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Plastic Particles in Fulmar Stomachs in the North Sea

Common indicator assessment

OSPAR
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OSPAR's Quality Status Report 2023

Plastic Particles in Fulmar Stomachs in the North Sea

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l´Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d´Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l´Allemagne, la Belgique, le Danemark, l´Espagne, la Finlande, la France, l´Irlande, l´Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume- Uni de Grande Bretagne et d´Irlande du Nord, la Suède, la Suisse et l´Union européenne

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Key Message

Currently 51% of beached North Sea fulmars have more than 0,1g of plastics in their stomachs, exceeding the Fulmar Threshold Value (Fulmar-TV) of 10%. This reflects the abundance of floating litter and provides an indication of harm. The amounts of ingested plastics have decreased significantly in the period 2009 to 2018.

Background (brief)

Litter is widespread in the marine environment and is harmful to wildlife and the ecosystem. OSPAR and the European Commission aim to substantially reduce the amount of marine litter in the OSPAR Maritime Area to levels where properties and quantities do not cause harm to the marine environment. The quantity of plastics ingested by marine wildlife mainly reflects the abundance of litter in their environment.

OSPAR monitors and assesses plastics in the stomachs of northern fulmars as one of its indicators of environmental quality. Fulmars are abundant and widespread seabirds known to regularly ingest litter, with nearly all individuals having at least some plastic in their stomachs. Although fulmars forage near the water surface, their stomachs may also contain items from deeper water or items that may be indirectly ingested through their prey.

The MSFD fulmar threshold value assessment uses the data from OSPAR Ecological Quality Objective approach (OSPAR EcoQO). The monitoring programme uses corpses of beached birds or individuals accidentally killed. OSPAR used to have a long-term goal of less than 10% of fulmars exceeding a level of 0,1gram of plastic in their stomachs. The MSFD and OSPAR Fulmar-TV was accepted by OSPAR's Environmental Impacts of Human Activities Committee (EIHA) and Coordination Group (CoG) in 2020. Therefore, this Fulmar-TV now formally replaces the previous fulmar OSPAR EcoQO (EIHA, 2021).

Research methods and results have been published in reports and peer-reviewed scientific literature and dedicated OSPAR fulmar Coordinated Environmental Monitoring Programme (CEMP) Guidelines. Whilst this indicator is currently only used in the OSPAR Region Greater North Sea (Region II) it is also suitable for implementation in Arctic Waters (Region I) and the Celtic Seas (Region III) and has already been used in fulmar studies elsewhere in the North Atlantic and North Pacific.

Figure 1: The monitoring system for plastics in stomachs of seabirds uses beached northern fulmars. *The fulmar in this photograph had beached on Texel, the Netherlands, on 25 December 2011. Photograph by J.A. van Franeker.*

Figure 2: Plastics from a fulmar stomach with industrial granules (left) and a mix of threadlike (centre left), sheet-like (centre), and fragment (right) consumer plastics. *Size indicated by the spherical industrial granules which are of 4 to 5mm diameter. (Fulmar sample NEE-2018-017 photo by J.A. van Franeker).*

Introduction

Many marine organisms, including seabirds, turtles, marine mammals, fish, crustaceans, shellfish, and zooplankton ingest man-made debris that they encounter in their marine environment (Kühn and van Franeker, 2020). The quantity of litter ingested and found in animal stomachs or intestines, in particular that of persistent materials such as plastics, reflects the abundance of marine litter, the associated harm to wildlife and the marine ecosystem, and socio-economic harm.

Policy

Within its system of Common Indicators, OSPAR has agreed to the monitoring of plastic abundance in stomachs of seabirds as an indicator for levels and trends in marine litter floating at the surface of the North Sea. Northern fulmars *(Fulmarus glacialis)* forage near the water surface, but stomachs may additionally contain items from deeper water or the seabed. These items could be indirectly ingested through prey or directly when litter is transported vertically from the deeper parts of the North Sea to the surface. The indicator has been implemented through long-term monitoring of plastic abundance in stomach contents of the northern fulmar (OSPAR EcoQO no. 3,3) (OSPAR 2009, 2010a,b; 2014a,b). The fulmar EcoQO approach has been taken up as an OSPAR Common Indicator Assessment for the Intermediate Assessment 2017 and Committee Assessments 2019 and 2021.

The European Commission, in its European Marine Strategy Framework Directive (MSFD), refers to marine litter policies under its Descriptor 10 which states that ‘Properties and quantities of marine litter do not cause harm to the coastal and marine environment’ (EC, 2008, 2010, 2017). Monitoring of plastic ingestion by marine wildlife is currently described under the criteria D10C3 (EC, 2017). In 2020, OSPAR adopted the regionally agreed OSPAR and MSFD Fulmar Threshold Value (Fulmar-TV) (EIHA, 2021), which is numerically almost identical to the OSPAR EcoQO.

Monitoring

Within the MSFD, the OSPAR Common Indicator for the fulmar has been presented as a species relevant in criteria D10C3 (ingested litter) for the Greater North Sea, Arctic Waters, and Celtic Seas (EC, 2008; EC, 2010; Galgani *et al.,* 2010; EC, 2017). Plastic objects ingested by fulmars may range in size from a few mm to several cm, and can be considerably larger for flexible items. Fulmars thus monitor both the litter and micro-litter described under D10C3 (EC, 2017). In addition, because fulmar feeding is largely restricted to surface feeding, the indicator has also relevance for the criteria D10C1 and D10C2 for litter and micro-litter, respectively, in the surface layer of the water column. The fulmar approach has been taken as example for other biota indicators. The purpose of such monitoring of plastic abundance ingested by wildlife is:

- to obtain a quantitative measure for spatial and temporal patterns in the abundance and composition of marine litter, in particular plastics, mainly floating at the surface; and
- to provide an indication of ecological harm caused by such litter.

In its recent wording (EC, 2017) the MSFD has broadened its monitoring scope to ingestion of litter and micro-litter by marine species, and the earlier concept (OSPAR and EC, 2010) of ecological harm has been redefined as *'a level that does not adversely affect the health of the species concerned'*. Fulmar monitoring methods and results have been published in regular reports and peer-reviewed scientific literature (Van Franeker *et al.*, 2011; Van Franeker & Law 2015; Van Franeker *et al.*, 2021). Dedicated OSPAR guidelines have been published in 2015, and updated in 2019, to guarantee consistent monitoring methods and uniform submission of data by all OSPAR Contracting Parties (OSPAR, 2015a,b; *http://www.ospar.org/convention/agreements?q=fulmar*).

Sweden has requested to mention that, after two years of fulmar collection (2003 to 2004), it has formally opted out of participation in the fulmar monitoring programme. This is due to a low rate of collected fulmars and a coastline which makes it hard to run surveys with a sampling programme of beached birds. Fulmars are therefore not seen as a suitable indicator for Swedish conditions.

