor gemiddeld plastic gewicht in ***Figuur ii*** tonen meer detail in de tijdsreeksen. Gedurende de 80er jaren nam de hoeveelheid plastic af (Totaal plastic 1979-1989, n=70, p=0.034; de afzonderlijke categorien industrieel en gebruiksplastic toonden vergelijkbare afnames, maar ieder op zich niet significant). Daaropvolgend was een sterke stijging zichtbaar naar midden 90er jaren die geheel te wijten was aan gebruiksafval. Het gebruiksafval nam daarna ook weer vrij snel af maar stabiliseerde zich in het begin van de 21^{e} eeuw. Het huidig niveau van plastic massa in de magen van stormvogels (***Figuur ii A***) is vergelijkbaar met dat in de jaren '80, maar ***Figuur ii B*** laat zien dat de ontwikkelingen voor industrieel plastic sterk hebben verschild met die van gebruiksplastic. Gebruiksafval was verantwoordelijk voor het wisselend patroon in de totale hoeveelheid plastic in magen, terwijl industrieel granulaat tussen de jaren '80 en '90 halveerde en sindsdien een hele trage afname lijkt voort te zetten. (recente 5-jaar-gemiddeldes lijken daarop een uitzondering, maar die worden veroorzaakt door 2 vogels in 2010 en 2011 die zo extreem veel pellets in hun maag hadden, dat zelfs de rekenkundige 5-jaars-gemiddeldes daardoor vertekend worden).
In de EcoQO methodiek zijn de statische toetsen voor trendanalyse gebaseerd op rechtlijnige verbanden (lineaire regressie). De toe- en afnames in gebruiksplastic en totaal plastic over de lange termijn zijn daarom niet zichtbaar in ***Figuur iii A*** (details in ***Tabel ii A***). Het gewicht aan gebruiksplastic is op de lange termijn vrijwel onveranderd. Industrieel plastic daarentegen is sterk afgenomen sinds de jaren '80, hetgeen resulteert in een hoog significante (p<0.001) afnemende lange termijn trend, ondanks de geringere afname in recentere jaren en zelfs enkele extreem hoge waardes. Als gevolg van de verschillende lange termijn trends is de verhouding industrieel en gebruiksplastic sinds de jaren '80 sterk veranderd. Het aandeel industrieel plastic gewicht is afgenomen van ca. 50% van het totaal tot nog slechts zo'n 20%, terwijl het aandeel van gebruiksplastics is gegroeid. De in stormvogels waargenomen afname in industrieel plastic in het Noordzee gebied, is ook waargenomen in de Noord-Pacifische en Zuid-Atlantische Oceaan. Dankzij de lange termijn afname in industrieel plastic, is de lange termijn trend voor totaal plastic significant afnemend (p=0.038). Opgemerkt mag worden dat, hoewel geen enkele recente trend statistisch significant is (***Table ii B***) , dat alle indicatoren op een zeer voorzichtige afname duiden (negatieve t-waarders)

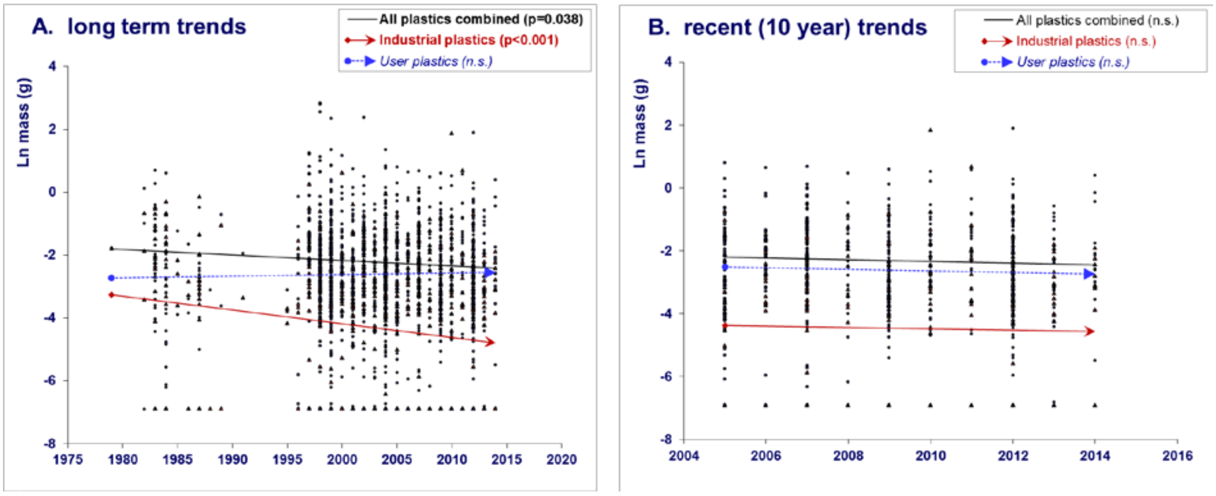
Tabel ii ***Lineaire regressie analyses van trends in hoeveelheid plastic in magen van Nederlandse Stormvogels op (A) de lange termijn en (B) recente 10-jaars periode.*** *Trends zijn gebaseerd op ln-getransformeerde plastic gewichten in magen van individuele vogels en het jaartal van verzamelen. De trend in EcoQO percentage is getoetst op basis van een simpele numerieke score voor vogels onder of boven de kritische grens van 0.1 gram plastic in de maag (0 onder; 1 boven).*

A. **LONG TERM TRENDS 1979-2014**
for plastics in Fulmar stomachs, the Netherlands

	n	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	*1010*	84.1	-0.0441	0.0100	-4.41	<.001	- - - ↓
User plastics (lnGUSE)	*1010*	-12.8	0.0051	0.0086	0.59	0.556	*n.s.*↑
All plastics combined (lnGPLA)	*1010*	32.6	-0.0174	0.0084	-2.07	0.038	- ↓
EcoQO performance (birds with >0.1g)	*1010*	11.9	-0.0056	0.0022	-2.52	0.012	- ↓

B. **RECENT 10-YEAR TRENDS 2005-2014**
for plastics in Fulmar stomachs, the Netherlands

	n	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	*398*	41.2	-0.0227	0.0406	-0.56	0.576	*n.s.*↓
User plastics (lnGUSE)	*398*	48.8	-0.0256	0.0349	-0.73	0.463	*n.s.*↓
All plastics combined (lnGPLA)	*398*	51.4	-0.0268	0.0345	-0.78	0.438	*n.s.*↓
EcoQO performance (birds with >0.1g)	*398*	17.5	-0.0084	0.0093	-0.90	0.367	*n.s.*↓

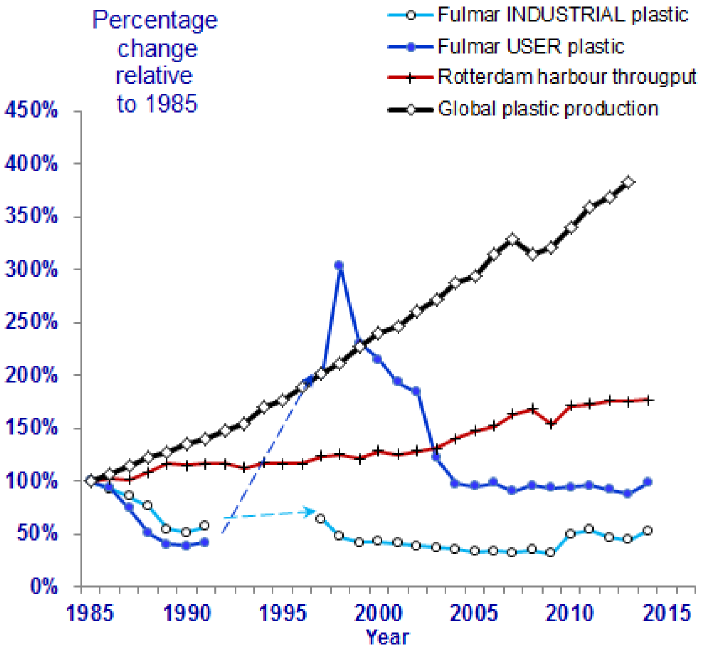


Figuur iii ***Lineaire regressie analyses van trends in hoeveelheid plastic in magen van Nederlandse Stormvogels 1979-2014 op (A) de lange termijn en (B) recente 10-jaars periode.*** *Trends zijn gebaseerd op ln-getransformeerde plastic gewichten in magen van individuele vogels en het jaartal van verzamelen. De trend in EcoQO percentage is getoetst op basis van een numerieke score voor onder of boven de kritische grens van 0.1 gram plastic in de maag (0 onder; 1 boven).*

Recente 10-jaar trend 2005-2014

De regressie analyses voor recente trends (***Tabel ii B*** en ***Figuur iii B***) tonen geen significante verandering over de 10-jaars periode 2005-2014. Significante verandering werd voor het laatst gezien in de periode 1997-2006. Nadien vertonen zowel industrieel als gebruiks-plastic geen significante verandering. Negatieve t-waardes voor alle toetsen in in ***Tabel ii B*** wijzen mogelijk op zeer langzame afnames maar de waardes zijn verre van significant.

