Fulmar Litter Monitoring in the Netherlands – Update 2021

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Photo cover: Dead northern fulmar collected on Texel in March 2021. Photo: Job ten Horn

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Summary

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Marine debris has serious economic and ecological consequences. Economic impacts are most severe for coastal communities, tourism, shipping and fisheries. Marine wildlife suffers from entanglement and ingestion of debris, with 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 (EcoQOs) (North Sea Ministerial Conference 2002). At that time, in the Netherlands, marine litter was already monitored by the abundance of plastic debris in stomachs of a seabird species, the Northern Fulmar *(Fulmarus glacialis)*. In 2020 the fulmar EcoQO was formally replaced and is now called Fulmar Threshold Value (Fulmar-TV or FTV; for more details see Van Franeker et al. 2021 and Kühn et al. 2021a).

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. Initial 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 0.3 mm) to pass into the intestines (Bravo Rebolledo 2012). 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 2021 update of monitoring data for the Netherlands

This report adds new data for year 2021 to the previous report (Kühn et al. 2021a). A total of 81 fulmar corpses were collected, of which 71 were suitable for monitoring. Annual numbers of beached birds may vary considerably for unknown reasons. For our monitoring purposes, we do not use birds that have spent more than three days alive under human care, 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 2021, we did receive seven fulmars from rehabilitation centres, of which four had survived more than three days in care, so only the three other individuals were used. Unlike what occasionally happens, we have received no fulmars from earlier years this time, so older data have not changed. The desired annual sample size is ±40 birds or more (Van Franeker & Meijboom 2002). In 2021 the number was much larger with 71 suitable birds.

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 (2017-2021), in a sample of 179 birds, 50% of the fulmars contained more than 0.1 g plastic (FTV%). This is a substantial increase compared to earlier 5-year periods and substantially exceeds the Fulmar-Threshold Value. Over the past five years, 94% of fulmars contained some plastic, with an average over all birds of 26.5 plastic particles per stomach, weighing 0.25 gram.

Looking at annual samples, the large 2021 sample confirms the results from the small sample in 2020 that the percentage of fulmars with more than 0.1 gram in their stomach has increased.

This report includes data on chemical stomach contents, specifically paraffin-like substances. In 2021, 27% of the analysed fulmars contained some paraffin-like substances. For the 2017-2021 period, the average mass was 1.8 gram per bird due to a few stomachs with exceptional high loads of paraffine-like materials.

Table i. ***Data summary for study year added to the existing monitoring series****. The table presents actual year or period of sampling with sample size in brackets, 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**
2021	*(71)*	**72%**	94%	36.7	0.33
period					
2017_21	*(179)*	**50%**	94%	26.5	0.25

Photo 1. A representative fulmar stomach content for the year 2021.

On average, fulmars from the Dutch coast in 2021 contain about 37 plastic particles weighing 0.33 g (Table i). The stomach content on the photo (NET-2021-048) is then a fairly representative example. This stomach contained 36 plastic particles weighing together 0.37 gram, slightly higher than the average for 2021. This bird was an emaciated (starved) juvenile female, collected on Ameland by Johan Krol. The stomach shows the great variety of different plastic categories: one irregularly shaped industrial pellet (left), nine sheets, three foams (centre top), one thread (centre bottom), 20 fragments and two 'other plastics' (rubber-like; right).