Suitability of fulmars for monitoring marine litter

Fulmars are pelagic (open sea) seabirds that belong to the large group of the tubenoses (*Procellariiformes)* of which the albatrosses are the best-known representatives. These birds forage exclusively at sea and never on land, and rarely forage close to shore. The fulmar is a poor diver, and thus feeds on what is available at or within a few metres from the water surface. Like most tubenosed seabirds, fulmars regularly ingest a variety of marine debris, probably mostly taken directly and intentionally because resembling prey, or unintentionally when mixed with attractive food wastes. But indirect ingestion will also occur, e.g. through preying on fish with ingested plastics or scavenging on guts of other dead animals. Size details of plastics ingested indicated that roughly 90% of ingested plastic items (not threads or soft sheets) found in the first glandular stomach of fulmars is 10mm or less in size, and over 50% is 5mm or less (Bravo Rebolledo 2011). The definition for micro-plastics as items smaller than 5mm was introduced by an international expert workshop (Arthur *et al.*, 2009), and this definition has been copied into particle size definitions used in the Marine Strategy Framework Directive (MSFD). MSFD defines litter smaller than 5mm as micro-particles, between 5mm and 25mm as meso-particles, and items over 25mm as macro-debris (MSFD-TSGML 2011). Thus, litter ingested by fulmars is mostly in the micro- and meso-size ranges. Unlike most gulls, fulmars normally do not regurgitate indigestible components of their diet, but gradually grind these in their muscular stomach (gizzard) until particles are worn or broken into sizes small enough to pass into the intestines and be excreted (which appears to happen at particle size of roughly 2mm to 3mm (Bravo Rebolledo, 2011)). As a consequence, fulmar stomach contents integrate litter abundance encountered during feeding for a number of days to weeks (Van Franeker & Law, 2015).

Previous assessments

OSPAR's Quality Status Report (OSPAR, 2010a) included an assessment of the North Sea EcoQO on plastic particles in seabird stomachs. The percentage of fulmars in the Greater North Sea with more than 0,1g of plastic in the stomach ranged from 45% to over 60%. The English Channel area was the most heavily polluted area while the Scottish Islands were the 'cleanest' with a mean mass for plastics in fulmars of about a third of the level encountered in the English Channel. Data from the Faroe Islands were included for comparison. The EcoQO is probably only achieved in High Arctic populations. A long monitoring series from the Netherlands showed a significant reduction in plastic abundance from 1997 to 2006, mainly through a reduction in raw industrial plastics.

In OSPAR's first (fulmar) assessment (OSPAR, 2017) among 525 fulmar stomachs analysed over the period 2010 to 2014, 93% had some ingested plastic, 58% contained more than 0,1g of plastic, and average values per bird were 33 particles and 0,31g. Fulmars from the English Channel had the highest plastics load, slightly lower levels being observed further north. No significant increases or decreases in ingested plastic mass were observed in the North Sea as a whole or in any of the five sub-regions.

In OSPAR's second (fulmar) assessment (OSPAR, 2019) among 514 fulmars analysed between 2012 to 2016, 95% had some ingested plastic and 56% contained more than 0,1g of plastic, whereas OSPAR's long term goal is to reduce this EcoQO% to less than 10%. The average fulmar stomach contained 31 plastic particles weighing 0,28g. Regionally the EcoQO% ranged from 50% in the Skagerrak to 75% in the Channel.

The Fulmar EcoQO methodology is also being used elsewhere in the North Atlantic and North Pacific areas (e.g. Provencher *et al.*, 2009; Nevins *et al.*, 2011; Avery-Gomm *et al.*, 2012, 2018; Kühn & Van Franeker 2012; Bond *et al.*, 2014; Donnelly-Greenan *et al.*, 2014; Trevail *et al.*, 2015; Herzke *et al.*, 2016; Poon *et al.*, 2017; Terepocki *et al.*, 2017; Baak 2020) allowing wide spatial comparisons of marine litter in European waters and other North Atlantic and Pacific regions.

Long term monitoring in the Netherlands

In the Dutch sector of the North Sea, changes in stomach contents of fulmars have been monitored since the 1980s. Although overall abundance of plastics in stomachs have shown unexplained changes over time (**Figure a**), rapid reductions in abundance of industrial plastic within one to two decades (**Figure b**) have shown that fulmar stomach contents rapidly reflect changes in source-specific plastic abundances in their environment (Van Franeker *et al.*, 2011; Van Franeker & Law, 2015), and are thus an effective way to assess the success of policy measures, reflecting the improved environmental quality for marine organisms and the pelagic marine environment. The early rapid reduction of industrial plastic litter is believed to reflect a response from industry and transport sectors to media attention for omnipresent industrial plastic debris in the 1980s in combination with the economic incentive to reduce loss of valuable source materials. Lack of similar incentives for consumer types of plastic debris is believed to explain the different trend in these materials.

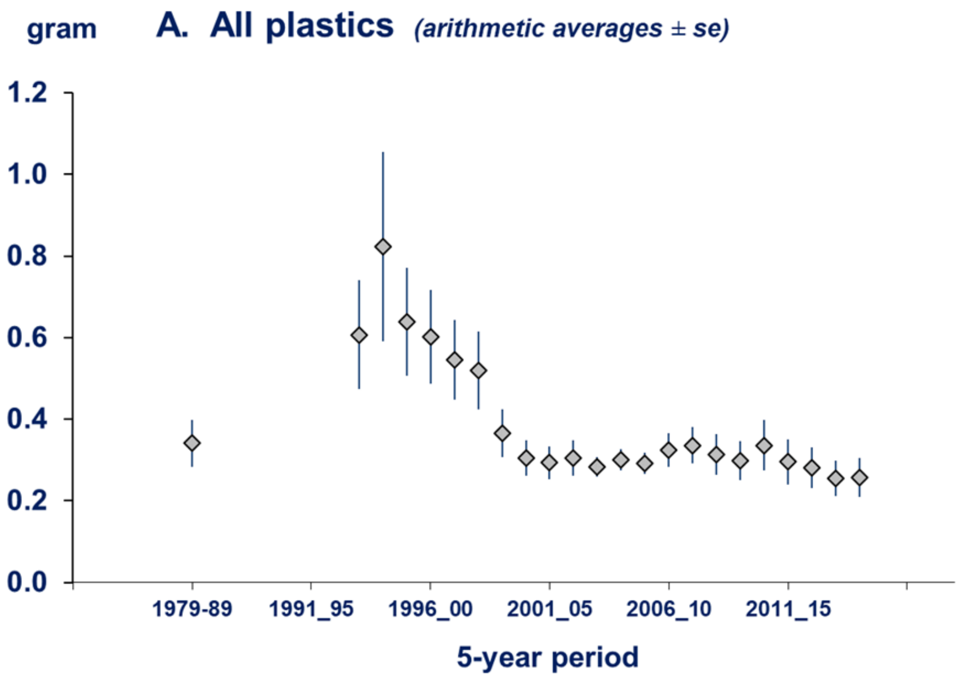

Figure a: Plastic mass in stomachs of fulmars recorded in the Netherlands between 1980 and 2018, for all plastics combined. *Data are shown by arithmetic average ± standard error of the mean for mass in running* *five-year averages (i.e. data points shift one year ahead at a time). It should be noted that this data visualisation does not represent a statistical trend analysis. [source: Van Franeker & Kühn 2019]*

