Fulmar Litter Monitoring in the UK – Update 2022

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Photo cover: Two northern fulmars on the cliffs of the Icelandic coast. Photo: S. Kühn

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Contents

Summary

The aim of this project is to provide UK authorities with monitoring data of plastic ingestion by northern fulmars, as required under OSPAR and UK Marine Strategy agreements. The (undated) long term OSPAR target requires that no more than 10% of fulmars exceed a critical level of 0.1 gram of plastic in the stomach (Fulmar Threshold Value or Fulmar-TV), a level which would indicate ecological quality of the marine environment for marine debris. The criterion has been copied in the definition for Good Environmental Status under the UK Marine Strategy: currently, 'A downward trend in the number of northern fulmars with more than 0.1 g of plastic particles in their stomach' is proposed by DEFRA as a target in the UK Marine Strategy. The monitoring provides internationally tested and agreed methods to offer clear conclusions on trends and levels of pollution. This report updates the British fulmar monitoring data to include plastics in stomach contents of fulmars found up to the year 2022.

Like in all parts of the North Sea, plastic ingestion levels of fulmars from the UK remain far off the OSPAR and UK Marine Strategy long term policy target. Measured over the 5-year period 2018-2022, 43% of the UK North Sea fulmars exceed that level. This recent 5-year period is the best on record for the UK in terms of the policy target. Over the current 2018-2022 period, 108 fulmar stomachs were investigated, among which 81% contained some plastic. On average a fulmar had 22.9 plastic pieces in the stomach weighing 0.16 gram (Summary Table 1).

Table 1. Five-year average plastic ingestion level for fulmars from the United Kingdom, 2018 to 2022. *The Frequency of Occurrence (%FO) is the percentage of birds with plastics in the stomach. The Fulmar Threshold Value Percentage (FTV%) gives the percentage of fulmars having more than 0.1 g plastic in the stomach. The long term policy target is that this percentage should be reduced to 10% or less.*

United Kingdom All coasts		TOTAL PLASTICS			
period	number of birds		average number	average mass	Fulmar-TV performance %
	n	%FO	n ± se	g ± se	*(% > 0.1 g)*
2018_22	*108*	81%	22.9 ± 4.0	0.16 ± 0.02	43%

National and international targets are worded as ‘Fulmar-Threshold Value percentages’ (FTV%). Over the longer 2002-2022 period, the annual FTV% decreased significantly (p=0.007) in the UK. Therefore a prediction can be made of the estimated year in which the OSPAR/UKMS target in FTV% might be reached. For the UK, the model predicts that in 2056 less than 10% of the fulmars may have more than 0.1 gram plastic in their stomach (Summary Figure 1). This estimation implies continuous efforts to further reduce plastic litter input into the ocean.

With the national target still far off, it is worthwhile to not only look into the past but also to evaluate recent trends in plastic mass, as observed during the last decade. The standard linear regression test using individual data over the most recent 10-year period 2013-2022 shows a significant downward trend in mass of ingested plastic (p<0.001) for the UK North Sea coast. Subregional differences within the UK occur, but without consistent pattern. These overall UK results contrast with the Dutch situation, where, after earlier decreases, no further change in the latest 10-year period for ingested plastic mass was observed.