Trend and prediction

In order to provide policy makers with simple straightforward information, this summary report focuses on the new predictive model to estimate when in future the Fulmar-TV may be reached if the current trend persists (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 to binomial data (bird yes or no above threshold) resulting in a trend within the observed data, which if statistically significant can be extrapolated to the future. OSPAR guidelines request trend analyses of ingested plastic mass to be conducted over a recent 10-year period, but that applies to a large number of individual bird data over those years. The new logistic GLM calculation has only one data-point per year, and longer time series are required. In relation to international comparisons we focus on the period starting 2002, the year when international fulmar monitoring was started in the EU Interreg IIB project 'Save the North Sea' (Save the North Sea, 2004).
GLM analysis over the 20-year period 2002-2021 for the Netherlands indicated a significant improvement in Fulmar-TV Performance (FTV% decreased significantly at $p<0.029$ *Fig. i*). The model used evaluates the proportion of birds exceeding 0.1 g of plastic in relation to year, with the age composition in the sample (proportion adult) as covariant. When the calculated trend is projected into the future, results suggest that the OSPAR/EU long-term target may be reached in year 2066. This predicted year is later than in the previous report (2049), a consequence of the higher percentage of birds in 2021 with more than 0.1 g plastic in their stomach (FTV=72%).

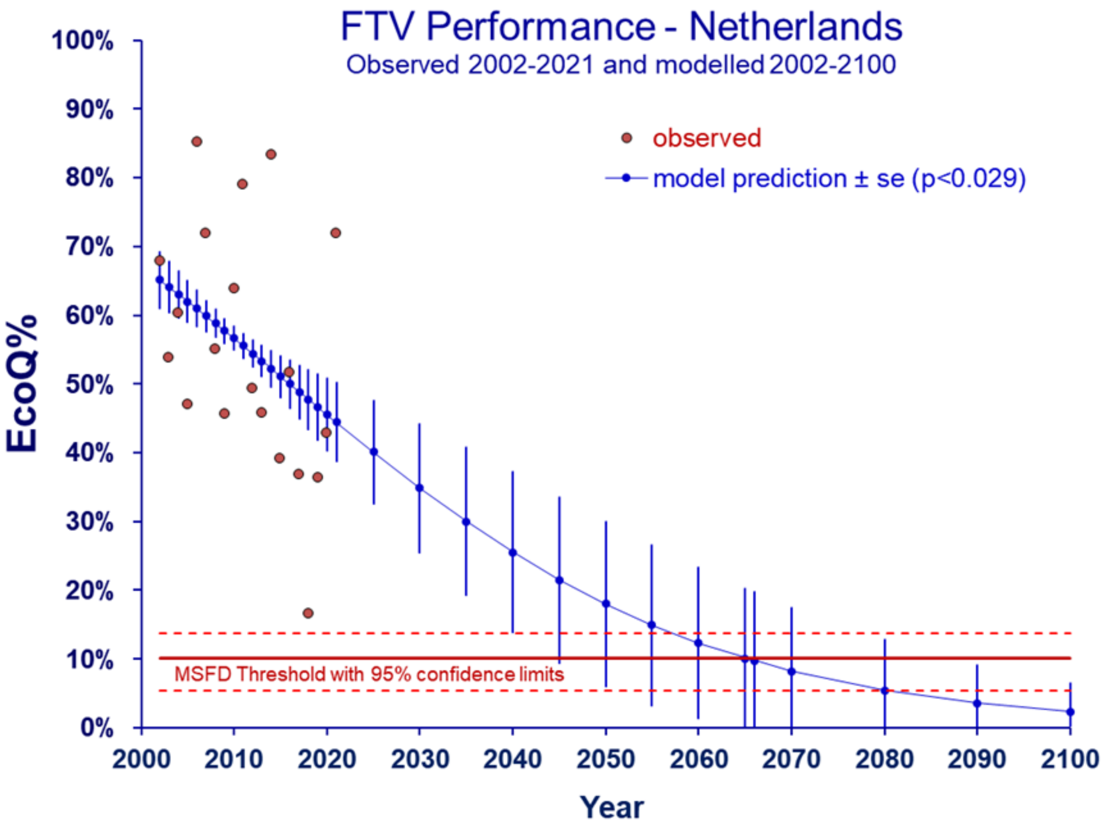


Figure i. GLM model analyses of annual Fulmar-TV Performance using 20 years of fulmar data (2002-2021).

Observed data are the red circles in the graphs. When the model is significant, the predicted annual values and standard errors (vertical lines) are shown by blue closed circles and solid lines, connected by a trendline. When the model from observed data is not significant, predicted values and standard error lines are dashed, and no trendline is shown.

