
Fulmar Litter EcoQO monitoring in the Netherlands - Update 2015



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Photo: *Beached Northern Fulmar.* Not all fulmars found on beaches can be used for the monitoring of their stomach contents. Intestines of this beached fulmar had been scavenged by likely gulls and crows. As over 90% of fulmars have plastic in the stomach, there is a high likelihood that the scavengers have indirectly ingested plastics.

Summary

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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 species, 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 centimetres, 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). This 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). International guidelines on the monitoring methods and data presentation have been published (OSPAR 2015a,b).

OSPAR has identified a long term (undated) target for acceptable ecological conditions 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".*

The European MSFD uses a short term target date for Good Environmental Status by the year 2020, and different countries may therefore define an MSFD target for ingested plastics differently. For European 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 accidentally 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 in the same area. Standard procedures for dissection and stomach analyses have been documented in a manual, reports, scientific literature and condensed OSPAR guidelines. 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 or prevalence** – The percentage of birds having plastic in the stomach (% 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 facilitate comparison between smaller samples. To include zero values in the geometric 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 long term 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.
- **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 1979-2015 for the Netherlands) and the 'recent trend', which is defined as the trend over the past 10 years (now: 2006-2015).

Update of monitoring data for the Netherlands

This report adds new data for year 2015 to earlier updates (Van Franeker et al. 2015). The sample size of 22 stomachs of Dutch beached fulmar corpses was an improvement to the previous year, but was still below the desired annual sample. One further sample could be added to earlier years. Our program aims for an annual sample size of ±40 birds or more. A smaller annual sample is not a problem for the monitoring system, as the 'current' situation is calculated from 5 years of data (159 birds) and trend analyses use a minimum of 10 years of data (372 birds). Annual data and the most recent pooled 5-year details are summarized in *Table i*.

- Current data for the Netherlands (years 2011 to 2015; 159 fulmars) are that 93% of fulmars had plastic in the stomach. The average number of items per stomach was 23 particles with a mass of 0.29 gram. The critical EcoQO value of 0.1 gram plastic was exceeded by 53% 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.*

Year	n	INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (ind+user)			EcoQO
		%	n	g	%	n	g	%	n	g	
2015	22	45%	1.1	0.02	91%	10.8	0.24	95%	12.0	0.26	36%
period											
2011_15	159	59%	2.4	0.05	91%	20.6	0.24	93%	23.0	0.29	53%



Photo: *Fulmar stomach content* On average, present day beached fulmars have only 2 to 3 industrial plastic pellets in their stomach, and approximately five times as much mass of plastic consumer debris. But stomach contents are highly variable and the photo shows stomach contents of a fulmar that had ingested 13 pellets and a roughly similar amount of various fragments.

Long-term trend 1979-2015

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 53% of fulmars exceeding the 0.1 gram threshold is an improvement compared to the previous 5-year period. EcoQO performance is slowly but significantly improving both over the long term data ($p=0.003$) and over the recent 10-year period ($p=0.002$) (*Table ii*).

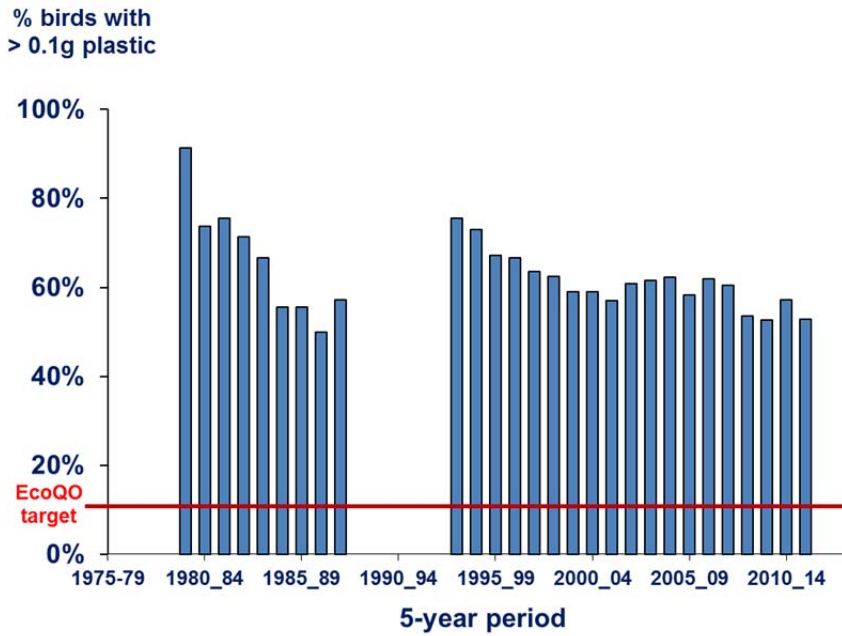


Figure i *EcoQO performance among fulmars from the Netherlands 1979-2015. Data are shown by annually updated 5 year performances (i.e. data points shift one year ahead at a time). Data for early 1990s not shown because of small sample size (≤ 10). This graphic visualization does not represent a statistical trend analysis.*

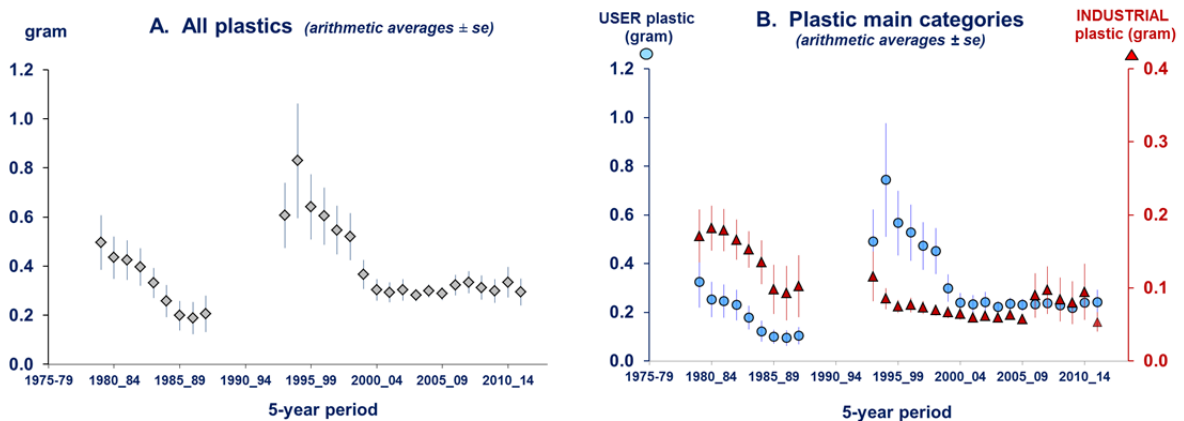


Figure ii *Plastic mass in stomachs of fulmars from the Netherlands 1979-2015 A: all plastics combined (grey diamonds) and B: user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average \pm standard error for mass for running 5 year 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 average 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 aberrations 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 ($p<0.001$) and a moderately continued significance over the most recent decade ($p=0.015$). 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 both North and South Atlantic oceans. Thanks to the long term decrease in industrial plastics, also the long term trendline for total plastic is significantly downwards ($p=0.015$), as is the simple EcoQO trend ($p=0.003$).

