Fulmar Litter Monitoring in the UK – Update 2024

Author(s): Susanne Kühn & Jan Andries van Franeker

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- Update 2024

Authors: Susanne Kühn & Jan Andries van Franeker

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Client Defra Department for Environment, Food and Rural Affairs
Attn.: Lilley, Dr M. (Martin)
Marine Evidence Team - Marine & Fisheries
Seacole Block, 2 Marsham Street, London
SW1P 4DF England UK

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Photo cover: Northern fulmar (and a hidden puffin) on Skokholm Island, Wales. Photo: S. Kühn

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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 for the period 2002-2024.

After the previous report could not report any new birds for 2023, for this current report four birds from 2023 and one bird from 2024 could be retrieved. This low sampling numbers are caused by restrictions to collect beached seabirds due to High Pathogenic Avian Flu (HPAI) detected in other seabird species. Additional birds collected in 2023 (not yet reported here) that were tested negatively for HPAI will hopefully be released for further analysis. 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 2020-2024, 25% of the 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 2020-2024 period, 48 fulmar stomachs were investigated, among which 83% contained some plastic. On average a fulmar had 12.9 plastic pieces in the stomach weighing 0.11 gram (Summary Table 1).

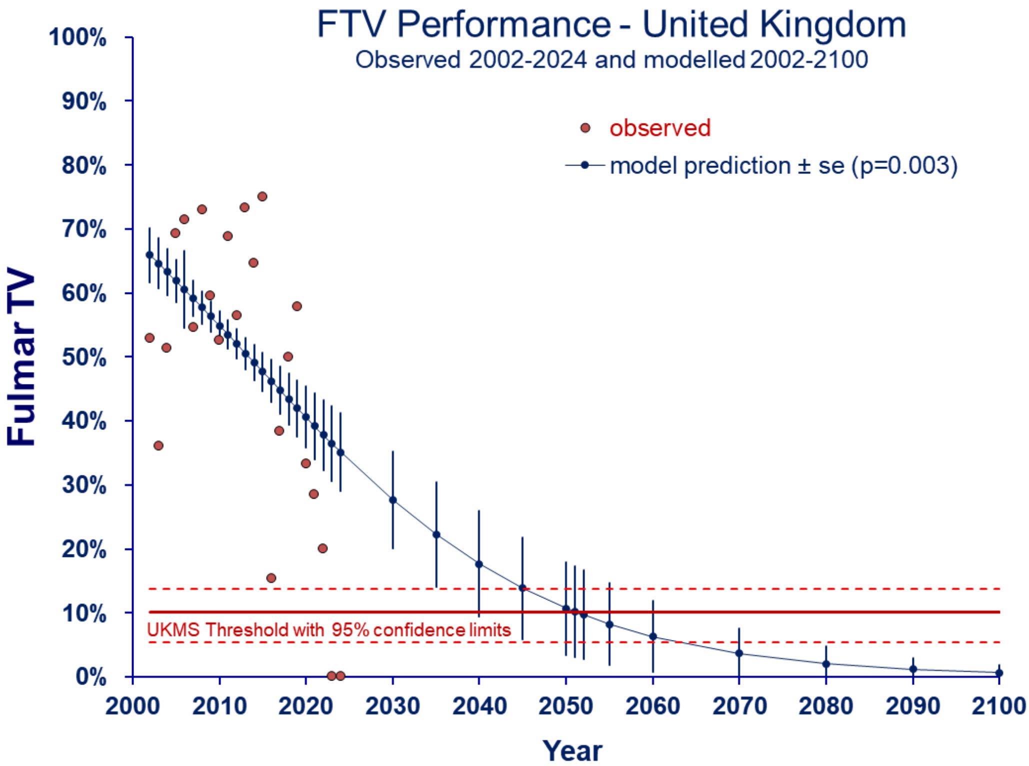
Summary Table 1. Five-year average plastic ingestion level for fulmars from the United Kingdom, 2020 to 2024. The Frequency of Occurrence (%FO) is the percentage of birds with plastics in the stomach. The Fulmar Threshold Value Percentage (FTV%) gives the percentage of fulmars having more than 0.1 g 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)*
2020_24	*48*	83%	12.9 ± 4.7	0.11 ± 0.03	25%