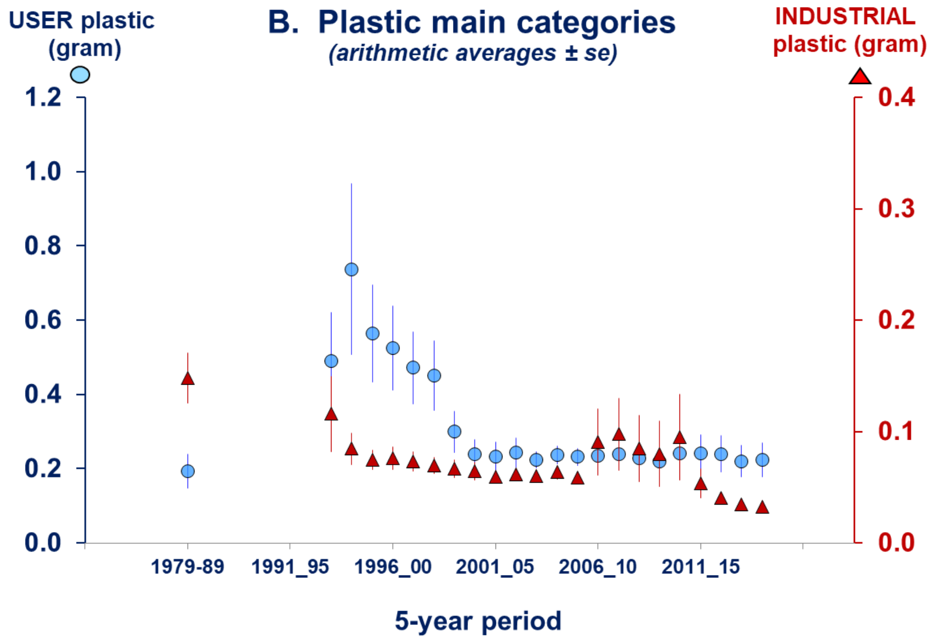

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Figure b: Plastic mass in stomachs of fulmars recorded in the Netherlands between 1980 and 2018 for separate consumer plastics (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). *Data are shown by arithmetic average ± standard error for mass in running five-year averages (i.e. data points shift one year ahead at a time). It should be noted that this data visualisation does not represent a statistical trend analysis. [source: Van Franeker & Kühn 2019]*

Assessment Method

A regionally agreed OSPAR and MSFD Fulmar Threshold Value (Fulmar-TV) has been formally accepted by OSPAR in 2020 (EIHA, 2021). The Fulmar-TV is based on plastic quantities found in stomachs of fulmars in the most pristine situation for which data are available, the Canadian Arctic (Van Franeker *et al.*. 2021). The Fulmar-TV is that no more than 10,06% of stomachs may contain more than 0,1g of plastic, which is thus almost identical to the arbitrary level of 10% of such birds in the OSPAR EcoQO. EU countries can use these fulmar assessment results for their MSFD reporting.

Full details of methods have been provided in the OSPAR Guidelines for Monitoring and Assessment of plastic particles in stomachs of fulmars in the North Sea area (http://www.ospar.org/convention/agreements?q=fulmar) and repeated here only in a descriptive summary.

Corpses of dead beached birds or accidentally killed specimens are collected mostly by volunteer networks, but processed at experienced laboratories. At dissection, in addition to date, the finding location is specified by a system of area codes and geographical coordinates for the area or more detailed location. Based on several internal and external anatomical characters, birds are classified as either adult or non-adult age group. The pilot study for fulmar monitoring (Van Franeker & Meijboom, 2002) showed that age is a relevant variable as younger birds generally have more plastics in the stomach than adults. Thus, in cases where samples to be compared have strongly different age compositions, analyses may need to be specified for separate age groups. Because age characteristics are sex specific, data recording includes sex, although there is currently no evidence of a relevant influence of gender on plastic abundance in stomachs.

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 1mm mesh is used because smaller meshes become easily 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 1mm are very rare in the stomachs (Bravo Rebolledo, 2011) and thus contribute little to numerical abundance of particles and even less to plastic mass.

Two main plastic categories are distinguished in the OSPAR Common Indicator. Industrial plastic granulate (‘pellets’) are separated from consumer debris such as sheets, foams, threadlike materials, hard fragments etc. For each of these categories the number of particles and mass (in gram to 4th decimal) is recorded. The final assessment is based only on total weight of plastic in stomachs, but industrial and consumer waste plastics have different sources and backgrounds and as such provide very useful information for the interpretation of the monitoring data and thus for priorities in policy measures to be considered.
Data thus collected can be used to calculate for specified samples:

- the frequency of occurrence (%FO) the proportion of birds having plastic in the stomach (also referred to as ’incidence’ or ‘prevalence’);
- arithmetic average and standard error (avg±se) of the mean for number or mass of plastic;
- Fulmar TV-performance (FTV%), being the percentage of birds exceeding the level of 0,1g of ingested plastic as defined in the Fulmar-TV.

The reference level for presence of plastics in stomachs of northern fulmars (or any marine organism) is zero, as synthetic materials are solely man-made, and were only introduced into the marine environment since about the mid-1900s. However, accepting that incidental losses are unavoidable OSPAR (2008, 2009), has defined an (undated) long term goal for the fulmar EcoQO 3,3 in the North Sea as:

> “There should be less than 10% of northern fulmars (*Fulmarus glacialis*) having more than 0,1g plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 areas of the North Sea over a period of at least five years”.

Thus, from this definition, the basic monitoring information required is the total mass of plastic in individual stomachs, and the percentage of stomachs exceeding the 0,1g level (referred to as ‘EcoQO performance’ or ‘EcoQ%’). These terms have now been replaced by Fulmar TV-performance and FTV%, in line with the new formally adopted Fulmar-TV.

The OSPAR Assessment for abundance of plastics in stomachs of northern fulmars is therefore calculated as percentage of investigated birds exceeding the 0,1g level of plastics in the stomach (FTV-performance in %) over the most recent five-year period of available data.

In this third (fulmar) assessment, this is the five-year period of 2014 to 2018. It is important to emphasize that all data on average ingested debris or FTV performances are so called ‘population averages’, meaning that clean birds without any plastic in the stomachs are included in all the calculations. Analyses in the pilot study by Van Franeker & Meijboom (2002) have shown that about 40 stomachs are the recommended minimum sample size to obtain a reliable figure for plastic ingestion representative for a selected area and period of time. This recommended sample size should be taken into account when spatial aggregations of data are being made.
For the fulmar indicator, OSPAR has sub-divided the Greater North Sea into five sub-regions.

Figure c: The five fulmar EcoQO sub-regions within the Greater North Sea (OSPAR Region II) and additional locations named in text. *1) Scottish Islands (Orkney and Shetland), 2) East England (includes incidental data East Scotland), 3) Channel, 4) South-eastern North Sea (Belgium, Netherlands, Germany), 5) Skagerrak (Denmark, Norway, Sweden).*

OSPAR has set the same long-term goal for all these North Sea areas, however the timeline for reaching this long-term goal is not specified, but is certainly relevant for policies under the European Marine Strategy Framework Directive (MSFD) in Descriptor 10. Good Environmental Status (GES) has to be achieved by 2020 (EC, 2008, 2010, 2017). However, OSPAR's Regional Action Plan for marine litter (OSPAR, 2014a) has not yet identified regional or overall targets to be achieved by 2020. It appears that current national ambitions vary widely from the original OSPAR EcoQO long-term goal (now Fulmar-TV) to unspecified rates of change (Van Acoleyen *et al.,* 2014). Tendency seems a wording which requires by 2020 a significant change in the direction of the Fulmar-TV. Power analyses of Dutch data in the pilot study by Van Franeker & Meijboom (2002) indicated that fulmar monitoring data may be expected to be able to detect statistically significant trends ($p<0,05$) over time periods of at least 4-8 years depending on the type of plastics considered: periods of significant change indeed have been observed in early monitoring years, for consumer plastics, but for industrial plastics in particular (Van Franeker *et al.*, 2011; Van Franeker & Law, 2015). Trends in quantities of plastics ingested can be visually illustrated as the annual updates of running five-year averages in plastic mass or the five-year figures for FTV-performance. In such graphs, each data point thus overlaps with four years of data from the previous data point. This 'smoothens' most ad-hoc variability in the data and emphasizes longer-term trends. However, these are only graphic illustrations without statistical meaning. As agreed in OSPAR and published in scientific peer-reviewed literature, the method to statistically evaluate trends of increase or decrease in plastic ingestion, use linear regression analysis of log transformed mass of plastics in individual birds against the year of sampling over a period of the most recent ten years. An additional less detailed way to test for change is a GLM approach (Generalised Linear Modelling), in which annual data for sample size and proportions of birds with over 0,1g of plastic in the stomach are evaluated in a logistic analysis dedicated for binomial distributions and using logit transformed data (Van Franeker *et al.,* 2021).