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, to take and maintain new policy measures and if we *continue* to create further changes in awareness and behaviour. No extra effort means that the trendline will level off 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.
Existing OSPAR guidelines (2015a,b) prescribe the tests for trends over time as analyses over the most recent 10 years, 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 2012-2021, 350 birds were available. The trend was, in contrast to earlier time periods not significant (p=0.347). Over the 2002-2021 period as used in the GLM procedure, the test is not significant (861 birds: p=0.136).

A non-statistical way to illustrate and double-check the trends in plastic ingestion over time is by comparison of 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. ii* 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 red data-points for observed data in *Fig. i*), and certainly so when sample size is reduced by splitting into subgroups. Data for the 1980s have been grouped into a single data-point. 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. Data from running 5-year averages cannot be used for statistical trend analysis as those figures entail repeated use of the same individuals.

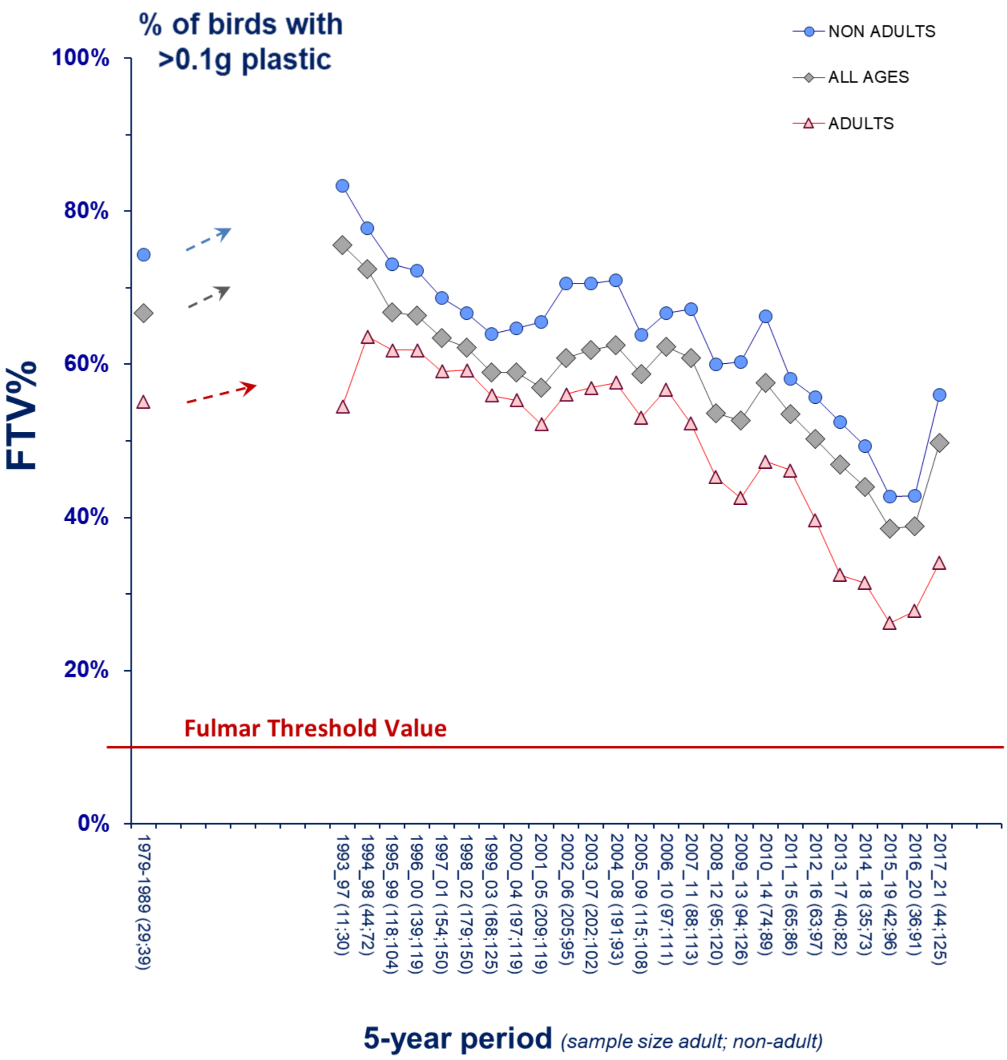


Figure ii. Visualisation of Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2021.