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 0.1 gram threshold level (0 below; 1 above).*

A.	LONG TERM TRENDS 1979-2015						
	for plastics in Fulmar stomachs, the Netherlands						
	<i>n</i>	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	1035	87.7	-0.0459	0.0097	-4.76	<.001	--- ↓
User plastics (lnGUSE)	1035	-5.0	0.0012	0.0083	0.14	0.889	n.s.
All plastics combined (lnGPLA)	1035	37.1	-0.0196	0.0081	-2.43	0.015	- ↓
EcoQO performance (birds with >0.1g)	1035	13.7	-0.0065	0.0022	-3.01	0.003	-- ↓

B.	RECENT 10-YEAR TRENDS 2006-2015						
	for plastics in Fulmar stomachs, the Netherlands						
	<i>n</i>	constant	slope	s.e.	t	p	
Industrial plastics (lnGIND)	372	208.3	-0.1059	0.0431	-2.45	0.015	- ↓
User plastics (lnGUSE)	372	147.5	-0.0747	0.0376	-1.99	0.047	- ↓
All plastics combined (lnGPLA)	372	137.9	-0.0697	0.0372	-1.88	0.062	n.s. ↓
EcoQO performance (birds with >0.1g)	372	63.3	-0.0312	0.0099	-3.16	0.002	-- ↓

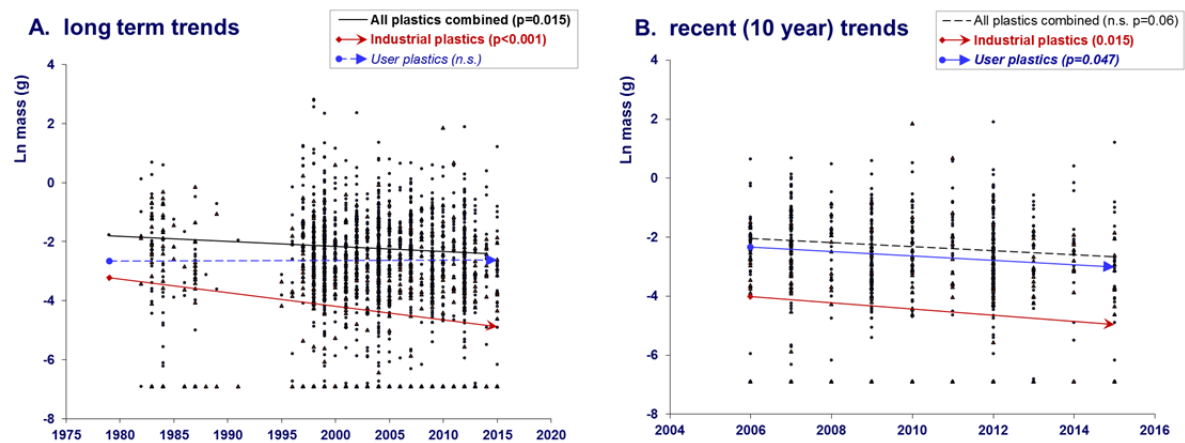


Figure iii Trends in plastic mass in stomachs of fulmars from the Netherlands 1979-2015, for (A) long-term and (B) recent 10-year data series. Graphs show \ln transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for 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 2006-2015

The recent 10-year changes ([Table ii B](#);

[Figure iii B](#)) are hopeful for an improving environmental situation. In the previous (update 2014) report, it was already noted that although none of the 2005-2014 trends was then significant, all indicators suggested that the direction of change (negative t values) was towards a cleaner environment. The current analyses confirm this, as the 2006-2015 trends for both mass of industrial- ($p=0.015$) and user plastics ($p=0.047$) are now demonstrating a statistically significant reduction ([Table ii B](#)). The reduction in their combined mass is nearly significant ($p=0.062$). The simple EcoQO performance also indicates significant improvement.

It is difficult to pinpoint specific events that triggered the strong increase in consumer plastics and simultaneous decrease in industrial plastics from the 1980s to the 1990s, nor can we identify a clear background for the subsequent decrease in user debris. In earlier reports, no significant changes were observed in the fulmar monitoring approach since the early 2000s, at best weak patterns of reduction. But now, in the 2006-2015 analysis, for the first time a gradual but statistically significant reduction in both industrial and user plastics in fulmar stomachs can be demonstrated. High media attention raised for the 'Pacific garbage patch' and 'plastic soup' started in the early 2000s. That likely has led to increased awareness, with associated policies and actions by authorities, industry and general public gradually taking effect. Developments are underway for implementation of the European Marine Strategy Directive (2008/56/EC) and its requirements towards Good Environmental Status. To evaluate the changes observed so far, the slow reduction in the ingested quantities of plastics in fulmar stomachs is best viewed in the light of strong and continuing increases in shipping traffic and the proportion of plastics in wastes ([Figure iv](#)).

CONCLUSIONS

1. Over the period 2011-2015, among 159 fulmars beached in the Netherlands, 93% contained plastic, on average 23 particles per stomach, weighing 0.29 gram. In this sample, 53% of the birds had more than 0.1 gram plastic in the stomach whereas North Sea governments aim at a long term OSPAR Ecological Quality Objective (EcoQO) of less than 10% of such birds.
2. Trend analyses over the past ten years (2006-2015) show a modest, but statistically significant decrease in mass of ingested plastics in both industrial granulate and consumer waste in stomachs of fulmar beached in the Netherlands.
3. It is not possible to pinpoint a clear cause for the observed change. Increased awareness among all stake-holders may lead to gradually improved policy measures and implementation by marine industries and general public.