Het is niet duidelijk welke factoren hebben geleid tot de sterke wisselingen in hoeveelheid gebruiksplastic en afname in industrieel plastic van de jaren 1980 tot de jaren 1990. Ten aanzien van gebruiksafval heeft een gedetailleerd onderzoek aan zwerfvuil op Texelse stranden in 2005 bevestigd dat het meeste vuil afkomstig was uit de Noordzee regio 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. Helaas heeft de specifiek op scheepsafval afgestemde EU Richtlijn 2000/59/EC voor Haven Ontvangst Voorzieningen sinds invoering in 2004 geen significante verbetering kunnen brengen in het Stormvogel EcoQO percentage in Nederland. 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 (***Figuur iv***). In die zin hebben beleidsmaatregelen, waaronder de EU Havenrichtlijn vermoedelijk bijgedragen aan een stabilisatie van plastic afval in de Nederlandse Noordzee. Op dit moment is het nog niet mogelijk om de effecten van meer recente ontwikkelingen te toetsen. Sterke media aandacht voor plastic zwerfvuil in zee (plastic soep, ophoping in oceanische maalstromen, microplastics) in recente jaren heeft het publieke en bedrijfsmatige bewustzijn rond de zwerfvuil problematiek sterk doen toenemen. De regelgeving voor afvalbehandeling in de scheepvaart (MARPOL Annex V) is met ingang van 2013 sterk verbeterd. Daarnaast worden maatregelen voorbereid voor de invulling van de Europese KaderRichtlijn Marien (2008/56/EC) en het bereiken van de daaronder vereiste ‘Goede MilieuToestand. De waarde voor plastics in stormvogelmagen in het jaar 2014 zijn minder positief dan die voor 2012 en 2013, maar vertegenwoordigen een kleine steekproef die de totaal conclusie van stabiliteit of op zijn best uiterst langzame verbetering niet aantasten.



Figuur iv ***Trendvergelijking*** *van wereldwijde plastic productie, scheepsvracht doorgevoerd in de Rotterdamse haven in verhouding tot trends in de hoeveelheid industrieel en gebruiks plastic in magen van Noordse Stormvogels (5-jaars gemiddeldes). Trends uitgedrukt als procentuele veranderingen ten opzichte van het jaar 1985.*

Foto: Industrieel plastic granulaat

Industrieel plastic granulaat van het Nederlandse strand. Deze korrels of 'pellets' zijn een half-fabricaat: de eerste vorm waarin plastics, i.h.a. uit aardolie, worden gemaakt. De korrels gaan naar verwerkende fabrieken die ze omsmelten waarbij allerlei hulpstoffen worden toegevoegd om de diverse gebruiksplastics te produceren. De pellets kunnen zowel in fabrieken als tijdens transport verloren gaan. Met een doorsnede van ca 4 a 5 mm vallen ze onder de zogenaamde 'micro-plastics' en worden geregeld door zeevogels gegeten.

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 57% van de stormvogels meer dan 0.1 gram plastic in de maag *(171 stormvogels 2010-2014: 93% heeft plastic in de maag, gemiddeld 32 stukjes en 0.34g).*

3. Lange termijn gegevens voor Nederland tonen een snelle toename van zwerfvuil vanaf de 1980er jaren tot midden jaren ’90, gevolgd door een vergelijkbaar snelle afname, maar daarna een stabilisatie.

4. Analyses van de recente 10 jaar (2005-2014) tonen geen significante verbeteringen.

5. De samenstelling van door stormvogels ingeslikt plastic is sinds de jaren 1980 wel sterk veranderd met een significant afgenomen deel industrieel plastic en een toegenomen deel gebruiksplastics.

6. Scheepvaart en visserij zijn nog steeds te beschouwen als belangrijkste bron van zwerfvuil in de Noordzee. Tegen de trends van toename in activiteiten op zee en gebruik van plastics, hebben gerichte beleidsmaatregelen zoals de EU Richtlijn voor Haven Ontvangst Voorzieningen waarschijnlijk bijgedragen aan de stabilisatie van de hoeveelheid zwerfafval, maar hebben niet geleid tot een afname. Verwacht mag worden dat recent toegenomen bewustzijn, verbetering van de regels voor scheepsafval in MARPOL, en maatregelen voor de Europese KaderRichtlijn Marien een positieve uitwerking zullen hebben, maar deze zijn op dit moment nog niet aantoonbaar.

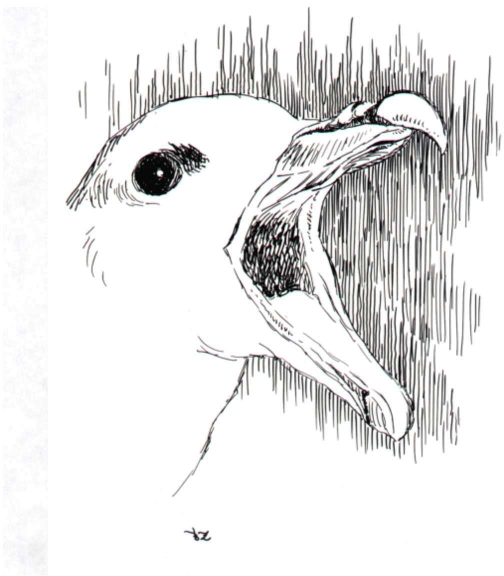


Photo: Fulmar in breeding condition

Somewhat unexpectd on coasts where no fulmars are found breeding: an emaciated female fulmar with a fully developed hardshelled egg in the oviduct. The bird was found by Arnold Gronert on the Hondsbossche Zeewering in the Netherlands in June 2014.

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 at 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 (Laist 1987, 1997; Derraik 2002; Kühn et al. 2015). 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 (Browne et al. 2015). Plastics gradually break down to microscopically small particles, but these may pose an even more serious problem (Thompson et al. 2004; Bergmann et al. 2014). Concern about microplastics is increasing as plastics strongly bind organic pollutants from the surrounding water and, although model predictions are not all in agreement, once ingested, have been found to release chemicals into marine organisms with associated negative effects (Arthur et al., 2009; Browne et al. 2008, 2013; Endo et al. 2005; 2013; Gouin et al. 2011; Koelmans et al. 2013a&b, 2014; Moore 2008; Teuten et al. 2007, 2009; ; Chua et al. 2014; Rochman et al. 2013, 2014a, 2014b; Tanaka et al. 2013; Thompson et al. 2009; Van Cauwenberghe & Janssen 2014). 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 adding to 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; Sebille 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 a revision of MARPOL Annex V (MEPC 2011) and the European Marine Strategy Framework Directive 2008/56/EC (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. As of 2010, updates of the fulmar monitoring reports have been commissioned by Rijkswaterstaat (RWS Water, Traffic and Living Environment RWS-WVL).

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 wide updates in reports (Van Franeker & the SNS Fulmar Study Group 2013), including peer reviewed scientific publications on the EcoQO methods with data up to 2007 (Van Franeker *et al. 2011*) and 2012 (Van Franeker & Law 2015). 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), Svalbard (Trevail et al. 2015), Atlantic Canada (Bond et al. 2014) , 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; Donnelly et al. 2014), 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. 2013; Foekema et al. 2013). Currently there is no funding dedicated to international coordination and integrated data analysis and reporting.

The current assignment from the Dutch Ministry of Infrastructure and the Environment (I&M), through its section Rijkswaterstaat Water, Traffic and Living Environment RWS-WVL included:

- Update of the Dutch time series on litter in stomachs of fulmars with the data of year 2014
- Continued co-ordination of the beached Fulmar sampling in the Netherlands

It was further agreed to provide a digital table containing:

- the basic data on individual birds underlying analyses back to year 2000 for RWS CIV (Centrale Informatie Voorziening, Lelystad) or via CIV to third parties like OSPAR.

Not formally under this contract, but an unavoidable side task developed during the writing of an JAMP-CEMP Guidelines for the Fulmar monitoring program. In this, CIV and OSPAR demanded the addition of an AreaCode system plus associated latitutude-longitude data to the data table. This had to be developed in consultation with North Sea partners, and required restructuring of forms, data entry programs and databases. Much of this is still ongoing.

2. Marine litter and policy measures

In historic times, waste products from ships and coastal communities were often discarded at sea or along the coast. The low intensity and degradable nature of wastes allowed such practices to continue for centuries without significant problems except maybe inside harbours. However, exponential population growth and global industrialization has boosted the amounts of debris generated of often poorly or non-degradable materials, in particular plastics.

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 2013, the world production of plastics reached almost 300 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 2015). Recently it has been estimated that annually 4.8 to 12.7 million tonnes are lost from global land-based sources to the marine environment (Jambeck et al. 2015).