National and international targets are worded as ‘Fulmar-Threshold Value percentages’ (FTV%). A GLM model offers the opportunity to predict the year when this Threshold can be expected to be reached. Adding new data from 2023 and 2024, it is estimated that not before 2052 less than 10% of the fulmars will have more than 0.1 gram plastic in their stomach (Summary Figure 1). This estimate 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 2015-2024 shows a significant downward trend in mass of ingested plastic (p=0.028) for the UK North Sea coast. Subregional differences within the UK occur, but without consistent pattern. These overall UK results contrast with the Dutch and German situation, where, after earlier decreases, no further change in the latest 10-year period for ingested plastic mass was observed (Kühn et al. 2025; Guse et al. subm.), but could be caused by low sample sizes decelerating the detection of statistical changes.



Summary Figure 1. Predicted trajectory to the OSPAR longterm Fulmar-TV target for plastics ingested by all fulmars (n=514) 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 23-year period 2002-2024 (p=0.003) and includes age composition of the annual samples as a covariate. For 2023 and 2024, none of the 5 birds samples exceeded the threshold, leading to the two red sampling point at the 0% line. Annual Threshold percentages are presented in Supplement 2.

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 (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 responses 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 an 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). A new Intermediate Assessment covering data from the entire North Sea and the Arctic Ocean up to the year 2023 is currently under review and is expected to be published in 2025.

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 2002-2023 (Kühn & Van Franeker 2025). 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 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 mattresses 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 a 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

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 it was used to graphically illustrate trends in age dependent plastic ingestion in Figure 2, 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

This report updates the British fulmar monitoring data on plastics in stomach contents up to the year 2024. In 2023 and 2024, the UK surveyor network collected some fulmar corpses, of which a few have been withheld for highly pathogenic avian influenza (HPAI) testing by Defra's APHA (Animal and Plant Health Agency). Besides these birds, four fulmars from 2023 and one fulmar from 2024 were collected on the Orkney Islands and processed for this report.

3.1 The year 2024

The low number of fulmars collected in recent years is a consequence of the major outbreak of highly pathogenic avian influenza (HPAI) in seabirds in 2022. Considerable mortality was observed among great skuas (*Stercorarius skua)*, Sandwich terns (*Thalasseus sandvicensis*), common guillemots (*Uria aalge*) and northern gannets (*Morus bassanus*) in the UK (Camphuysen et al. 2022; Lane et al. 2023; Knief et al. 2023; Birkhead & Hatchwell 2025). Consequently, Defra guidelines restricted the collection of dead bird corpses on UK coasts and the ability to involve new volunteers suffered. Until summer 2025, the number of positively tested northern fulmars was low in the UK (sixteen individuals; APHA 2025) and cases were only reported incidentally elsewhere in Europe (e.g. Caliendo et al. 2025). In September 2024, a large number of dead fulmars beached on the eastern English coast and were collected (Dan Turner; personal information). Eight specimens were tested for HPAI and proved to be positive. These birds were therefore destroyed by APHA. For the remaining (likely HPAI-positive) birds, possibilities for analysis are evaluated, as strict guidelines must be followed to avoid contamination of the environment or the researchers. Stomachs of birds that were tested negatively by APHA are made available for stomach content analyses. Currently, 5-7 stomachs are about to be released for analysis and will be reported as soon as possible. Although stomachs are made available, unfortunately essential data on age, sex, condition etc. (partly explaining the amounts of plastic in fulmar stomachs) may be lost.

The desired annual 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.

3.2 Current situation (2020-2024)

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, 48 fulmars were available for the period 2020-2024 which is less than the requested 100 birds. For the longterm, it would be necessary to increase the sample size again, as trends may only be detected with some delay. Of these 48 birds, 83% were found with ingested plastics. On average fulmars contained 12.9 plastic particles, weighing 0.11 gram per bird (Table 1). The majority of plastic in fulmar stomachs consisted of user plastics (0.10 gram per bird), and to a lesser extent of industrial plastics (0.01 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 adopted the same target within the UK Marine Strategy. Details for fulmars from the entire UK over the 2020-24 period are given in Table 1, showing 25% of birds having more than 0.1 g of plastic in the stomach. This value has improved compared to the value of the previous period (2019-2023), where 37% of the birds had more than 0.1 gram of plastic in their stomach. However, to see if this decrease follows a trend, stable sample sizes of above 100 birds for a 5-year period are needed.