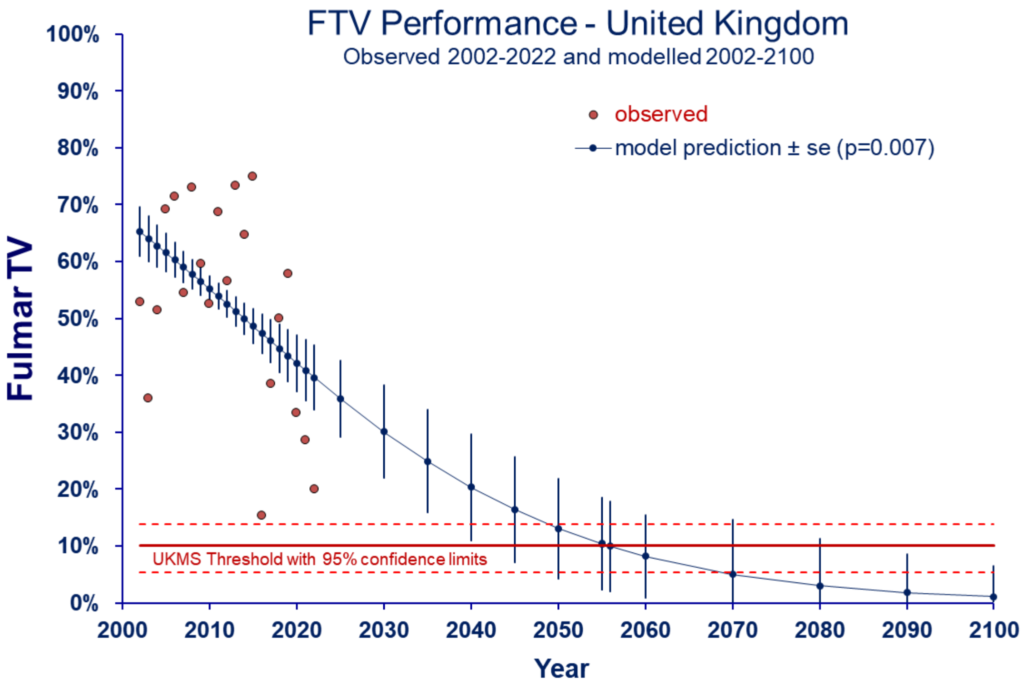

Figure 1. Predicted trajectory to the OSPAR longterm Fulmar-TV target for plastics ingested by all fulmars (n=509) in the UK, *based on a logistic binomial model from annual Fulmar-TV Performances. This model is based on annually observed FTV Performance over the 21-year period 2002-2022 (p=0.007) and includes age composition of the annual samples as a covariate.*

1 Introduction

Marine debris has serious economic and ecological consequences. Economic impacts are most severe for coastal communities, tourism, shipping and fisheries (Newman et al. 2015). Marine wildlife suffers from entanglement and ingestion of debris, with micro-particles potentially affecting marine food chains up to the level of human consumers (e.g. Galloway 2015). Ingestion of debris is common among a wide range of marine species including many seabirds, marine mammals and turtles (Laist 1987; Laist 1997; Kühn et al. 2015; Kühn & Van Franeker 2020). 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. Despite spectacular examples of mortality caused by entanglement in, or ingestion of marine litter, the real impact on marine wildlife therefore remains difficult to estimate (Browne et al. 2015; Rochman et al. 2016; Werner et al. 2016). A growing body of literature reports mechanic effects or lesions to organs associated with plastic uptake. For example, Rivers-Auty et al. (2023) and Charlton-Howard et al. (2023) report inflammatory response in seabird organs that were in contact with ingested plastics. Plastics may also impact the gut microbiome of northern fulmars (*Fulmarus glacialis*) and Cory's shearwaters (*Calonectris borealis*) as shown by Fackelmann et al. (2023). Leaching of toxic additives and adsorbed organic pollution substances from ingested plastics to seabirds has been demonstrated by Tanaka et al. (2018), Yamashita et al. (2021), Kühn et al. (2020) and Sühring et al. (2022).

Northern fulmars (hereafter 'fulmars') are purely offshore foragers that ingest all sorts of litter from the sea surface and normally do not regurgitate poorly degradable diet components or debris like plastics. Items must gradually wear down in the muscular stomach to a size small enough to pass into the intestines. During this process, plastics accumulate in the stomach, reflecting litter levels encountered in their foraging area for a period of probably up to a few weeks (Van Franeker & Law 2015). The OSPAR/MSFD monitoring system uses fulmars found dead on beaches, often slowly starved but also accidentally killed e.g. as in fisheries bycatch. In a pilot study, it has been shown that the amount of plastic in stomachs of slowly starved beached birds was not statistically different from that of healthy birds killed in instantaneous accidents in the same area (Van Franeker & Meijboom 2002). Plastics monitored include micro-, meso and occasionally macroplastics. The lower limit is determined by sieve mesh size (1 mm), however a upper size limit is difficult to define as flexible plastic items such as sheets or threads can be compressed in bird stomachs. In general, most items are 4 to 5 mm in length (Bravo Rebolledo 2011).

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 forage exclusively at sea, usually offshore (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 surface 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 from the UK since 2002; and literature is available on other locations and related species worldwide (Van Franeker 1985; Van Franeker & Bell 1988; Kühn & Van Franeker 2020).

- 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 kittiwakes *Rissa tridactyla*).

In 2002, North Sea Ministers in the Bergen Declaration, decided to start a system of '*Ecological Quality Objectives (EcoQO's) for the North Sea*'. One of the EcoQO's to be developed was for the issue of marine litter pollution, using stomach contents of the fulmar, to monitor developments, and to set a target for 'ecological quality'. As proposed by Van Franeker et al. (2021), this target was replaced by the similar OSPAR/ UK Marine Strategy Fulmar Threshold Value (Fulmar-TV; FTV) (OSPAR 2020; DEFRA 2022). The Fulmar-TV is worded as:

*"Over a period of at least five consecutive years, no more than 10% of northern fulmars (*Fulmarus glacialis*) in samples of at least 100 birds may exceed the level of 0.1 g of plastic particles in the stomach."*

The most recent international overview of the monitoring of plastics in stomach contents of fulmars in the North Sea area includes data up to 2018 (OSPAR 3rd Intermediate Assessment; Kühn et al. 2022). The same data was used in a paper proposing an EU-MSFD threshold level and a new modelling approach using the trends since 2002 to predict the potential data of meeting such threshold level (Van Franeker et al. 2021). The detailed history of the development of the OSPAR EcoQO and its successor the EU MSFD Fulmar Threshold Value can be found in e.g. Van Franeker & Kühn (2020).