For evaluation of sub-regional differences, plastic data were fitted in a negative binomial generalised linear model with region included as a factor, and the test statistic is a t-score based on residual variance for the region (Van Franeker *et al.*, 2011). Data for the current analyses were stored in Oracle. Graphs were made in Microsoft Excel and statistical analyses for time trends or regional differences were conducted in Genstat, 19th Edition (VSN International 2017). Frequencies of occurrence between two data sets (time periods, or regions) were tested using the 2-sample z-test to compare sample proportion according to Brown *et al*. (2001) using http://epitools.ausvet.com.au/content.php?page=z-test-2.

At the meeting of OSPAR's intersessional correspondence group on marine litter (ICG-ML) 2020-2, Iceland and Denmark asked if recently collected data for Iceland and North East Greenland could be added to the fulmar Assessment. Therefore, Annexes with fulmar data and indicative assessment values based on these data for these areas for Iceland, Denmark and Norway, respectively, were included in Annex II to IV. Please note that these indicative assessment values are not formal fulmar assessment values.

Results (brief)

Assessment 2014 to 2018

Over the five-year period 2014 to 2018, the OSPAR long-term goal in terms of plastic litter ingestion by seabirds was not reached anywhere in the North Sea. Among 393 fulmar stomachs analysed over the 2014 to 2018 period, 51% contained more than 0,1g of plastic, whereas OSPAR's long -term goal is to reduce this FTV% to less than 10%. Of all birds analysed, 92% had some ingested plastic, and average values per individual were 21 particles and 0,26g per bird. Regionally the FTV% ranged from 49% in the Skagerrak and on the Scottish Islands to 68% in the Channel. Within the North Sea the earlier tendency for decreasing plastic loads further north has become less clear. In the early analyses the Channel was significantly more polluted than the more northern sub-regions. This appears to continue but not at a statistically significant level. **Figure 3** shows the sub-regional differences in ingested plastics in the North Sea.

On the larger scale of the North-East Atlantic, a latitudinal pattern remains evident (Van Franeker *et al*., 2011; Van Franeker & Law, 2015; Van Franeker *et al.*, 2021). Only in the far North-western Atlantic (the Canadian Arctic), plastic ingestion levels are by definition close to the Fulmar-TV. In the first assessment period 2010 to 2014 numbers were 58% and 0,31g. The 56% and 0,28g calculated for the second assessment period 2012 to 2016 and the new values for the third period suggest a continued decrease, that however has to be evaluated in the agreed statistical approach.

Trends 2000 to 2018

Time related trends in the fulmar monitoring programme are tested over periods of ten years. The first Intermediate Assessment 2005 to 2014 had not revealed any change. However, over all North Sea sub-regions combined, the 2007 to 2016 analyses showed significant decline in the ingested plastic mass ($p<0,001$). In the current 2009 to 2018 period the decline is continued ($p=0,011$), although less pronounced as in the earlier 2007 to 2016 assessment.

Statistical significant progress in the direction of the Fulmar-TV, as an informal provisional aim for MSFD for the North Sea as a whole is thus achieved. Trends for the separate five sub-regions (**Figure 4**) showed no statistically significant changes except for the South-eastern North Sea sub-region ($p=0,034$). This illustrates the statistical advantage of the regional North Sea assessment, combining all samples from the different sub-regions.

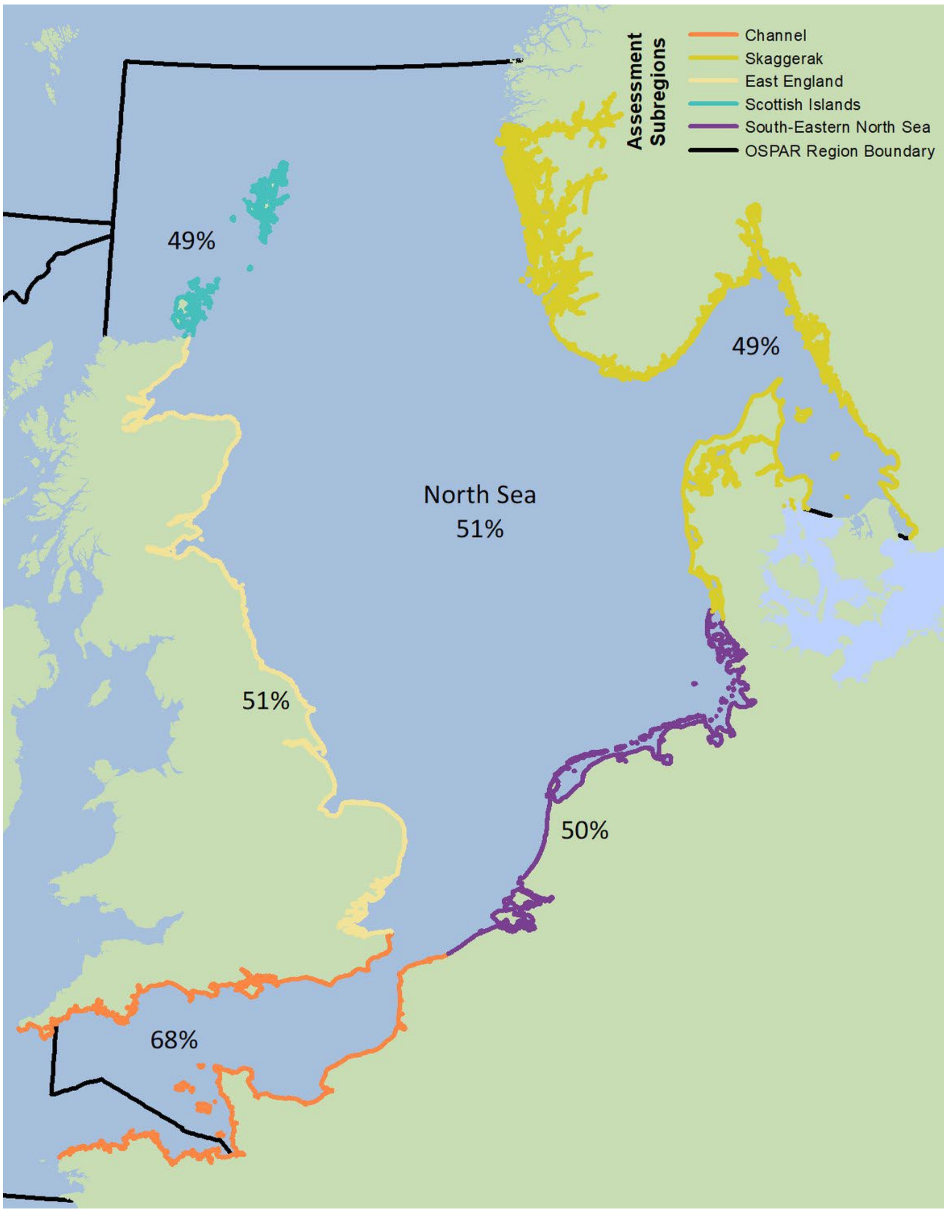

Figure 3: Proportions of fulmars having more than 0,1g plastic in the stomach (EcoQO performance) in different sub-regions of the North Sea over the period 2014 to 2018. *Details on sample sizes and average number and mass of ingested plastics are shown in Extended Results Table a.*