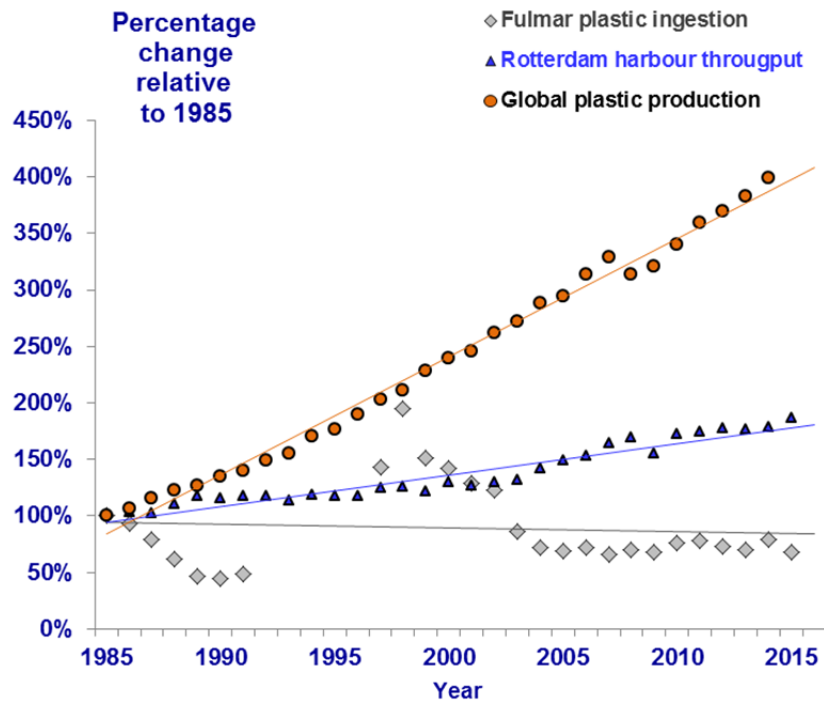


Figure iv Comparative trends in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of plastics in stomachs of fulmars (5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985. (Source: Port of Rotterdam, 2016)



photo: *Symbols of growing awareness.* In recent years, on beaches of Texel, increasing numbers of tourists pick up marine debris from the beach and deposit it near the beach access points to be collected by the municipality. In part, these accumulations are used by creative people to build marine-litter-art, in this case a modern variation of the famous ghost ship 'The Flying Dutchman'.

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 large study along the full 30 km coast length of 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 was 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 & Mouat 2009; Mouat et al. 2010; Newman et al. 2015).

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 species 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 caused by 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. 2015). Concern about microplastics is increasing as plastics strongly bind organic pollutants from the surrounding water and, although experimental results and 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; Cole et al. 2015; Watts et al. 2015; Peda et al. 2016). Thus, in addition to the toxic substances incorporated into plastics in the manufacturing process, plastics may concentrate 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 (Hauser et al. 2015; Hunt et al. 2016). 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; Van Sebille et al. 2012; Van Sebille et al. 2015).

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 (EcoQOs) (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, 2015a,b). 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 (Wageningen Marine Research) working towards a Fulmar-Litter-EcoQO. The first pilot project for the North Sea Directorate of I&M 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 IIB 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 by 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 Ireland (Acampora et al. 2016), 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 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 2015
- Continued co-ordination of the beached fulmar sampling in the Netherlands.

It was further agreed to provide:

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

Not formally under this contract, but an unavoidable side task developed during the writing of a JAMP-CEMP Guidelines for the Fulmar monitoring program, was the addition of an AreaCode system plus associated latitude-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.

2 Marine litter and policy measures

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 2014, the world production of plastics reached a new height of 311 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 of plastics are lost from global land-based sources to the marine environment (Jambeck et al. 2015).

Litter in the marine environment 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 north-western Europe during the previous century. For example, in the 1950s 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 the western European 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 from 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 contained the following main prohibitions for discharge of solid wastes:

- No discharge of plastics.
- No discharge of buoyant dunnage, 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; Trouwborst 2011; 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 at sea is allowed except*' has been replaced 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 it 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%'. The 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 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 strongly developing instrument for initiation 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 as published in earlier reports and peer reviewed literature (Van Franeker et al. 2011; Van Franeker & Law 2015).

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 numbers of birds from the years in between.

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

- Fulmars are abundant in the North Sea area (and elsewhere) and are regularly found in beached bird surveys, which guarantee 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), subsequent peer reviewed publications (Van Franeker et al. 2011; Van Franeker & Law 2015) and OSPAR Guidelines (OSPAR 2015a,b).

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 errors 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 stomach than younger birds. Possibly, adults lose 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 and specific time period are obtained at a sample size of about 40 birds and that reliable conclusions on change or stability in ingested litter quantities can be made after periods of 4 to 8 years, depending on the category of litter. Lower annual sample sizes are no problem, but will lengthen the periods needed to draw conclusions on regional levels and trends.

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

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

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 (EcoQOs) for the North Sea*'. One of the EcoQOs 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). Formal guidelines and assessment methods have recently been published (OSPAR 2015a,b).

As indicated in Chapter 1, 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 (Galvani 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. 2014). 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 (UNEP, 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. The example of fulmar monitoring methods and its long term character were extensively used in the most recent UNEP report on the marine plastic issue (UNEP 2016).

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Dossier

Plastic waste and Marine wildlife

Wageningen Marine Research studies the problems related to plastic debris in the marine environment. In the plastic dossier you can find news, backgrounds en results of our research on the effects of plastic waste in the sea, also known as Plastic Soup.

Seabirds and other marine wildlife may ingest plastic debris or become entangled in it. The Ecosystems department of Wageningen Marine Research is founder of a permanent monitoring program of the amount of plastic in stomachs of Northern Fulmars in the North Sea. This research approach has been copied into the European Marine Strategy Directive (MSFD) as a basis for litter monitoring in other European seas. That may involve ingestion of plastics by other bird species, turtles, mammals and fish in European waters and elsewhere. In addition entanglement issues and distribution of debris in marine and coastal environments has our attention.

News:

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August 24, 2016
Seabird plastic monitoring in Ireland
- In Ireland, Heidi Acampora has focused her PhD study on using seabirds to monitor plastics. Of course, the fulmar is among the studied species....
- 

July 25, 2016
Dubious honour for the Gannet
- Northern Gannets started breeding on the German island Helgoland about 25 years ago. In 1991 the first breeding record ended tragically because the...
- 

July 13, 2016
Research plastic in Northern fulmars is a global example
- During late May 2016, in Nairobi, the UN Environment Assembly meeting was held to discuss global environmental issues. In relation with marine plastic...
- 

July 13, 2016
Feathers with a story
- Our research into plastics ingested by Northern Fulmars has additional benefits. As a standard component of our study, moult of the feathers is...
- June 23, 2016

Contact
dr. JA (Jan Andries) van Franeker
[Contact form](#)



IMARES has a new name: Wageningen Marine Research

Plastic in sea & fresh water

Microplastics & Nanoplastics

93% of the Northern Fulmars have plastics in their stomachs



32 pieces of plastic
On average, there are 32 pieces of plastic in the stomachs of Northern Fulmars.

1 lunchbox
Translated to humans, this is a lunchbox full of plastic.