Litter in the marine evironment originates from a variety of sources, including merchant shipping, fisheries, offshore industry, recreational boating, coastal tourism, influx from rivers, sewage outflows, or direct dumping of wastes at sea or along seashores. Coastal dumping of debris was common practise in many areas of northwestern Europe during the previous century. For example, in the 1950’s the city of Den Helder in the Netherlands operated dedicated ships to dispose of municipal waste at sea. But most of such dumpings in western Europe have stopped tens of years ago. Also sewage treatment systems and risk for overflow during periods of excessive rain have strongly improved in our region. The relative importance of various sources differs strongly in different parts of the world, and is almost impossible to quantify in detail. As for the Netherlands, 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. More recent analyses of OSPAR beach survey data have not yet ventured in new estimates of proportional roles of sources (Schulz et al. 2013; Dagevos et al. 2013). A lot of attention is being given to touristic sources of debris on beaches and consumer behaviour in general.

In spite of the uncertainties in details, there is little doubt that waste disposal by ships is one of the important remaining sources of marine litter around the North Sea and worldwide, a fact also recognized by the International Maritime Organization (IMO) in its stepwise strengthening of the 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.

Unfortunately, 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.

Finally, MARPOL Annex V was recently revised by the Marine Environment Protection Committee (MEPC 2011). The important change is that the former approach of '*waste disposal ate sea is allowed except …….*' has been replace by an approach of '*waste disposal is forbidden except …*'. Under the new regulations, entering into force on 1 January 2013, nearly all waste disposal is thus 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.

The EU Marine Strategy Framework Directive (MSFD) (EC 2008, 2010; Galgani et al. 2010; MSFD GES Technical Subgroup on Marine Litter 2011) is a promising instrument for development of new policies. The MSFD aims for 'Good Environmental Status (GES)' in which regionally important sources of debris need to be specifically addressed. A start was made in the OSPAR Regional Action Plan (OSPAR 2014) which does not yet specify a target for fulmar plastic ingestion by the year 2020 in relation to GES.

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 reflectthe 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 concern on 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 and funding 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 2013) 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). Currently formal guidelines and assessment methods are being prepared.

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; Trevail et al. 2015; Van Franeker & Law 2015) and is used by researchers in the Canadian Atlantic and arctic and in the Pacific (Mallory 2008; Provencher et al. 2009; Nevins et al. 2011; Avery-Gomm et al. 2012; Donnelly et al. 2014; Bond et al. 2015). 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.

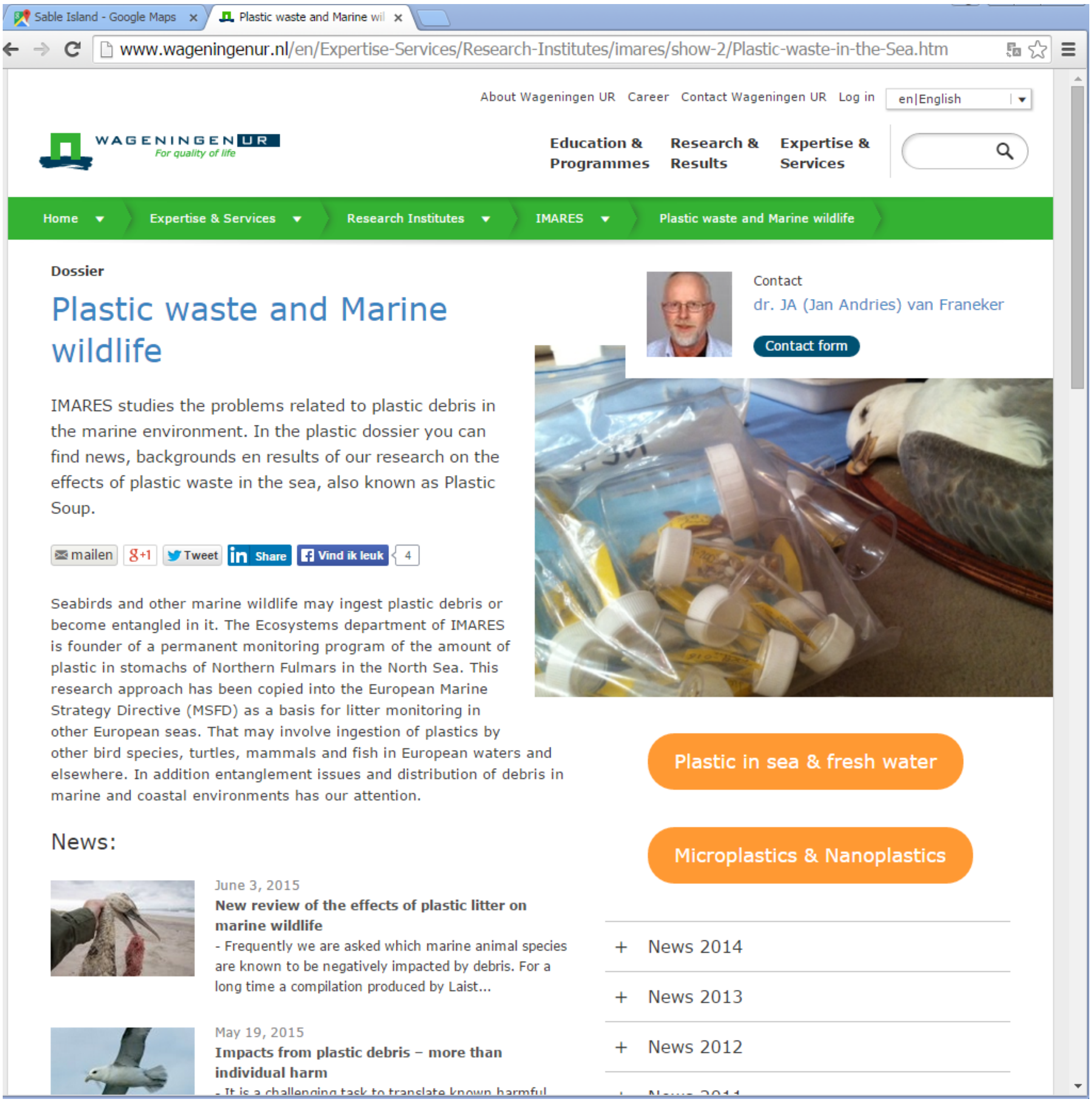


Photo: Outreach

In the Fulmar monitoring project, we aim to disseminate knowledge widely and promote participation. Through a web-dossier ***www.wageninenur.nl/plastics-fulmars*** *we inform general public, policy makers, scientific colleagues and volunteers involved in the program on our achievements and important developments.*

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. 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 has co-ordinated 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. Lack of funding currently threathens continuation of international coordination and integrated data analysis and reporting.

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; Van Franeker & Law 2015).

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 ideally used for plastics and other rubbish found in the stomachs, with acronyms between parentheses. However, please note that for financial efficiency in OSPAR EcoQO monitoring, the required dataset has been restricted to just categories 1.1 (Industrial Plastics) and 1.2 (User Plastics) without further subcatecories (JAMP-CEMP Guidelines in prep).

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 (foam)**, as in foamed polystyrene cups or packaging or foamed polyurethane in matrasses or construction foams;
     - 1.2.4. **fragments (frag)** 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 (poth)**, 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 (rubvar)** is used for e.g. pieces of timber (manufactured wood); paint chips, pieces of metals etc.;
   2.4. **fish hook (hook)** 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. Geometric mean is calculated as the average of logarithmically transformed data values, which is then back calculated to the normal arithmetic equivalent. 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: at work in the dissection lab. *Foreign colleagues regularly visit the IMARES labs to cooperate in fulmar research projects (author and Kosuke Tanaka from Tokyo University Japan)*

5. Results & Discussion

Monitoring in the Netherlands 1979-2014 and trends

With only 11 intact fulmar stomachs collected in 2014, our sample size was well under the desired annual sample of around 40 birds (Van Franeker & Meijboom 2002). 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 2012 and 2013, plastic abundance in the fulmar stomachs was relatively low, with average plastic mass 0.30 and 0.18 grams and EcoQO performance under 50%; the small 2014 sample did not really follow this trend with average mass per stomach 0.38 grams and 82% of birds exceeding the 0.1g EcoQO mass level (Tables 1 and 2) but this cannot lead to any conclusions due to the very small sample. Current levels for the Netherlands (2009-2013). Focus should be on the 5 year period described below.

Because of occasional years of low sample size and incidental variability the 'current pollution level' on the basis of average stomach contents over the most recent 5 years, the period also used in the OSPAR EcoQO target definition.

- **Current 5 year data for the 2010-2014 period (Table 1b) for the Dutch coast are that 93% in a sample of 171 beached fulmars had plastic debris in the stomach, in an average number of 32 particles and mass of 0.34 gram. The critical EcoQO value of 0.1 gram plastic is currently exceeded by 57% of the birds (Table 3B)**

In the past 3 years, the number of industrial plastic granules returned to the level of 2009 and before. Exceptional outliers affected the averages for 2010 and 2011, and even increased the 5-year figures for industrial plastics (Table 2A, and 3A; Fig. 2B).

