



Fulmar Litter Monitoring in the Netherlands – Update 2024

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Summary

Fulmar Litter monitoring in the Netherlands - Update 2024

Marine litter has serious economic and ecological consequences. Economic impacts are most severe for coastal communities, tourism, shipping and fisheries. Marine wildlife suffers from entanglement and ingestion of debris, with micro-particles potentially affecting marine food chains up to the level of human consumers. In the North Sea, marine litter problems were firmly recognized in 2002 when surrounding states assigned to OSPAR the task to include marine plastic litter in its system of Ecological Quality Objectives (EcoQO's) (North Sea Ministerial Conference 2002). At that time, in the Netherlands, marine litter was already monitored by the abundance of plastic debris in stomachs of a seabird species, the northern fulmar (*Fulmarus glacialis*). In 2020 the Fulmar EcoQO was formally replaced and is now called Fulmar Threshold Value (Fulmar-TV or FTV).

Fulmars are purely offshore foragers that ingest all sorts of litter from the sea surface and normally do not regurgitate poorly degradable diet components like plastics. Size of ingested debris is usually in the range of three to five millimetres to centimetres, but may be considerably larger for flexible items as for instance threadlike or sheetlike materials. Items must gradually wear down in the muscular stomach to a size small enough (likely smaller than 2 to 3 mm) to pass into the intestines (Bravo Rebolledo 2011). During this process, plastics accumulate in the stomach to a level that integrates litter levels encountered in their foraging area for a period of probably up to a few weeks (van Franeker and Law 2015). The 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 and Meijboom 2002).

The 2024 update of monitoring data for the Netherlands

This report adds new data for year 2024 to the previous report (Kühn et al. 2024). A total of 37 fulmar corpses were collected, of which 32 were suitable for monitoring. Annual numbers of beached birds may vary considerably for unknown reasons.

The OSPAR and EU long-term target requires an FTV% under 10% for at least 5 consecutive years. Therefore data are also pooled in 5-year periods, as 'current period' in *Table i*. Over the most recent 5 years (2020-2024), in a sample of 228 birds, 53% of the fulmars contained more than 0.1 g plastic (FTV%). This is similar to earlier 5-year periods and substantially exceeds the Fulmar-Threshold Value (*Fig. i*). Over the past five years, 92% of fulmars contained some plastic, with an average of 24.2 plastic particles per stomach, weighing 0.28 gram per bird.

Looking at annual samples, the years since 2020 showed a relatively high number and mass of plastics compared to the remarkably low figures in 2018 and 2019, for unclear reasons. After a few years of high plastic loads, the new sample from 2024 exhibits one of the lowest quantities of ingested plastics measured in one single year.

This report includes data on suspected chemical stomach contents, often paraffin- or palmfat-like substances. In 2024, 9% of the analysed fulmars contained some paraffin- or palmfat-like substances. For the 2020-2024 period, the average mass was 0.13 gram per bird showing a decrease in comparison with previous 5-year periods. Recent high values were caused by a few stomachs with exceptional high loads of paraffine-like materials in 2021.

Table i. Data summary for the study year added to the existing monitoring series. The table presents actual year or current period of sampling with sample size and then the percentage of birds that exceeds 0.1 g of plastic mass in the stomach (FTV%), followed by details for the proportion of birds with any plastic particles (Frequency of Occurrence; %FO) the average number of particles (n) and the associated average mass of plastic per bird in gram (g).

year	sample size	FTV%	%FO	average n	average g
2024	32	31%	88%	12.7	0.12
period					
2020_24	228	53%	92%	24.2	0.28

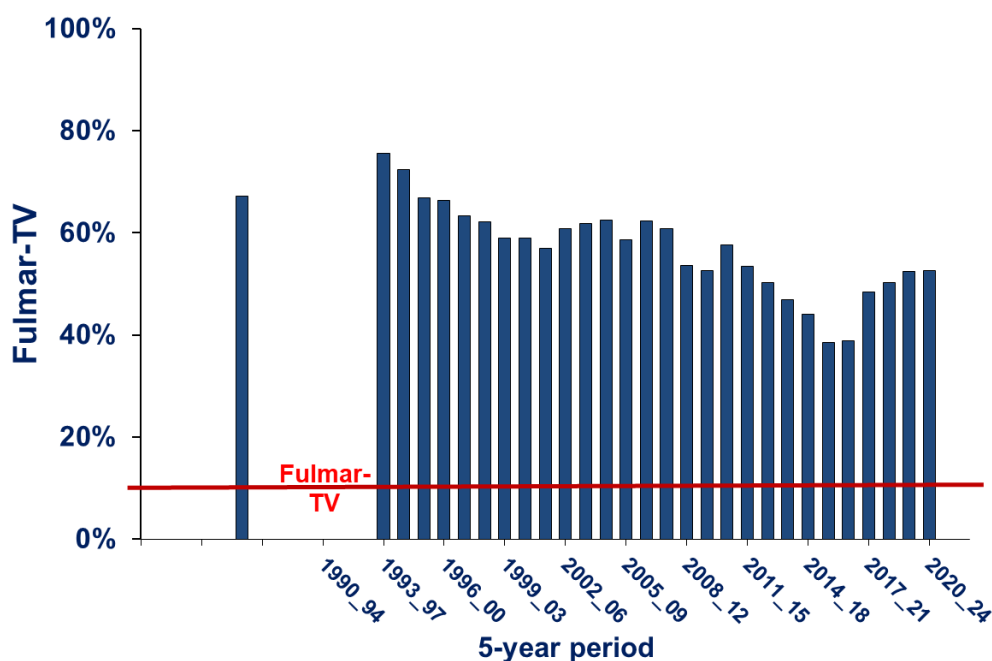


Figure i. Fulmar-TV Performance of fulmars in the Netherlands over running 5-year periods up to 2024. Data for the 1980s were combined due to relatively small sample size. The red line illustrates the Fulmar-Threshold Value. This graphic visualization does not represent a statistical trend analysis.

Trends and predictions

In order to provide policy makers with simple straightforward information, this report focuses on the predictive model to estimate when in future the Fulmar-TV may be reached (Van Franeker et al. 2021). This model simply uses the existing annual figures for sample size plus the number of birds within that sample exceeding the 0.1 g Threshold. These data are analysed in a General Linearized Model (GLM) which uses a logistic approach based on annual binomial data of birds yes or no above the Threshold to model a trend in the observed data. If statistically significant, the modelled trend may be extrapolated to the future.

GLM analysis over the 23-year period 2002-2024 for the Netherlands indicated a significant improvement in Fulmar-TV Performance (FTV% decreased significantly at $p < 0.010$; Fig. ii). When the calculated trend is projected into the future, results suggest that the EU MSFD long-term target may be reached in year 2077. This predicted year is ten years earlier than the year 2087 calculated in the

previous report. This is a consequence of the low percentage of birds with more than 0.1 g plastic in their stomach in 2024 compared to the higher values seen in the years before.

It has to be emphasized that the predictive trendline does not imply that no further action is needed. The model predicts the future development if we continue at the same rate as we have done so far, with taking additional (national and regional) policy measures and with improving awareness and behaviour. No extra effort means that the trendline will flatten at its current value and that the Fulmar-TV will not be reached. Intensifying further measures and efforts could mean that the target might be reached earlier than predicted by the current model.

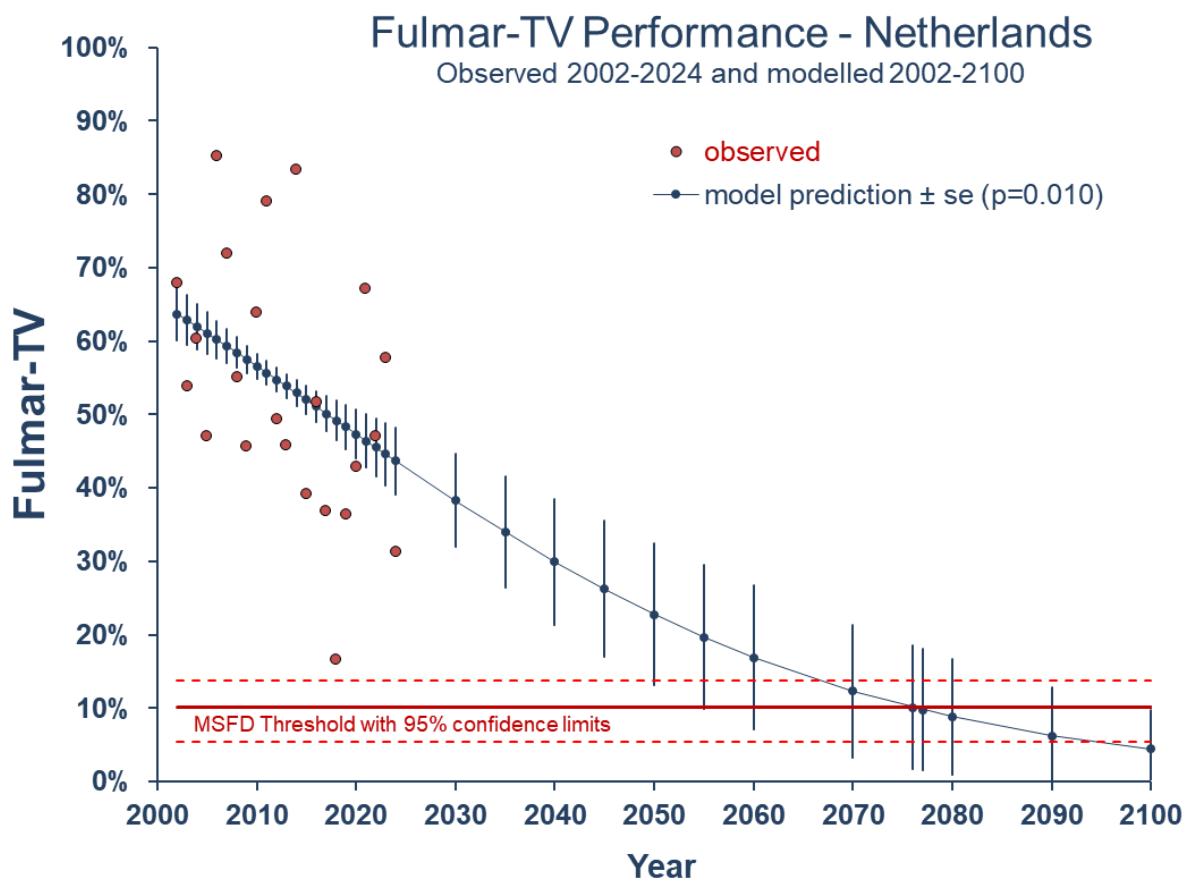
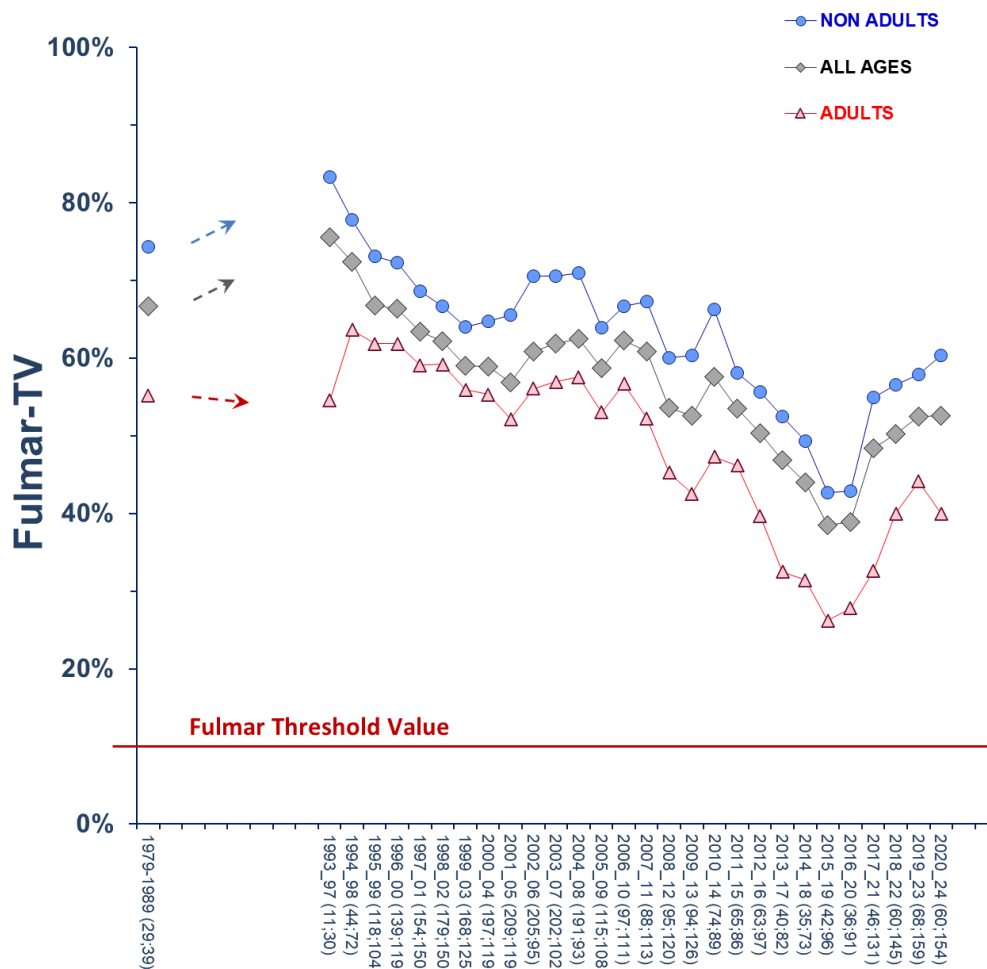


Figure ii. GLM model analysis of annual Fulmar-TV Performance using 23 years of fulmar data (2002-2024). Observed data are the red closed circles. Since the modelled trend is significant ($p=0.010$), the predicted annual values and standard errors (vertical lines) are shown by blue dots and a solid trendline.

Existing OSPAR guidelines (2015a,b) prescribe tests for trends over time, covering the most recent 10 years, by using linear regression analyses of log transformed values of individual plastic mass against year of collection. Those tests (see Table 4C) do show the correlations between plastics and the year of observation. For the 10-year period 2015-2024, 376 birds were available. Currently, this 10-year mass trend is not significant ($p=0.698$). However, over the 2002-2024 period as used in the GLM procedure, the FTV test is significant (1004 birds: $p=0.010$), indicating a decrease of plastic mass over this period. Similarly, when considering all data available for the Netherlands, (1979-2024), a significant decrease can be observed ($p<0.001$).