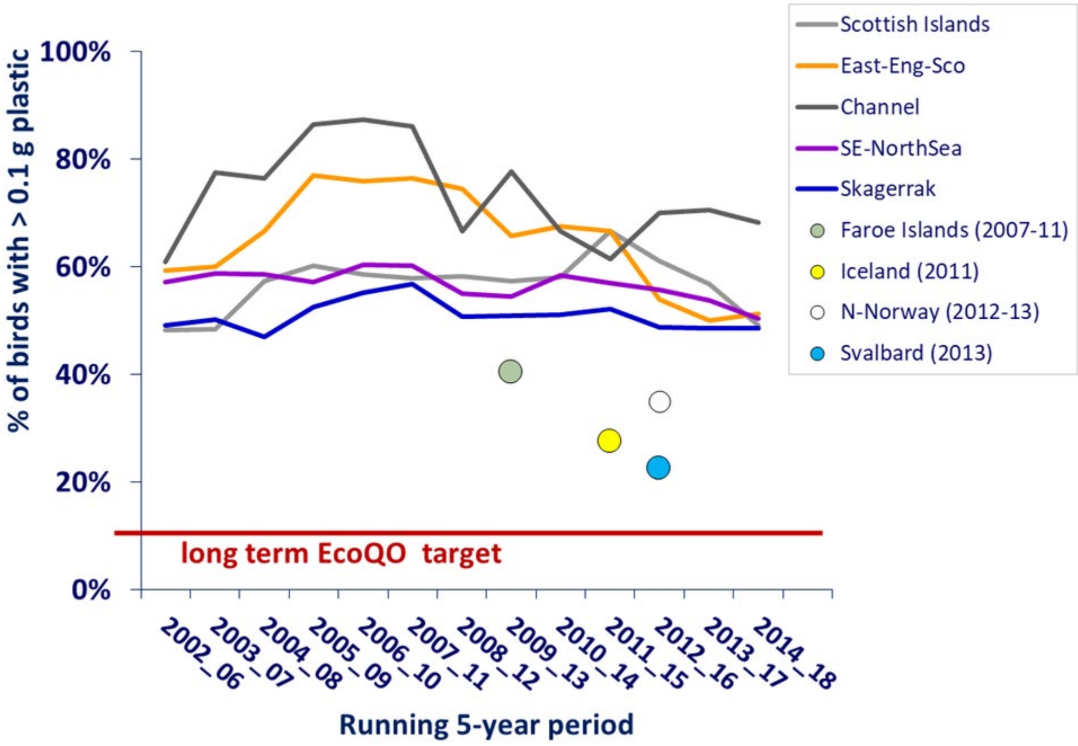

Figure 4: Running five-year averages for the percentage of fulmars having more than 0,1g of plastic in the stomach since the year 2002. *Incidental data published for Faroe Islands, Iceland, North Norway and Svalbard have been inserted to illustrate lower levels of ingested plastic further north in the OSPAR area, but all still well above the OSPAR long-term goal. Please note that this graph is just a visual aid, and not a statistical analysis.*

There is high confidence in both the methodology and data availability.

Results (extended)

Sub-regional and overall data on frequency of occurrence, average number and mass of ingested plastics and the FTV% are detailed in **Table a**. Although the highest numbers for plastic ingestion are still seen in the Channel, the difference with the other sub-regions is no longer significant. Within the entire North Sea the current ten year trend 2009 2018 shows a significant decrease (p=0,011) in mass of ingested plastics. Underlying this overall figure, it can be seen in **Table b** that all sub-regions show negative regression slopes, but the sub-regional trend was only significant for the South-Eastern North Sea (p=0,034). At the larger scale of the North-East Atlantic, the pattern shows significant lower plastic abundance on Faroe Islands, Iceland, North Norway and Svalbard than in the North Sea (**Figure d**).

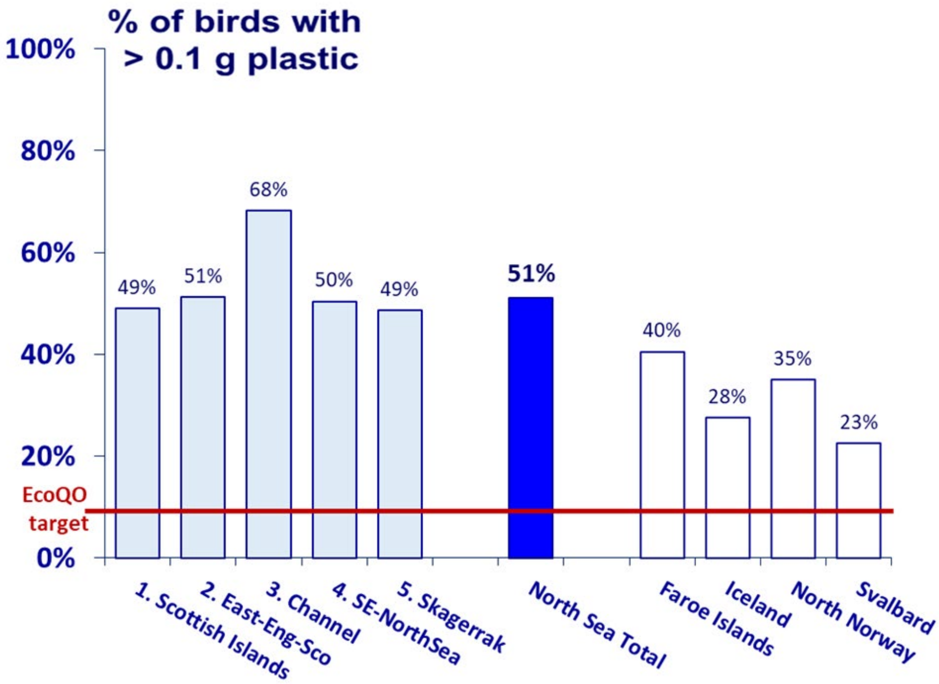

Figure d: Proportions of fulmars having more than 0,1g plastic in the stomach (FTV performance) in different sub-regions of the North Sea (light blue bars) over the period between 2014 and 2018. *Details shown in Table a. The overall value for the North Sea (dark blue bar) is compared to more incidental data (white bars) published for OSPAR areas to the north of the North Sea: Faroe Islands (Van Franeker & the SNS Fulmar Study Group 2013), Iceland (Kühn & van Franeker 2012), North Norway (Herzke et al., 2016) and Svalbard (Trevail et al., 2015) Please note that this graph is just a visual aid, and not a statistical analysis.*

Table a: Plastic ingestion by fulmars in the Greater North Sea in the assessment period 2014-2018.