Photo ***Average stomach content*** **-** *Plastics from the stomach content of Fulmar NET-2014-002, with a variety of categories. Top row from left to right shows industrial granules, foamed particles and a bundle of conglomerated threadlike materials; In the bottom row, the left group shows hard plastic fragments, and the right hand group sheetlike plastics. With an overall number of 2 industrial pellets, and 24 user plastic particles, all together weighing 0.26 gram, this birds is slightly below the Dutch current average for contents of plastics in the stomach.*

Table 1 *Summary of sample characteristics and stomach contents of fulmars collected for Dutch marine litter monitoring in a) the year 2014 and b) the current 5-year period 2010-2014. The top line in each 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). 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 2014

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2014	**11**	**60%**	**40%**	**100%**	**0%**	**1.2**	

		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%**	**22.6 ± 4.026**	**0.379 ± 0.148**	**1.6**	**0.1831**
1.1	**INDUSTRIAL PLASTIC**	**73%**	**2.4 ± 0.866**	**0.049 ± 0.014**	**0.1**	**0.0183**
1.2	**USER PLASTIC**	**100%**	**20.3 ± 3.522**	**0.330 ± 0.142**	**1.5**	**0.1184**
1.2.1	sheets	55%	1.7 ± 0.662	0.002 ± 0.001	0.0	0.0008
1.2.2	threads	27%	0.3 ± 0.141	0.004 ± 0.003	0.0	0.0007
1.2.3	foamed	55%	4.2 ± 1.962	0.040 ± 0.037	0.4	0.0023
1.2.4	fragments	100%	14.0 ± 2.876	0.283 ± 0.116	1.1	0.1037
1.2.5	other plastic	9%	0.1 ± 0.091	0.001 ± 0.001	0.0	0.0002
2	**OTHER RUBBISH**	**0%**	**0.0 ± 0.000**	**0.000 ± 0.000**	**0.0**	**0.0000**
2.1	paper	0%	0.0 ± 0.000	0.000 ± 0.000	0.0	0.0000
2.2	kitchenwaste (food)	0%	0.0 ± 0.000	0.000 ± 0.000	0.0	0.0000
2.3	rubbish various	0%	0.0 ± 0.000	0.000 ± 0.000	0.0	0.0000
2.4	fishhook	0%	0.0 ± 0.000	0.000 ± 0.000	0.0	0.0000

b) 5-year period 2010-2014

	The Netherlands	nr of birds	adult	male	LL colour	death oil	avg condition	
	2010_14	**171**	**45%**	**44%**	**88%**	**1%**	**2.0**	

		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**	**93%**	**31.7 ± 4.337**	**0.337 ± 0.063**	**6.9**	**0.0939**
1.1	**INDUSTRIAL PLASTIC**	**61%**	**4.3 ± 1.694**	**0.095 ± 0.039**	**6.3**	**0.0107**
1.2	**USER PLASTIC**	**92%**	**27.4 ± 3.529**	**0.241 ± 0.044**	**6.6**	**0.0678**
1.2.1	sheets	58%	4.0 ± 0.635	0.014 ± 0.005	0.6	0.0022
1.2.2	threads	45%	1.4 ± 0.192	0.014 ± 0.004	0.6	0.0016
1.2.3	foamed	57%	7.0 ± 1.769	0.037 ± 0.010	1.1	0.0039
1.2.4	fragments	87%	14.6 ± 2.150	0.160 ± 0.035	5.5	0.0399
1.2.5	other plastic	21%	0.4 ± 0.134	0.016 ± 0.005	0.6	0.0011
2.0	**OTHER RUBBISH**	**25%**	**1.4 ± 0.446**	**0.084 ± 0.055**	**9.3**	**0.0014**
2.1	paper	2%	0.1 ± 0.058	0.006 ± 0.005	0.8	0.0001
2.2	kitchenwaste (food)	14%	1.0 ± 0.408	0.071 ± 0.055	9.3	0.0007
2.3	rubbish various	12%	0.3 ± 0.142	0.008 ± 0.004	0.6	0.0004
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 A. separate and B. 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. Mass data for total plastics are also shown in terms of geometric mean mass (for comparative purposes reducing the influence of outliers) and as 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. 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 (only years with samplesize over 10 birds printed in bold).*

Table 2A.

Netherlands		Industrial granules			User plastics		
YEAR	*sample n*	Inc. %	avg number n ± se	avg mass g ± se	Inc. %	avg number n ± se	avg mass g ± se
1979	*1*	100%	2.0	0.07	100%	3.0	0.17
1980	*0*						
1981	*0*						
1982	*3*	100%	5.0 ± 2.1	0.11 ± 0.04	67%	6.0 ± 3.2	0.50 ± 0.33
1983	***19***	**84%**	**8.8 ± 2.2**	**0.19 ± 0.04**	**89%**	**7.2 ± 1.8**	**0.31 ± 0.12**
1984	***20***	**70%**	**9.6 ± 2.6**	**0.19 ± 0.05**	**90%**	**8.4 ± 3.1**	**0.17 ± 0.09**
1985	*3*	100%	5.3 ± 1.2	0.14 ± 0.05	100%	5.0 ± 2.5	0.14 ± 0.08
1986	*4*	50%	0.8 ± 0.5	0.02 ± 0.01	75%	4.8 ± 1.7	0.06 ± 0.04
1987	***17***	**82%**	**3.9 ± 1.8**	**0.11 ± 0.05**	**71%**	**9.7 ± 2.7**	**0.09 ± 0.04**
1988	*1*	0%	0.0	0.00	100%	2.0	0.04
1989	*2*	50%	6.5 ± 6.5	0.17 ± 0.17	100%	6.0 ± 3.0	0.25 ± 0.23
1990	*0*						
1991	*1*	0%	0.0	0.00	100%	11.0	0.14
1992	*0*						
1993	*0*						
1994	*0*						
1995	*2*	100%	1.5 ± 0.5	0.02 ± 0.01	100%	3.5 ± 0.5	0.03 ± 0.01
1996	*8*	75%	2.9 ± 1.2	0.07 ± 0.03	100%	24.5 ± 13.7	0.19 ± 0.10
1997	***31***	**74%**	**5.9 ± 1.9**	**0.13 ± 0.04**	**97%**	**29.8 ± 6.8**	**0.60 ± 0.17**
1998	***74***	**69%**	**3.1 ± 0.5**	**0.07 ± 0.01**	**95%**	**25.9 ± 5.2**	**0.88 ± 0.35**
1999	***107***	**58%**	**3.4 ± 0.8**	**0.06 ± 0.01**	**97%**	**31.8 ± 5.7**	**0.38 ± 0.11**
2000	***38***	**61%**	**3.4 ± 1.8**	**0.08 ± 0.05**	**100%**	**18.6 ± 3.7**	**0.27 ± 0.09**
2001	***55***	**64%**	**2.5 ± 0.6**	**0.06 ± 0.01**	**96%**	**20.1 ± 3.8**	**0.18 ± 0.05**
2002	***56***	**68%**	**4.6 ± 0.8**	**0.09 ± 0.01**	**96%**	**47.2 ± 11.9**	**0.41 ± 0.19**
2003	***39***	**51%**	**2.3 ± 0.6**	**0.05 ± 0.01**	**92%**	**26.3 ± 6.9**	**0.12 ± 0.03**
2004	***131***	**54%**	**2.6 ± 0.4**	**0.06 ± 0.01**	**91%**	**20.8 ± 2.8**	**0.22 ± 0.04**
2005	***51***	**53%**	**2.0 ± 0.5**	**0.05 ± 0.01**	**96%**	**15.8 ± 2.7**	**0.22 ± 0.06**
2006	***27***	**78%**	**3.5 ± 0.7**	**0.08 ± 0.01**	**93%**	**30.4 ± 7.2**	**0.23 ± 0.07**
2007	***61***	**70%**	**3.1 ± 0.5**	**0.07 ± 0.01**	**90%**	**32.5 ± 5.6**	**0.30 ± 0.05**
2008	***20***	**65%**	**3.8 ± 1.2**	**0.08 ± 0.03**	**95%**	**40.8 ± 11.2**	**0.23 ± 0.08**
2009	***68***	**46%**	**1.7 ± 0.5**	**0.04 ± 0.01**	**96%**	**17.6 ± 3.2**	**0.18 ± 0.03**
2010	***36***	**58%**	**10.7 ± 7.7**	**0.23 ± 0.17**	**94%**	**45.7 ± 12.5**	**0.23 ± 0.06**
2011	***19***	**63%**	**6.6 ± 4.1**	**0.15 ± 0.10**	**95%**	**37.0 ± 10.4**	**0.27 ± 0.09**
2012	***81***	**59%**	**1.8 ± 0.3**	**0.04 ± 0.01**	**89%**	**18.8 ± 3.3**	**0.26 ± 0.08**
2013	***24***	**63%**	**2.2 ± 0.6**	**0.04 ± 0.01**	**92%**	**24.6 ± 7.9**	**0.14 ± 0.03**
2014	***11***	**73%**	**2.4 ± 0.9**	**0.05 ± 0.01**	**100%**	**20.3 ± 3.5**	**0.33 ± 0.14**

Table 2B.