A non-statistical way to illustrate and check the trends in plastic ingestion over time is by comparing separate age classes. Monitoring results are mostly presented for birds of all ages together, but the pilot study for the fulmar monitoring project (Van Franeker & Meijboom 2002) showed that younger birds on average carry a higher load of ingested plastic than adult birds. As long as age composition shows no substantial persistent change, age groups may be combined. The difference between age groups should also be reflected in the respective FTV% data. Fig. iii illustrates Threshold Performance for separate adult and non-adult age groups. This is done by means of running 5-year data-points

because annual figures are often too variable (see the scattered red data-points for observed data in Fig. ii), and certainly so when sample size is reduced by splitting into subgroups. The graph clearly illustrates similarity in trends for the separate age groups both in a longer-term and in several shorter-term variations. This supports the validity of GLM modelling using annual data with age included as a covariate in the model. Data from running 5-year averages cannot be used for statistical trend analysis as those figures entail repeated use of the same individuals.



5-year period (sample size adult; non-adult)

Figure iii. Visualisation of Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2024. Trendlines for all birds combined (grey diamonds, including birds of unknown age), for adult birds (red triangles) and for non-adults (blue circles). This graphic visualization is based on a single data-point for the 1980s and overlapping running 5-year averages in later periods. Periods with less than 10 birds in the sample during the late 1980's and early 1990s are not shown in the graph. This visualization in itself does not represent a statistical trend analysis.

It is difficult to pinpoint specific events that may have triggered increases in ingested plastics from the 1980s into the 1990s, subsequent decreases and the very recent increase. Different trends for industrial plastics and consumer waste further complicate the issue. Since the start of the 'Save the North Sea' project in 2002 and up to 2014, no significant trends were detected in the ingested mass of plastics over 10-year time series. However, starting with 10-year period 2006-2015 an in absolute terms moderate, but statistically significant decrease in ingested plastic mass was observed. This slow change has persisted over later running decades, usually close to or statistically significant for both plastic types and their combination (Table 4D). While the 2011-2020 period already showed a less prominent significant reduction in combined plastic mass, the 10-year periods since 2012-2021 were

not significant anymore. Ongoing significant reduction may be considered an intermediate aim in terms of the European MSFD and GES by the year 2020, but will be hard to show at a significant level within 10-year periods.

MAIN POINTS

1. North Sea governments and the EU aim at a long-term threshold value in which for at least 5 consecutive years, the proportion of fulmars with more than 0.1 gram of plastic in the stomach (FTV%) remains under 10%.
2. Over the 5-year period 2020-2024, among 228 fulmars beached in the Netherlands, the FTV% was 53%. In this period, 92% of fulmars had ingested some plastic, with an average over all birds of 24.2 particles per stomach, weighing 0.28 gram.
3. In 2024, plastic mass and numbers were at a low level compared to previous years. The linear regression trend of the mass data over the recent 10 years 2015-2024 indicates no significant change.
4. Logistic trend analyses of annual FTV% over the longer period 2002-2024 do still indicate a significant overall decrease since 2002 and suggest that the Fulmar Threshold-Value may be reached in the year 2077. After a few years of delay, with this data update the expected year to reach the threshold is now 10 years earlier than predicted in the previous year. The initial calculation for the Dutch data years 2002-2018 predicted that the target may be reached in 2049. The delay reflects increased ingested plastic mass in the years 2020-2023 in comparison to low values observed earlier.
5. The model prediction of expected FTV compliance in 2077 is not based on a status-quo, but on the current rate of change, which is assumed to reflect intensified (national and regional) policy measures and improved awareness and behaviour. This implies that the predicted future change will require further policy measures and further changes in stakeholder awareness and behaviour. Without extra effort, it is unlikely that the Fulmar Threshold Value will be reached in the predicted time period.
6. It is not possible to pinpoint single clear causes for the observed changes. Gradual improvement since the early 2000s may be linked to media attention for oceanic garbage patches and plastic soup. Increased awareness among all stakeholders may slowly lead to gradually improved policy measures and implementation by marine industries and general public. The apparent increase in annual figures between 2020-2023 cannot be explained at the moment, but also lacks statistical evidence for significant change in recent 10-year periods.
7. Over the 5-year period 2020-2024, 9% of the birds had ingested paraffin-like substances, with an average mass of 0.13 gram per bird.

CONCLUSION

On the longer term, stomach contents of fulmars beached in the Netherlands indicate that the marine litter situation off the Dutch coast has gradually improved, but without statistical significant further improvement in recent years. At its current level, plastic ingestion is still far off the Fulmar Threshold Value. When considering the trend over the 2002-2024 period, the Fulmar-TV might be reached around the year 2077. Within 10-year evaluation periods the linear regression trend of individually ingested plastic mass is not consistent and showed no significant change over the most recent decade (2015-2024). Although not significant, current data may suggest a reversal in the longer term trend. It is clear that the further reduction of marine litter is required to reach the Fulmar Threshold Value.

1 Introduction

Marine litter, in particular plastic waste, represents an environmental problem in the North Sea and elsewhere, with considerable economic and ecological consequences.

The **economic consequences** of marine litter affect many stakeholders. Coastal municipalities are confronted with excessive costs for beach clean-ups. Tourism suffers damage because visitors avoid polluted beaches especially when health-risks are involved. Fisheries are confronted with a substantial bycatch of marine litter, which causes loss of time, damage to gear, and tainted catch. Shipping suffers financial damage and -more importantly- safety-risks from fouled propellers or blocked water-intakes. Marine litter blowing inland can even seriously affect farming practices. The overall economic damage from marine litter is difficult to estimate, but a detailed study in the Shetlands with additional surveys elsewhere indicate that even local costs may run into millions of Euros (Hall 2000; Lozano & Mouat 2009; Mouat et al. 2010; Newman et al. 2015).

The **ecological consequences** of marine litter are most obvious in the suffering and death of marine birds, turtles or mammals entangled in debris. Entangled whales are front-page news and attract a lot of public attention. However, only a small proportion of entanglement mortality becomes visible among beached animals. Even less apparent are the consequences from the ingestion of plastics and other types of litter. Ingestion is common among a wide range of marine species including many seabirds, marine mammals and turtles (Kühn & Van Franeker 2020). It can cause direct mortality, but the major impact most likely occurs through reduced fitness of many individuals, thus posing a risk for populations of marine animals.

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). Plastics gradually break down to microscopically small particles, but these may pose an even more serious problem (Thompson et al. 2004). 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 from ingested plastics to seabirds has been shown by Tanaka et al. (2013, 2015, 2019, 2020), Yamashita et al. (2018), Kühn et al. (2020) and Sühning et al. (2022). Microplastics can also adsorb and concentrate organic pollutants from the surrounding water, but experimental results and model predictions are not all in agreement concerning release of such chemicals into marine organisms or associated negative effects (Browne et al. 2013; Endo et al. 2005, 2013; Koelmans et al. 2014, 2016; Moore 2008; Teuten et al. 2009; Rochman et al. 2013, 2014a,b; Tanaka et al. 2013; Cole et al. 2015; Hermabessiere et al. 2017; Sørensen et al. 2020). Thus, in addition to the toxic substances incorporated into plastics in the manufacturing process, plastics may concentrate pollutants from the environment and act as a pathway adding to their accumulation in marine organisms. Evidently, this same mechanism operates at all levels of organisms and sizes of ingested plastic material, from small zooplankton filter-feeders to large marine birds and mammals. However, it is especially the ingestion of microplastics by small filter-feeders that has emphasized the potential scale and urgency of the problem of marine plastic litter, as it may ultimately affect human food quality and safety as well (Hauser et al. 2015; Hunt et al. 2016). Concerns have also been expressed for the even smaller particles, those in the nano-size range (<1 µm), which can penetrate into tissues and cells with potential chemical and mechanical damage to e.g. DNA, but presence and impact of these nanoplastics are extremely difficult to quantify in non-experimental situations (Koelmans et al. 2015; Booth et al. 2016; Gigault et al. 2016; Jahnke et al. 2017; Mintenig et al. 2018).

Recognizing the negative impacts from marine debris, a variety of international policy measures has attempted to reduce the input of litter. Examples of these are the London Dumping Convention 1972; Special Area status North Sea MARPOL Annex V 1991; and the OSPAR Convention 1992. In the

absence of significant improvements, political measures have been intensified by for example the EU-Directive 2000/59/EC on Port Reception Facilities (EC 2000), the Declaration from the North Sea Ministerial Conference (2002) in Bergen, the revision of MARPOL Annex V (MEPC 2011), the European Marine Strategy Framework Directive (MSFD) 2008/56/EC (EC 2008, 2010, 2017) and recently, the EU ban of single use plastics (EU Directive 2019/904; EU 2019). Currently, international discussions are underway to prepare a UN Convention that aims at a global reduction of plastics (<https://www.unep.org/about-un-environment/inc-plastic-pollution>). These strategies can lead to an improvement of the situation. For example, recent data on Dutch beach litter suggest a decrease in the median number and mass of small plastics over the period 2017-2022 (Boonstra & Hougee 2024).

Policy initiatives have recognized the need to use quantifiable and measurable aims. Therefore, the North Sea Ministers in the 2002 Bergen Declaration decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQO's) (North Sea Ministerial Conference 2002). For example, the oil pollution situation in the North Sea is measured by the rate of oil-fouling among beached Guillemots (*Uria aalge*) with an EcoQO of less than 10% of beached Guillemots having oil on the plumage (OSPAR 2005). Similarly, as proposed by ICES Working Group on Seabird Ecology (ICES-WGSE 2003), OSPAR decided to use the abundance of plastic in stomachs of seabirds, *in casu* the northern fulmar to measure quality objectives for marine litter (OSPAR 2008, 2009, 2010a,b, 2015a,b). The fulmar EcoQO monitoring has been included as an indicator for marine litter in the approach for Good Environmental Status (GES) in the European Marine Strategy Framework Directive (EC 2010; Galgani et al. 2023).

Internationally, as of 2002, the Dutch fulmar research was expanded to all countries around the North Sea as a project under the **Save the North Sea (SNS)** program. Main initiators of the SNS campaign were the Keep Sweden Tidy Foundation and KIMO. SNS was co-funded by EU Interreg IIIB over period 2002-2004 and aimed to reduce littering in the North Sea area by increasing stakeholder awareness. The fulmar acted as the symbol of the SNS campaign. Findings strongly supported the important role of shipping (incl. fisheries) in the marine litter issue. For further publications of the SNS fulmar study see e.g. Save the North Sea (2004), Van Franeker (2004), Edwards (2005), Guse et al. (2005, 2020, 2024), Olsen (2005) and Kühn et al. (2022a). After completion of the European SNS project, the international work was continued through CSR awards from the NYK Group Europe Ltd and support from Chevron Upstream Europe. These funds contributed to further North Sea EcoQO wide updates in reports (Van Franeker & the SNS Fulmar Study Group 2013), including peer-reviewed scientific publications on the EcoQO methods with data up to 2007 (Van Franeker et al. 2011) and 2012 (Van Franeker & Law 2015). These awards also led to the promotion of fulmar work in other areas of the world such as Ireland (Acampora et al. 2016), the Faroe Islands (Van Franeker 2012; Collard et al. 2022a), Iceland (Kühn & Van Franeker 2012; Snæþórsson 2024), Svalbard (Trevail et al. 2015; Collard et al. 2022b, 2023, 2024; Tulatz et al. 2023), Atlantic Canada (Bond et al. 2014; De Bruin et al. 2025), the Canadian Arctic (Mallory et al. 2006; Mallory 2008; Provencher et al. 2009; Poon et al. 2017; Avery-Gomm et al. 2018; Baak et al. 2020), Greenland (Van Franeker et al. 2022) and the Pacific (Nevins et al. 2011; Avery-Gomm et al. 2012; Donnelly-Greenan et al. 2014; Terepocki et al. 2017; Shugart & Nania 2021) and has been promoted as plastic monitoring species in the Arctic Ocean (AMAP 2021) and the North Pacific (Savoca et al. 2022).

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 (3rd Intermediate Assessment, Kühn et al. 2022b). The same data were 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). Currently the 4th OSPAR Intermediate Assessment is in preparation. The detailed history of the development of the OSPAR EcoQO and its successor the EU MSFD Fulmar Threshold Value can be found in earlier reports (e.g. Van Franeker & Kühn 2020).

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

- Update of the Dutch time series on litter in stomachs of fulmars with the data of year 2024.
- Continued coordination of the beached fulmar sampling in the Netherlands in 2025.
- Addition of the basic raw plastic data to the database of RWS CIV (Centrale Informatievoorziening, Lelystad) and via CIV to third parties like OSPAR.
- Basic data on presence of paraffin-like substances in the annual fulmar report.

There are two information needs of I&W which are the major driving forces to finance the monitor fulmar data on Dutch coastlines. First, there is an agreement of The Netherlands with OSPAR to (a) deliver fulmar plastics data annually and (b) to lead the OSPAR assessments of fulmar plastics. Second, since the introduction of the EU MSFD in 2008, the Netherlands have a legal obligation to deliver data for plastics ingested by marine animals (MSFD criterion D10C3; represented for NL by fulmars) to Europe and to assess these data using a threshold value. The fulmar data presented in this report serve both these two major information needs. Obviously, Wageningen Marine Research also has its own scientific information need, using the fulmar monitoring data for related scientific research.

2 The Fulmar as an ecological monitor for marine litter

The interpretation of monitoring information presented in this report requires a summary of earlier findings as published in earlier reports and peer-reviewed literature.

Since the early days of plastic pollution of our oceans, the Northern Fulmar has been known as a species that readily ingests marine plastic debris (Bourne 1976; Baltz & Morejohn 1976; Day et al. 1985; Furness 1985; Van Franeker 1985; Denkinger 1990; Moser & Lee 1992; Robards et al. 1995; Blight & Burger 1997). Nevertheless, it took until the pilot study of Van Franeker & Meijboom (2002) to properly investigate the feasibility of using stomach contents of Northern Fulmars to monitor changes in marine litter abundance in an ecological context.

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

- Fulmars are abundant in the North Sea area (and elsewhere) and are regularly found in beached bird surveys, which guarantee supply of an adequate number of bird corpses for research.
- Fulmars are known to consume a wide variety of marine litter items.
- Fulmars avoid inshore areas and forage exclusively at sea (never on land).
- Fulmars do not normally regurgitate indigestible items but accumulate these in the stomach (digestive processes and mechanical grinding gradually wear down particles to sizes that are passed on to the gut and are excreted).
- Thus, stomach contents of fulmars are representative for the wider offshore environment, averaging 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 1979 and literature is available on other locations and related species worldwide (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*).