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 1980s 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 decades, usually close to or statistically significant for both plastic types and their combination (Table 4D). 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. While the previous 2011-2020 period already showed a less prominent significant reduction in combined plastic mass, the most recent period 2012-2021 is not significant anymore and even shows an increasing plastic mass in fulmars. The reason for this increase is unclear. A higher percentage of younger birds may have contributed but as seen in Figure ii, also the adult birds contained more plastics than in previous time periods.

MAIN POINTS

1. North Sea governments and 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 2017-2021, among 179 fulmars beached in the Netherlands, the FTV% was 50%. In this period, 94% of fulmars had ingested some plastic, with an average over all birds of 26.5 particles per stomach, weighing 0.25 gram.

3. The year 2021 proved to be an unusual one, with a high FTV% and high average plastic mass. The reason for this increase is unclear. The linear regression trend over the recent 10 years 2012-2021 showed no recent change.

4. Logistic trend analyses of annual FTV% over the longer period 2002-2021 do still indicate a significant overall decrease since 2002 and suggest that the Fulmar Threshold-Value may be reached in the year 2066. This is 17 years later than the previous prediction (2002-2020; to be reached in 2049) and reflects the poor results for the recent years 2020 and 2021.

5. The model prediction of expected FTV compliance in 2066 is not based on a status-quo, but on the current rate of change, which is assumed to reflect intensified 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 could 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 increase in annual figures in 2020 and 2021 and lack of significant change in recent 10-year periods, however, cannot be explained at the moment.

7. Over the 5-year period 2017-2021, 24% of the birds had ingested paraffin-like substances, with an average mass of 1.8 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 is gradually improving, but still far off the Fulmar Threshold Value. At the current rate of the trend, the Fulmar-TV might be reached around the year 2066. Within 10-year evaluation periods the trend is not consistent, and showed no significant change over the most recent 2012-2021 decade. Future data must reveal if this reflects a temporary deviation, or a reversal in the longer term trend.

1 Introduction

Marine litter, in particular plastic waste, represents an environmental problem in the North Sea and elsewhere, with considerable economic and ecological consequences. In 2005, a large study along the full 30 km coast length of the island of Texel revealed that each day, on each km of beach, 7 to 8 kg of debris washed ashore (Van Franeker 2005). Roughly half of the debris was wood, the other half was synthetic materials, with minor contributions from other materials such as glass and metals. On Texel, the main source of the debris, estimated at up to 90% of mass, was related to activities at sea, i.e. shipping, fisheries, aquaculture and offshore industries.

The **economic consequences** of marine litter affect many stakeholders. Coastal municipalities are confronted with excessive costs for beach clean-ups. Tourism suffers damage because visitors avoid polluted beaches especially when health-risks are involved. Fisheries are confronted with a substantial 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 (Laist 1987, 1997; Kühn et al. 2015; Kühn & Van Franeker 2020). It can cause direct mortality but the major impact most likely occurs through reduced fitness of many individuals.