(Sub) Regions		Total plastics			
2014 - 2018	**sample n**	**EcoQO% (over 0,1g)**	**Frquency of Occurrence**	**average number n ± se**	**average mass g ± se**
1. Scottish Islands	53	49%	87%	21,7 ± 5,6	0,32 ± 0,10
2. East Eng-Sco	41	51%	90%	25,1 ± 5,1	0,17 ± 0,05
3. Channel	22	68%	86%	24,4 ± 7,6	0,43 ± 0,14
4. SE-NorthSea	240	50%	93%	20,8 ± 3,0	0,27 ± 0,03
5. Skagerrak	37	49%	97%	19,1 ± 4,3	0,15 ± 0,03
North Sea Total	393	51%	92%	21,4 ± 2,1	0,26 ± 0,03

Table b: Linear regression analyses for time trends between 2009 and 2018 in plastic abundance in stomachs of fulmars in sub-regions assessed and in the total North Sea. *Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. By standard, analyses are conducted over the most recent 10 years of data. The regression line is described by y = constant + slope*x in which y is the calculated value of the regression-line for year x. Negative values for slope and t-value indicate plastics decrease, but a trend is considered significant when the probability (p) is less than 5% (p<0,05).*

10-year trend 2009-2018 - linear regression results							
(Sub) Regions	**All plastics**						
	n	**constant**	**slope**	**s.e.**	**t**	**p**	
1. Scottish Islands	128	106	-0,054	0,053	-1,020	0,308	n.s.
2. East-Eng-Sco	79	154	-0,078	0,070	-1,120	0,268	n.s.
3. Channel	31	130	-0,067	0,168	-0,400	0,694	n.s.
4. SE NorthSea	783	97	-0,050	0,023	-2,120	0,034	-
5. Skagerrak	96	120	-0,061	0,067	-0,910	0,368	n.s.
North Sea Total	1117	95	-0,048	0,019	-2,550	0,011	-

Over the period of the first assessment (2005 to 2014) no significant increases or decreases in ingested plastic mass were observed in the North Sea as a whole or in any of the five sub-regions. However, over the decade 2007 to 2016 the trend measured over the whole North Sea was that of a significant decline in ingested plastics and this trend continues for the current time period of 2009 to 2018 (**Table b**). Regression lines showed negative slopes in all five sub-regions, although only data for the South-Eastern North Sea sub-region has decreased significantly.

Trends over time differ between industrial plastic granules and consumer plastic waste. Industrial plastics are often referred to as ‘pre-production or resin pellets’, ‘nurdles’ or ‘mermaids tears’ and are the raw granular stock from which consumer objects are made by melting the granules, with additives giving the plastic its desired characteristics. Most industrial pellets are either cylindrical or spherical in shape, with diameter about 4mm to 5mm, and mass usually around 25mg per particle. Consumer plastics are often fragments of larger objects, the remains of consumer products discarded or lost to the environment. They range from parts of bottles to car-bumpers, and from fishing nets to plastic shopping bags or styrofoam packaging materials. See photo 2 for an illustration of both types of plastics recovered from a fulmar stomach.

In long-term data for the Netherlands, industrial plastics were significantly reduced within one to two decades during the 1980s and 1990s. That reduction was counteracted by increased consumer waste. These important and rapid changes cannot be documented for the other sub-regions in the North Sea because data collection started only after the period of major changes. However, the early Dutch data have been supported by very similar results in various other seabird studies around the world, as has been detailed in Van Franeker & Law (2015). The rapid reduction in industrial plastic granules was not only seen in source areas such as the North Sea, but was followed by similar reductions in densities of industrial plastic granules in the large oceanic gyres. Rapid reductions were probably achieved because the industrial pellets represent raw feedstock with economic value. Considerable publicity in the 1970s and 1980s on losses of industrial pellets to the marine environment (Colton *et al.*, 1974; Wong *et al.*, 1974; Gregory 1978; Shiber, 1979, 1982; Morris, 1980) and their ingestion by a wide range of marine wildlife (e.g. Bourne and Imber 1982; Connors and Smith 1982; Day *et al.,* 1985; Van Franeker, 1985) have led to measures reducing losses around factories, processing plants and during transport. Although no published information on dedicated measures by industry or transport sectors is known from the 1980s, industrial concern was flagged in 1991 by the dedicated Ocean Clean Sweep campaign (U.S. EPA 1993). Because of these early changes, it is important to continue to make a distinction in monitoring of industrial as opposed to consumer plastics, as they have provided evidence that rapid improvements in environmental quality are a realistic possibility if input of debris is effectively reduced.

Currently, industrial plastic granules are found in 50% of fulmar stomachs from the North Sea, with on average two granules and mass of 0,05g **(Table c)**. This is less than half the quantity observed in the 1980s. User plastic particles occur in 91% of the birds and average at a number of 19,4 particles and mass of 0,22g.

Table c. Details of plastic ingestion for industrial and consumer categories by fulmars in the Greater North Sea in the assessment period 2014-2018.

(Sub) Regions		Industrial granules			User plastics		
2014 - 2018	sample n	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
1. Scottish Islands	53	38%	1,3 ± 0,3	0,03 ± 0,01	87%	20,4 ± 5,5	0,29 ± 0,10
2. East-Eng-Sco	41	56%	1,9 ± 0,5	0,04 ± 0,01	90%	23,3 ± 4,7	0,13 ± 0,04
3. Channel	22	59%	3,0 ± 1,2	0,07 ± 0,03	86%	21,5 ± 7,1	0,36 ± 0,12
4. SE-Northsea	240	51%	2,1 ± 0,3	0,05 ± 0,01	93%	18,7 ± 2,9	0,22 ± 0,03
5. Skagerrak	37	51%	1,8 ± 0,5	0,04 ± 0,01	95%	17,2 ± 3,9	0,11 ± 0,02
North Sea Total	393	50%	2,0 ± 0,2	0,05 ± 0,01	91%	19,4 ± 2,0	0,22 ± 0,02

The rapid early decrease in industrial plastic granules in the North Sea was not continued at the same rate into the 2000s and the recent decrease (2009 to 2018) is not significant anymore. No strong patterns are visually evident in **Figure e** and no significant changes were identified in the first assessment over the period 2005 to 2014. However, over the most recent 2009 to 2018 decade, as measured over the whole of the North Sea, **Table d** provides evidence for statistical significant declines in ingested mass of user plastics (p=0,01). It should be emphasized that this represents the first statistical evidence for a significant reduction of plastic consumer waste. For separate sub-regions, the tests are not significant for industrial plastics and for user plastics, only the South-Eastern North Sea region shows a remarkable significant decrease of user plastics (**Figure f**).

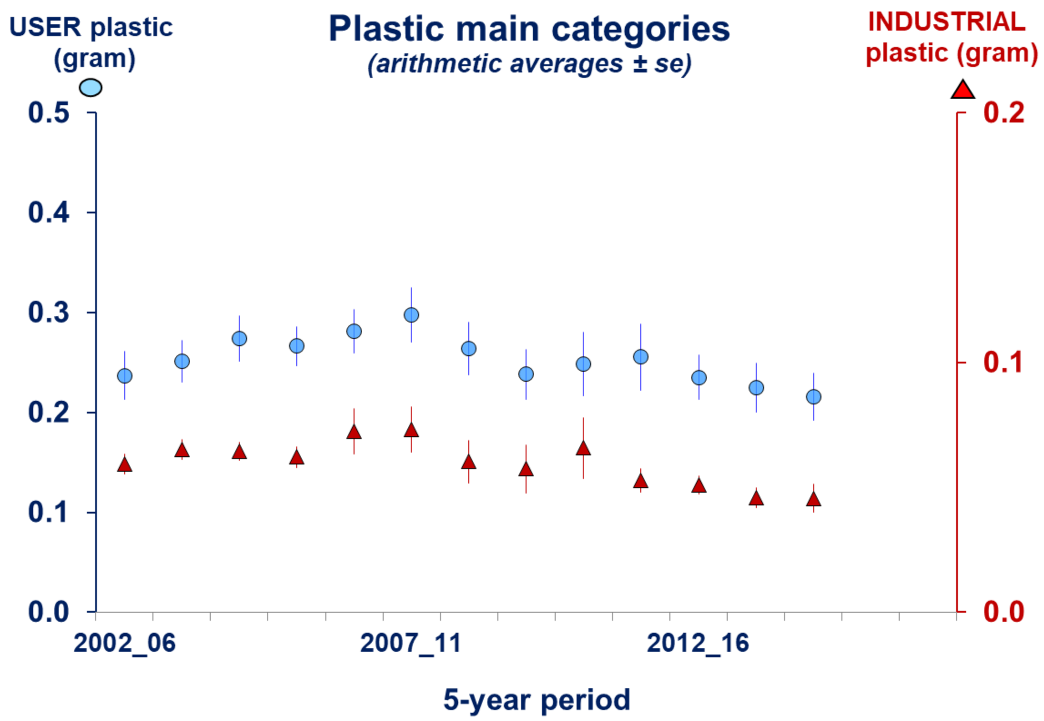

Figure e: Plastic mass in stomachs of fulmars in the North Sea (all five sub-regions combined) since the year 2002, for separate consumer plastics (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis).