Beached fulmars may have died for a variety of reasons. For some birds, plastic accumulation in the stomach appears to be the direct cause of death, e.g. by plastic sheets blocking food passage. More often the effects of litter ingestion act at sub-lethal levels, except maybe in cases of ingestion of chemical substances. For other birds, fouling of the plumage with oil or other pollutants (Camphuysen 2023), collisions with ships or other structures, drowning in nets, extremely poor weather or food-shortage may have been direct or indirect causes of mortality. Currently few cases of avian influenza were detected in fulmars (Caliendo et al. 2025) but have - for the time being - not led to mass mortalities as in other seabird species (e.g., Camphuysen et al. 2022; Rijks et al. 2022).

In general, fulmar population estimates suggest a considerable decline in numbers throughout their entire North Atlantic distribution range. This decline includes colonies in Germany (Dierschke et al. 2022), the UK and Ireland (Burnell 2023), the Faroe Islands (Hammer et al. 2014), Norway (Anker-Nilssen et al. 2021), Iceland (Garðarsson et al. 2011) and the Canadian Arctic (Mallory et al. 2020). Davies et al. (2024) predicted a further decline of 70% until 2050. Reasons for this decline are unclear but authors mainly refer to climate change and associated shifts in prey availability and fisheries including bycatch (Dias et al. 2019; Dierschke & Garthe 2022).

The pilot study by Van Franeker and Meijboom (2002) undertook extensive analyses to check whether time-related changes in litter abundance were susceptible to errors caused by bias from variables such as sex, age, origin, condition, cause of death, or season of death. If any of these would substantially

affect quantities of ingested litter, changes in sample composition over the years could hamper or bias the detection of time-related trends. A very important finding of the same pilot study was that no statistical difference was found in litter in the stomach between birds that had slowly starved to death and 'healthy' birds that had died instantly (e.g. because of collision or drowning). This means that our results, which are largely based on beached starved birds, are representative also for the 'average' healthy fulmar living in the southern North Sea. Only age was found to have an effect on average quantities of ingested litter, adults having less plastic in their stomach than younger birds. Possibly, adults lose some of the plastics accumulated in their stomach when they feed chicks or spit stomach-oil during defence of nest-sites. Another factor could be that foraging experience may increase with age. Our understanding of the observed age difference in plastic accumulation is poor. In search of better understanding of such issues, Chevron Upstream Europe had funded a cooperative project with the Faroese Fisheries Laboratory. Using fulmars from the Faroe Islands, seasonal and age-related variations in stomach contents were analysed. On the Faroe Islands, fulmars are hunted for consumption and large numbers of samples are easily obtained. Additional samples have been obtained from fisheries by-catch in the area (Kühn et al. 2024). Stomach contents are analysed for both normal diet (Danielsen et al. 2010) and for accumulated litter. General litter results were published in Van Franeker (2012), but detailed analyses of samples obtained from all months of the year during several years continue.

Although age has been shown to affect absolute quantities of litter in stomach contents, changes over time follow a similar pattern in adults or non-adults. As long as no structural directional change in age composition is observed, trends may be analysed for the combined age groups. However, background information for the presentation of results and their interpretations always requires insight in age composition of samples.

Significant long-term trends from 1979 to 2000 were detected in incidence (Frequency of Occurrence %FO), number of items and mass of industrial plastics, user plastics and suspected chemical pollutants (often paraffin-like substances). Over the 1979-2000 period, only industrial plastics decreased while user plastics significantly increased. When comparing averages in the 1980s to those in the 1990s, industrial plastics approximately halved from 6.8 granules per bird (77% incidence; 0.15 g per bird) to 3.6 granules (64%; 0.08 g). User plastics almost tripled from 7.8 items per bird (84%; 0.19 g) to 27.6 items (97%; 0.52 g). Since about 2015 the analyses indicated a trend of slow decrease, but reversed over the past four years.

Analysis of variability in data and Power Analysis revealed that reliable figures for litter in stomachs in a particular region and specific time period are obtained at a sample size of about 40 birds and that reliable conclusions on change or stability in ingested litter quantities can be made after periods of 4 to 8 years, depending on the category of litter. Lower annual sample sizes are no problem but will lengthen the periods needed to draw conclusions on regional levels and trends (Van Franeker & Meijboom 2002).

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

The pilot study by Van Franeker & Meijboom (2002) concluded that stomach content analysis of beached fulmars offers a reliable monitoring tool for (changes in) the abundance of marine litter off the Dutch coast. By its focus on small-sized litter in the offshore environment, such monitoring has little overlap with, and high additional value to beach litter surveys of larger waste items. Furthermore, stomach contents of fulmars reflect the potential ecological consequences of litter ingestion on a wide range of marine organisms and create public awareness of the fact that environmental problems from marine litter persist even when larger items are broken down to sizes below the range of normal human perception. As indicated, there is an increasing concern on the dangers from microplastics, but monitoring quantities and effects in these species is more difficult than that of intermediate sized plastics in seabirds.

The same pilot study recommended that Dutch fulmar litter monitoring should focus on mass of plastics (industrial plastic and user) and suspected chemical substance. Each of these represents different sources of pollution, and thus specific policy measures aimed at reduced inputs. Data-recording procedures are such that at the raw data-level, various sub-categories of plastics and other rubbish continue to be recorded by number and mass, and can be extracted from databases, should the need and funding arise.

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

As recommended from the Dutch studies, the **mass** of plastics forms the basis of the Fulmar-TV monitoring system. Rather than using average plastic mass for the target definition, a combination is used of frequency of occurrence of plastic masses above a certain critical mass level (10%; 0.1 g). The background of such approach is that a few exceptional outliers can have a strong influence on the calculated average. The wording of the target level basically excludes influence of exceptional outlying values.

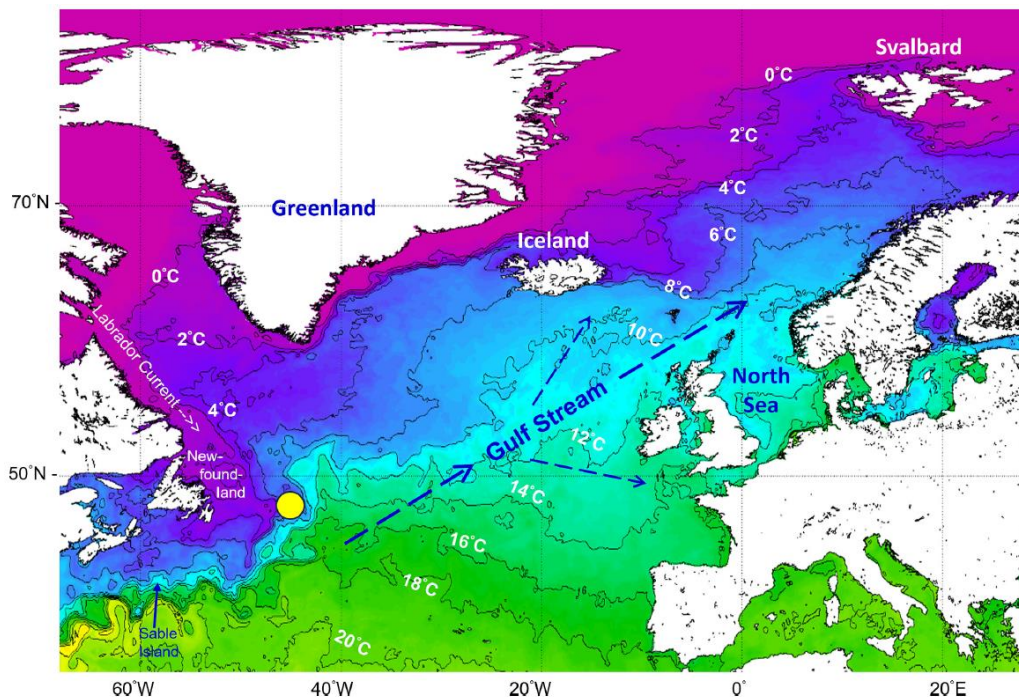
Info Box 1: Ocean currents influence plastic loads in fulmars

The lack of funding usually restricts the possibility to accommodate students within the fulmar monitoring project. However, sometimes, the request of a student and available data for which no budget is available coincide and can lead to interesting outcomes. In this case, Wageningen Marine Research retrieved a set of fulmar stomachs collected close to the coasts of Newfoundland, collected by a Faroese fisherman. At the same time, a Bachelor's student from Utrecht University, Sterre De Bruin, was looking for an internship. In 2024, she spent 4 months at the institute, analysing the stomach contents of 37 fulmars. Seen the southerly sampling location, high quantities of litter were expected, as plastic loads in fulmars seemed to be correlated to latitude and associated human activities (Kühn & Van Franeker 2012). However, after finding unusual low amounts of plastic, this theory was revised. Rather than simply the latitude, plastic abundance was more related to ocean currents. While in the eastern Atlantic, litter loads are influenced by the Gulf Stream, bringing high litter loads northwards, the eastern coast of Canada relies on ocean currents directly from the Arctic, the Labrador current. Close to the Newfoundland coast, these two currents meet and the birds collected now were suspected to feed mainly in the cold and clean stream (see Graph 1). The results of this study were not only published within the Bachelor's thesis of Sterre, but also resulted in a peer-reviewed publication in *Marine Pollution Bulletin*, a great reminder of the value of student involvement in research projects. The full publication can be found here:



Photo 1. Sterre de Bruin dissecting a fulmar und supervision of Jan van Franeker.

De Bruin, S, Van Franeker, JA, Meijboom, A, Jensen, J-K, Jacobsen, B, Kühn, S (2025) *Plastics in stomachs of northern fulmars (Fulmarus glacialis) collected at Flemish Cap, Grand Banks of Newfoundland. Marine Pollution Bulletin* 215: 117894. doi <https://doi.org/10.1016/j.marpolbul.2025.117894>



Info Box Figure 1. Position of the Newfoundland Bank sampling location in the North Atlantic Ocean in the context of geographical latitude, major ocean currents and Sea Surface Temperature (SST) gradients in early June 2024. The yellow circle shows the sampling location at Flemish Cap. The Newfoundland Banks have an average annual Sea Surface Temperature of around 2 °C to 4 °C, but are close to a sharp border with much warmer water in the Gulf Stream.

3 Materials and Methods

Wageningen Marine Research continues the collection of beached fulmars from Dutch beaches with the assistance of the Dutch Seabird Group (Nederlandse Zeevogelgroep - NZG) through its Working Group on Beached Bird Surveys (Nederlands Stookolieslachtoffer Onderzoek - NSO). Beached fulmars are collected by volunteers along the Dutch coast. These volunteers consist of regular beach-walkers, whereby some of them combine the collection of dead fulmars with the beached bird surveys. These regular beach bird surveys give the opportunity to continuously monitor the amount and species distribution of beached birds and can give early indications of larger bird mortalities (e.g. in Atlantic puffins (*Fratercula arctica*) and common guillemots (*Uria aalge*); Camphuysen 2023). Other beached fulmars are occasionally recorded on waarneming.nl. These birds are then retrieved by volunteers if possible. In addition, several coastal bird rehabilitation centres support the collection program. Sampling effort for the Dutch fulmar study is spread over the full Dutch coastline. In general, most fulmars in our study originate from the more northern part of the Netherlands, with next in line fulmars from the Zeeland area. The lower number of beached fulmars from the more central parts of the Dutch coast may be due to lower observer effort, but also to more rapid disappearance of corpses due to higher numbers of scavenging foxes or cleaning activities on the touristic beaches.

With the **Save the North Sea (SNS)** project in 2002, Wageningen Marine Research started and co-ordinated similar sampling projects at a range of locations in all countries around the North Sea. Organizations involved in different countries differ widely and range from volunteer bird groups to governmental beach cleaning projects. *Fig. 1* shows all locations that were involved in the SNS monitoring program, and their regional grouping. Lack of funding has led to a stop of the international coordination, although separate countries, except Sweden, have committed to continued monitoring and submission of basic data to OSPAR, also as a part of their involvement in the European Marine Strategy Framework Directive (MSFD). These data are analysed in Intermediate Assessments (OSPAR 2017, 2019 and Kühn et al. 2022b) and in a peer-reviewed scientific publication by Van Franeker et al. (2021). For the upcoming 4th OSPAR Intermediate Assessment, OSPAR data from Arctic countries will be included.



Figure 1. Fulmar-Litter study areas in the Save the North Sea Project (SNS). Colour of symbols indicates original regional grouping into Scottish Islands (red), East England (blue), Channel area (white), South-eastern North Sea (yellow), and Skagerrak area (white). Not all locations are equally active. The Faroe Islands study area (green) is considered as an external reference monitoring site for the North Sea. For further details, see the online supplement of Van Franeker et al. (2011).

Standardized dissection methods for fulmar corpses have been published in a dedicated manual and in OSPAR Guidelines (Van Franeker 2004, OSPAR 2015a,b) and are internationally calibrated during regular workshops. In the future, an updated version of the manual should be published to improve details and maximize efficiency and standardisation of methods. For convenience, some of the methodological information is repeated here in a condensed form.

Dissection

At dissections, a full series of data is recorded that is of use to determine sex, age, breeding status, likely cause of death, origin (based on colourphase, whereby darker birds indicate an Arctic origin; Van Franeker 1995), condition index and other issues. Age, the only variable found to influence litter quantities in stomach contents (Van Franeker & Meijboom 2002), is largely determined on the basis of development of sexual organs (size and shape) and presence of *Bursa of Fabricius* (a gland-like organ positioned near the end of the gut which is involved in immunity systems of young birds. *Bursa of Fabricius* is well developed in chicks but disappears within the first year of life or shortly after).

Stomach content analysis procedure

Stomachs of fulmars have two compartments: initially food is stored and digested in a large glandular stomach (the *proventriculus*) after which it passes into a small muscular stomach (the *gizzard*) where harder prey remains can be processed through mechanical grinding. In early phases of the project, data for the two individual stomachs were recorded separately, but for the purpose of reduction in monitoring costs, the contents of proventriculus and gizzard are now combined.

Stomach contents are carefully rinsed in a sieve with a 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 particles smaller than 1 mm seemed rare in the stomachs, and when present, contribute little to plastic mass.

If oil or chemical types of pollutants are present, these may be sub-sampled and weighed before rinsing the remainder of stomach content. If sticky substances hamper further processing of the litter objects, hot water and detergents are used to rinse the material clean as needed for further sorting and counting under a binocular microscope.

Categorization of debris in stomach contents

The following categorization is ideally used for plastics and other rubbish found in the stomachs, with acronyms between parentheses. However, please note that for financial efficiency in FTV monitoring, the required dataset has been restricted to just categories 1.1 (Industrial Plastics) and 1.2 (User Plastics) without further subcategories (OSPAR 2015a,b).