Sub-lethal effects on animal populations remain largely invisible. Despite spectacular examples of mortality caused by entanglement in, or ingestion of marine litter, the real impact on marine wildlife therefore remains difficult to estimate (Browne et al. 2015; Rochman et al. 2016; Werner et al. 2016). Plastics gradually break down to microscopically small particles, but these may pose an even more serious problem (Thompson et al. 2004). 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. (2020a) and very recently by Sühring 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. 2013a,b, 2014, 2016; Moore 2008; Teuten et al. 2007, 2009; Rochman et al. 2013, 2014a,b; Tanaka et al. 2013; Thompson et al. 2009; Cole et al. 2015; CBD 2016; Beaman & Bergeron 2016; Peda et al. 2016; Hermabessiere et al. 2017; Ribeiro et al. 2017). 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 might penetrate into tissues and cells with potential chemical and mechanical damage to e.g. DNA but are extremely difficult to quantify in non-experimental situations (Koelmans et al. 2015; Booth et al. 2016; Gigault et al. 2016; Liu 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; EC 2010; EC 2017) and most recently, the EU ban of single use plastics (EU Directive 2019/904; EU 2019).

Policy initiatives have recognized the need to use quantifiable and measurable aims. Therefore, the North Sea Ministers in the 2002 Bergen Declaration decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQOs) (North Sea Ministerial Conference 2002). For example, the oil pollution situation in the North Sea is measured by the rate of oil-fouling among beached Guillemots (*Uria aalge*) with an EcoQO of less than 10% of beached Guillemots having oil on the plumage (OSPAR 2005). Similarly, as proposed by ICES Working Group on Seabird Ecology (ICES-WGSE 2003), OSPAR decided to use the abundance of plastic in stomachs of seabirds, *in casu* the Northern Fulmar (*Fulmarus glacialis*) to measure quality objectives for marine litter (OSPAR 2008, 2009, 2010a, 2010b, 2015a,b). The fulmar EcoQO monitoring has been included as an indicator for marine litter in the approach for Good Environmental Status (GES) in the European Marine Strategy Framework Directive (EC 2010; MSFD GES Technical Subgroup on Marine Litter 2011).

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. The SNS fulmar study was published by Van Franeker et al. (2005). Findings strongly supported the important role of shipping (incl. fisheries) in the marine litter issue. For further publications of the SNS fulmar study see e.g. Save the North Sea (2004), Van Franeker (2004), Edwards (2005), Guse et al. (2005, 2020), Olsen (2005) and Kühn et al. (in prep.). After completion of the European SNS project, the international work was continued through CSR awards from the NYK Group Europe Ltd and support from Chevron Upstream Europe. These funds contributed to further North Sea EcoQO wide updates in reports (Van Franeker & the SNS Fulmar Study Group 2013), including peer-reviewed scientific publications on the EcoQO methods with data up to 2007 (Van Franeker et al. 2011) and 2012 (Van Franeker & Law 2015). These awards were used also to promote fulmar work in other areas of the world such as Ireland (Acampora et al. 2016), the Faroe Islands (Van Franeker 2012), Iceland (Kühn & Van Franeker 2012; Snaethorsson & Brynjólfsson 2021), Svalbard (Trevail et al. 2015), Atlantic Canada (Bond et al. 2014), 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 et al. 2014; Terepocki et al. 2017) and has been promoted as monitoring species in the Arctic Ocean (AMAP 2021).
The same method has been applied to explore the potential use of other marine species for ingestion monitoring as intended in the European MSFD (Bravo Rebolledo et al. 2013; Foekema et al. 2013; Matiddi et al. 2017; van Franeker et al. 2018; Kühn et al. 2020b). The most recent international overview of the monitoring of plastics in stomach contents of fulmars in the North Sea area includes data up to 2016 (Second Intermediate Assessment, OSPAR 2019). A third intermediate assessment using data up to 2018 has been prepared and will be published by OSPAR at some point. 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) 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). Currently there is no structural funding dedicated to international coordination and integrated data analysis and reporting.

The current assignment from 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 2021.
- Continued co-ordination of the beached fulmar sampling in the Netherlands in 2022.
- 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 the Dutch Ministry of Infrastructure and Water Management 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 their own scientific information need, using the fulmar monitoring data.

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 (Van Franeker et al. 2011; Van Franeker & Law 2015, Van Franeker et al. 2021).