2 Materials and Methods

Starting 2014, monitoring in the UK has been commissioned by DEFRA to Wageningen Marine Research in the Netherlands. Reports on levels and trends have been provided for the years 2002-2021. Fulmar corpses for this monitoring project are provided by a diverse range of volunteer individuals or groups from the Shetland Islands, Orkney Islands, the Scottish mainland coast and the East England coast. Occasionally also birds from other UK regions become available. For monitoring purposes, we do not use birds that have been alive in rehabilitation for more than three days, because during treatment, plastic particles break and wear down in the muscular stomach of the bird (Van Franeker & Law 2015).

Bird corpses are stored frozen until analysis. Standardised dissection methods for fulmar corpses have been published in a dedicated manual (Van Franeker 2004) and are internationally calibrated during regular workshops with colleagues and volunteers from the North Sea OSPAR region. 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; OSPAR 2010). Scientific reliability of the methodology was established by its publication in the peer-reviewed scientific literature (e.g. Van Franeker et al. 2011; Van Franeker & Law 2015; Van Franeker et al. 2021) with guidelines for formal future assessments published by OSPAR (2015). For convenience, some of the methodological information is repeated here in a condensed form.

Dissection
At dissections, a full set 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, so far the only variable found to influence litter quantities in stomach contents within the North Sea, is assessed mainly 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. *Bursa of Fabricius* is well developed in chicks, but disappears within the first year of life or shortly after).

Stomach content analysis procedure
Fulmars have two stomach '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. For the purpose of reducing monitoring costs, the contents of proventriculus and gizzard have been combined.

Stomach contents are carefully rinsed in a sieve with a 1 mm 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 therefore costly) and particles smaller than 1 mm seemed rare in the stomachs, and when present contributed very little to plastic mass, which is the main parameter used for monitoring.

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/FTV monitoring, the required dataset has been restricted to just two main categories 1.1 (Industrial Plastics) and 1.2 (User Plastics) without further subcategories (OSPAR 2015).

PLASTICS (PLA)

Industrial plastic pellets (IND) are small, often cylindrically shaped granules of ± 4 mm diameter, but also disc and rectangular shapes occur. Various names are used, such as pellets, mermaid tears, beads or granules. They can be considered as "raw" plastic or a half-product in the form of which plastics are first produced. 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. Included in this category are very small, often transparent or milky spherical granules ('microbeads'), which are a raw industrial product as well, but occur infrequently and only in small numbers in fulmars.

User plastics (USE) all non-industrial remains of plastic objects may be further differentiated in the following subcategories:

- **sheetlike user plastics (she)**, as in plastic bags, foils etc., usually broken up in smaller pieces;
- **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;
- **foamed user plastics (foam)**, as in foamed polystyrene cups or packaging or foamed polyurethane in matrasses or construction foams;
- **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.);
- **other plastic (poth)**, for example cigarette filters, rubber, elastics etc., so items that are 'plastic-like' or do not fit into a clear category.

Particle counts and category weights

For each bird and each (sub)category the following metrics are recorded:

- The number of particles (N=count of number of items in each (sub)category).
- The mass (W=weight in grams) using Sartorius electronic weighing scale after at least a two-day period of air drying at laboratory temperatures. This is done separately for all subcategories. Weights are recorded in grams accurate to the 4th decimal (= tenth of milligram).

Data presentation

With the start of the new contract phase, a new report format has been agreed on. It now combines information relevant to policy-makers. In anticipation of future expansion of fulmar collections to other UK coasts, incidental data from all UK coasts has now been included. With this change six additional birds from outside the North Sea area (Western UK) are analysed together with the previous main areas. For the OSPAR Quality Status report (Kühn et al. 2022), the former area 'East England' was already expanded to 'Eastern England and Scotland mainland' to account for recently added birds from the Scottish mainland. For consistency the incidental birds from the western UK were combined to an area defined as 'Western England and Scotland'. The previously separately reported island groups Orkneys and Shetlands are now presented as Scottish Isles, again in line with the OSPAR Quality Status Report (Kühn et al. 2022).

On the basis of these records, data can be presented using the following formats:

Frequency of Occurrence (%FO)

The simplest form of data presentation is by proportional presence or absence. This metric is also referred to as Incidence or Prevalence. The %FO gives the percentage of all investigated stomachs that contained the category of debris discussed. The quantity of debris is irrelevant in this respect.

Arithmetic Average

Data for numbers or mass are frequently shown as averages with standard errors 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'). Usage of standard error (SE) is preferred over standard deviation (SD) because the SE reflects the reliability of the calculated average by taking into account the sample size where SD mainly considers the spread in the data. 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. In data presentation we frequently use data pooling over data periods of 5 years, in order to avoid the potentially misleading suggestions by strong variations in annual data.