1. PLASTICS (PLA)

1.1. **Industrial plastic pellets (IND)** are small, often cylindrically shaped granules of ± 4 mm diameter, but also disc and rectangular shapes occur. Various names are used, such as pellets, beads or granules. They can be considered as "raw" plastic or a half-product in the form of which plastics are usually first produced. 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.) depending on the user product to be made. For the time being, included in this category are a relatively small number of very small, usually transparent spherical granules, also considered to be a raw industrial product.

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

1.2.1. **sheetlike user plastics (she)**, as in plastic bags, foils etc., usually broken up in smaller pieces;

1.2.2. **threadlike user plastics (thr)** as in (remains of) ropes, nets, nylon line, packaging straps etc. Sometimes 'balls' of threads and fibres form in the gizzard;

1.2.3. **foamed user plastics (foam)**, as in foamed polystyrene cups or packaging or foamed polyurethane in mattresses or construction foams;

1.2.4. **fragments (frag)** of more or less hard plastic items as used in a huge number of applications (bottles, boxes, toys, tools, equipment housing, toothbrushes, lighters etc.);

1.2.5. **other (poth)**, for example cigarette filters, rubber, elastics etc., so items that are 'plastic-like' or do not fit into a clear category.

2. RUBBISH (RUB) other than plastic:

- 2.1. **paper (pap)** which besides normal paper includes silver paper, aluminium foil etc., so various types of non-plastic packaging material;
- 2.2. **kitchen food (kit)** for human food wastes such as fried meat, chips, vegetables, onions etc., probably mostly originating from ships' galley refuse;
- 2.3. **various rubbish (rubvar)** is used for e.g. pieces of timber (manufactured wood); paint chips, pieces of metals etc.;
- 2.4. **fishhook (hook)** from either sport-fishing or long-lining.

3. POLLUTANTS (POL)

For items indicating industrial or chemical waste remains such as slags (the remains of burning ovens, e.g. remains of coal or ore after melting out the metals); tar-lumps (remains of mineral oil); chemical (lumps or 'mud' of paraffin-like materials or sticky substances arbitrarily judged to be unnatural and of chemical origin, see Van Franeker et al. (2019)) and feather-lumps (indicating excessive preening by the bird of feathers sticky with oil or chemical pollutants). For this Dutch report, only chemicals (or paraffin-like substances) are considered in more detail. All other pollutants (slag, coal, feather lumps or fish hooks) are not included in this study.

Further optional categories of stomach contents (not included in this study):

4. NATURAL FOOD REMAINS (FOO)

- 4.1.1. Numbers of specific items may be recorded in separate subcategories (fish otoliths, eye-lenses, squid-jaws, crustacean remains, jelly-type prey remains, scavenged tissues incl. feathers, insects, other).

5. NATURAL NON-FOOD REMAINS (NFO)

- 5.1.1. Numbers of subcategories e.g. plant-remains, seaweed, pumice, stone and other may be recorded.

Non-plastic or debris categories

To be able to sort out items of categories 1 and 2, all other materials in the stomachs described in categories 3 to 5, have to be cleaned out. However, in these latter categories, further identification, categorization, counting, weighing and data-processing is not essential for the Fulmar-TV. Whether details are recorded depends on the interest of the participating research group and their reasons to collect beached fulmars.

Particle counts and category weights

For the main categories 1 (plastic) and 2 (rubbish) we record for each bird and each (sub)category:

- The number of particles (N=count of number of items in each (sub)category).
- The mass (W=weight in grams) using Sartorius electronic weighing scale after at least a two-day period of air drying at laboratory temperatures. For marine litter (categories 1 to 3 above), this is done separately for all subcategories. In the early fulmar study, we also weighed the natural-food and natural-non-food categories as a whole, but this was discontinued in 2006 to reduce costs. Weights are recorded in grams accurate to the 4th decimal (= tenth of milligram).

Data presentation

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 in a stomach 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.

Geometric Mean

For Figure iii and Figure 4, the age-dependent plastic mass presentation, the use of geometric means is used. 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. Geometric means are useful for comparative purposes between smaller sample sizes, for example when looking at annual data rather than at 5-year-periods. Logarithmic transformation cannot deal with the value zero, and thus the common approach chosen is to add a small value (e.g. 0.001 g in mass data) to all data-points, and then subtracting this again when the mean of log values is back-calculated to normal value. This however implies that geometric means become less reliable with an increasing number of zero values in a dataset. The natural logarithm (ln) is used to run calculations for geometric means.

Fulmar Threshold Value Performance (FTV%)

The 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 similar definition to the previous EcoQO allows direct comparisons of new and old data, not only in the North Sea, but with data reported all over the North Atlantic, North Pacific and the Arctic. Fulmar-TV 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 OSPAR and EU MSFD target is thus to reduce the FTV% to under 10%. The FTV format is a highly simplified form of data-presentation but through that simplicity escapes the problems faced by more sophisticated procedures as a consequence of excessive outliers or a large proportion of zero values in a 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 pooling

To avoid that short-term variations cause erratic information on the level of ingested plastics, data are frequently pooled into 5-year periods. Such pooled data for 5-year periods are not derived from the annual averages but are calculated from all individual birds over the full 5-year period. For data presentation, the **Current Situation** of plastic ingestion is defined as the figures for %FO, number or mass abundance, and FTV% for the most recent 5-year period. Time related changes are illustrated in graphs by running 5-year averages, each time shifting one year and thus overlapping for four years. Such graphs are useful to visualize patterns, which in annual data would be obscured by annual variability and smaller sizes. However, the 5-year running averages cannot be used for statistical analyses as the same source data were repeatedly used.

Trend analyses

Data from dissections and stomach content analysis are recorded in Excel spreadsheets and next 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, statistical trend analysis is conducted using plastic mass. Tests for trends over time are based on linear regressions fitting ln-transformed plastic mass values for individual birds on the year of collection. Logarithmic transformation is needed because the original data are strongly skewed and need to be normalized for the statistical procedures. Logarithmic transformed data are initiated by 'ln' (natural logarithm); mass data are characterized by capital G (gram) and numerical data by N (number). For example, lnGIND refers to the dataset that uses ln-transformed data for the mass of industrial plastics in the stomachs;

acronym NUSE refers to a dataset based on the number of items of user plastics. Tests for '**long-term**' trends use the full dataset; '**recent**' trends only use the past 10 years of data.

In addition to the linear regressions a model is applied to directly evaluate the progress towards the MSFD long-term target in which the Fulmar-TV% should be reduced to under 10%. Simplified annual data as percentages above or below a threshold are used but have the problem that the dataset is reduced to periodic (annual) average values. The annual data are considered in a GLM approach (Generalized Linear Modelling), more specifically in a logistic analysis dedicated for binomial distributions (number of birds in the sample and number of birds above threshold) and logit transformed data. As suggested by Van Franeker et al. (2021), the factor age was included as covariate. A similar type of analysis is already used in the analyses of oil-rates among seabirds for OSPAR (cf. Camphuysen 2023 and earlier publications on that topic). The statistical trend based on observed data, if significant, can be used to predict FTV Performance in future years.

Info Box 2: Reliability of plastic studies on the Faroe Islands

A recent study by Wageningen Marine Research and colleagues highlights a problem faced by fishermen near the Faroe Islands: northern fulmars that regularly steal bait from longline hooks. In longline fishing, fishermen use long lines with hundreds of baited hooks to catch large fish near the seabed. Fulmars often follow these vessels in large numbers, trying to snatch the bait from the hooks. Usually, they succeed, but sometimes the birds get caught and drown as the lines sink.



Photo 2. A group of fulmars following a longline vessel (left); pieces of bait retrieved from a fulmar stomach (top right); fulmar with longline hook in bill (bottom right). All photo's by J. A. Van Franeker.

Some of these birds were collected to study the presence of plastic in their stomachs. Initial findings on plastic content were published by Van Franeker et al. (2011), but a more detailed analysis is still ongoing. Meanwhile, the current study focused on the bait found in fulmars stomachs. The results show that fulmars are highly specialized in their feeding behaviour. While most birds had an average of two pieces of bait in their stomachs, some had more than 10 pieces when they got entangled.

To ensure accurate data on plastic content, it's important to know whether bycaught fulmars regurgitate part of their stomach contents when stressed, as it has been observed in hunted birds. However, the presence of bait in most of the bycaught fulmars suggests that regurgitation is uncommon in these cases. This finding supports the conclusion that fulmars retrieved from longline fishing vessels are suitable for plastic monitoring because the results are reliable and comparable to samples from other sources.

The results of this study are available here:

Kühn, S, van Franeker, JA, Jensen, J-K, Olsen, B, Danielsen, J, Simonsen, P-J (2025) Increased longline bait predation by northern fulmars (*Fulmarus glacialis*) around the Faroe Islands during the breeding season. *ICES Journal of Marine Science* 82: fsae175. doi <https://doi.org/10.1093/icesjms/fsae175>

4 Results and Discussion

This chapter follows the approach recommended in the OSPAR Guidelines (OSPAR 2015a). That approach has its focus on detailed analyses and statistics of the data on mass of plastics found in individual birds, taking into account the details of different plastic categories (industrial versus user plastics) and the differences between adult and non-adult birds. In addition, a statistical analysis of annual FTV%'s is included, which, if significant, can be used to predict future developments, as the FTV% is the most relevant for policy makers.

The detailed analyses remain essential to properly understand the Fulmar-TV Performance model as a basis for policy decisions.

4.1 The year 2024

In 2024, our loyal surveyor network collected 37 fulmar corpses, of which 32 were suitable for analysis of the stomach contents. For our monitoring purposes, we do not use birds that have spent more than three days alive under human care in rehabilitation, because particles break and wear down in the muscular stomach and disappear through the intestines (Van Franeker & Law 2015) and are not replaced by new plastics from the marine environment. In 2024, we did receive one fulmar from a rehabilitation centre, which was taken care of for seven days, so this bird was not included.

Occasionally birds from earlier years are added to the current dataset. This does not hamper the data analysis, but slight differences with previous reports may occur. In 2024, one suitable fulmar from 2021, one bird from 2022 and seven fulmars from 2023 were added to the dataset. The desired annual sample size is ± 40 birds or more (Van Franeker & Meijboom 2002). In 2024 we were able to include 32 suitable birds.

Compared to 2022 and 2023, the year 2024 showed a much lower average mass of plastic in the stomachs (0.12 g) (Table 1A and 2A). In 2021 an exceptionally high proportion of fulmars exceeded the 0.1 g Threshold of plastic in the stomach (67%) but has decreased since with now only 31%. Short-term annual variations are reason to focus analyses on 5-year periods. Out of 32 birds, 88% of the birds did have plastic in the stomach and the average fulmar had 12.7 plastic particles ingested (Table 1A). Out of 32 birds, 9 (28%) contained paraffin-like material in their stomachs. In 2023, 15% of 26 birds contained paraffin-like substances, but annual data seem to be even more variable in these substances than in plastics (Van Franeker et al. 2019).

4.2 Current levels for the Netherlands (2020-2024)

The OSPAR long-term target requires a FTV% under 10% for at least 5 consecutive years. Therefore, data are pooled in 5-year periods. Also because of occasional years of low sample size or incidental variability it is advised to focus on the average stomach contents over the most recent 5 years.

In the 'current' 5-year period (2020-2024) (Table 1B, Table 3), in a sample of 228 birds, 53% of stomachs contained more than 0.1 g plastic (FTV%). This number is similar to the previous period, and much higher than earlier running 5-year averages (e.g. 2016-2020: 39%). The achievement of the OSPAR/MSFD long-term target remains far away.

In the 2020-2024 sample, 92% of fulmars contained some plastic, similar to the previous periods. The average number of particles was 24.2 plastic particles per stomach, weighing 0.28 gram. Industrial plastics were rare compared to consumer debris plastics.

In the period of 2020-2024, 20% of the birds had paraffin-like substances, on average 1.13 gram per bird. The mass remains high, influenced by a few individuals with particular high paraffin-like mass in 2021, including an extreme outlier of an individual with 70 grams of ingested paraffin-like substance.

In some cases, extreme outliers cannot be smoothed out, even by summarizing data in running 5-year averages and therefore this case has influenced upcoming 5-year-periods.

Fulmars ingest different chemical materials from the water surface, including paraffin, natural fats (e.g. palm oil) and substances of unknown origin. For a pilot study, a detailed chemical analysis was done to analyse a subsample of these materials ingested by fulmars (van Franeker et al. 2019). Results indicate that 31% of the ingested materials consisted of paraffin. However, the distinction between paraffin and natural fatty substances cannot be made without complex and costly analyses. Not much is known about the consequences of the ingestion of either paraffin or natural fatty substances for the organism. Chemicals added during production or cleaning of ship tanks may be harmful and sometimes the pure volume or mass of the substances may block the stomach or diminish its functioning. Aesthetical and economic effects have been recorded by KIMO (2017) and calculated that 91 reported spills between 2012 and 2019 in the North Sea have caused costs of 1.4 million Euro, with a high uncertainty regarding all unnoticed smaller spills.

Table 1. Summary of sample characteristics and stomach contents of fulmars collected for Dutch marine litter monitoring in A) the year 2024 and B) the current 5-year period 2020-2024. The top line in each 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). For each litter-(sub)category the table lists: Incidence, representing the proportion of birds with one or more items of the litter category present; average number of plastic items per bird stomach \pm standard error; average mass of plastic \pm standard error per bird stomach; and the maximum mass observed in a single stomach.