Netherlands		Total plastics				
YEAR	*sample n*	Incidence %	average number n ± se	average mass g ± se	Geometric mean mass	EcoQO % *(over 0.1g)*
1979	*1*	100%	5.0	0.24		
1980	*0*					
1981	*0*					
1982	*3*	100%	11.0 ± 4.0	0.61 ± 0.34		
1983	***19***	**100%**	**16.0 ± 2.5**	**0.49 ± 0.13**	**0.284**	**89%**
1984	***20***	**90%**	**17.9 ± 5.5**	**0.35 ± 0.13**	**0.073**	**55%**
1985	*3*	100%	10.3 ± 1.5	0.28 ± 0.07		
1986	*4*	75%	5.5 ± 1.8	0.08 ± 0.05		
1987	***17***	**82%**	**13.6 ± 4.0**	**0.19 ± 0.08**	**0.056**	**59%**
1988	*1*	100%	2.0	0.04		
1989	*2*	100%	12.5 ± 9.5	0.43 ± 0.40		
1990	*0*					
1991	*1*	100%	11.0	0.14		
1992	*0*					
1993	*0*					
1994	*0*					
1995	*2*	100%	5.0 ± 1.0	0.06 ± 0.02		
1996	*8*	100%	27.4 ± 13.7	0.26 ± 0.11		
1997	***31***	**97%**	**35.8 ± 7.3**	**0.73 ± 0.17**	**0.298**	**84%**
1998	***74***	**96%**	**29.0 ± 5.3**	**0.95 ± 0.36**	**0.168**	**72%**
1999	***107***	**98%**	**35.3 ± 6.2**	**0.44 ± 0.11**	**0.123**	**61%**
2000	***38***	**100%**	**22.0 ± 5.2**	**0.35 ± 0.13**	**0.129**	**61%**
2001	***55***	**96%**	**22.7 ± 4.2**	**0.24 ± 0.05**	**0.088**	**49%**
2002	***56***	**98%**	**51.8 ± 12.5**	**0.50 ± 0.20**	**0.154**	**68%**
2003	***39***	**95%**	**28.5 ± 7.2**	**0.17 ± 0.03**	**0.068**	**54%**
2004	***131***	**91%**	**23.4 ± 3.0**	**0.27 ± 0.04**	**0.081**	**60%**
2005	***51***	**98%**	**17.8 ± 2.8**	**0.27 ± 0.06**	**0.089**	**47%**
2006	***27***	**93%**	**33.9 ± 7.6**	**0.30 ± 0.08**	**0.131**	**85%**
2007	***61***	**92%**	**35.6 ± 5.8**	**0.37 ± 0.05**	**0.129**	**70%**
2008	***20***	**95%**	**44.5 ± 12.3**	**0.31 ± 0.10**	**0.104**	**55%**
2009	***68***	**97%**	**19.3 ± 3.6**	**0.22 ± 0.04**	**0.084**	**46%**
2010	***36***	**94%**	**56.4 ± 16.3**	**0.46 ± 0.20**	**0.112**	**64%**
2011	***19***	**100%**	**43.6 ± 13.1**	**0.43 ± 0.19**	**0.183**	**79%**
2012	***81***	**90%**	**20.6 ± 3.4**	**0.30 ± 0.09**	**0.075**	**49%**
2013	***24***	**92%**	**26.8 ± 8.3**	**0.18 ± 0.04**	**0.067**	**46%**
2014	***11***	**100%**	**22.6 ± 4.0**	**0.38 ± 0.15**	**0.183**	**82%**

Table 3 ***Running averages by 5-year period for plastic abundance in fulmars from the Netherlands.*** *For A. separate and B. 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. Mass data for total plastics are also shown in terms of geometric mean mass (for comparative purposes reducing the influence of outliers) and as 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. Results not shown where sample size was 10 stomachs or less.*

Table 3A.

NETHERLANDS		Industrial granules			User plastics		
5-year period	*sample n*	Inc. %	avg number n ± se	avg mass g ± se	Inc. %	avg number n ± se	avg mass g ± se
1979_83	*23*	87%	8.0 ± 1.8	0.17 ± 0.04	87%	6.9 ± 1.5	0.32 ± 0.10
1980_84	*42*	79%	8.9 ± 1.6	0.18 ± 0.03	88%	7.7 ± 1.7	0.25 ± 0.07
1981_85	*45*	80%	8.6 ± 1.5	0.18 ± 0.03	89%	7.5 ± 1.6	0.25 ± 0.07
1982_86	*49*	78%	8.0 ± 1.4	0.17 ± 0.03	88%	7.3 ± 1.4	0.23 ± 0.06
1983_87	*63*	78%	7.0 ± 1.2	0.15 ± 0.02	84%	8.0 ± 1.3	0.18 ± 0.05
1984_88	*45*	73%	6.1 ± 1.4	0.14 ± 0.03	82%	8.2 ± 1.7	0.12 ± 0.04
1985_89	*27*	74%	3.6 ± 1.2	0.10 ± 0.03	78%	7.9 ± 1.8	0.10 ± 0.03
1986_90	*24*	71%	3.4 ± 1.4	0.09 ± 0.04	75%	8.3 ± 2.0	0.10 ± 0.03
1987_91	*21*	71%	3.8 ± 1.5	0.10 ± 0.04	76%	9.0 ± 2.3	0.10 ± 0.04
1988_92	*4*						
1989_93	*3*						
1990_94	*1*						
1991_95	*3*						
1992_96	*10*						
1993_97	*41*	76%	5.1 ± 1.5	0.12 ± 0.03	98%	27.5 ± 5.8	0.49 ± 0.13
1994_98	*115*	71%	3.8 ± 0.6	0.09 ± 0.01	96%	26.5 ± 3.9	0.74 ± 0.23
1995_99	*222*	65%	3.6 ± 0.5	0.07 ± 0.01	96%	29.1 ± 3.4	0.57 ± 0.13
1996_00	*258*	64%	3.6 ± 0.5	0.08 ± 0.01	97%	27.7 ± 3.0	0.53 ± 0.11
1997_01	*305*	64%	3.4 ± 0.4	0.07 ± 0.01	97%	26.4 ± 2.6	0.47 ± 0.10
1998_02	*330*	63%	3.4 ± 0.4	0.07 ± 0.01	97%	29.6 ± 3.1	0.45 ± 0.09
1999_03	*295*	60%	3.3 ± 0.4	0.07 ± 0.01	97%	30.1 ± 3.3	0.30 ± 0.06
2000_04	*319*	59%	3.0 ± 0.3	0.06 ± 0.01	94%	25.7 ± 2.7	0.24 ± 0.04
2001_05	*332*	58%	2.8 ± 0.3	0.06 ± 0.01	94%	25.0 ± 2.6	0.23 ± 0.04
2002_06	*304*	58%	2.9 ± 0.3	0.06 ± 0.01	93%	26.4 ± 2.8	0.24 ± 0.04
2003_07	*309*	59%	2.6 ± 0.2	0.06 ± 0.01	92%	23.8 ± 2.0	0.22 ± 0.02
2004_08	*290*	60%	2.8 ± 0.3	0.06 ± 0.01	92%	24.7 ± 2.1	0.24 ± 0.02
2005_09	*227*	59%	2.6 ± 0.3	0.06 ± 0.01	94%	24.8 ± 2.3	0.23 ± 0.02
2006_10	*212*	61%	4.1 ± 1.3	0.09 ± 0.03	93%	30.5 ± 3.2	0.23 ± 0.02
2007_11	*204*	59%	4.4 ± 1.4	0.10 ± 0.03	94%	31.1 ± 3.4	0.24 ± 0.02
2008_12	*224*	56%	3.8 ± 1.3	0.08 ± 0.03	93%	26.2 ± 2.9	0.23 ± 0.04
2009_13	*228*	56%	3.6 ± 1.3	0.08 ± 0.03	93%	24.8 ± 2.8	0.22 ± 0.03
2010_14	*171*	61%	4.3 ± 1.7	0.10 ± 0.04	92%	27.4 ± 3.5	0.24 ± 0.04

Table 3 B.