Geometric Mean

The 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 consequently 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. To avoid confusion we do not provide tabulated data on geometric means, but the smoothing by the combination of pooling in 5-year periods and geometric means, has been used to graphically illustrate trends in age dependent plastic ingestion in Figure 1, explaining the use of age as a covariate in trend calculations (see modelling trends below).

Fulmar Threshold Value Performance (FTV%)

Recently, following the study by Van Franeker et al. (2021), the earlier OSPAR EcoQO has been replaced by the Fulmar-Threshold Value (Fulmar-TV or FTV; OSPAR 2020; EC 2022; DEFRA 2022). The definition however remained unchanged to the previous OSPAR EcoQO target, the similar definition allows direct comparisons of new and old data, not only in the North Sea, but also with data reported all over the North Atlantic, North Pacific and the Arctic.
The new Fulmar-Threshold Value definition states:

"*Over a period of at least five consecutive years, no more than 10% of northern fulmars (*Fulmarus glacialis*) in samples of at least 100 birds may exceed the level of 0.1 g of plastic particles in the stomach.*"

The information requested for OSPAR and the Fulmar-TV 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 plastics. Fulmar-TV 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 (FTV%). The target is thus to reduce the FTV% to 10% or less. The FTV format is a highly simplified form of data-presentation but through that simplicity it escapes the problems faced by more sophisticated but complex statistical procedures as a consequence of excessive outliers or a large proportion of zero values in a dataset. In the background however, details of various subcategories of litter continue to play an important role for correct interpretation of the FTV metric.

Data processing

Data from dissections and stomach content analysis are recorded in Excel spreadsheets and stored in an Oracle relational database. GENSTAT 22nd Edition was used for statistical tests. As concluded in the pilot study (Van Franeker & Meijboom 2002) and later reports, the current situation and statistical trend analyses are conducted using data on mass of plastics in the fulmar stomachs.

Current FTV compliance

The 'current' situation with regards to the FTV target is assessed from the proportion of all birds studied in the most recent 5 years that exceed the limit of 0.1 gram of plastic in the stomach. This 5-year period was chosen because annual samples may contain too few birds and could be affected by short interannual variability. Five-year averaged data are shown in a tabulated format. Data for the most recent year in annual reports are only shortly discussed in texts.

Modelling trends

The OSPAR EcoQO monitoring guideline (OSPAR 2015) only discussed analysis of trends by the use of linear regressions fitting ln-transformed plastic mass values for individual birds on the year of collection. The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x.

Above-mentioned tests can indicate the direction and significance of change, but have no direct link to the actual FTV target definition. Therefore, Van Franeker et al. (2021) proposed to use a Generalized Linear Model (GLM), more specifically a logistic analysis using logit transformed data to test for a trend in the annual FTV%. The model is based on binomial distributions of the number of birds in the sample and the number of those birds above the Fulmar Threshold Value. Relevant co-variates such as the age composition of each annual sample can be included. If the model based on observed data proves to be significant, the observed trend can be used to predict when in future the target of 10% or less fulmars with 0.1 g or more plastic might be reached. For the time being, this logistic model will be based on annual data since the start of the North Sea wide monitoring of fulmars in 2002 (Save the North Sea 2004). Analyses using shorter periods will suffer from a too small sample size, as each year supplies only a single FTV% data point.

In order to predict the future year in which the target might be reached, the model assumes similar rates of change to continue in future years. In order to check if recent years support the direction and significance of change, the older OSPAR EcoQO test using plastic mass data from individual birds over the most recent years may be used. This test is restricted to individual bird data from the most recent 10 years. The 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 this approach, this period was arbitrarily increased to a standard period of ten years for tests of current time related trends.

3 Results and Discussion

This report updates the British fulmar monitoring data on plastics in stomach contents up to the year 2022. Since a few years, aside from the contractual monitoring report, WMR has provided complementary reports with summarized information and photographs of plastic in the stomach of individual birds. These documents are intended for the surveyors in the monitoring program. Also this 2022 monitoring report is accompanied by such illustrated counterpart (Van Franeker et al. 2024).

In 2022, the UK surveyor network collected 15 fulmar corpses, of which four have been withheld for highly pathogenic avian influenza (HPAI) testing by DEFRA's APHA (Animal and Plant Health Agency). At this stage it is uncertain whether stomachs of these four fulmar corpses will become available for the plastic monitoring study. Consequently, the current report adds only 11 fulmars for the year 2022. One fulmar, found in south-eastern England was too scavenged with an incomplete stomach, therefore this bird had to be excluded from further analysis, limiting the number of stomach contents available for analysis to 10 birds. None of the birds collected were treated in rehabilitation centres for more than three days. No additional fulmars from previous years were reported.
Therefore a total of 10 fulmars was available for stomach content analysis over 2022.