Source: Van Franeker, J.A. (2015). Fulmar Litter EcoQO monitoring in the Netherlands - Update

Photo: Outreach

In the Fulmar monitoring project, we aim to disseminate knowledge widely and promote participation. Through a web-dossier

www.wur.eu/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

Wageningen Marine Research 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 Stookolieslactoffer 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, now Wageningen Marine Research, has co-ordinated similar sampling projects at a range of locations in all countries around the North Sea. Organizations involved in different countries 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 threatens 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) with condensed guidelines for future assessments recently published by OSPAR (OSPAR 2015a,b)

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 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 subcategories ((OSPAR 2015a,b).

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) may be 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 mattresses 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 in 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, %FO) 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 average 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 data-points, and then subtracting 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 it 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 an Oracle relational database. GENSTAT 18th Edition was 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 binomial 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: Balloon remains ingested by a fulmar. Balloon rubber fragments, ingested by wildlife are a recurrent issue in public interest and media attention. They appear in roughly 2% of stomachs opened in the fulmar monitoring study.

5 Results & Discussion

Monitoring in the Netherlands 1979-2015 and trends

With 22 intact fulmar stomachs collected on beaches in the Netherlands in 2015, our sample size was somewhat under the desired sample of around 40 birds for a specific area and time-frame (Van Franeker & Meijboom 2002). An incidental lower sample size is not a problem for the monitoring system, as it only reduces certainty on events on the very short term.

Among the 22 birds collected in 2015, plastics were found in 21 (95%) but in relatively low average number (12 ± 3.3) and mass ($0.26 \pm 0.16\text{g}$). Only 36% of birds exceeded the 0.1g plastic level (Table 1a). These data contrasted the even smaller 2014 sample (77% of 13 birds over 0.1g), but were in more in line with data obtained in 2012 and 2013. These interannual variations in smaller samples sizes emphasize the need to describe the 'current situation' in terms of 5-year averages.

5.1 Current levels for the Netherlands (2011-2015)

Because of occasional years of low sample size and incidental variability the 'current pollution level' is considered 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 2011-2015 period (Table 1b) for the Dutch coast are that 95% in a sample of 159 beached fulmars had plastic debris in the stomach, in an average number of 23 particles and mass of 0.29 gram. The EcoQO threshold of 0.1 gram plastic is currently exceeded by 53% of the birds (Table 3B)**



Photo *Dark coloured fulmar (NET-2015-002). The header of table 1a and 1b provides the proportion of LL (Double Light) birds in the sample. This gives a general indication of the origin of birds in the sample. Double light (LL) birds usually have their origin in nearby populations from temperate climate zones, whereas dark ones, as on the photo, almost certainly are high Arctic birds wintering in the North Sea. In most winters the proportion of such northern visitors in the samples is roughly 10% to 20%.*

Table 1 Summary of sample characteristics and stomach contents of fulmars collected for Dutch marine litter monitoring in a) the year 2015 and b) the current 5-year period 2011-2015. The top line in each table shows sample composition in terms of age, sex, origin (by colour-phase; 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 \pm standard error; average mass of plastic \pm 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 2015

The Netherlands 2015		nr of birds 22	adult 32%	male 57%	LL colour 86%	death oil 0%	avg condition 1.5
		incidence	average number of items (n/bird) \pm se	average mass of litter (g/bird) \pm se	max. mass recorded	geometric mean mass (g/bird)	
1	ALL PLASTICS	95%	12.0 \pm 3.336	0.263 \pm 0.156	3.5	0.0584	
1.1	INDUSTRIAL PLASTIC	45%	1.1 \pm 0.443	0.024 \pm 0.009	0.2	0.0042	
1.2	USER PLASTIC	91%	10.8 \pm 3.013	0.238 \pm 0.150	3.3	0.0380	
1.2.1	sheets	45%	1.4 \pm 0.537	0.003 \pm 0.002	0.0	0.0009	
1.2.2	threads	32%	0.5 \pm 0.171	0.002 \pm 0.001	0.0	0.0005	
1.2.3	foamed	55%	2.5 \pm 0.797	0.033 \pm 0.018	0.3	0.0035	
1.2.4	fragments	86%	6.4 \pm 1.939	0.060 \pm 0.020	0.4	0.0225	
1.2.5	other plastic	5%	0.1 \pm 0.136	0.139 \pm 0.139	3.1	0.0004	
2	OTHER RUBBISH	23%	0.5 \pm 0.215	0.042 \pm 0.039	0.9	0.0010	
2.1	paper	0%	0.0 \pm 0.000	0.000 \pm 0.000	0.0	0.0000	
2.2	kitchenwaste (food)	18%	0.4 \pm 0.203	0.041 \pm 0.039	0.9	0.0008	
2.3	rubbish various	5%	0.1 \pm 0.091	0.000 \pm 0.000	0.0	0.0001	
2.4	fishhook	0%	0.0 \pm 0.000	0.000 \pm 0.000	0.0	0.0000	

b) 5-year period 2011-2015

The Netherlands 2011_15		nr of birds 159	adult 44%	male 43%	LL colour 85%	death oil 1%	avg condition 1.7
		incidence	average number of items (n/bird) \pm se	average mass of litter (g/bird) \pm se	max. mass recorded	geometric mean mass (g/bird)	
1.0	ALL PLASTICS	93%	23.0 \pm 2.767	0.295 \pm 0.055	6.7	0.0835	
1.1	INDUSTRIAL PLASTIC	59%	2.4 \pm 0.539	0.053 \pm 0.013	2.0	0.0092	
1.2	USER PLASTIC	91%	20.6 \pm 2.502	0.241 \pm 0.050	6.6	0.0589	
1.2.1	sheets	55%	3.1 \pm 0.575	0.013 \pm 0.005	0.6	0.0018	
1.2.2	threads	38%	1.0 \pm 0.168	0.011 \pm 0.004	0.6	0.0011	
1.2.3	foamed	54%	5.5 \pm 1.646	0.035 \pm 0.008	1.0	0.0038	
1.2.4	fragments	86%	10.9 \pm 1.186	0.154 \pm 0.037	5.5	0.0358	
1.2.5	other plastic	18%	0.2 \pm 0.051	0.029 \pm 0.020	3.1	0.0009	
2.0	OTHER RUBBISH	23%	1.3 \pm 0.468	0.094 \pm 0.059	9.3	0.0013	
2.1	paper	2%	0.1 \pm 0.057	0.006 \pm 0.005	0.8	0.0001	
2.2	kitchenwaste (food)	14%	0.9 \pm 0.425	0.080 \pm 0.059	9.3	0.0007	
2.3	rubbish various	11%	0.3 \pm 0.153	0.008 \pm 0.004	0.6	0.0004	
2.4	fishhook	0%	0.0 \pm 0.000	0.000 \pm 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 threshold 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 sample size over 10 birds are printed in bold).*

Table 2A.