Table 1 Current five year average plastic ingestion level for fulmars from the United Kingdom 2020 to 2024. 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%.

2020_24		TOTAL PLASTICS			
			average number	average mass	Fulmar-TV
UK Subregion	*n*	%FO	n ± se	g ± se	*(% > 0.1g)*
Scottish Isles	27	81%	5.7 ± 1.1	0.12 ± 0.05	26%
Eastern England and Scotland mainland	19	84%	24.0 ± 11.6	0.10 ± 0.04	26%
UK Channel	0				
Western England and Scotland	2	100%	4.5 ± 1.5	0.02 ± 0.01	0%
UK All coasts	**48**	**83%**	**12.9 ± 4.7**	**0.11 ± 0.03**	**25%**

Table 2 Summary of sample characteristics and stomach contents of fulmars collected for the UK marine litter monitoring the current 5-year period 2020-2024. 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
2020_24	**48**	**50%**	**53%**	**96%**	**0%**	**2.9**

		%FO	average number of items (n/bird) ± se	average mass of litter (g/bird) ± se	max. mass recorded
1	**ALL PLASTICS**	**83%**	**12.9 ±4.7**	**0.11 ±0.03**	**1.05**
1.1	**INDUSTRIAL PLASTIC**	**29%**	**0.5 ±0.1**	**0.01 ±0.00**	**0.14**
1.2	**USER PLASTIC**	**83%**	**12.4 ±4.7**	**0.10 ±0.03**	**1.02**
1.2.1	sheets	29%	2.1 ±0.9	0.01 ±0.00	0.15
1.2.2	threads	31%	0.6 ±0.2	0.01 ±0.01	0.33
1.2.3	foamed	25%	1.4 ±0.7	0.01 ±0.01	0.52
1.2.4	fragments	79%	8.1 ±3.2	0.06 ±0.01	0.44
1.2.5	other plastic	10%	0.2 ±0.1	0.01 ±0.01	0.42

3.3 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 an 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 (2002-2024), 514 birds were available. The decrease of the number of birds with ingested plastics above 0.1 gram remains significant for the UK (p=0.003),

therefore the logistic model can be applied to predict future developments. The model predicted that the UK could reach the Fulmar-Threshold Value in 2052 (Figure 1). However, it should be noted that for the yeas 2023 and 2024 only five birds were available, all of them contained less than 0.1 gram of plastic, leading to a Fulmar-TV performance of 0% for both years, a percentage likely to be much higher with increased sample size. 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). For the Dutch data, recent results showed that the Threshold Value may be reached only in the year 2077 (Kühn et al. 2025), thus much later than 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 observed in beached fulmars from the Netherlands over the past 10 years.