The desired sample size for a reliable average in our monitoring program is ±40 birds or more (Van Franeker & Meijboom 2002). Within a single year, that number is often not reached, certainly at a subregional basis. Therefore, as a rule of thumb in monitoring reports, we report 'the current situation' as the combined data from the most recent 5-years of sampling. This 5-year period also directly links to the FTV target definition.

The relative low number of fulmars collected in year 2022 is mainly a consequence of the major outbreak of highly pathogenic avian influenza (HPAI) in seabirds. Considerable mortality was observed among great skuas (*Stercorarius skua)*, Sandwich terns (*Thalasseus sandvicensis*) and northern gannets (*Morus bassanus*) in the UK (Camphuysen et al. 2022; Lane et al. 2023; Knief et al. 2023). Consequently, DEFRA guidelines restricted the collection of dead bird corpses on UK coasts and therefore also the ability to involve new volunteers. This restriction will have contributed to the low number of fulmars collected in 2022. All available birds were collected in early 2022, before the restrictions came in place. Currently (*January 2024*), the number of positively tested northern fulmars is low, with four fulmars in the UK (three individuals in 2022 and one individual in 2023; APHA 2024; Serafini et al. 2023) and eight cases globally (Serafini et al. 2023). For England, has been established in collaboration with APHA and DEFRA to test beached fulmars. If tested negative for HPAI, the stomachs may be made available for plastic monitoring. Although stomach data may become available, unfortunately essential data on age, sex, condition etc. (partly explaining the amounts of plastic in fulmar stomachs) cannot be delivered.

3.1 Current situation (2018-2022)

As indicated, annual data may show strong variability, e.g. due to small sample sizes, therefore the emphasis of the plastic monitoring in fulmars is on the most recent 5-year period. For the entire UK 108 fulmars are available for the period 2018-2022. Of these 108 birds, 81% were found with ingested plastics. On average fulmars contained 22.9 plastic particles, weighing 0.16 gram per bird (Table 1). The majority of plastic in fulmar stomachs consisted of user plastics (0.13 gram per bird), and to a lesser extent of industrial plastics (0.03 gram per bird; Table 2).

The major figure to consider in terms of national and international policy, is that of the Fulmar-Threshold Value Percentage (FTV%). This is the percentage of birds exceeding the level of 0.1 gram of plastic in the stomach. OSPAR's long term policy target aims that the percentage of fulmars with more than 0.1 g of plastic in the stomach must be reduced to under 10% for at least five consecutive years. The UK has adapted the same target within the UK Marine Strategy. Details for fulmars from the entire UK over the 2018-22 period are given in Table 1, showing 43% of birds having more than 0.1 g of plastic in the stomach. This value is comparable to the previous period (2017-2021), for which 45% of the birds had more than 0.1 gram of plastic in their stomach.

Table 1. Current five year average plastic ingestion level for fulmars from the United Kingdom 2018 to 2022. *The Frequency of Occurrence (%FO) is the percentage of birds with plastics in the stomach. The Fulmar-TV gives the percentage of fulmars having more than 0.1 g in the stomach. The long term policy target is that this percentage should be reduced to equal or under 10%.*

2018_22		TOTAL PLASTICS						
			average number		average mass		Fulmar-TV
UK areas	*n birds*	%FO	n	± se	g	± se	*(% > 0.1g)*
Scottish Isles	54	78%	19.5	± 5.8	0.18	± 0.04	41%
Eastern England and Scotland mainland	50	86%	27.8	± 5.9	0.14	± 0.03	46%
UK Channel	1	100%	27.0		0.56	± 0.00	100%
Western England and Scotland	3	67%	3.0	± 1.7	0.01	± 0.01	0%
UK (All areas)	**108**	**81%**	**22.9**	**± 4.0**	**0.16**	**± 0.02**	**43%**

Table 2. Summary of sample characteristics and stomach contents of fulmars collected for the UK marine litter monitoring the current 5-year period 2018-2022. *The top line in the table shows the sample composition in terms of age, sex, origin (colour-phases darker than Double Light (LL) indicate distant Arctic origin), death cause oil, and the average condition-index (which ranges from emaciated condition=0 to very good condition=9; Van Franeker 2004). For each litter-(sub)category the table lists: the proportion of birds with items of the litter category present (%FO); average number of plastic items per bird ± standard error; average mass of plastic per bird stomach ± standard error; and the maximum mass observed in a single stomach.*

United_Kingdom	*n*	% adult	% male	% LL	% oil	condition
2018_22	**108**	**50%**	**52%**	**92%**	**0%**	**2.5**