Table 1	The Netherlands	nr of birds	% adult	% male	% LL colour	death oil	avg condition
A	2024	32	21%	54%	94%	0%	3.2
		incidence	average number of items (n/bird) \pm se		average mass of litter (g/bird) \pm se		max. mass recorded
1	ALL PLASTICS	88%	12.7 \pm 2.140		0.115 \pm 0.027		0.5
1.1	INDUSTRIAL PLASTIC	50%	1.1 \pm 0.341		0.023 \pm 0.007		0.1
1.2	USER PLASTIC	88%	11.6 \pm 1.910		0.093 \pm 0.021		0.4
1.2.1	sheets	50%	1.4 \pm 0.391		0.003 \pm 0.001		0.0
1.2.2	threads	47%	1.0 \pm 0.279		0.003 \pm 0.001		0.0
1.2.3	foamed	38%	1.2 \pm 0.386		0.003 \pm 0.001		0.0
1.2.4	fragments	81%	7.8 \pm 1.372		0.075 \pm 0.020		0.4
1.2.5	other plastic	9%	0.1 \pm 0.074		0.009 \pm 0.006		0.2
2	OTHER RUBBISH	16%	0.3 \pm 0.144		0.001 \pm 0.001		0.0
2.1	paper	3%	0.0 \pm 0.031		0.000 \pm 0.000		0.0
2.2	kitchenwaste (food)	6%	0.1 \pm 0.087		0.000 \pm 0.000		0.0
2.3	rubbish various	9%	0.1 \pm 0.074		0.001 \pm 0.001		0.0
2.4	fishhook	0%	0.0 \pm 0.000		0.000 \pm 0.000		0.0
3	POLLUTANTS	25%	0.3 \pm 0.105		0.002 \pm 0.001		0.0
3.3	paraffin-like substances	9%	0.1 \pm 0.074		0.000 \pm 0.000		0.0

Table 1	The Netherlands	nr of birds	% adult	% male	% LL colour	death oil	avg condition
B	2020_24	228	28%	46%	92%	1%	2.1
		incidence	average number of items (n/bird) ± se	average mass of litter (g/bird) ± se	max. mass recorded		
1.0	ALL PLASTICS	92%	24.2 ± 2.974	0.275 ± 0.042	7.1		
1.1	INDUSTRIAL PLASTIC	53%	1.8 ± 0.296	0.042 ± 0.007	1.0		
1.2	USER PLASTIC	91%	22.4 ± 2.778	0.233 ± 0.040	7.1		
1.2.1	sheets	53%	2.6 ± 0.555	0.008 ± 0.002	0.4		
1.2.2	threads	39%	1.3 ± 0.176	0.006 ± 0.001	0.1		
1.2.3	foamed	52%	4.2 ± 0.674	0.016 ± 0.004	0.8		
1.2.4	fragments	86%	13.8 ± 1.835	0.163 ± 0.033	6.7		
1.2.5	other plastic	22%	0.6 ± 0.254	0.040 ± 0.013	2.3		
2.0	OTHER RUBBISH	23%	1.2 ± 0.319	0.017 ± 0.006	1.3		
2.1	paper	2%	0.1 ± 0.070	0.001 ± 0.001	0.2		
2.2	kitchenwaste (food)	14%	0.6 ± 0.231	0.013 ± 0.006	1.3		
2.3	rubbish various	9%	0.5 ± 0.212	0.003 ± 0.001	0.2		
2.4	fishhook	0%	0.0 ± 0.000	0.000 ± 0.000	0.0		
3.0	POLLUTANTS	28%	2.3 ± 0.996	1.131 ± 0.496	70.0		
3.3	paraffin-like substances	20%	1.7 ± 0.946	1.126 ± 0.496	70.0		

Table 2. Annual details for plastic abundance in fulmars from the Netherlands in the period 1979-2024. **A.** all plastic categories combined; **B.** separate data for industrial and user plastic categories. Sample size is given with the proportion of adult birds in brackets. Frequency of Occurrence (%FO) represents the proportion of birds with one or more items of that litter present. Average number ($n \pm SE$) gives the abundance by number of plastic particles per bird with standard error, and average mass ($g \pm SE$) the weight of plastic per bird in grams with standard error. FTV% shows the percentage of birds having more than the threshold of 0.1 gram of plastic in the stomach. Note sample sizes (n) to be very low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures (only years with sample size over 10 birds are printed in bold).

A	Netherlands		Total plastics				
	YEAR	sample n	(% ad)	%FO	average number $n \pm se$	average mass $g \pm se$	FTV% (over 0.1 g)
	1979	1	(0%)	100%	5.0	0.24	
	1980	0					
	1981	0					
	1982	3	(0%)	100%	11.0 \pm 4.0	0.61 \pm 0.34	
	1983	19	(41%)	100%	16.0 \pm 2.5	0.49 \pm 0.13	89%
	1984	20	(40%)	90%	17.9 \pm 5.5	0.35 \pm 0.13	55%
	1985	3	(33%)	100%	10.3 \pm 1.5	0.28 \pm 0.07	
	1986	4	(25%)	75%	5.5 \pm 1.8	0.08 \pm 0.05	
	1987	17	(59%)	82%	13.6 \pm 4.0	0.19 \pm 0.08	59%
	1988	1	(0%)	100%	2.0	0.04	
	1989	2	(100%)	100%	12.5 \pm 9.5	0.43 \pm 0.40	
	1990	0					
	1991	1	(0%)	100%	11.0	0.14	
	1992	0					
	1993	0					
	1994	0					
	1995	2	(50%)	100%	5.0 \pm 1.0	0.06 \pm 0.02	
	1996	8	(62%)	100%	27.4 \pm 13.7	0.26 \pm 0.11	
	1997	31	(16%)	97%	35.8 \pm 7.3	0.73 \pm 0.17	84%
	1998	75	(44%)	95%	28.6 \pm 5.2	0.94 \pm 0.35	71%
	1999	107	(70%)	98%	35.3 \pm 6.2	0.44 \pm 0.11	61%
	2000	38	(58%)	100%	22.0 \pm 5.2	0.35 \pm 0.13	61%
	2001	55	(37%)	96%	22.7 \pm 4.2	0.24 \pm 0.05	49%
	2002	56	(54%)	98%	51.8 \pm 12.5	0.50 \pm 0.20	68%
	2003	39	(56%)	95%	28.5 \pm 7.2	0.17 \pm 0.03	54%
	2004	131	(80%)	91%	23.4 \pm 3.0	0.27 \pm 0.04	60%
	2005	51	(68%)	98%	17.8 \pm 2.8	0.27 \pm 0.06	47%
	2006	27	(62%)	93%	33.9 \pm 7.6	0.30 \pm 0.08	85%
	2007	64	(45%)	92%	35.9 \pm 5.5	0.37 \pm 0.05	72%
	2008	20	(58%)	95%	44.5 \pm 12.3	0.31 \pm 0.10	55%
	2009	68	(40%)	97%	19.3 \pm 3.6	0.22 \pm 0.04	46%
	2010	36	(46%)	94%	56.4 \pm 16.3	0.46 \pm 0.20	64%
	2011	19	(37%)	100%	43.6 \pm 13.1	0.43 \pm 0.19	79%
	2012	81	(46%)	90%	20.6 \pm 3.4	0.30 \pm 0.09	49%
	2013	24	(42%)	92%	26.8 \pm 8.3	0.18 \pm 0.04	46%
	2014	12	(64%)	100%	21.4 \pm 3.9	0.36 \pm 0.14	83%
	2015	23	(30%)	96%	12.1 \pm 3.2	0.26 \pm 0.15	39%
	2016	31	(18%)	87%	31.7 \pm 12.9	0.29 \pm 0.10	52%
	2017	38	(31%)	92%	26.8 \pm 14.1	0.24 \pm 0.07	37%
	2018	12	(50%)	100%	15.8 \pm 7.8	0.12 \pm 0.06	17%
	2019	44	(34%)	95%	11.4 \pm 2.2	0.09 \pm 0.02	36%
	2020	14	(8%)	93%	30.9 \pm 18.9	0.42 \pm 0.30	43%
	2021	80	(19%)	95%	34.5 \pm 6.6	0.31 \pm 0.05	66%
	2022	69	(39%)	94%	18.1 \pm 4.0	0.29 \pm 0.11	48%
	2023	33	(41%)	85%	20.4 \pm 4.3	0.27 \pm 0.07	55%
	2024	32	(21%)	88%	12.7 \pm 2.1	0.12 \pm 0.03	31%

B**Netherlands****Industrial granules****User plastics**

YEAR	sample <i>n</i>	%FO	avg number <i>n</i> ± <i>se</i>	avg mass <i>g</i> ± <i>se</i>	%FO	avg number <i>n</i> ± <i>se</i>	avg mass <i>g</i> ± <i>se</i>
1979	1	100%	2.0	0.07	100%	3.0	0.17
1980	0						
1981	0						
1982	3	100%	5.0 ± 2.1	0.11 ± 0.04	67%	6.0 ± 3.2	0.50 ± 0.33
1983	19	84%	8.8 ± 2.2	0.19 ± 0.04	89%	7.2 ± 1.8	0.31 ± 0.12
1984	20	70%	9.6 ± 2.6	0.19 ± 0.05	90%	8.4 ± 3.1	0.17 ± 0.09
1985	3	100%	5.3 ± 1.2	0.14 ± 0.05	100%	5.0 ± 2.5	0.14 ± 0.08
1986	4	50%	0.8 ± 0.5	0.02 ± 0.01	75%	4.8 ± 1.7	0.06 ± 0.04
1987	17	82%	3.9 ± 1.8	0.11 ± 0.05	71%	9.7 ± 2.7	0.09 ± 0.04
1988	1	0%	0.0	0.00	100%	2.0	0.04
1989	2	50%	6.5 ± 6.5	0.17 ± 0.17	100%	6.0 ± 3.0	0.25 ± 0.23
1990	0						
1991	1	0%	0.0	0.00	100%	11.0	0.14
1992	0						
1993	0						
1994	0						
1995	2	100%	1.5 ± 0.5	0.02 ± 0.01	100%	3.5 ± 0.5	0.03 ± 0.01
1996	8	75%	2.9 ± 1.2	0.07 ± 0.03	100%	24.5 ± 13.7	0.19 ± 0.10
1997	31	74%	5.9 ± 1.9	0.13 ± 0.04	97%	29.8 ± 6.8	0.60 ± 0.17
1998	75	68%	3.1 ± 0.5	0.07 ± 0.01	93%	25.6 ± 5.2	0.87 ± 0.35
1999	107	58%	3.4 ± 0.8	0.06 ± 0.01	97%	31.8 ± 5.7	0.38 ± 0.11
2000	38	61%	3.4 ± 1.8	0.08 ± 0.05	100%	18.6 ± 3.7	0.27 ± 0.09
2001	55	64%	2.5 ± 0.6	0.06 ± 0.01	96%	20.1 ± 3.8	0.18 ± 0.05
2002	56	68%	4.6 ± 0.8	0.09 ± 0.01	96%	47.2 ± 11.9	0.41 ± 0.19
2003	39	51%	2.3 ± 0.6	0.05 ± 0.01	92%	26.3 ± 6.9	0.12 ± 0.03
2004	131	54%	2.6 ± 0.4	0.06 ± 0.01	91%	20.8 ± 2.8	0.22 ± 0.04
2005	51	53%	2.0 ± 0.5	0.05 ± 0.01	96%	15.8 ± 2.7	0.22 ± 0.06
2006	27	78%	3.5 ± 0.7	0.08 ± 0.01	93%	30.4 ± 7.2	0.23 ± 0.07
2007	64	72%	3.3 ± 0.5	0.07 ± 0.01	91%	32.6 ± 5.3	0.30 ± 0.04
2008	20	65%	3.8 ± 1.2	0.08 ± 0.03	95%	40.8 ± 11.2	0.23 ± 0.08
2009	68	46%	1.7 ± 0.5	0.04 ± 0.01	96%	17.6 ± 3.2	0.18 ± 0.03
2010	36	58%	10.7 ± 7.7	0.23 ± 0.17	94%	45.7 ± 12.5	0.23 ± 0.06
2011	19	63%	6.6 ± 4.1	0.15 ± 0.10	95%	37.0 ± 10.4	0.27 ± 0.09
2012	81	59%	1.8 ± 0.3	0.04 ± 0.01	89%	18.8 ± 3.3	0.26 ± 0.08
2013	24	63%	2.2 ± 0.6	0.04 ± 0.01	92%	24.6 ± 7.9	0.14 ± 0.03
2014	12	75%	2.4 ± 0.8	0.05 ± 0.01	100%	19.0 ± 3.5	0.31 ± 0.13
2015	23	43%	1.1 ± 0.4	0.02 ± 0.01	91%	11.0 ± 2.9	0.23 ± 0.14
2016	31	48%	2.0 ± 0.7	0.04 ± 0.01	87%	29.7 ± 12.7	0.25 ± 0.10
2017	38	32%	1.4 ± 0.7	0.03 ± 0.01	92%	25.5 ± 13.5	0.21 ± 0.07
2018	12	50%	1.3 ± 0.5	0.02 ± 0.01	100%	14.5 ± 7.3	0.09 ± 0.05
2019	44	41%	0.8 ± 0.2	0.02 ± 0.01	95%	10.6 ± 2.2	0.08 ± 0.01
2020	14	64%	4.1 ± 3.1	0.10 ± 0.07	93%	26.8 ± 15.8	0.32 ± 0.23
2021	80	63%	2.2 ± 0.5	0.05 ± 0.01	94%	32.3 ± 6.3	0.26 ± 0.05
2022	69	42%	1.1 ± 0.2	0.03 ± 0.01	94%	17.1 ± 3.8	0.26 ± 0.10
2023	33	48%	2.1 ± 0.7	0.06 ± 0.02	82%	18.3 ± 4.0	0.21 ± 0.07
2024	32	50%	1.1 ± 0.3	0.02 ± 0.01	88%	11.6 ± 1.9	0.09 ± 0.02

Table 3. Running averages by 5-year period for plastic abundance in fulmars from the Netherlands in the period 1979-2024. A. all plastic categories combined; B. separate data for industrial and user plastic categories. Sample size is given with the proportion of adult birds in brackets. Frequency of Occurrence (%FO) represents the proportion of birds with one or more items of that litter present. Average number ($n \pm SE$) gives the abundance by number of plastic particles per bird with standard error, and average mass ($g \pm SE$) the weight of plastic per bird in grams with standard error. FTV% shows the percentage of birds having more than the threshold of 0.1 gram of plastic in the stomach. Note sample sizes (n) to be very low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures.