NETHERLANDS		Total plastics				
5-year period	*sample n*	Incidence %	average number n ± se	average mass g ± se	Geometric mean mass	EcoQO % *(over 0.1g)*
1979_83	*23*	**100%**	**14.9 ± 2.2**	**0.50 ± 0.11**	**0.298**	**91%**
1980_84	*42*	**95%**	**16.5 ± 2.9**	**0.43 ± 0.09**	**0.154**	**74%**
1981_85	*45*	**96%**	**16.1 ± 2.7**	**0.42 ± 0.08**	**0.159**	**76%**
1982_86	*49*	**94%**	**15.3 ± 2.5**	**0.40 ± 0.07**	**0.137**	**71%**
1983_87	*63*	**90%**	**15.0 ± 2.2**	**0.33 ± 0.06**	**0.102**	**67%**
1984_88	*45*	**87%**	**14.3 ± 2.9**	**0.26 ± 0.07**	**0.064**	**56%**
1985_89	*27*	**85%**	**11.5 ± 2.6**	**0.20 ± 0.06**	**0.063**	**56%**
1986_90	*24*	**83%**	**11.7 ± 3.0**	**0.19 ± 0.07**	**0.052**	**50%**
1987_91	*21*	**86%**	**12.8 ± 3.3**	**0.21 ± 0.07**	**0.063**	**57%**
1988_92	*4*					
1989_93	*3*					
1990_94	*1*					
1991_95	*3*					
1992_96	*10*					
1993_97	*41*	**98%**	**32.6 ± 6.1**	**0.61 ± 0.13**	**0.217**	**76%**
1994_98	*115*	**97%**	**30.3 ± 4.0**	**0.83 ± 0.23**	**0.184**	**73%**
1995_99	*222*	**97%**	**32.7 ± 3.7**	**0.64 ± 0.13**	**0.151**	**67%**
1996_00	*258*	**98%**	**31.3 ± 3.2**	**0.60 ± 0.12**	**0.149**	**67%**
1997_01	*305*	**97%**	**29.9 ± 2.8**	**0.55 ± 0.10**	**0.137**	**64%**
1998_02	*330*	**98%**	**33.0 ± 3.3**	**0.52 ± 0.10**	**0.130**	**62%**
1999_03	*295*	**98%**	**33.5 ± 3.6**	**0.37 ± 0.06**	**0.112**	**59%**
2000_04	*319*	**95%**	**28.7 ± 2.9**	**0.30 ± 0.04**	**0.095**	**59%**
2001_05	*332*	**95%**	**27.8 ± 2.7**	**0.29 ± 0.04**	**0.091**	**57%**
2002_06	*304*	**94%**	**29.3 ± 3.0**	**0.30 ± 0.04**	**0.094**	**61%**
2003_07	*309*	**93%**	**26.5 ± 2.1**	**0.28 ± 0.02**	**0.092**	**61%**
2004_08	*290*	**93%**	**27.4 ± 2.2**	**0.30 ± 0.03**	**0.096**	**62%**
2005_09	*227*	**95%**	**27.3 ± 2.5**	**0.29 ± 0.03**	**0.102**	**58%**
2006_10	*212*	**94%**	**34.5 ± 3.8**	**0.32 ± 0.04**	**0.107**	**62%**
2007_11	*204*	**95%**	**35.5 ± 4.0**	**0.33 ± 0.04**	**0.110**	**60%**
2008_12	*224*	**94%**	**30.0 ± 3.6**	**0.31 ± 0.05**	**0.092**	**54%**
2009_13	*228*	**94%**	**28.4 ± 3.4**	**0.30 ± 0.05**	**0.088**	**53%**
2010_14	*171*	**93%**	**31.7 ± 4.3**	**0.34 ± 0.06**	**0.094**	**57%**

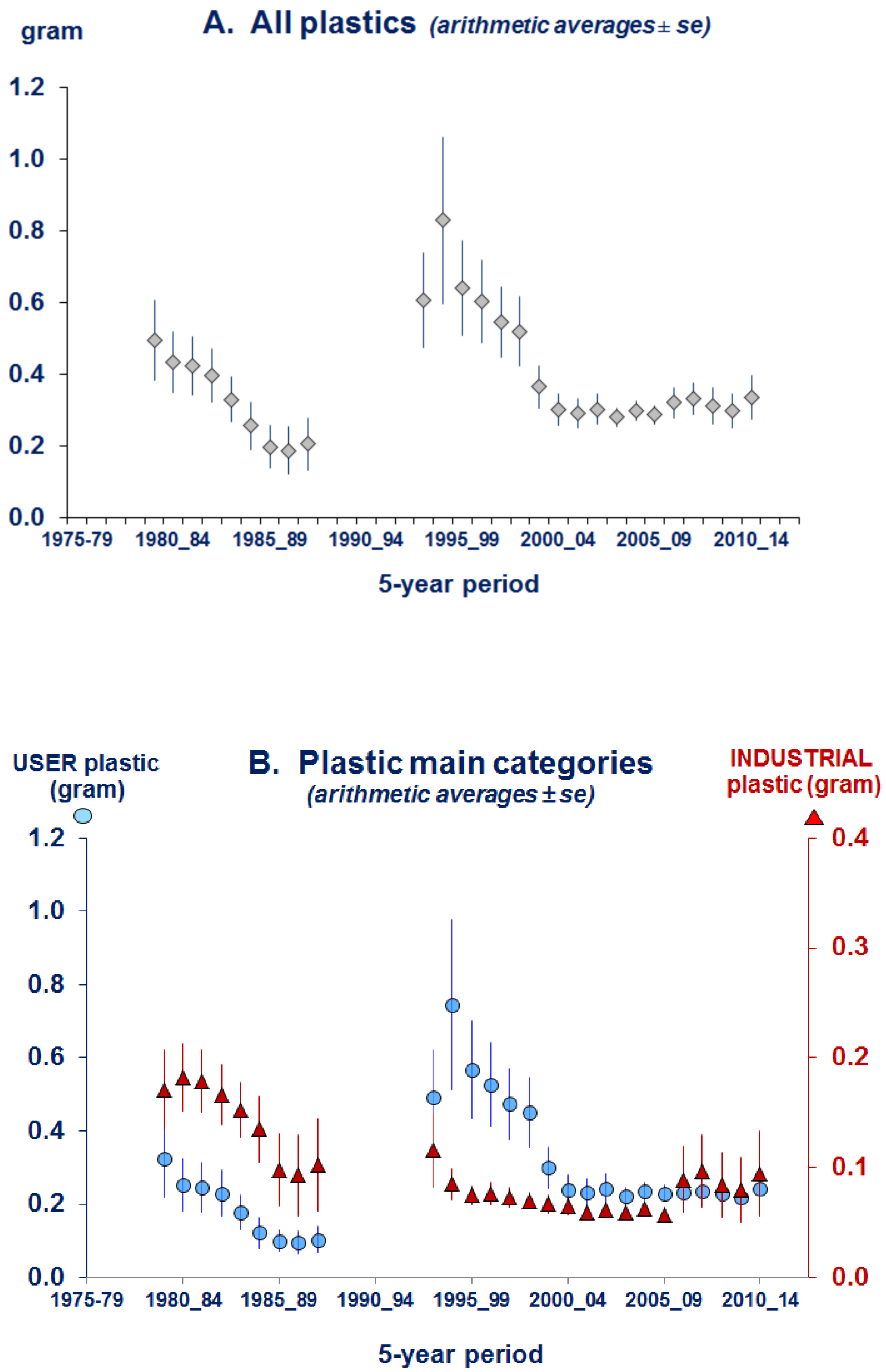


Figure 2 ***Plastic mass in stomachs of fulmars from the Netherlands 1980s-2014.*** *A: Data for all plastics combined; B: same data but split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average ± standard error for mass in running 5 year averages (i.e. data points shift one year ahead at a time).*

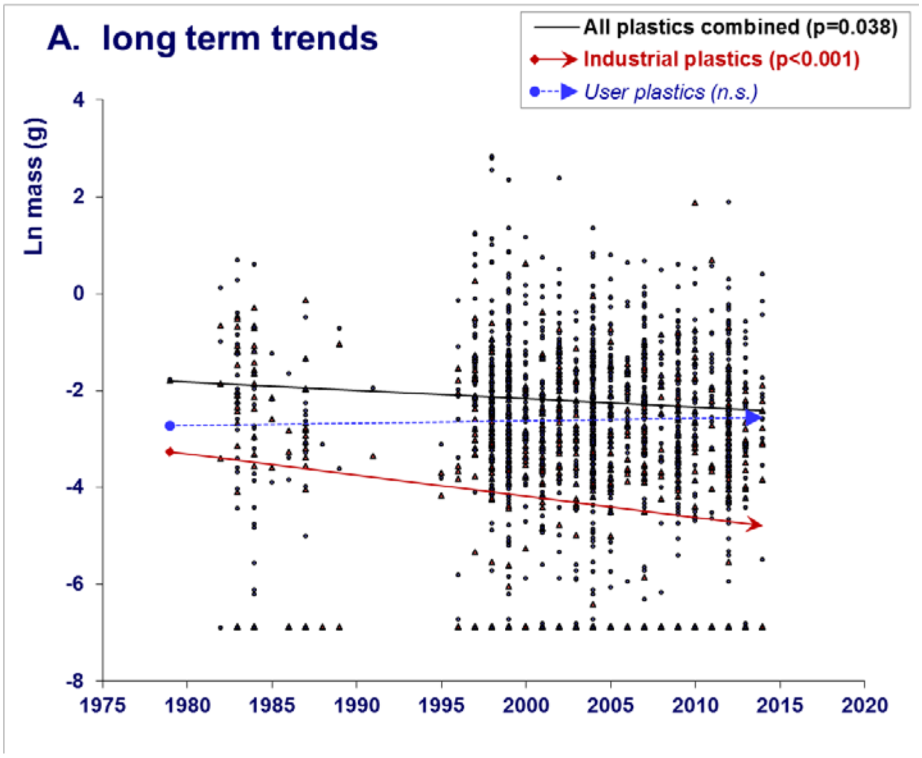
Table 4 ***Details of linear regression analyses for time related trends in plastic abundance by massin stomachs of fulmars in the Netherlands*** *. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over the full time period (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 1979-2014
for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
all ages	*1010*	84.1	-0.0441	0.0100	-4.41	<.001	- - - ↓
adults	*529*	67.5	-0.0360	0.0154	-2.33	0.020	- ↓
non adults	*458*	91.9	-0.0478	0.0132	-3.63	<.001	- - - ↓
User plastics (lnGUSE)	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
all ages	*1010*	-12.8	0.0051	0.0086	0.59	0.556	*n.s.* ↑
adults	*529*	1.6	-0.0022	0.0139	-0.16	0.872	*n.s.* ↓
non adults	*458*	-28.5	0.0131	0.0107	1.21	0.225	*n.s.* ↑
All plastics combined (lnGPLA)	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
all ages	*1010*	32.6	-0.0174	0.0084	-2.07	0.038	**-** ↓
adults	*529*	22.3	-0.0124	0.0137	-0.90	0.368	*n.s.* ↓
non adults	*458*	34.5	-0.0182	0.0101	-1.80	0.072	*n.s.* ↓
EcoQO performance (all ages)	*1010*	11.9	-0.0056	0.0022	-2.52	0.01	- ↓