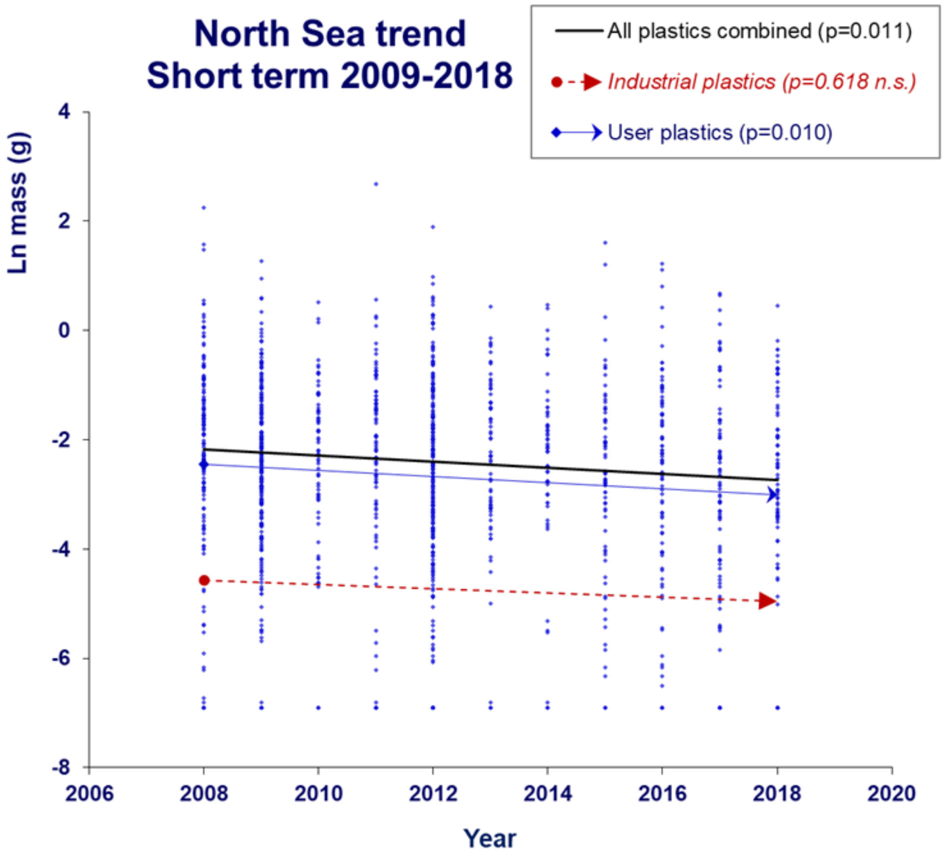

Figure f: Trends in plastic mass in stomachs of fulmars in the North Sea over the most recent ten-year period (2009-2018). *Graphs show ln transformed mass data for industrial plastic and consumer plastic in stomachs of individual fulmars, plotted against year, and linear regression lines for industrial (lower, red line), consumer (middle blue line) and total plastics (top black line). Trendlines are drawn as continuous lines when the regression is significant, and as dashed lines when a regression was not significant (n.s.) For a simpler expression of changes over time, see* ***Figure a*** *with five-year running averages of mass for the two main categories of plastic.*

Table d: Linear regression analyses for time related trends between 2009 and 2018 in industrial and consumer plastic abundance in stomachs of fulmars in the EcoQO sub-regions and in the total North Sea.

10-year trend 2009-2018 - linear regression results														
(Sub) Regions	Industrial plastics							User plastics						
	n	constant	slope	s.e.	t	p		n	constant	slope	s.e.	t	p	
1. Scottish Islands	128	103	-0,054	0,051	-1,050	0,294	n.s.	128	87	-0,045	0,053	-0,850	0,399	n.s.
2. East-Eng-Sco	79	101	-0,053	0,072	-0,730	0,467	n.s.	79	189	-0,095	0,070	-1,360	0,178	n.s.
3. Channel	31	130	-0,067	0,168	-0,400	0,694	n.s.	31	-89	0,043	0,161	0,270	0,791	n.s.
4. SE NorthSea	783	11	-0,008	0,028	-0,270	0,786	n.s.	783	93	-0,048	0,023	-2,040	0,042	-
5. Skagerrak	96	-44	0,020	0,078	0,250	0,804	n.s.	96	171	-0,087	0,066	-1,310	0,192	n.s.
North Sea Total	1117	17	-0,011	0,022	-0,500	0,618	n.s.	1117	96	-0,049	0,019	-2,590	0,010	

Conclusion (brief)

This assessment shows that the Fulmar-TV of less than 10% of northern fulmars exceeding 0,1g of plastic in their stomachs, was not reached in the North Sea. During the 2014 to 2018 period, 92% of North Sea fulmars had some plastic in the stomach, with 51% exceeding the 0,1g level. On average each fulmar contained 21 plastic particles weighing 0,26g. Over the past ten years there has been a significant reduction in the mass of plastic in fulmar stomachs. In contrast to earlier years, the reduction is driven by decreases in user plastics and to a less extent by industrial plastics. In the first assessment, 93% of the fulmars had some ingested plastic, 58% contained more than 0,1g of plastic, and average values per bird were 33 particles and 0,31g. The conclusion is that we appear to move in the direction of fewer plastics in the North Sea marine environment, but that we are still far above the Fulmar-TV. The North Sea fulmar populations have suffered substantial decline over the past decades. Although evidence for the causes of decline is not available, the ingestion of plastic litter is considered a potential contributing factor, because sub-lethal effects of reduced body condition and health affect almost all individuals in the population. Measures in the OSPAR Regional Action Plan aim to reduce litter and are expected to lead to a reduction of litter ingested.

Conclusion (extended)

Responsiveness of the indicator

Since the early 2000s, plastic ingestion levels by fulmars in the North Sea appeared to stabilise around a level of roughly 60% of individuals exceeding the 0,1g critical level of plastic ingestion that is used in the OSPAR long-term goal definition. Only recently it has become clear that the ingestion of plastics in very slowly reducing. When considering the growth in marine activity and the increasing proportion of plastics in wastes, these observations should be viewed positively. Fulmars in the North Sea currently have an average of about 21 plastic particles in the stomach with a combined mass of 0,26g. However, less than one out of ten fulmars has no plastic in the stomach at the moment of death, so sub-lethal impacts may affect virtually the whole population. Less than 20% of plastic mass is industrial plastic pellets, the remainder being consumer plastic waste. In the early 1980s that ratio was about fifty-fifty, so plastic composition has undergone a substantial change, even if total mass of plastic in stomachs has not changed dramatically compared to the 1980s. The early rapid changes in different sub-categories of plastic are important to emphasise, as they provide evidence that effective measures to reduce loss of plastics to the marine environment have a rapid effect, not only close to the source as evidenced by fulmars in the North Sea, but also in the main oceanic gyres at great distance from sources (Van Franeker & Law, 2015).
Sometimes, periods of small national sample sizes occur and are unfortunate, but are certainly not inhibitive for the monitoring programme. When only small samples sizes are available, national or sub-regional trends will take longer to reach levels of statistical significance. However, they certainly do contribute to sub-regional and North Sea wide data analyses. Assessments have shown that sub-regional trends mostly do not reach statistical significance, but over the whole of the North Sea the combined sample size is well able to provide evidence of statistically significant change (decline) (**Table b**).