A	Netherlands		Total plastics			
	5-year period	sample n (% ad)	%FO	average number n ± se	average mass g ± se	FTV% (over 0.1g)
	1979-89	70 (43%)	91%	14.4 ± 2.0	0.34 ± 0.06	67%
	1990_94	1				
	1991_95	3				
	1992_96	10				
	1993_97	41 (27%)	98%	32.6 ± 6.1	0.61 ± 0.13	76%
	1994_98	116 (38%)	96%	30.0 ± 4.0	0.82 ± 0.23	72%
	1995_99	223 (53%)	97%	32.5 ± 3.6	0.64 ± 0.13	67%
	1996_00	259 (54%)	97%	31.2 ± 3.2	0.60 ± 0.12	66%
	1997_01	306 (51%)	97%	29.8 ± 2.8	0.54 ± 0.10	63%
	1998_02	331 (54%)	97%	32.9 ± 3.3	0.52 ± 0.10	62%
	1999_03	295 (57%)	98%	33.5 ± 3.6	0.37 ± 0.06	59%
	2000_04	319 (62%)	95%	28.7 ± 2.9	0.30 ± 0.04	59%
	2001_05	332 (64%)	95%	27.8 ± 2.7	0.29 ± 0.04	57%
	2002_06	304 (68%)	94%	29.3 ± 3.0	0.30 ± 0.04	61%
	2003_07	312 (66%)	93%	26.6 ± 2.1	0.28 ± 0.02	62%
	2004_08	293 (67%)	93%	27.6 ± 2.2	0.30 ± 0.03	62%
	2005_09	230 (52%)	95%	27.5 ± 2.5	0.29 ± 0.03	59%
	2006_10	215 (47%)	94%	34.6 ± 3.8	0.32 ± 0.04	62%
	2007_11	207 (44%)	95%	35.6 ± 4.0	0.34 ± 0.04	61%
	2008_12	224 (44%)	94%	30.0 ± 3.6	0.31 ± 0.05	54%
	2009_13	228 (43%)	94%	28.4 ± 3.4	0.30 ± 0.05	53%
	2010_14	172 (45%)	93%	31.5 ± 4.3	0.34 ± 0.06	58%
	2011_15	159 (43%)	93%	23.1 ± 2.8	0.30 ± 0.05	53%
	2012_16	171 (39%)	91%	22.4 ± 3.1	0.28 ± 0.05	50%
	2013_17	128 (33%)	92%	24.9 ± 5.5	0.26 ± 0.04	47%
	2014_18	116 (32%)	93%	23.5 ± 5.9	0.26 ± 0.05	44%
	2015_19	148 (30%)	93%	20.1 ± 4.6	0.20 ± 0.04	39%
	2016_20	139 (28%)	93%	22.5 ± 5.2	0.21 ± 0.04	39%
	2017_21	188 (26%)	95%	26.1 ± 4.3	0.24 ± 0.04	48%
	2018_22	219 (29%)	95%	23.4 ± 3.1	0.25 ± 0.04	50%
	2019_23	240 (30%)	93%	23.4 ± 2.8	0.26 ± 0.04	53%
	2020_24	228 (28%)	92%	24.2 ± 3.0	0.28 ± 0.04	53%

B

Netherlands		Industrial granules				User plastics		
5-year period	sample <i>n</i>	%FO	avg number <i>n</i> ± se	avg mass ± se	g	%FO	avg number <i>n</i> ± se	avg mass g ± se
1979-89	70	77%	6.8 ± 1.1	0.15 ± 0.02		84%	7.7 ± 1.2	0.19 ± 0.05
1990_94	1							
1991_95	3							
1992_96	10							
1993_97	41	76%	5.1 ± 1.5	0.12 ± 0.03		98%	27.5 ± 5.8	0.49 ± 0.13
1994_98	116	71%	3.8 ± 0.6	0.08 ± 0.01		95%	26.3 ± 3.9	0.74 ± 0.23
1995_99	223	65%	3.6 ± 0.5	0.07 ± 0.01		96%	28.9 ± 3.4	0.56 ± 0.13
1996_00	259	64%	3.6 ± 0.5	0.08 ± 0.01		97%	27.6 ± 3.0	0.53 ± 0.11
1997_01	306	63%	3.4 ± 0.4	0.07 ± 0.01		96%	26.3 ± 2.6	0.47 ± 0.10
1998_02	331	63%	3.4 ± 0.4	0.07 ± 0.01		96%	29.5 ± 3.1	0.45 ± 0.09
1999_03	295	60%	3.3 ± 0.4	0.07 ± 0.01		97%	30.1 ± 3.3	0.30 ± 0.06
2000_04	319	59%	3.0 ± 0.3	0.06 ± 0.01		94%	25.7 ± 2.7	0.24 ± 0.04
2001_05	332	58%	2.8 ± 0.3	0.06 ± 0.01		94%	25.0 ± 2.6	0.23 ± 0.04
2002_06	304	58%	2.9 ± 0.3	0.06 ± 0.01		93%	26.4 ± 2.8	0.24 ± 0.04
2003_07	312	59%	2.7 ± 0.2	0.06 ± 0.01		92%	23.9 ± 2.0	0.22 ± 0.02
2004_08	293	61%	2.8 ± 0.3	0.06 ± 0.01		92%	24.8 ± 2.1	0.24 ± 0.02
2005_09	230	60%	2.6 ± 0.3	0.06 ± 0.01		94%	24.9 ± 2.3	0.23 ± 0.02
2006_10	215	61%	4.1 ± 1.3	0.09 ± 0.03		93%	30.5 ± 3.2	0.23 ± 0.02
2007_11	207	59%	4.4 ± 1.4	0.10 ± 0.03		94%	31.1 ± 3.3	0.24 ± 0.02
2008_12	224	56%	3.8 ± 1.3	0.08 ± 0.03		93%	26.2 ± 2.9	0.23 ± 0.04
2009_13	228	56%	3.6 ± 1.3	0.08 ± 0.03		93%	24.8 ± 2.8	0.22 ± 0.03
2010_14	172	61%	4.3 ± 1.7	0.10 ± 0.04		92%	27.3 ± 3.5	0.24 ± 0.04
2011_15	159	59%	2.4 ± 0.5	0.05 ± 0.01		91%	20.7 ± 2.5	0.24 ± 0.05
2012_16	171	57%	1.8 ± 0.2	0.04 ± 0.01		90%	20.5 ± 3.0	0.24 ± 0.05
2013_17	128	48%	1.7 ± 0.3	0.03 ± 0.01		91%	23.1 ± 5.3	0.22 ± 0.04
2014_18	116	45%	1.6 ± 0.3	0.03 ± 0.01		92%	21.9 ± 5.7	0.22 ± 0.05
2015_19	148	41%	1.3 ± 0.2	0.03 ± 0.00		93%	18.8 ± 4.5	0.17 ± 0.04
2016_20	139	43%	1.6 ± 0.4	0.03 ± 0.01		93%	20.9 ± 5.0	0.18 ± 0.04
2017_21	188	51%	1.8 ± 0.4	0.04 ± 0.01		94%	24.3 ± 4.1	0.20 ± 0.03
2018_22	219	51%	1.6 ± 0.3	0.04 ± 0.01		95%	21.8 ± 2.9	0.22 ± 0.04
2019_23	240	51%	1.7 ± 0.3	0.04 ± 0.01		93%	21.7 ± 2.7	0.22 ± 0.04
2020_24	228	53%	1.8 ± 0.3	0.04 ± 0.01		91%	22.4 ± 2.8	0.23 ± 0.04

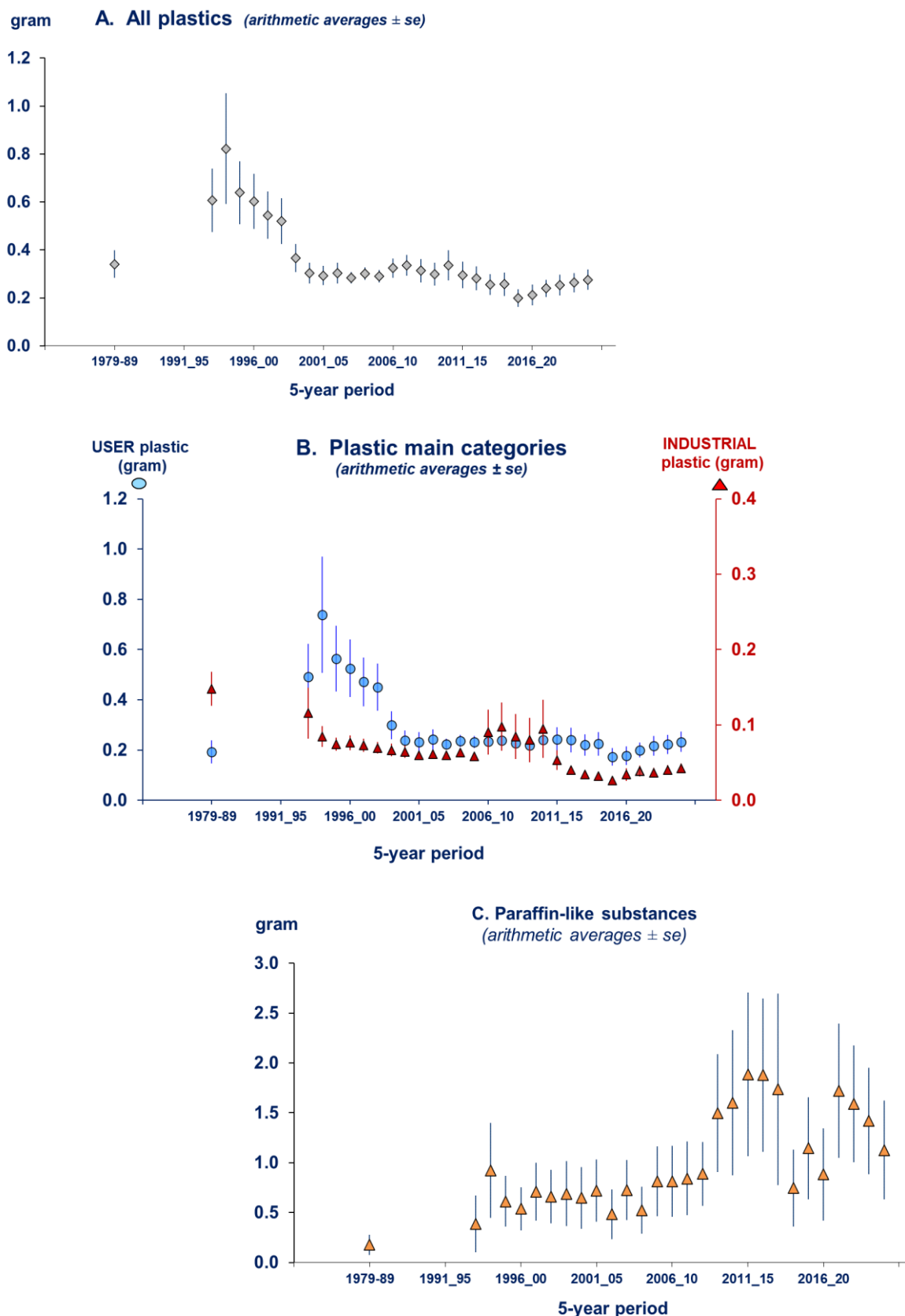


Figure 2. Plastic and paraffin-like substance mass in stomachs of fulmars from the Netherlands in the period 1979-2024. Shown by 5-year running averages, except all data combined for the early period 1979-1989. Data only shown where sample size over 40 stomachs. **A:** Data for all plastics combined visualising changes in arithmetic average mass \pm SE. **B:** Arithmetic mass data, split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Please note the different scales for user and industrial plastics. **C:** Arithmetic mass \pm SE for paraffin-like substances (orange triangles). Data are visualized as running 5-year averages (i.e. data-points shift one year ahead at a time) and do not represent statistical trends.

4.3 Trends

In the Fulmar Threshold Value approach, the emphasis in detailed trend analyses is on the mass of plastics in stomachs of beached fulmars rather than on incidence or number of plastic particles. In trend discussions, a distinction is made between long-term trends and recent trends.

4.3.1 Long-term trends (linear regressions)

The '**long-term trend**' is defined as the trend over all years in the dataset (now 1979-2024). The current dataset holds records for 1391 fulmars, with 635 adult birds and 710 non-adults, which are juveniles to immatures several years of age. For 46 birds, insufficient information was available to assess the age-group. Long-term trends are influenced by the fact that in initial years, trends for industrial and user plastics were opposite (Fig. 2B, Table 3B, Table 4A).

The industrial plastics halved from early 1980s to mid-1990s while user plastics nearly tripled in mass. Measured over the full period of over 45 years of data for the Netherlands, the initial strong decrease of industrial plastics still contributes strongly to a long-term significant decline in industrial plastic ($p < 0.001$), in spite of the fact that since the early 2000s changes have been much less evident (Table 2). The decrease in abundance of industrial plastics in the marine environment has been signalled in different oceanographic regions all over the globe (Van Franeker & Meijboom 2002, Vlietstra & Parga 2002, Ryan 2008, Van Franeker & Law 2015; Campbell et al. 2025).

For user plastics, the initial increase from the 1980s to mid-1990s was largely 'compensated' by a rapid decrease from late 1990s to around 2003, and relatively small changes after that being non-significant.

Trends in different age groups (adults/non-adults) are decreasing similarly in industrial plastics. For user plastics the mass is decreasing in both adults and non-adults, but for the adults the decrease is significant ($p = 0.024$). For all plastics combined, the total plastic mass is decreasing significantly, both for adult ($p < 0.001$) and non-adult ($p < 0.001$) birds.

4.3.2 Recent trends (linear regressions)

The '**recent trend**' is defined as the trend in plastic mass in fulmar stomachs over the past 10 years, so in this report: 2015-2024 (Figure 3, Table 4C). After the early 2000s, and up to 2014, recent trends were generally described as stable or as potential slow but non-significant decline (Table 4D). The 10-year analysis over years 2007-2016 ($n = 378$) for the first time demonstrated an overall significant 10-year decline ($p = 0.034$) mainly based on a similar reduced mass of user plastic ($p = 0.036$) and industrial plastics ($p = 0.035$). Since then, up to the period 2011-20, the strength of the 10-year decreasing trends has weakened. More recently (from 2012-2021 onwards), significance has been lost and the slope is not negative anymore, indicating a potential although non-significant increase. This is also true for all sub-groups, such as user and industrial plastics and for adults and non-adults respectively. This change is driven by an increase in user plastic mass ingested by fulmars since 2020 (Table 4C).

The FTV Performance has added a wider perspective of the time periods to be considered in analysing trends. Consequently, trends since the start of the international fulmar monitoring in the North Sea in 2002 are evaluated. Trends in ingested mass of plastics over this period (Table 4B) are clearer than over the recent 10 years (Table 4C). Industrial plastics show a strongly significant decrease over the 2002-2024 period ($p < .001$), also for separate age groups. User plastics decreased significantly only for adults ($p = 0.014$). However, combined for all plastics and both age groups, the 2002-2024 decrease is still significant ($p = 0.039$).

Table 4. Details of linear regression analyses for time related trends in plastic abundance by mass in stomachs of fulmars in the Netherlands. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over **A.** full time period of data, **B.** the period since start of the Save the North Sea project in 2002, and **C.** the most recent 10 years of data, which is the recommended period in OSPAR guidelines for testing in the Fulmar-TV. **D.** significance of sequential decadal trends for 1980s and 10-year periods starting 1997. The regression line ('trend') is described by $y = \text{Constant} + \text{estimate} \times x$ in which y is the calculated value of the regression-line for year x . When the t -value of a regression is negative, it indicates a decrease in the tested litter-category; a positive t -value indicates increase. A trend is considered significant when the probability (p) of misjudgement of data is less than 5% ($p < 0.05$). Significant trends in the table are labelled with positive signs in case of increase (+) in plastic mass or negative signs in case of decrease (-). Significance at the 5% level ($p < 0.05$) is labelled as - or + ; at the 1% level ($p < 0.01$) as -- or ++; and at the 0.1% level ($p < 0.001$) as --- or +++. Where test results are not significant (*n.s.*) but close ($p < 0.1$), upward or downward arrow indicates the potential direction of change.