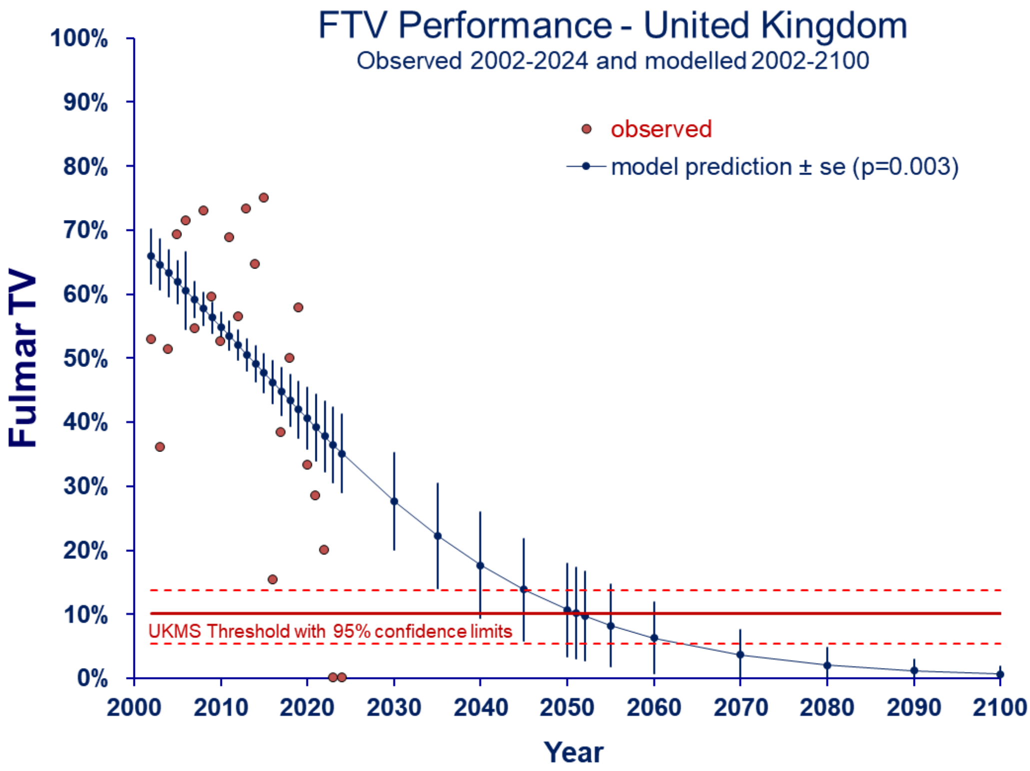


Figure 1. Predicted trajectory to the OSPAR longterm Fulmar-TV target for plastics ingested by all fulmars (n=514) in the UK, based on a logistic binomial model from annual Fulmar-TV Performances. This model is based on annually observed FTV Performance over the 23-year period 2002-2024 (p=0.003) and includes age composition of the annual samples as a covariate. For 2023 and 2024, none of the 5 birds samples exceeded the threshold, leading to the two red sampling point at the 0% line. Annual Threshold percentages are presented in Supplement 2.

The use of age as a covariate in the long term (2002-2024) 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 2002-2024, which strengthens the validity of the monitoring approach combining data for all birds.