Netherlands		Industrial granules			User plastics		
YEAR	<i>sample n</i>	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	62	71%	3.2 ± 0.5	0.07 ± 0.01	90%	32.3 ± 5.5	0.30 ± 0.04
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	13	69%	2.2 ± 0.8	0.05 ± 0.01	100%	17.6 ± 3.5	0.29 ± 0.12
2015	22	45%	1.1 ± 0.4	0.02 ± 0.01	91%	10.8 ± 3.0	0.24 ± 0.15

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	62	92%	35.5 ± 5.7	0.37 ± 0.05	0.131	71%
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	13	100%	19.8 ± 3.9	0.34 ± 0.13	0.143	77%
2015	22	95%	12.0 ± 3.3	0.26 ± 0.16	0.058	36%

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 0.1 gram threshold of plastic in the stomach. Results are 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	310	59%	2.7 ± 0.2	0.06 ± 0.01	92%	23.8 ± 2.0	0.22 ± 0.02
2004_08	291	60%	2.8 ± 0.3	0.06 ± 0.01	92%	24.7 ± 2.1	0.24 ± 0.02
2005_09	228	60%	2.6 ± 0.3	0.06 ± 0.01	94%	24.7 ± 2.3	0.23 ± 0.02
2006_10	213	61%	4.1 ± 1.3	0.09 ± 0.03	93%	30.4 ± 3.2	0.23 ± 0.02
2007_11	205	59%	4.4 ± 1.4	0.10 ± 0.03	94%	31.0 ± 3.3	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	173	61%	4.3 ± 1.7	0.09 ± 0.04	92%	27.1 ± 3.5	0.24 ± 0.04
2011_15	159	59%	2.4 ± 0.5	0.05 ± 0.01	91%	20.6 ± 2.5	0.24 ± 0.05

Table 3 B.

NETHERLANDS		Total plastics				
5-year period	sample <i>n</i>	Incidence %	average number <i>n</i> ± <i>se</i>	average mass <i>g</i> ± <i>se</i>	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	310	93%	26.5 ± 2.1	0.28 ± 0.02	0.092	62%
2004_08	291	93%	27.4 ± 2.2	0.30 ± 0.03	0.097	62%
2005_09	228	95%	27.3 ± 2.5	0.29 ± 0.03	0.103	58%
2006_10	213	94%	34.5 ± 3.8	0.32 ± 0.04	0.108	62%
2007_11	205	95%	35.4 ± 4.0	0.33 ± 0.04	0.111	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	173	93%	31.4 ± 4.3	0.33 ± 0.06	0.093	57%
2011_15	159	93%	23.0 ± 2.8	0.29 ± 0.05	0.084	53%

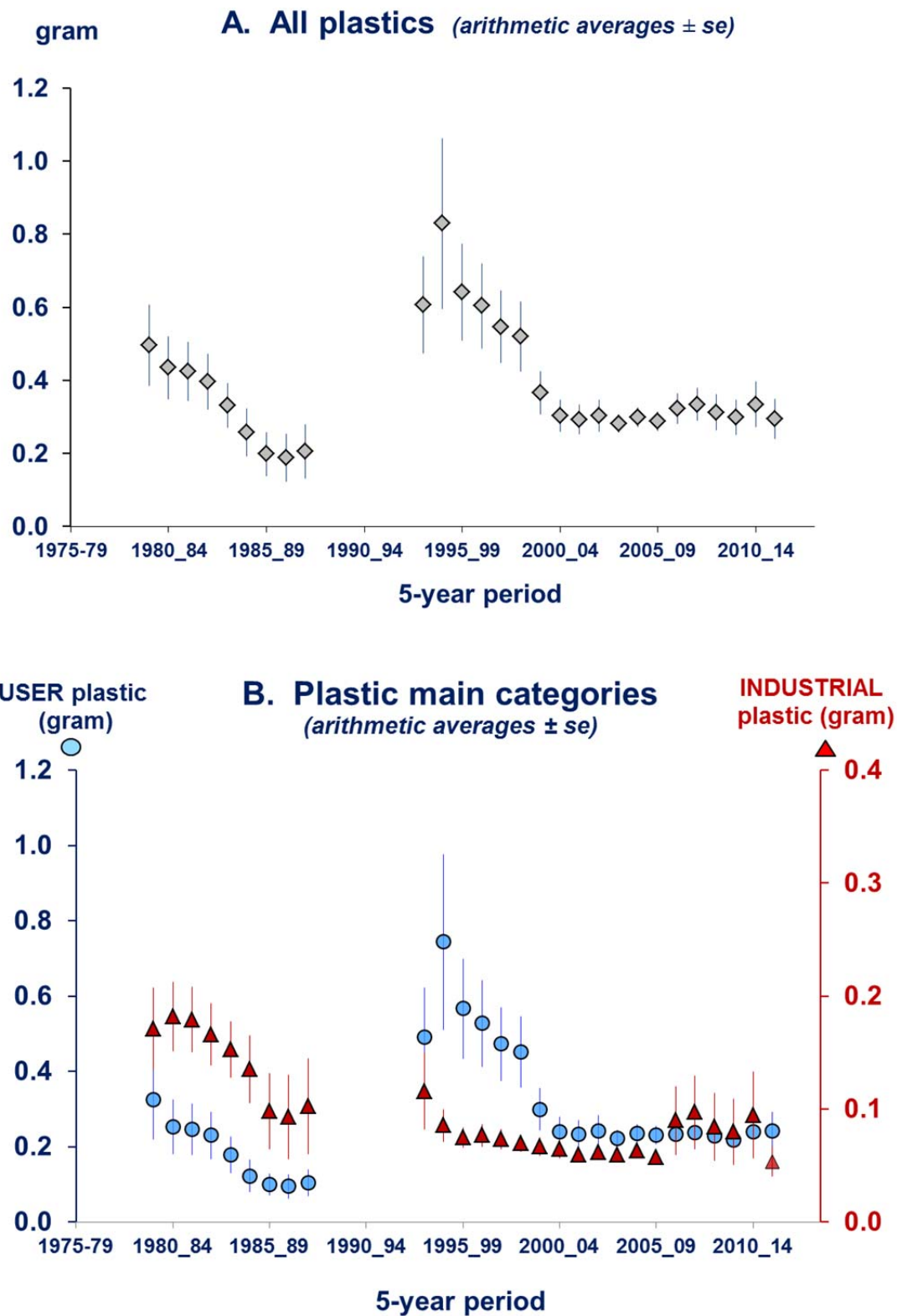


Figure 2 *Plastic mass in stomachs of fulmars from the Netherlands 1980s-2015. A: Data for all plastics combined; B: same data but split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Data are shown by arithmetic average \pm standard error for mass in running 5 year averages (i.e. data points shift one year ahead at a time).*

5.2 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 1979-2015).