		%FO	average number of items (n/bird) ± se	average mass of litter (g/bird) ± se	max. mass recorded
1	**ALL PLASTICS**	**81%**	**22.9 ±4.0**	**0.16 ±0.02**	**1.05**
1.1	**INDUSTRIAL PLASTIC**	**39%**	**1.2 ±0.3**	**0.03 ±0.01**	**0.43**
1.2	**USER PLASTIC**	**81%**	**21.7 ±3.9**	**0.13 ±0.02**	**1.02**
1.2.1	sheets	40%	2.4 ±0.5	0.01 ±0.00	0.15
1.2.2	threads	36%	0.9 ±0.2	0.01 ±0.00	0.33
1.2.3	foamed	41%	5.9 ±2.2	0.01 ±0.01	0.52
1.2.4	fragments	79%	12.3 ±2.1	0.09 ±0.01	0.69
1.2.5	other plastic	10%	0.2 ±0.1	0.02 ±0.01	0.62

3.2 Fulmar-Threshold Value trends and forecasting

Policy-makers involved in OSPAR asked us to provide models that might predict plastic ingestion rates by fulmars in future years. Such information can assist in focused planning of actions aiming at reaching policy targets by specific dates and will therefore be provided for relevant stakeholders involved in UK Marine Strategy developments. Therefore, the earlier trend analyses over the past 10 years, were supplemented with a new approach that considers a longer time period to predict future developments (Van Franeker et al. 2021). For this analysis, all years since 2002 were included. A Generalized Linear Modelling (GLM) was applied. As this model showed significant decrease, the next step can be made by applying the data to the forecast model.

For the period since the start of the fulmar project (2002-2022), 509 birds were available. The decrease of the number of birds above 0.1 gram was significant for the UK (p=0.007), therefore the logistic model can be applied to predict future developments. The model predicts that the UK could reach the Fulmar-Threshold Value in 2056 (Figure 1). When applied to the entire North Sea region and over the years 2002-2018, it was predicted that the Fulmar-TV could be reached in 2054 (Van Franeker et al. 2021). Recent results for the Dutch data showed that the Threshold Value may be reached only in the year 2074 (Kühn et al. 2023), thus much later than currently in the UK. This is in line with the lack of significant change and even slightly upward slope of the regression line for plastic mass in beached fulmars from the Netherlands over the past 10 years.

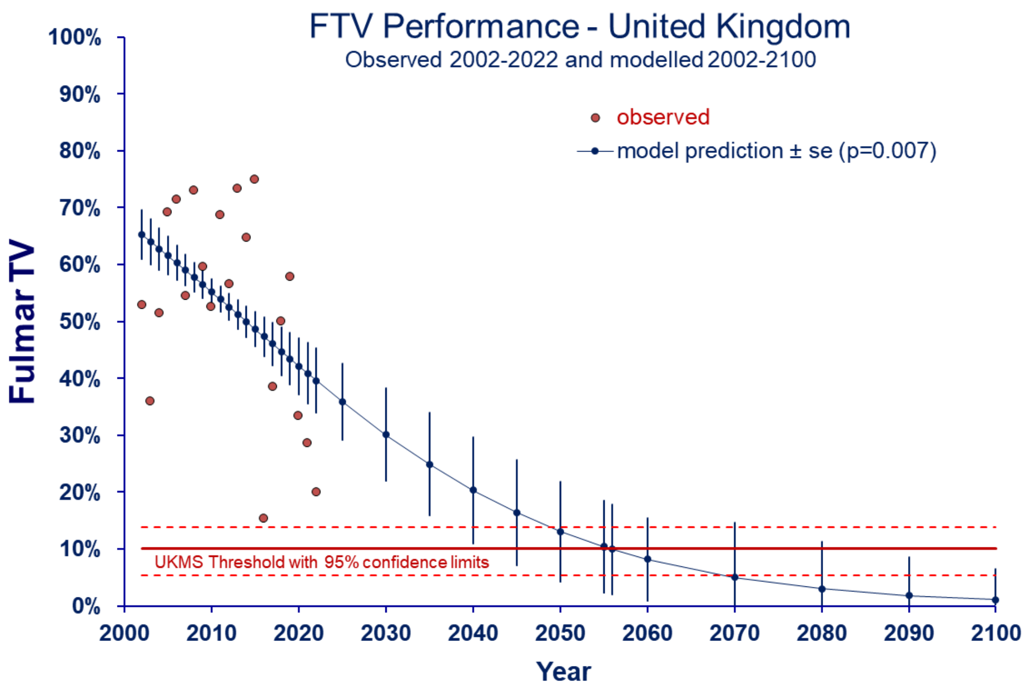

Figure 1. Predicted trajectory to the OSPAR longterm Fulmar-TV target for plastics ingested by all fulmars (n=509) in the UK, *based on a logistic binomial model from annual Fulmar-TV Performances. This model is based on observed FTV Performance over the 21-year period 2002-2022 (p=0.007) and includes age composition of the annual samples as a covariate.*

The use of age as a covariate in the long term (2002—2022) logistic model needs some explanation. Younger fulmars (the 'non-adult' category which includes first year juveniles, second year birds and immatures up to several years of age), have consistently higher levels of ingested plastics than adult birds. Nevertheless, in Fulmar-TV 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. Figure 2 illustrates age-related variations in our monitoring data by running 5-year averages and geometric means. The consistent, although variable difference in plastic loads between adults and non-adults is very clear. However, both age groups follow, at a different level, a highly comparable pattern in the period 2002-2022, which strengthens the validity of the monitoring approach combining data for all birds.