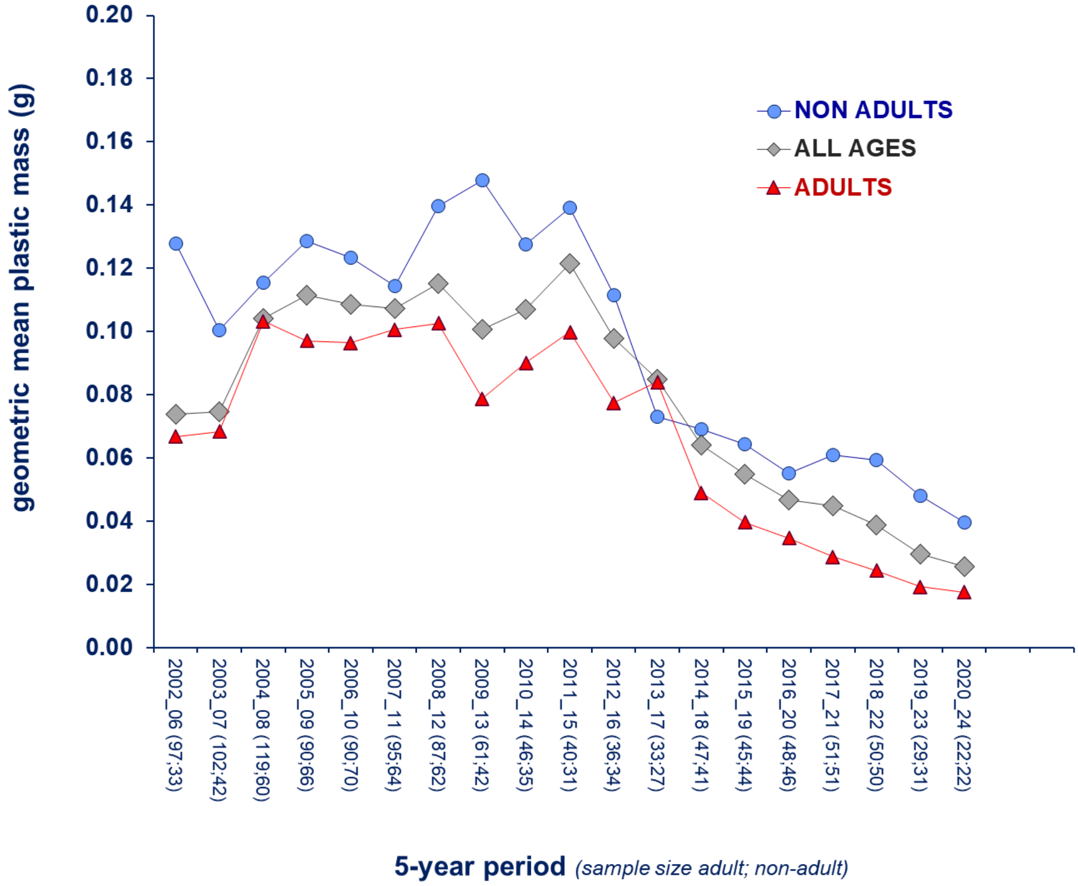


Figure 1 Geometric mean mass of plastics in stomachs of beached fulmars from the UK 2002-2024 shown as 5-year period values for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults (blue circles), with respective sample sizes in brackets 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 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 2015-2024 decade, the available sample of fulmars is 147 birds. Over this period, a significant decrease was observed in ‘all plastics’ mass (p=0.028) as well as in its sub-category ‘user plastics’ (p=0.043) but not in ‘industrial plastics’ (p=0.145) (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 10-year 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			**2015**	to	**2024**	
	plastics in fulmar stomachs in the UK						
	n	**constant**	**slope**	**se**	**t**	**p**	
Industrial Plastics (lnGIND)	*147*	220.0	-0.1117	0.0762	-1.47	0.145	*n.s.*
User Plastics (lnGUSE)	*147*	340.0	-0.1700	0.0835	-2.04	0.043	↓ -
All plastics combined (lnGPLA)	*147*	371.0	-0.1855	0.0836	-2.22	0.028	↓ -

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. However, avian flu outbreaks in other seabird species have led to restrictions regarding the collection of fulmars and have hampered this effort since 2022 resulting in low sample numbers. Once the restrictions on bird collection are lifted, additional effort will be needed to restore the volunteer network and increase search efforts.

- Over the current 2020-2024 period, 48 fulmars from the UK were investigated, among which 83% contained some plastic. Each fulmar on average had 12.9 plastic pieces in the stomach weighing 0.11 g. Overall, 25% 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 2014, indicating that the marine litter situation seems to be improving. The Fulmar-TV model indicates that the Fulmar-Threshold Value may be reached in 2052. 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.

5 Acknowledgements

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Beached fulmars are mainly collected by volunteers without whom a project such as this is 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.

A. Jay van der Reijden, Adam Hough, Alan Thompson, Andrew Craggs, Andy Gear, Anthony Hurd - Yorkshire Wildlife Living Seas Centre, Barry & Jean Robinson, Brian Ribbands, Brian Ward, Brydon Thomason, BTO, C. J. Corse, Cat Spink, Chris Andrews, Chris Beneke, Cris Sellares, Dan M. Turner, Dave Hall, Dave Oakill, David Jenkins, David Parnaby, E. Harrop, E. M. Ross, Eric Meek, Ewan Edwards, G.Burgess, Gavin Dudley, George D.R. Moody, Gordon Hyslop & George McVitie, Hannah Meinertzhagen, Hazel Terry, Helen Aiton, Helen Moncrieff RSPB, Helen Wilson, Howard Towell, Iain Johnson, J. Brown, J. & B. McCutcheon, Jan Pritchard, Jane Dudley, Jean Williams, Jenni Kakkonen, Jim Williams, Jo Wells RSPB, Jonathan Ford, Juan Brown, Kate Williams, Katie Dyke, Keith Barrow, Keith Fairclough, Kelly McIntosh, Kevin Monaghan, Laura Shearer - Coast Care, Lee Shields RSPB, Leighton Newman, Linda Charlton, Liz Gillard, Lucy Quinn, Maggie Sheddan, Mark Grantham, Martin A. Blick, Martin Gray, Martin Heubeck, Martin Schofield, Matthew Livsey, Maurice Hepple, Mick Mellor, Mo Dewar, Nathalie Pion, NIFCA, P. Collins, Paul Morrison, Pauline Gilbertson, Pauline Wilson, Pete Ellis, Peter Collins, Peter Kirmond, Phil Gilbert, Raymond Besant, Roger Riddington, RSPB, RSPCA, Russell Davis, Sally Huband, Samuel Langlos, Steve Holliday, Steven Lowe, Stewart Sexton, Sue Edwards, Tom Patterson, Vivi Bolin, Wendy Dickson, Wesley Davis, Will Miles