B. RECENT 10-YEAR TRENDS 2005-2014
for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*398*	41.2	-0.0227	0.0406	-0.56	0.576	*n.s.* ↓
adults	*185*	114.0	-0.0591	0.0557	-1.06	0.290	*n.s.* ↓
non adults	*197*	12.0	-0.0082	0.0621	-0.13	0.895	*n.s.* ↓
User plastics (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*398*	48.8	-0.0256	0.0349	-0.73	0.463	*n.s.* ↓
adults	*185*	38.0	-0.0201	0.0534	-0.38	0.707	*n.s.* ↓
non adults	*197*	121.3	-0.0615	0.0465	-1.32	0.187	*n.s.* ↓
All plastics combined (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*398*	51.4	-0.0268	0.0345	-0.78	0.438	*n.s.* ↓
adults	*185*	41.0	-0.0217	0.0519	-0.42	0.676	*n.s.* ↓
non adults	*197*	112.2	-0.0569	0.0471	-1.21	0.229	*n.s.* ↓
EcoQO performance (all ages)	*398*	17.5	-0.0084	0.0093	-0.90	0.367	*n.s.* ↓



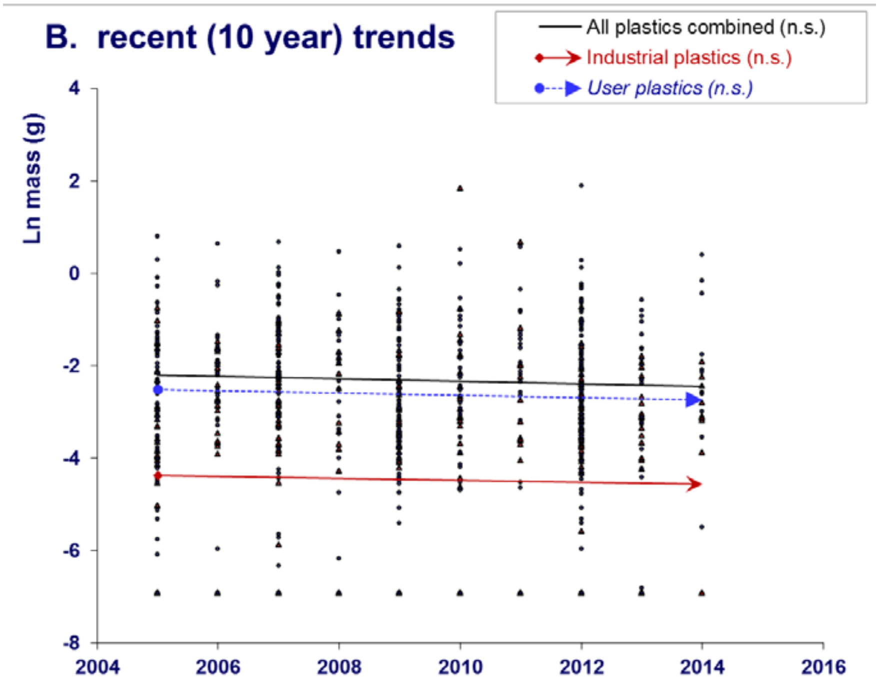


Figure 3 ***Statistical trends in plastic mass in stomachs of fulmars from the Netherlands 1979-2014.*** *Graphs show plotted ln-transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for industrial (lower, red line), 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.*

5.1. 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:

- **'long-term trend'** defined as the trend over all years in the dataset (now 1979-2014).

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 when user plastics nearly 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 (Table 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; Van Franeker & Law 2015). 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. For user plastics the long term trend shows no change. However, due to the decrease in industrial plastic, the long-term trend for all plastics combined is a weakly significant reduction ($p=0.021$). In terms of EcoQO performance, the decrease is even clearer ($p=0.005$).

- **'recent trend'** defined as trend over the past 10 years (now: 2005-2014)

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. However, years 2012 and 2013 were both relatively low in levels of ingested plastics compared to earlier years for industrial as well as user plastics. The decreases are strong enough to also visibly influence the 5-year averages even though the small 2014 sample did not fit the downwared pattern. This is especially true for metrics that reduce the influence of outliers, such as the geometric mean mass and EcoQO performance (Table 3B).

Younger fulmars (the 'non-adult' category which includes both juveniles and immatures up to several years of age), have consistently higher levels of ingested plastics than adult birds. Nevertheless, in EcoQO monitoring, all age groups are combined on the assumption that in the long term, there will be no major directional change in the age-composition of beached birds. Fig. 4 illustrates age related variations in our monitoring data: in geometric means, the persistent difference in plastic loads between adults and non-adults is very clear: both age groups follow, at a different level, a very similar pattern, which strengthens the validity of the monitoring approach. The graph shows a drop over the three most recent running 5-year averages in both age groups. These changes are not yet evidenced in the statistical tests, but may suggest a change for the good.

Photo: *Fulmar EcoQO Monitoring around the North Sea is based on beached fulmars collected by volunteers.*

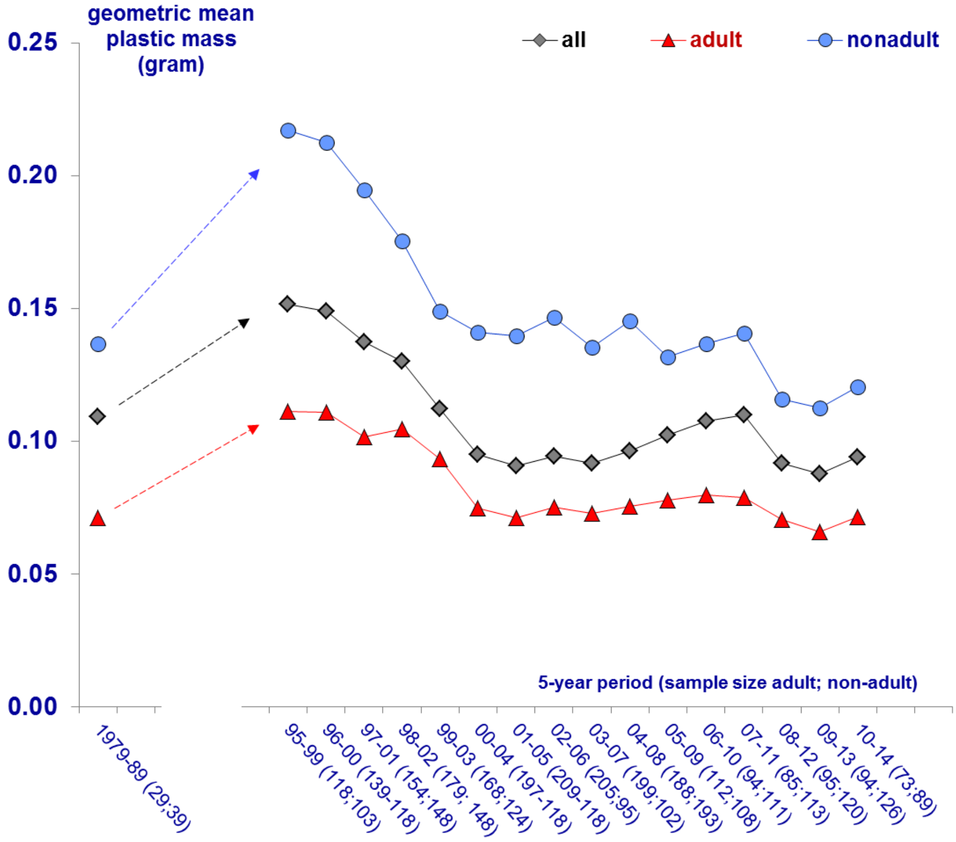


Figure 4 ***Geometric mean mass of plastics in stomachs of beached fulmars from the Netherlands 1979-2014*** *for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults, with respective sample sizes in brackets in the x-axis labels. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trend-line in the summary.*

5.2. 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 arithmetic averages versus geometric means 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. However, at that scale of the axis the graph insufficiently shows the smaller changes since the mid 1990's. Therefore, the same data are displayed at a finer scale in Fig. 5B showing much of the same patterns also seen in Fig's 2A and 4: fairly rapid decreases in the proportion of birds exceeding 0.1 gram level in the 1980s, increased pollution by mid-1990s, followed by an initially clear decrease that however slowed down and became more erratic in the 21st century. Over the integrated recent 5-year period 2010-2014, 57% of Dutch fulmars exceed the 0.1 gram critical EcoQO level, which is not as good as the previous two periods (Van Franeker et al. 2014), but still relatively low in the overall series.