Since the early days of plastic pollution of our oceans, the Northern Fulmar has been known as a species that readily ingests marine plastic debris (Bourne 1976; Baltz & Morejohn 1976; Day et al. 1985; Furness 1985; Van Franeker 1985; Moser & Lee 1992; Robards et al. 1995; Blight & Burger 1997). 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. Samples of fulmars available for a feasibility study of monitoring in the Netherlands mainly originated from the periods 1982 to 1987 and 1996 to 2000, with smaller numbers of birds from the years in between.

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

- Fulmars are abundant in the North Sea area (and elsewhere) and are regularly found in beached bird surveys, which guarantee supply of an adequate number of bird corpses for research.
- Fulmars are known to consume a wide variety of marine litter items.
- Fulmars avoid inshore areas and forage exclusively at sea (never on land).
- Fulmars do not normally regurgitate indigestible items, but accumulate these in the stomach (digestive processes and mechanical grinding gradually wear down particles to sizes that are passed on to the gut and are excreted).
- Thus, stomach contents of fulmars are representative for the wider offshore environment, averaging pollution levels over a foraging space and time span that avoids bias from local pollution incidents.
- Historical data are available in the form of a Dutch data series since 1982 (one earlier 1979 specimen); and literature is available on other locations and related species worldwide (Van Franeker 1985; Van Franeker & Bell 1988; 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 Kittiwake *Rissa tridactyla*).

Beached birds may have died for a variety of reasons. For some birds, plastic accumulation in the stomach is evidently the direct cause of death, e.g. by plastic sheets blocking food passage. 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 2021), collisions with ships or other structures, drowning in nets, extremely poor weather or food-shortage may have been direct or indirect causes of mortality.

At dissection of birds, their sex, age, origin, condition, likely cause of death and a range of other potentially relevant parameters are determined. Standardized dissection procedures for EcoQO monitoring have been described in detail in a manual (Van Franeker 2004), subsequent peer-reviewed publications (Van Franeker et al. 2011; Van Franeker & Law 2015) and OSPAR Guidelines (OSPAR 2015a,b).
Stomach contents are sorted into main categories of plastics (industrial and user plastics), non-plastic rubbish, pollutants, natural food remains and natural non-food remains. Each of these categories has a number of subcategories of specific items. For each individual bird and litter category, data are recorded on presence or absence ("incidence"), the number of items, and the

mass of subcategory (see methods). For efficiency/economy reasons, some of the details described in the manual and earlier reports were discontinued in the current research projects.

The pilot study 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 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 loose 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 has funded a cooperative project with the Faroese Fisheries Laboratory. Using fulmars from the Faroe Islands, we investigate seasonal and age related variations in stomach contents. On the Faroe Islands, fulmars are hunted for consumption and large numbers of samples are easily obtained. Additional samples have been obtained from fisheries by-catch in the area. Stomach contents are analysed for both normal diet (Faroese component in the study; Danielsen et al. 2010) and for accumulated litter (Dutch contribution to the study). General results were published in Van Franeker (2012), but detailed analyses of samples obtained from all months of the year during several years continue to be analysed.

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

Significant long-term trends from 1982 to 2000 were detected in incidence (Frequency of Occurrence %FO), number of items and mass of industrial plastics, user plastics and suspected chemical pollutants (often paraffin-like substances). Over the 1982-2000 period, only industrial plastics decreased while user plastics significantly increased. When comparing averages in the 1980s to those in the 1990s, industrial plastics approximately halved from 6.8 granules per bird (77% incidence; 0.15 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 (Van Franeker & Kühn 2019), the analyses indicate a continuing trend of slow but significant decrease.