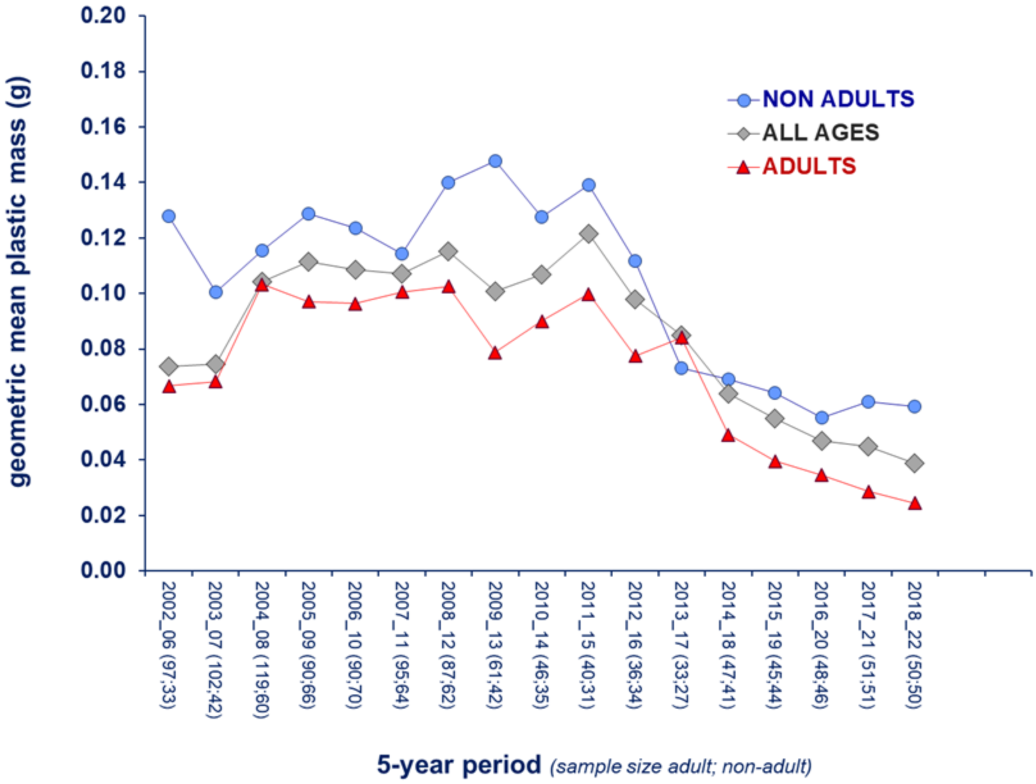

Figure 2. Geometric mean mass of plastics in stomachs of beached fulmars from the UK 2002-2022 for all age groups combined *(grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults (blue circles), with respective sample sizes in brackets in the x-axis labels. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trendline in the summary. This graphic visualization by itself does not represent a statistical trend analysis.*

It has to be emphasized that a predicted trend of reaching target by a specific year does not imply that no further action is needed. The model prediction is not based on a status-quo, but on the current rate of change. We assume the observed change to be the result of increased policy measures and improved awareness and behaviour. This implies that the predicted future change will require continued new policy measures and further improvements in awareness and behaviour. Without extra effort, it is unlikely that the FTV target can be reached within the predicted time period.

Although the trend of fulmars with more than 0.1 gram of plastic is decreasing significantly, the Fulmar-Threshold Value is currently still far off the UKMS target. Consequently, it is important to interpret the recent trends in plastic mass ingested by fulmars following the traditional OSPAR Guidelines (OSPAR 2015). Those 'current' trends in ingested plastic mass are evaluated over the most recent decade, by linear regression analysis of log transformed individual plastic mass data against the year of collection of each bird. For the UK, over the 2013-2022 decade, the available sample of fulmars is 174 birds. Over this period, significant decrease is observed in 'all plastics' mass as well as in its sub-categories of 'user plastics' ($p<0.001$) and 'industrial plastics' ($p=0.014$) (Table 3). These findings illustrate that the longer term model predicting decrease is still present in recent data.