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 while user plastics nearly tripled. Measured over the full period of over 30 years of data for the Netherlands, the initial strong decrease of industrial plastics still makes the long term trend highly significant ($p < 0.001$), in spite of the fact that since the early 2000s changes in industrial plastics were much less evident (Table 2). The decreased abundance of industrial plastics in the marine environment has been signalled before in different 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 ($p = 0.15$). In terms of EcoQO performance, the decrease is even clearer ($p = 0.005$).

- **'recent trend'** defined as trend over the past 10 years (now: 2006-2015)

After the early 2000s, changes were not evident, and recent trends generally described as stable or potential slow non-significant decline. However, the most recent 10 years, 2006 to 2015 demonstrate moderately significant declines in industrial plastics ($p = 0.015$) as well as user plastics ($p = 0.047$). The trend for their combined occurrence is not significant, but very close ($p = 0.06$) (Fig. 3B; Table 4B). The data show that following sharp decreases of industrial plastics since the 1980, and of user plastics after the mid-1990s, slowed down considerably after the early 2000s, but did continue at a slow, but now significant rate.



Photo: *During the early 1980s, industrial pellets of different types were a common feature in nearly every new tideline. Nowadays, such chronic pollution seems replaced by more incidental occurrences of a single type of pellet.*

Table 4 *Details of linear regression analyses for time related trends in plastic abundance by mass in stomachs of fulmars in the Netherlands*. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over the full time period (Table 4A) and the most recent 10 years of data (Table 4B). The regression line ('trend') is described by $y = \text{Constant} + \text{estimate} * x$ 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 decrease 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 are 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 +++. Where test results are not significant (n.s.) but close ($p < 0.1$), upward or downward arrow indicates the potential direction of change.

A. LONG TERM TRENDS 1979-2015
for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	n	constant	slope	s.e.	t	p	
all ages	1035	87.7	-0.0459	0.0097	-4.76	<.001	--- ↓
adults	539	69.8	-0.0372	0.0149	-2.49	0.013	- ↓
non adults	474	98.7	-0.0513	0.0127	-4.05	<.001	--- ↓
User plastics (lnGUSE)	n	constant	slope	s.e.	t	p	
all ages	1035	-5.0	0.0012	0.0083	0.14	0.889	n.s.
adults	539	5.8	-0.0043	0.0134	-0.32	0.747	n.s.
non adults	474	-15.3	0.0065	0.0105	0.62	0.538	n.s.
All plastics combined (lnGPLA)	n	constant	slope	s.e.	t	p	
all ages	1035	37.1	-0.0196	0.0081	-2.43	0.015	- ↓
adults	539	26.7	-0.0146	0.0132	-1.10	0.272	n.s.
non adults	474	41.6	-0.0218	0.0098	-2.22	0.027	- ↓
EcoQO performance (all ages)	1035	13.7	-0.0065	0.0022	-3.01	0.003	-- ↓

B. RECENT 10-YEAR TRENDS 2006-2015
for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	n	Constant	estimate	s.e.	t	p	
all ages	372	208.3	-0.1059	0.0431	-2.45	0.015	- ↓
adults	161	256.0	-0.1297	0.0642	-2.02	0.045	- ↓
non adults	196	179.0	-0.0913	0.0601	-1.52	0.130	n.s.
User plastics (lnGUSE)	n	Constant	estimate	s.e.	t	p	
all ages	372	147.5	-0.0747	0.0376	-1.99	0.047	- ↓
adults	161	140.0	-0.0712	0.0611	-1.16	0.246	n.s.
non adults	196	174.7	-0.0881	0.0477	-1.85	0.066	n.s. ↓
All plastics combined (lnGPLA)	n	Constant	estimate	s.e.	t	p	
all ages	372	137.9	-0.0697	0.0372	-1.88	0.062	n.s. ↓
adults	161	141.0	-0.0716	0.0601	-1.19	0.236	n.s.
non adults	196	149.3	-0.0753	0.0473	-1.59	0.113	n.s.
EcoQO performance (all ages)	372	63.3	-0.0312	0.0099	-3.16	0.002	-- ↓