Validity of the Fulmar-TV

The OSPAR long-term goal of no more than 10% of fulmars exceeding the 0,1g of plastic in the stomach could be seen as a global background level because this level currently does exist in relatively clean arctic marine environments such as the Canadian Arctic (Van Franeker *et al.,* 2021). Pessimistically seen, this global background level can only change in the long term, however the results by Van Franeker & Law (2015) indicated that even the global levels could change relatively fast if input of new debris is effectively stopped. In 2020 a new fulmar threshold value has been accepted in OSPAR, based on the peer-reviewed publication of Van Franeker *et al.,* 2021. This article includes a formal proposal for the Threshold Value (Fulmar-TV) based on Canadian data with a fixed statistical test to decide whether fulmar samples from other areas or time periods reach the required TV. The regionally agreed MSFD and OSPAR Fulmar Threshold Value' (in short: Fulmar-TV) is that no more than 10,06% of fulmars may have more than 0,1g of plastic in the stomach (EIHA 2021, Van Franeker *et al.,* 2021), and is thus near identical to the existing OSPAR EcoQO that used an arbitrary 10% figure. The Fulmar-TV assessment has been combined with a model approach to evaluate trends in monitored populations and the likely year that the TV may be reached (Van Franeker *et al.,* 2021).

Harm to biota

The 0,1g level of plastic mass in the stomach, in combination with a percentage of fulmars not allowed to exceed that level is not based on a quantitative assessment of harm to fulmars. Without doubt, individual fulmars and other wildlife can die and suffer severely from the ingestion of excessive quantities of plastic. However, such effects are hard to quantify in terms of reductions in populations or species. However, in that sense, the sub-lethal effects of many individuals may have population effects, even if they are difficult to quantify for fulmars, as well as for other species in the ecosystem. Further research to document such individual effects are therefore warranted.

Descriptor 10 of the European Marine Strategy Framework Directive (MSFD) states that levels of marine litter should 'not cause harm' to the marine and coastal environment. The concept of 'harm' to wildlife is a very complicated concept, which in spite of various dedicated publications (Rochman *et al.*, 2016; Browne *et al.*, 2015; Werner *et al.*, 2016) cannot be unambiguously defined. Some will define individual suffering or death of animals as evident harm, whereas others interpret it that 'large numbers' of individuals must suffer or die, or even more extreme that populations must be in serious decline before being harmed, including the firm evidence that it is specifically marine litter that causes such decline.

Lacking ways to properly assess 'harm' it has been agreed in MSFD that a new regionally agreed MSFD and OSPAR Fulmar Threshold Value (Fulmar-TV) may be derived from the situation in a near pristine area for which ingestion rates of fulmars are known.

By principle one should oppose the idea that an indicator species in the MSFD should be in decline before it gives evidence of harm. Species are chosen as useful indicators because of their abundance, which usually also means they are 'strong' species. Other more vulnerable and/or threatened (e.g. International Union for Conservation of Nature (IUCN) red-listed) species may become threatened to extinction because of marine litter even in a situation where the indicator species such as the fulmar is still abundant.

However, it is useful to mention that the fulmar population after two centuries of growth is not doing well in recent years. In Europe, the population of fulmars is estimated to have declined by more than 40% since about the mid-1980s (Birdlife International, 2015). Similar or even stronger declines have been reported for other large fulmar populations in the North Atlantic such as a 35% decline over about three decades in Iceland (Garðarsson *et al.*, 2011), 58% decline in about 25 years on Bear Island, Svalbard (Fauchald *et al.*, 2015), and an alarming 87% in study colonies in the Canadian Arctic (Mallory *et al.*, 2020).

Within the EU, the IUCN Red List considers the fulmar population as being 'Endangered' (Birdlife International, 2015). At the global level, Birdlife International (2018) lists the species as of 'Least Concern', but in that qualification clearly has not yet included data-sources listed above. Conservation actions proposed in the BirdLife population assessment are identification and protection of important sites at sea, as well as for prey species and continued monitoring of marine litter ingestion, and increased efforts for the removal of plastic from oceans (Birdlife International, 2015). Although hard evidence for cause(s) of decline is impossible to obtain, the ingestion of plastic debris is thus considered a potential contributing threat to the fulmar population that needs to be addressed. It is also important to bear in mind that the fulmar is a single indicator species. To understand the full extent of the problem in a wider context further development of other indicator species will be necessary. For more information on harm, please see Werner *et al.* (2016).

Measures

Globally, it has been estimated that 80% of marine plastic debris originates from land (Faris & Hart 1994). Indeed, huge masses of plastics are estimated to enter the sea from land-based sources (Jambeck *et al.*, 2015) but proper estimates for sea-based litter are lacking. In the North Sea, at least for macro-debris on beaches, sea-based sources (shipping, fisheries, aquaculture, offshore industry) are thought to be a dominant source (van Franeker 2005; Fleet *et al.*, 2009). Similar results have been found in the Ocean Cleanup surveys in the Great Pacific Garbage Patch, where sea-based sources dominated mass of plastics, e.g. over 52% of mass were ropes and nets, and much fisheries related items were in other categories (Lebreton *et al.*, 2018). Sources of smaller marine plastic debris in the North Sea are less clear. It is to be expected that all (collective) measures in the OSPAR Regional Action Plan will contribute to a reduction of floating litter and thus to a reduction of debris ingested by fulmars.

Knowledge Gaps (brief)

The OSPAR Indicator on Plastic Particles in Fulmar Stomachs intends to reflect litter floating at the surface, and potential harm from marine litter in the environment to pelagic marine organisms. However, the fulmar monitoring effort does not give direct information on 'harm' or 'damage' but simply quantifies spatial and temporal patterns in abundance of plastics in fulmar stomachs as an indirect measure of harm. Dedicated experimental laboratory research into evidence of harm to fulmars from specified levels and types of plastics, as a specific example of harm, is urgently needed to strengthen the role of the OSPAR Common Indicator.

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Assessment Metadata

Field	Data Type	
Assessment type	List	Indicator Assessment
Summary Results (template Addendum 1)	URL	https://odims.ospar.org/en/submissions/ospar_plastic_fulmar_msfd_2022_06/
SDG Indicator	List	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
Thematic Activity	List	Biological Diversity and Ecosystems - Management of specific human pressures
Relevant OSPAR Documentation	Text	Agreement 2015-03. Coordinated Environmental Monitoring Programme (CEMP) Guidelines for Monitoring and Assessment of plastic particles in stomachs of fulmars in the North Sea area.
Date of publication	Date	2022-06-30
Conditions applying to access and use	URL	https://oap.ospar.org/en/data-policy/
Data Snapshot	URL	https://odims.ospar.org/en/submissions/ospar_plastic_fulmar_snapshot_2022_06/
Data Results	Zip File	https://odims.ospar.org/en/submissions/ospar_plastic_fulmar_dataresults_2022_06/

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Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

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