Table 3. Trend calculations according to OSPAR (2015) Guidelines, that is by linear regression using ln-transformed mass of plastic of each individual bird against its year of collection. *Tests are done for industrial plastics and user plastics, and for their combination of both. Test results are shown for the standard period. The sample size (n) and the constant and slope including standard error are presented. A negative t-value indicates a decrease in the tested litter-category. 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 (increase or decrease).*

	RECENT TREND			**2013**	to	**2022**	
	plastics in fulmar stomachs in the UK						
	n	**constant**	**slope**	**se**	**t**	**p**	
Industrial Plastics (lnGIND)	*174*	277.0	-0.1397	0.0565	-2.47	0.014	↓ -
User Plastics (lnGUSE)	*174*	403.0	-0.2013	0.0591	-3.41	<.001	↓ - - -
All plastics combined (lnGPLA)	*174*	431.0	-0.2153	0.0591	-3.64	<.001	↓ - - -

4 Key points

- Fulmars from the UK coast show significant declines in plastic mass in their stomachs, but are still far off the OSPAR/UKMS longterm policy target which requires that at most 10% of birds may exceed the level of 0.1 gram of plastic in the stomach.

- Considerable time has been dedicated to increase sampling effort at the different locations in the UK. This effort has resulted in new sampling locations on the Scottish mainland. However, avian flu outbreaks in other seabird species have led to restrictions regarding the collection of fulmars and have hampered this effort in 2022 and 2023.

- Over the current 2018-2022 period, 108 fulmars from the UK North Sea coast were investigated, among which 81% contained some plastic. Each fulmar on average had 22.9 plastic pieces in the stomach weighing 0.16 g. Overall, 43% of UK North Sea fulmars had more than 0.1 g of plastic in the stomach, which is still far off the policy target.

- In the UK, plastic mass in fulmars is decreasing significantly since 2013, indicating that the marine litter situation seems to be improving. With this report, the first UK specific Fulmar-TV model is presented, indicating that the Fulmar-Threshold Value may be reached in 2056. The prediction is highly comparable to the North Sea-wide prediction (up to the year 2018) that calculated that in 2054, no more than 10% of the fulmars could have 0.1 gram plastic in the stomach.

Photo 1. Photo illustration of plastics found in a fulmar from the Shetlands in 2022. *The bird has been collected by SOTEAG and was an emaciated juvenile male. It contained four sheets and three fragments, weighing 0.0381 gram, so much below the 5-year average mass of plastics in fulmars. More photo's from 2022 bird stomachs can be found in the report by Van Franeker et al. (2024).*

Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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Justification

Report C082/23
Project Number: 4312100145

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Dr. R.H. Jongbloed
Researcher

Signature:

Date: 1 May 2024

Approved: Dr. A.M. Mouissie
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Date: 1 May 2024

Annex 1 Plastic in fulmars per 5-year period

Supplement Table 1. Plastic in all available fulmars from the UK per 5-year period. Given are the sample size (n), the percentage of birds with plastics (Frequency of Occurrence; %FO), the average plastic number (n) and plastic mass (gram) per bird including the standard errors (± se) and the percentage of birds exceeding the policy target of 0.1 gram of plastic in their stomachs (Fulmar-TV).
The running 5-year data are often used to provide a graphical impression of trends, but by themselves have no statistical meaning.

UK All coasts		**Total plastics**			
PERIOD	*n*	%FO	average number n ± se	average mass g ± se	**Fulmar-TV** ***(% over 0.1 g)***
2002_06	*139*	93%	23.8 ±3.2	0.22 ±0.03	**53%**
2003_07	*155*	93%	25.1 ±3.3	0.22 ±0.02	**53%**
2004_08	*193*	94%	30.4 ±3.1	0.30 ±0.04	**62%**
2005_09	*165*	93%	31.3 ±3.2	0.36 ±0.05	**65%**
2006_10	*171*	93%	30.0 ±3.1	0.35 ±0.05	**64%**
2007_11	*173*	92%	29.5 ±3.0	0.35 ±0.05	**64%**
2008_12	*163*	94%	30.0 ±2.9	0.38 ±0.05	**64%**
2009_13	*115*	93%	37.4 ±9.3	0.34 ±0.05	**61%**
2010_14	*90*	94%	38.4 ±11.7	0.32 ±0.05	**62%**
2011_15	*79*	95%	44.0 ±13.3	0.41 ±0.08	**66%**
2012_16	*76*	95%	40.8 ±13.8	0.37 ±0.08	**57%**
2013_17	*66*	92%	38.1 ±15.7	0.32 ±0.08	**53%**
2014_18	*97*	89%	22.6 ±3.7	0.25 ±0.06	**48%**
2015_19	*99*	85%	23.7 ±3.8	0.23 ±0.05	**47%**
2016_20	*103*	85%	21.9 ±3.7	0.16 ±0.02	**44%**
2017_21	*111*	84%	23.3 ±3.9	0.17 ±0.02	**44%**
2018_22	*108*	81%	22.9 ±4.0	0.16 ±0.02	**43%**

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