A. LONG TERM TRENDS 1979-2024						
for plastics in Fulmar stomachs, the Netherlands						
Industrial plastics (lnGIND)	<i>n</i>	constant	slope	s.e.	t	p
all ages	1391	80.9	-0.0425	0.0059	-7.17	<.001 ↓ ---
adults	635	90.2	-0.0474	0.0099	-0.78	<.001 ↓ ---
non adults	710	88.5	-0.0462	0.0077	-6.02	<.001 ↓ ---
User plastics (lnGUSE)	<i>n</i>	constant	slope	s.e.	t	p
all ages	1391	17.1	-0.0099	0.0052	-1.89	0.059 ↓ <i>n.s.</i>
adults	635	41.8	-0.0223	0.0092	-2.42	0.024 ↓ --
non adults	710	9.9	-0.0062	0.0064	-0.96	0.337 <i>n.s.</i>
All plastics combined (lnGPLA)	<i>n</i>	constant	slope	s.e.	t	p
all ages	1391	44.7	-0.0234	0.0051	-4.57	<.001 ↓ ---
adults	635	60.4	-0.0314	0.0091	-3.44	<.001 ↓ ---
non adults	710	44.8	-0.0234	0.0061	-3.80	<.001 ↓ ---
B. TRENDS 2002-2024 since start SNS project						
for plastics in Fulmar stomachs, the Netherlands						
Industrial plastics (lnGIND)	<i>n</i>	Constant	slope	s.e.	t	p
all ages	1004	70.9	-0.0376	0.0095	3.72	<.001 ↓ ---
adults	446	110.1	-0.0572	0.0149	-3.85	<.001 ↓ ---
non adults	516	76.7	-0.0403	0.0136	-2.96	0.003 ↓ --
User plastics (lnGUSE)	<i>n</i>	Constant	slope	s.e.	t	p
all ages	1004	32.1	-0.0174	0.0084	-2.07	0.039 ↓ -
adults	446	67.8	-0.0353	0.0143	-2.46	0.014 ↓ -
non adults	516	40.2	-0.0212	0.0110	-1.93	0.054 ↓ <i>n.s.</i>
All plastics combined (lnGPLA)	<i>n</i>	Constant	slope	s.e.	t	p
all ages	1004	45.9	-0.0241	0.0083	-2.89	0.004 ↓ --
adults	446	83.6	-0.0430	0.0142	-3.02	0.003 ↓ --
non adults	516	52.1	-0.0270	0.0109	-2.48	0.013 ↓ -
C. RECENT 10-YEAR TRENDS 2015-2024						
for plastics in Fulmar stomachs, the Netherlands						
Industrial plastics (lnGIND)	<i>n</i>	constant	slope	s.e.	t	p
all ages	376	-89.9	0.0420	0.0392	1.07	0.285 <i>n.s.</i>
adults	102	-26.0	0.0102	0.0669	0.15	0.879 <i>n.s.</i>
non adults	250	-187.7	0.0905	0.0489	1.85	0.065 ↑ <i>n.s.</i>
User plastics (lnGUSE)	<i>n</i>	constant	slope	s.e.	t	p
all ages	376	-32.6	0.0147	0.0369	0.40	0.692 <i>n.s.</i>
adults	102	-44.0	0.0200	0.0762	0.26	0.794 <i>n.s.</i>
non adults	250	-68.0	0.0324	0.0428	0.76	0.451 <i>n.s.</i>
All plastics combined (lnGPLA)	<i>n</i>	constant	slope	s.e.	t	p
all ages	376	-31.7	0.0144	0.0369	0.04	0.698 <i>n.s.</i>
adults	102	-46.0	0.0212	0.0766	0.28	0.782 <i>n.s.</i>
non adults	250	-74.4	0.0356	0.0423	0.84	0.400 <i>n.s.</i>

D. Linear Regression tests over 10-year periods

Decade	n	Industrial plastic		User plastic		ALL PLASTICS	
		p		p		p	
1979-1991	(71)	0.028	↓ -	0.267	n.s.	0.037	↓ -
1995-2004	(542)	0.022	↓ -	0.002	↓ - -	<0.001	↓ - - -
1996-2005	(591)	0.007	↓ - -	0.001	↓ - - -	<0.001	↓ - - -
1997-2006	(610)	0.087	↓ n.s.	0.002	↓ - -	<0.001	↓ - - -
1998-2007	(643)	0.819	n.s.	0.289	n.s.	0.173	n.s.
1999-2008	(588)	0.253	n.s.	0.765	n.s.	0.626	n.s.
2000-2009	(549)	0.436	n.s.	0.936	n.s.	0.749	n.s.
2001-2010	(547)	0.537	n.s.	0.395	n.s.	0.755	n.s.
2002-2011	(511)	0.686	n.s.	0.320	n.s.	0.526	n.s.
2003-2012	(455)	0.488	n.s.	0.044	↑ +	0.079	↑ n.s.
2004-2013	(521)	0.901	n.s.	0.963	n.s.	0.844	n.s.
2005-2014	(402)	0.550	n.s.	0.411	n.s.	0.399	n.s.
2006-2015	(374)	0.010	↓ - -	0.049	↓ -	0.062	↓ n.s.
2007-2016	(378)	0.035	↓ -	0.036	↓ -	0.034	↓ -
2008-2017	(352)	0.050	↓ -	0.151	n.s.	0.091	↓ n.s.
2009-2018	(344)	0.104	n.s.	0.121	n.s.	0.072	↓ n.s.
2010-2019	(320)	<0.001	↓ - - -	0.006	↓ - -	0.002	↓ - -
2011-2020	(298)	0.006	↓ - -	0.049	↓ -	0.018	↓ -
2012-2021	(350)	0.603	n.s.	0.219	n.s.	0.347	n.s.
2013-2022	(340)	0.719	n.s.	0.300	n.s.	0.440	n.s.
2014-2023	(347)	0.570	n.s.	0.431	n.s.	0.526	n.s.
2015-2024	(376)	0.285	n.s.	0.692	n.s.	0.698	n.s.

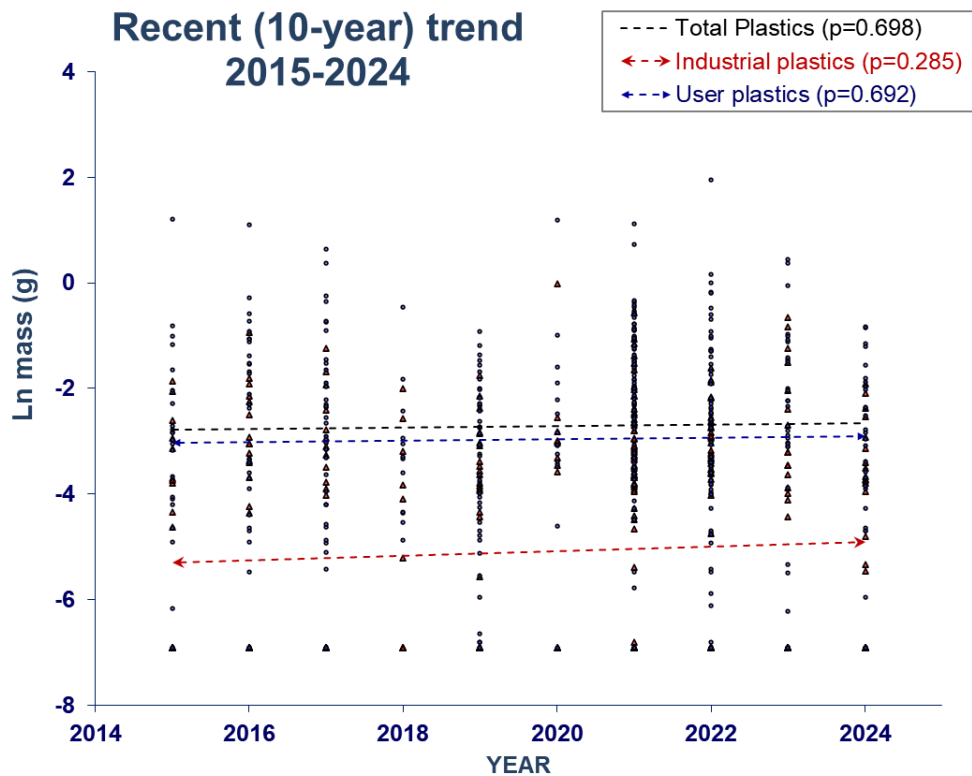


Figure 3. Statistical trend in plastic mass in stomachs of fulmars from the Netherlands 2015-2024. The graph, as an example of the statistical approach, shows plotted ln-transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for industrial (lower, red line), user (middle blue line) and total plastics (top black line). Full details for results of statistical tests for trends are available in Table 4C. Trendlines are shown as solid line when significant and dashed when non-significant.

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. Fig. 4 illustrates age-related variations in our monitoring data: in geometric means, the persistent difference in plastic loads between adults and non-adults is very clear. However, both age groups follow, at a different level, a similar pattern, which strengthens the validity of the monitoring approach combining data for all birds. Similar patterns can be found in Figure 6, where the same age-separated data is used to display changes in terms of the Fulmar-TV.

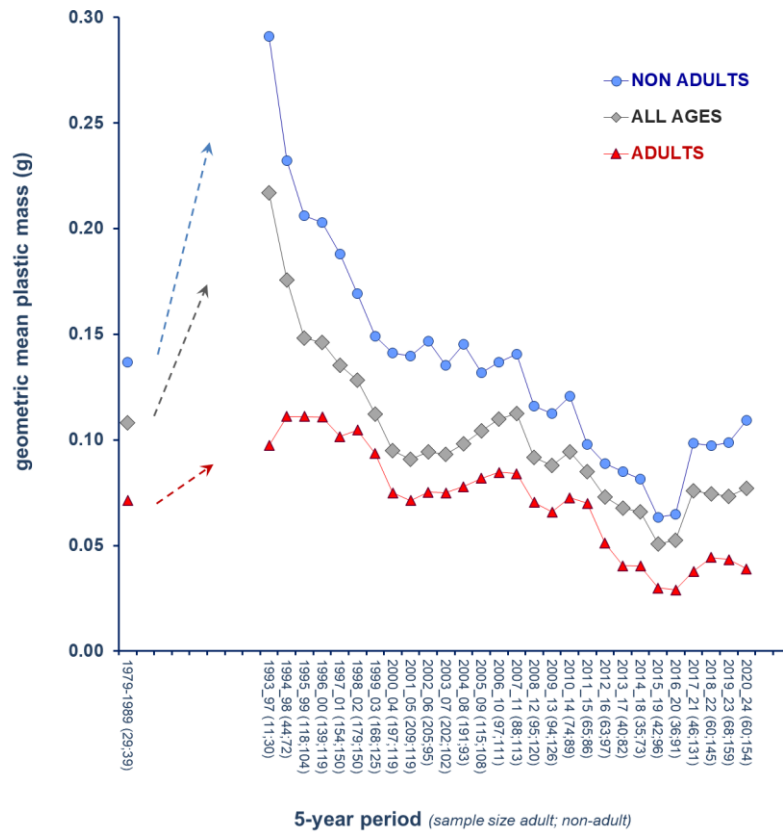


Figure 4. Geometric mean mass of plastics in stomachs of beached fulmars from the Netherlands 1979-2024 for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults (blue circles), with respective sample sizes in brackets in the x-axis labels. Full sample sizes available in e.g. Table 3A. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trendline in the summary. This graphic visualization does not represent a statistical trend analysis.

4.4 Dutch Fulmar-TV Performance

At first sight, one might argue that it would be easier to use a Fulmar-TV definition based on for example only the average mass of plastics. However, the 'percentage above threshold value' definition represents a simplified procedure to avoid the mathematical problems caused by a few excessive stomach content values that distort comparative analyses and averaged values. The Fulmar-TV metric avoids such problems by using a classification of birds in which the exceptional stomach contents lose their influence. The Fulmar Threshold Value 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."*

In such a definition, an excessive stomach content of e.g. 10 gram of plastic does not change the metric compared to the situation in which that bird would have had for example only 0.2 g in its stomach. Using the same data as in earlier sections of this report, Fig. 5 illustrates the time trends in the 5-year average FTV Performance of fulmars found in the Netherlands. Although the graph does indicate an improvement on the long-term, it also emphasizes the distance from the 10% FTV target set by OSPAR and the MSFD. Over the integrated recent 5-year period 2020-2024, 53% of the Dutch fulmars exceeded the critical FTV level of 0.1 g of plastic in the stomach, which is an increase in comparison to earlier 5-year periods (e.g. in the period 2016-20, this percentage was 39%). The exceptional high plastic mass in 2021 fulmars caused this high value and will likely influence the 5-year periods for the upcoming years.

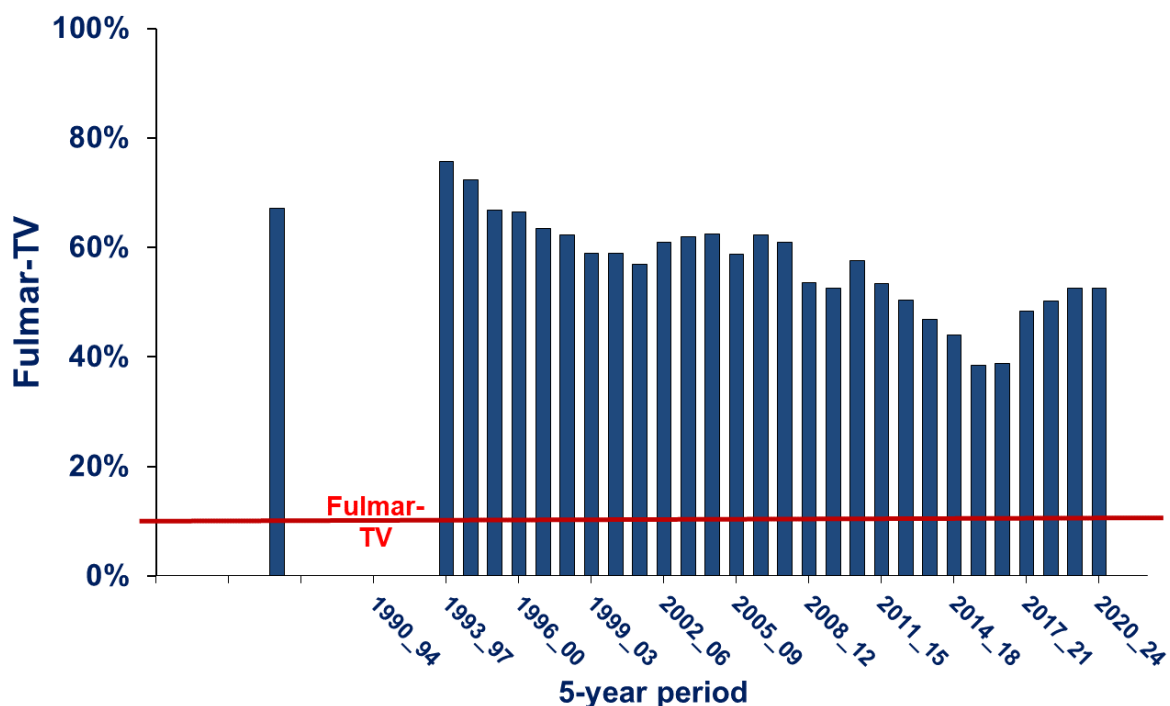


Figure 5. Fulmar-TV Performance of fulmars in the Netherlands over running 5-year periods up to 2024. Data for the 1980s were combined due to relatively small sample size. The red line illustrates the Fulmar-Threshold Value. This graphic visualization does not represent a statistical trend analysis.