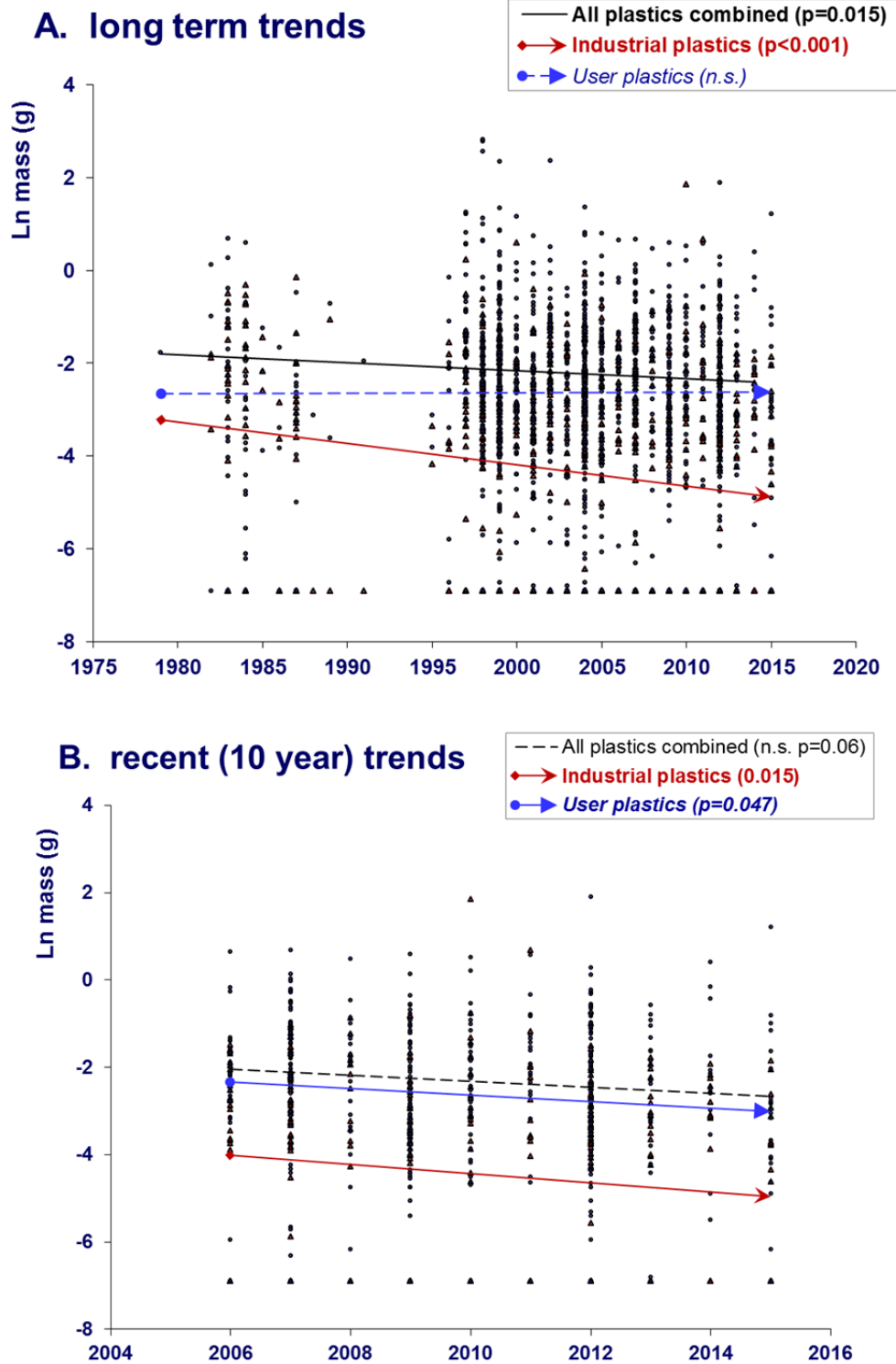


Figure 3 *Statistical trends in plastic mass in stomachs of fulmars from the Netherlands 1979-2015.* Graphs show plotted \ln -transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for industrial (lower, red line), 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. Significant test results indicated by solid trendline, non significant results by a dashed line.

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.

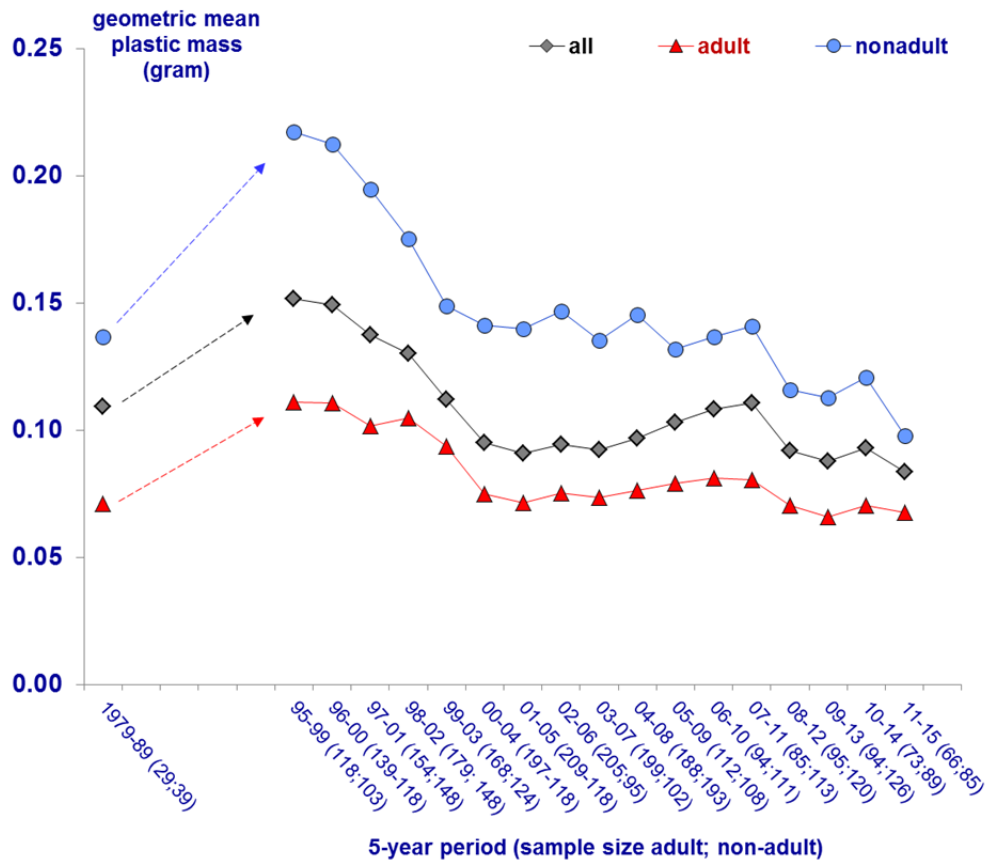


Figure 4 Geometric mean mass of plastics in stomachs of beached fulmars from the Netherlands 1979-2015 for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults, with respective sample sizes in brackets in the x-axis labels. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trend-line in the summary. This graphic visualization does not represent a statistical trend analysis.

5.3 Dutch data in terms of the OSPAR EcoQO metric

ICES working groups (e.g. 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 simplified procedure to avoid the mathematical problems caused by a few excessive stomach contents that distort comparative analyses. In the statistical 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”*.

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 and emphasizes the distance from the 10% EcoQO target set by OSPAR. Fairly rapid decreases in the proportion of birds exceeding the 0.1 gram level were seen during 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. Nevertheless, in the current data set 2006-2015, it can be shown there is a significant downward trend in plastic occurrence in fulmar stomachs: over the integrated recent 5-year period 2011-2015, 53% of Dutch fulmars exceed the 0.1 gram critical threshold EcoQO level.