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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.

Justification

Report: C001/26
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

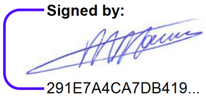
Approved: Dr. R.H. Jongbloed
Researcher

Signature:

Date: December 8, 2025

Approved: A.M. Mouissie, PhD
Business Manager Projects

Signature:



Date: December 8, 2025

Supplement 1 Plastic in UK fulmars per 5-year period

Supplement Table 1. Plastic in all available fulmars from the UK per 5-year period within the period 2002 - 2024. 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).

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%**
2019_23	*66*	80%	15.7 ±4.0	0.14 ±0.03	**35%**
2020_24	*48*	83%	12.9 ±4.7	0.11 ±0.03	**25%**

Supplement 2 Plastic in UK fulmars per year

Supplement Table 2. Plastic in all available fulmars from the UK per year within the period 2002 - 2024. 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).

UK All coasts		**Total plastics**					
YEAR	*n*	%FO	average number n	± se	average mass g	± se	**Fulmar TV** *(% over 0.1g)*
2002	*17*	82%	21.1	±6.5	0.34	±0.12	**53%**
2003	*25*	88%	16.2	±4.3	0.17	±0.06	**36%**
2004	*70*	96%	26.0	±5.2	0.20	±0.03	**51%**
2005	*13*	92%	17.8	±4.1	0.27	±0.08	**69%**
2006	*14*	100%	34.9	±13.8	0.22	±0.07	**71%**
2007	*33*	88%	28.7	±8.7	0.26	±0.05	**55%**
2008	*63*	95%	37.7	±5.3	0.45	±0.11	**73%**
2009	*42*	90%	26.6	±5.3	0.37	±0.11	**60%**
2010	*19*	95%	10.6	±2.0	0.20	±0.06	**53%**
2011	*16*	94%	29.0	±7.8	0.30	±0.09	**69%**
2012	*23*	96%	31.6	±8.6	0.41	±0.12	**57%**
2013	*15*	93%	119.7	±66.3	0.38	±0.12	**73%**
2014	*17*	94%	15.8	±4.0	0.30	±0.11	**65%**
2015	*8*	100%	27.8	±7.3	0.92	±0.59	**75%**
2016	*13*	92%	6.8	±1.8	0.06	±0.01	**15%**
2017	*13*	85%	10.7	±3.7	0.18	±0.07	**38%**
2018	*46*	85%	32.0	±7.3	0.18	±0.03	**50%**
2019	*19*	74%	22.1	±7.1	0.22	±0.06	**58%**
2020	*12*	100%	11.1	±4.3	0.07	±0.02	**33%**
2021	*21*	81%	19.8	±10.4	0.14	±0.06	**29%**
2022	*10*	60%	3.6	±1.4	0.12	±0.08	**20%**
2023	*4*	100%	8.3	±3.2	0.05	±0.02	**0%**
2024	*1*	100%	2.0	±0.0	0.09	±0.00	**0%**

Wageningen Marine Research
T +31 (0)317 48 70 00
E marine-research@wur.nl
www.wur.nl/marine-research

Visitors' address
- Ankerpark 27 1781 AG Den Helder
- Korringaweg 7, 4401 NT Yerseke
- Haringkade 1, 1976 CP IJmuiden