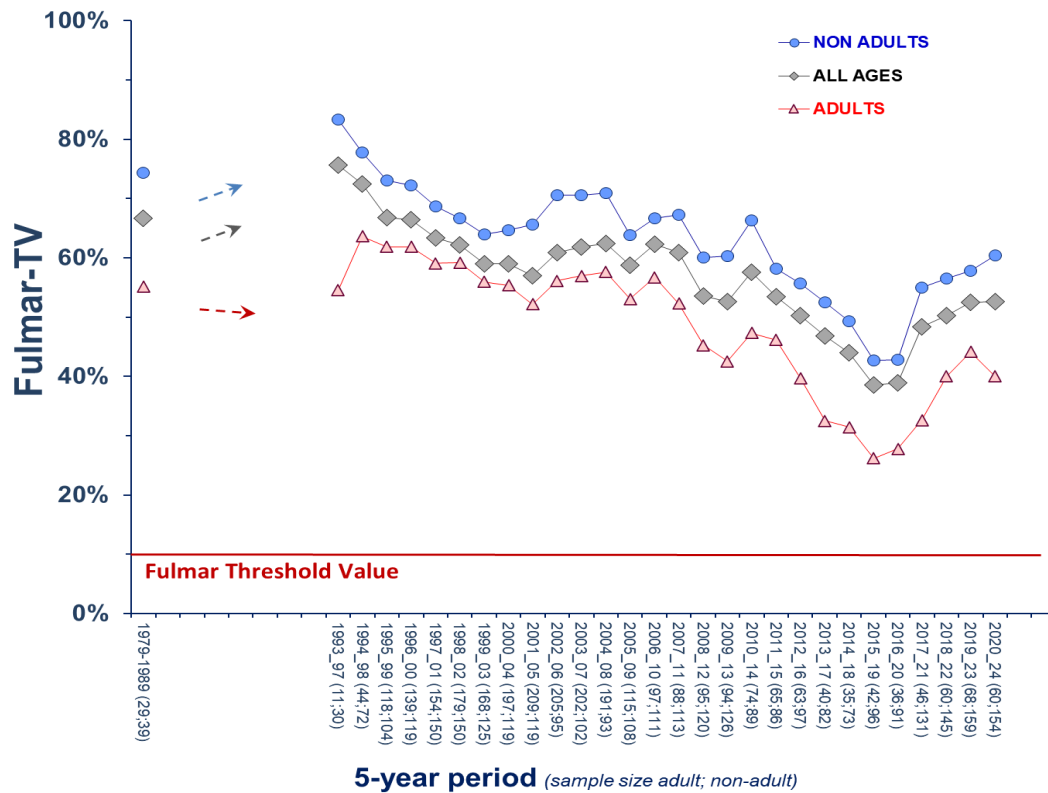


Figure 6. Visualisation of Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2024. Trendlines for all birds combined (grey diamonds, including birds of unknown age), for adult birds (red triangles) and for non-adults (blue circles). This graphic visualization is based on a single data-point for the 1980s and overlapping 5-year averages in later periods. Periods with less than 10 birds in the sample during the late 1980's and early 1990s are not shown in the graph. This visualization in itself does not represent a statistical trend analysis.

4.5 Modelling and forecasting future Fulmar-TV Performance

Policy makers involved in the OSPAR and MSFD process have asked to provide models that might predict plastic ingestion rates by fulmars in future years. Such information could assist in focused planning of actions aiming at reaching policy targets by specific dates.

Evaluating trends over a period of the most recent ten years, as recommended by OSPAR, the statistical procedure then would have only ten data-points available for statistical tests and modelling. Simple linear regression cannot be applied to this type of data, therefore the period since 2002 is considered. The data need to be analysed in a GLM (*Generalized Linear Modelling*), more specifically in a logistic analysis dedicated for binomial distributions (birds yes or no above threshold) and using logit transformed data.

Only when significant results are reached within the logistic model, the predicting trend can be calculated. In our first analysis of data up to 2017 (Van Franeker & Kühn 2018), the data since the start of the SNS project in 2002 produced significant results ($p=0.003$). That analysis predicted that the first year of the long-term Fulmar-TV target could be reached between years 2055 to 2060. Since then, the predicted date had been delayed up to the year 2087 in the previous report. By adding data for the year 2024, it is predicted that the Fulmar-TV will be reached in 2077. The larger standard errors in the current model (Figure 7) reflect the uncertainty caused by an unusual year.

Possibly the GLM analysis of annual data is somewhat more sensitive in assigning statistical significance than the linear regression of individual data, and it is advised to continue both types of analyses, with the focus on the recent 10-year period for ingested plastic mass, and a focus on the longer SNS period since 2002 for the binomial data of annual FTV Performances.

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 could be reached in the predicted time period.

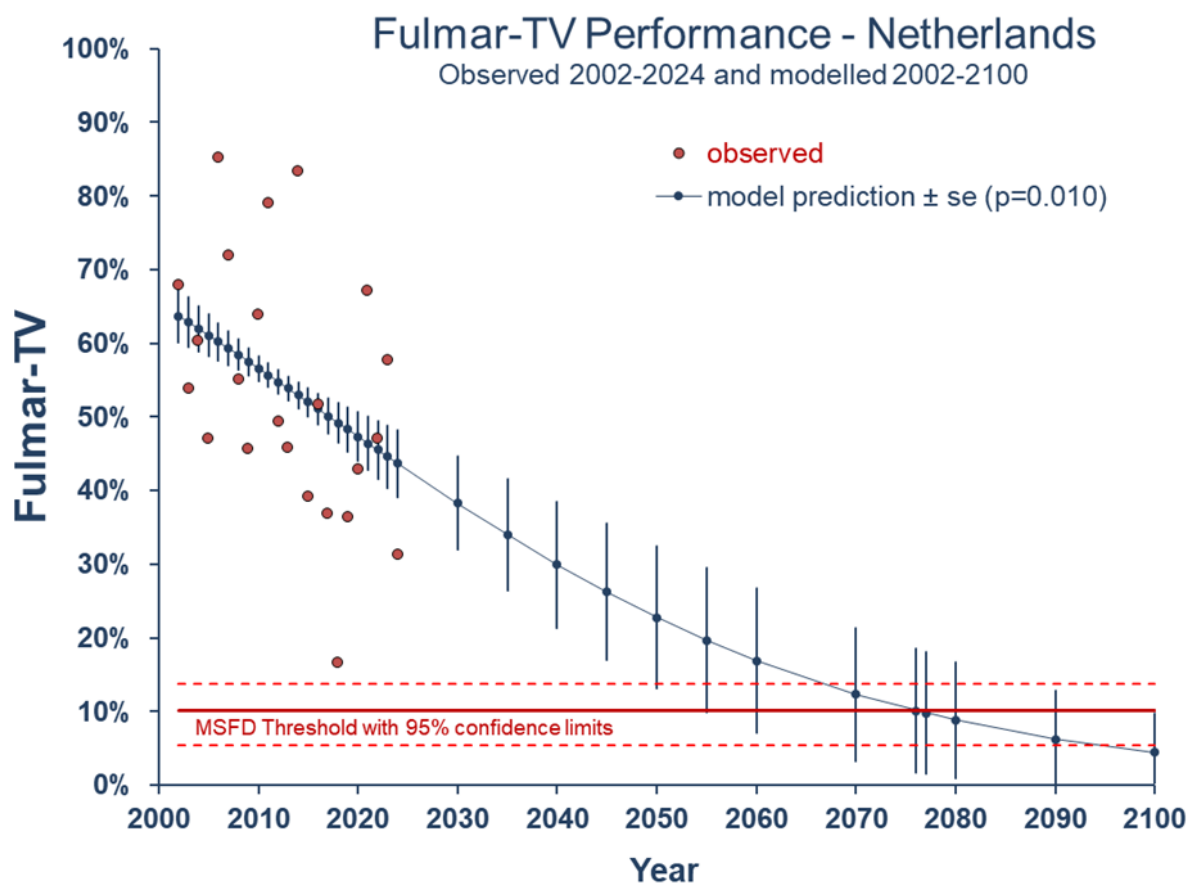


Figure 7. GLM model analysis of annual Fulmar-TV Performance using 23 years of fulmar data (2002-2024). Observed data are the red closed circles. Since the modelled trend is significant ($p=0.010$), the predicted annual values and standard errors (vertical lines) are shown by blue dots and a solid trendline.

5 Conclusions

After a few years with high plastic amounts, the year 2024 presents itself with low plastic numbers and mass in fulmar stomachs.

To avoid that occasional high or low sample sizes influence the overall data too much, it has been decided to combine data over several years and to look at different time periods to better understand trends. The benefit of this approach becomes visible in the current dataset.

While the recent dataset (10 years; 2015-2024) does not show a significant trend, the strongest decline becomes visible when including the data from 1979. The longer the considered period, the less affected is the data by extreme years.

Policy makers involved in the OSPAR and MSFD process have asked to provide models that might predict plastic ingestion rates by fulmars in future years. Such information could assist in focused planning of actions aiming at reaching policy targets by specific dates.

The considered 2002-2024 time period, shows a significant decrease in terms of birds above the threshold of 0.1 gram plastic in their stomachs. This significance allowed the prediction of future plastic ingestion rate in fulmars. According to the newest data, the Fulmar-TV of less than 10% of the birds having more than 0.1 g of plastic in their stomachs could be reached in 2077, which indicates an improvement in comparison with recent estimates.

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. Consequently the predicted future change will require further new policy measures and further changes in awareness and behaviour. Without extra effort, it is unlikely that the FTV target could be reached in the predicted time period.

CONCLUSION

On the longer term, stomach contents of fulmars beached in the Netherlands indicate that the marine litter situation off the Dutch coast has gradually improved, but without statistical significant further improvement in recent years. At its current level, plastic ingestion is still far off the Fulmar Threshold Value. At the current rate of the trend over the 2002-2024 period, the Fulmar-TV might be reached around the year 2077. Within 10-year evaluation periods the linear regression trend of individually ingested plastic mass is not consistent and showed no significant change over the most recent decade (2015-2024). It is clear that the further reduction of marine litter is required to reach the Fulmar Threshold Value.

6 Acknowledgements

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7 Main acronyms – abbreviations

OSPAR = Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic

OSPAR is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources of marine pollution and the offshore industry by the Paris Convention of 1974. These two conventions were unified, updated and extended as 1992 OSPAR Convention.

OSPAR EcoQO = Ecological Quality Objective

At the request of ministers of North Sea states in 2002, OSPAR developed a system of measurable targets for environmental/ecological quality in the North Sea and the OSPAR area in general. There is a broad range of EcoQO's for various types of pollution (oil, fouling paints, mercury, organochlorines, litter), eutrophication, biodiversity, bycatch, fish stocks, seabird populations etc. Ingestion of plastic particles by northern fulmars is one of these.

OSPAR ICG-ML = Intersessional Correspondence Group on Marine Litter, advises higher levels in OSPAR on issues related to marine litter

EcoQ% or EcoQ Performance = the percentage of fulmars in a sample that exceed the level of 0.1 gram of plastic in the stomach. The long-term OSPAR target is that this percentage should be reduced to under 10%.

The EcoQO has now been replaced by the 'Fulmar-TV' (see below for definition).

EU MSFD = European Marine Strategy Framework Directive

The aim of the European Union's MSFD is to protect more effectively the marine environment across Europe. It was adopted on 17 June 2008. In 2010 the Commission also produced a set of detailed criteria and methodological standards to help Member States implement the Marine Strategy Framework Directive. These were revised in 2017 leading to the new Commission Decision on Good Environmental Status.

EU-MSFD GES = Good Environmental Status

GES represents the MSFD concept in which a broad combination of indicators with objectives (similar to EcoQO's) indicates a healthy state of the marine environment.

MSFD-TGML = MSFD Technical Group on Marine Litter advises higher levels in EU on issues related to marine litter

FTV Performance (FTV%) = Fulmar Threshold Value Performance

MSFD requires a data-derived threshold value (Fulmar-TV) representing 'Good Environmental Status'. Such Fulmar-TV was calculated from near-pristine Canadian Arctic data where 10.06% of fulmars exceeded the level of 0.1 g ingested plastic. This Fulmar-TV is almost identical to the earlier OSPAR EcoQO, arbitrarily set at 10%.

ICES = International Council for the Exploration of the Sea

ICES is a leading multidisciplinary scientific forum for the exchange of information and ideas on all aspects of marine sciences pertaining to the North Atlantic, including the adjacent Baltic Sea and North Sea, and for the promotion and coordination of marine research by scientists within its member nations. It has many workgroups, for example **ICES WGSE (= Working Group on Seabird Ecology)**, which stood at the basis of several of the OSPAR EcoQO's.

KIMO = 'Kommunenes Internasjonale Miljøorganisasjon'

KIMO is a local authorities international environmental organisation in the northeast Atlantic, designed to give municipalities a political voice at regional, national and international level. KIMO joins forces for healthy seas, cleaner beaches, and thriving coastal communities. KIMO was an extremely important motivator for the SNS project.

MARPOL = International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78)

This is a global convention under the International Maritime Organization (IMO). The convention has several annexes focusing on specific ship environmental issues such as e.g. oil pollution (ANNEX I) or ships garbage (ANNEX V). Most MARPOL issues are dealt with in IMO's **Marine Environment Protection Committee (MEPC)**.

SNS = Save the North Sea

The SNS campaign ran from 2002 to 2004. It was a regional EU project which aimed at a reduction of marine litter in the North Sea through increases awareness. One of the SNS projects was to implement the fulmar plastic particle monitoring system in all countries around the North Sea. The SNS fulmar study group continued its work in an informal cooperation after the end of the formal SNS project. The SNS project was co-funded by the EU INTERREG program for cross-border cooperation, and was led by the Keep Sweden Tidy Foundation.

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9 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 C033/25

Project Number: 4315100164

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
Senior Researcher

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Date: 19 August 2025

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