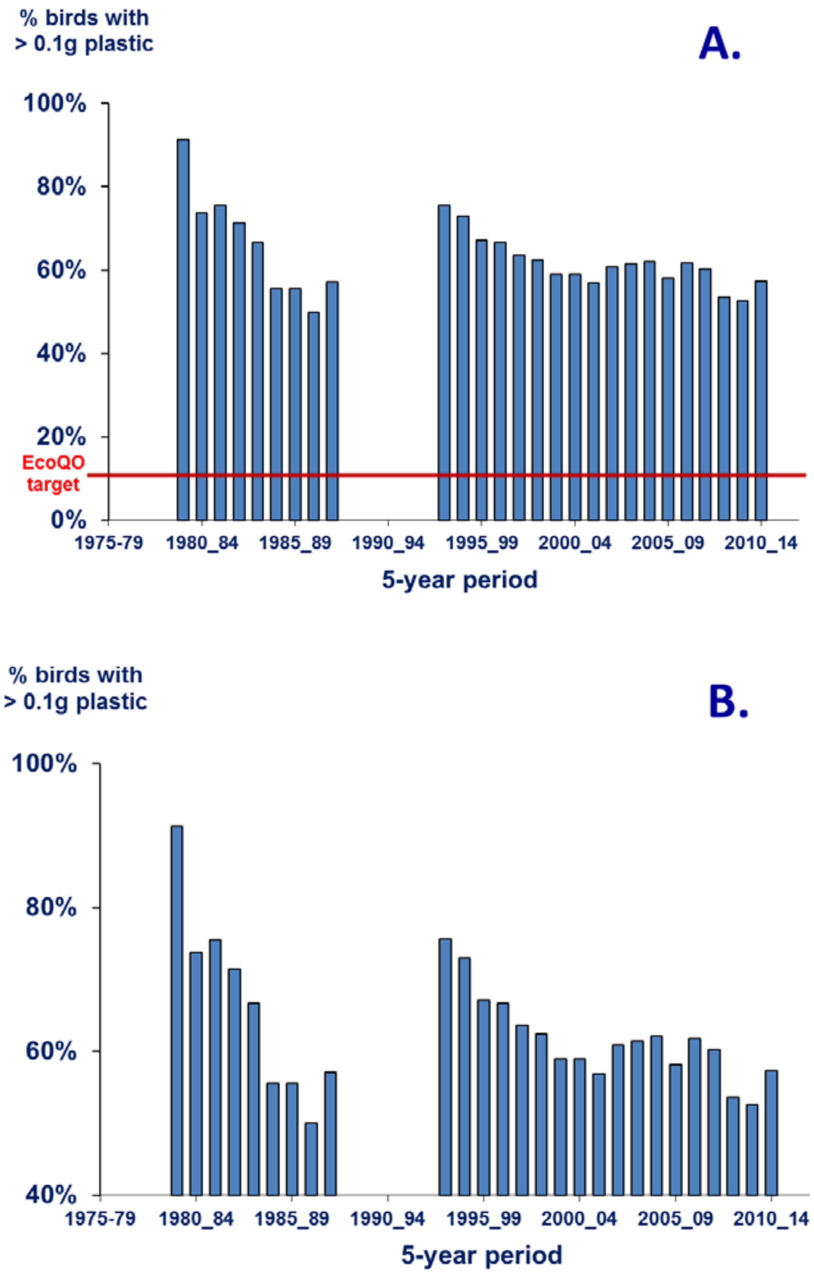


Figure 5 ***EcoQO performance of fulmars in the Netherlands*** *over running 5-year periods; graphs A and B show the same data. Fig A illustrates the distance from the OSPAR EcoQO target to reduce the percentage of birds with more than 0.1 gram of plastic in the stomach to below 10%. Fig B. provides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

As already indicated in our earlier OSPAR EcoQO reports, the interpretation of results of fulmar EcoQO monitoring should take into account that activities in the marine environment and the proportional use of plastic consumer goods have strongly increased. Fig. 6 illustrates trends in plastic production and shipping activity in comparison to the abundance of industrial and user plastics in stomachs of fulmars. Abundance of industrial plastics ingested by fulmars has been reduced while production and transport strongly increased. Ingested user plastics have shown erratic changes since the 1980s, but overall are now similar to levels observed almost 30 years ago. Even though the graphs in Fig. 6 should not be viewed proportionally, they do indicate that lack of improvement in EcoQO performance does not necessarily means that policy measures like various MARPOL regulations and the EU Directive on Port Reception Facilities have been without effect (Trouwborst 2011).

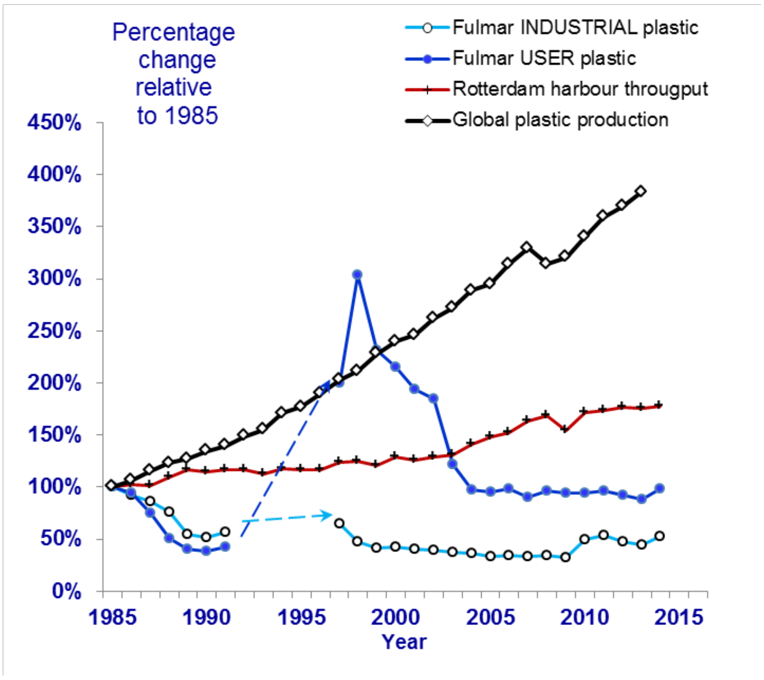


Figure 6 ***Comparative Trends*** *in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars (5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985.*

5.3. Conclusion

Stomach contents of fulmars in the Netherlands indicate that the marine litter situation off the Dutch coast over the last decade is stable or at best very slowly improving at insignificant rate. EcoQO performance, that is the proportion of fulmars exceeding the critical value of 0.1 gram of plastic in the stomach, is currently 57%, where OSPAR and Europe are aiming at a reduction of this figure to below 10%. At this stage it is unclear if recently increased awareness among public and stakeholders, the revision of MARPOL Annex V, and the start of policies towards good environmental status within the EU MSFD will be sufficient for a timely compliance with policy targets.

6. Acknowledgements

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Beached fulmars are mainly collected by volunteers without whom a project such as this is totally impossible. Below is a list of beach surveyors that contributed fulmars found. If people find that their name or group is listed incorrectly, or worse, not al all, our sincere apologies and please take up contact.

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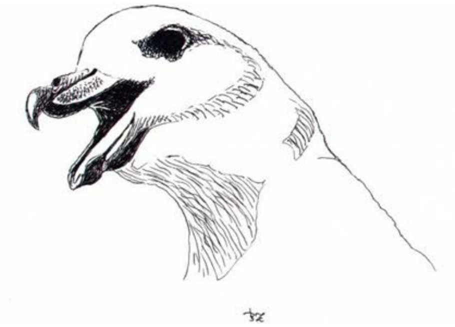
Relevant websites

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: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.



9. Justification

Report number : C123/15
Project number : IMARES 431 21000 11 Fulmar_EcoQO_NL2014

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

Approved : Edwin Foekema
Research scientist

Signature:

Date: 15 sep 2015

Approved: Jakob Asjes
Head of Department

Signature:

Date: 15-sep-2015