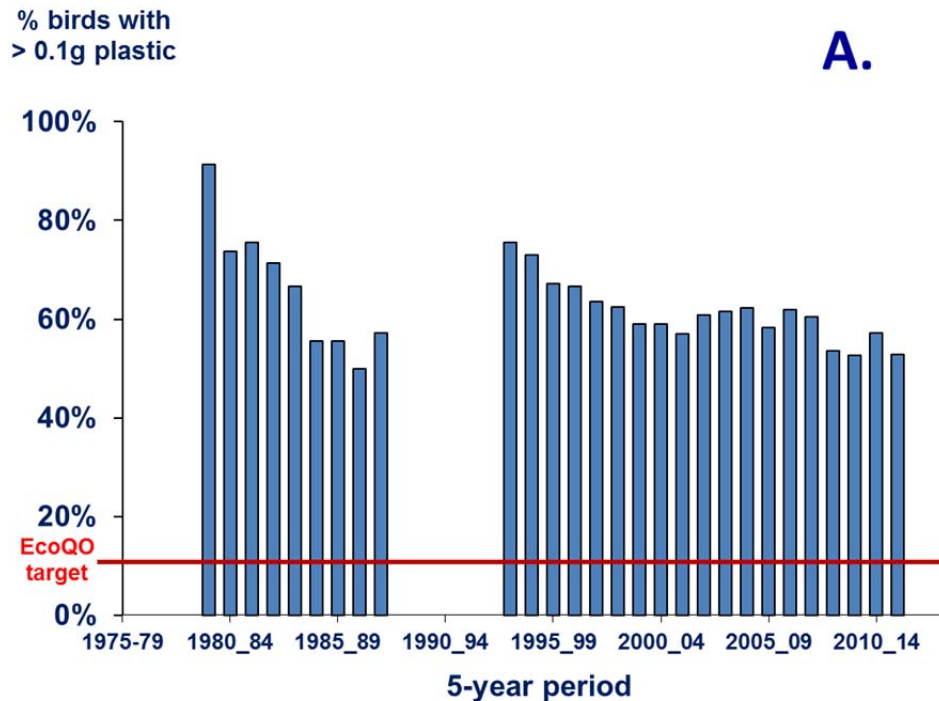


Figure 5 *EcoQO performance of fulmars in the Netherlands over running 5-year periods. The red line illustrates the OSPAR EcoQO target to reduce the percentage of birds with more than 0.1 gram of plastic in the stomach to below 10%. This graphic visualization does not represent a statistical trend analysis.*

5.4 Concluding remarks

It is difficult to pinpoint specific events that triggered the strong increase in consumer plastics and simultaneous decrease in industrial plastics from the 1980s to the 1990s, nor can we identify a clear background for the subsequent decrease in user debris. In earlier reports, no significant changes were observed in the fulmar monitoring approach since the early 2000s, at best weak patterns of reduction. But now, in the 2006-2015 analysis, for the first time a gradual but statistically significant reduction in both industrial and user plastics in fulmar stomachs can be demonstrated. High media attention raised for the 'Pacific garbage patch' and 'plastic soup' started in the early 2000s. That likely has led to increased awareness, with associated policies and actions by authorities, industry and general public gradually taking effect.

As an example of a gradually changing sector, the shipping industry may be considered. A detailed study on Texel in the Netherlands in 2005 showed that most beached 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 sea based activities. Using various other details of beached items, sea based sources were considered to be responsible for about 90% of the mass coastal debris found on Texel. With regard to shipping as a

source of debris, the implementation of the EU Directive 2000/59/EC on Port Reception Facilities since 2004 likely contributes to the gradual improvement. More recently, in 2013, international legislation for waste disposal by ships in MARPOL Annex V was strongly improved. Participation of the fishing industry has boosted in the 'Fishing for Litter' initiative. The general public is strongly involved in beach clean-ups. Developments are underway for governmental implementation of the European Marine Strategy Directive (2008/56/EC) and its requirements towards Good Environmental Status. 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 proportion of plastic in consumer wastes have strongly increased. Fig. 6 illustrates trends in plastic production and shipping activity in comparison to the abundance of plastics in stomachs of fulmars. The various graph lines should not be viewed proportionally, but do indicate that slow improvement in EcoQO performance does not necessarily mean that policy measures like various MARPOL regulations and the EU Directive on Port Reception Facilities have had little effect.

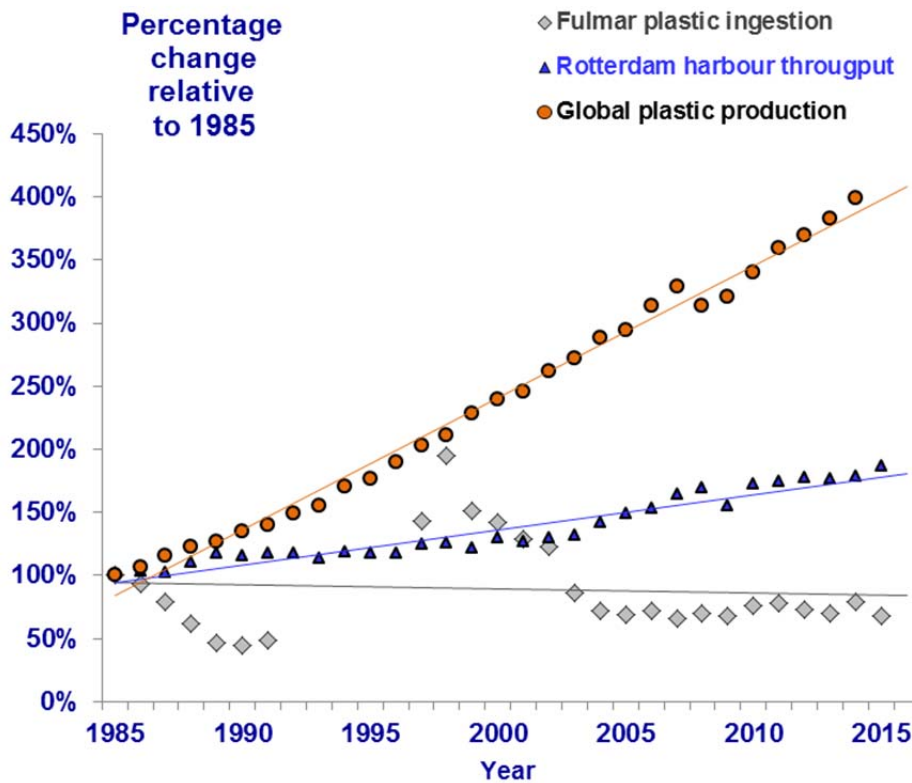


Figure 6 *Comparative Trends in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars (5-year arithmetic averages). Shown are cumulative percentage changes from reference year 1985.* (Source: Port of Rotterdam, 2016)

Conclusion

Stomach contents of fulmars in the Netherlands indicate that the marine litter situation off the Dutch coast over the last decade has shown slow but significant improvement. EcoQO performance, that is the proportion of fulmars exceeding a threshold value of 0.1 gram of plastic in the stomach, is currently 53%. Although still far off the long term goal set by OSPAR, aiming at a reduction of this figure to below 10%, the direction of change is positive. Clear-cut cause-effect relations are hard to show, but likely increased awareness and measures among public, stakeholders and authorities are gradually taking effect.

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 to the collection of beached fulmars. If people find that their name or group is listed incorrectly, or worse, not at all, our sincere apologies and please take up contact.

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Relevant websites

www.wur.eu/plastics-fulmars

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



Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

Furthermore, the chemical laboratory at IJmuiden 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. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according to a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of the accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.

In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

Justification

Report number: Wageningen Marine Research C091/16
RWS Centrale Informatievoorziening BM 16.12.

Project number : IMARES project 431 21000 31 Fulmar-EcoQO-NL2015-19

The scientific quality of this report has been peer reviewed by a colleague scientist and the relevant MT representative at Wageningen Marine Research.

Approved : Ruud Jongbloed
Research scientist

Signature:



Date: 11-Oct-2016

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Wageningen Marine Research is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector.

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The Wageningen Marine Research vision

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