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 (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. Because no funding was obtained to work on suspected chemicals so far, this element had been dropped and plastics have become the main focus. Since 2021, additional funding was available to present general data on chemical waste in fulmar stomachs. 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 (EcoQOs) for the North Sea*'. One of the EcoQOs to be developed was for the issue of marine litter pollution, using stomach contents of a seabird, the fulmar, to monitor developments, and to set a target for '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. A similar effect can be obtained by calculating mean values from logarithmically transformed data (Geometric means). The OSPAR Fulmar EcoQO has been published in a background document (OSPAR 2008) and its implementation was included in the OSPAR Quality Status Report (OSPAR 2010a,b). Formal guidelines and assessment methods have been published (OSPAR 2015a,b). OSPAR (2017, 2019) published two intermediate assessments of data up to 2016 for all five North Sea areas, indicating continued although less pronounced latitudinal differences as compared to Van Franeker et al. (2005, 2011), and a significant downward trend for the combined data. A third 'Intermediate Assessment' analysis data up to 2018 is awaiting publication.

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 wrecks (e.g. fulmars). 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, but hard to define in detail. In general, most fulmars in our study originate from the more northern part of the Netherlands, with next in line fulmars from the Zeeland area. The lower number of beached fulmars from the more central parts of the Dutch coast may be due to lower observer effort, but also to more rapid disappearance of corpses due to higher numbers of scavenging foxes or cleaning activities on the touristic beaches.

With the ***Save the North Sea (SNS)*** project in 2002, IMARES, now 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 in a recent publication by Van Franeker et al. (2021).

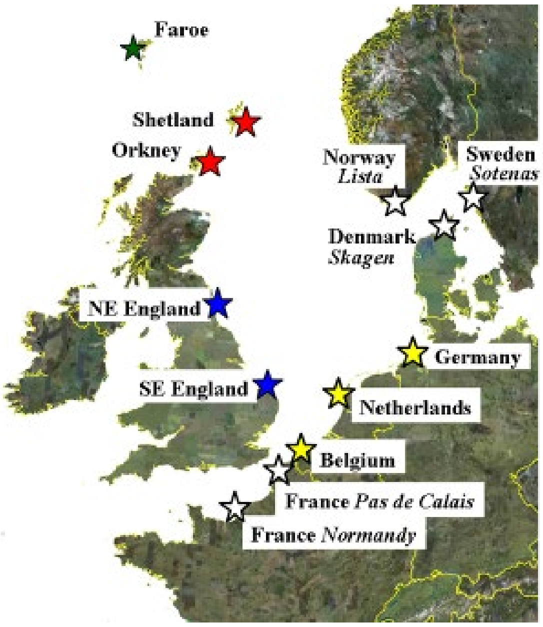


Figure 1. Fulmar-Litter study areas in the Save the North Sea Project (SNS). *Colour of symbols indicates original regional grouping into Scottish Islands (red), East England (blue), Channel area (white), South-eastern North Sea (yellow), and Skagerrak area (white). Not all locations are equally active. 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).*

Bird corpses are stored frozen until analysis. Standardized dissection methods for fulmar corpses have been published in a dedicated manual (Van Franeker 2004) and are internationally calibrated during regular workshops. Stomach content analyses and methods for data processing and presentation of results were described in full detail in Van Franeker & Meijboom (2002), further developed in consultation with ICES and OSPAR by updates in later reports and OSPAR documents (OSPAR 2008, 2010b). Scientific reliability of the methodology was established by its publication in the peer-reviewed scientific literature (van Franeker et al. 2011, 2021; Van Franeker & Law 2015) with condensed guidelines for future assessments published by OSPAR (OSPAR 2015a,b).

For convenience, some of the methodological information is repeated here in a condensed form.

Dissection
At dissections, a full series of data is recorded that is of use to determine sex, age, breeding status, likely cause of death, origin, condition index and other issues. Age, the only variable found to influence litter quantities in stomach contents (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). In the future, an updated version of the manual should be published to improve details and maximize efficiency and standardisation of methods.

Stomach content analysis procedure
Stomachs of fulmars have two 'units': initially food is stored and starts to digest in a large glandular stomach (the *proventriculus*) after which it passes into a small muscular stomach (the *gizzard*) where harder prey remains can be processed through mechanical grinding. In early phases of the project, data for the two individual stomachs were recorded separately, but for the purpose of reduction in monitoring costs, the contents of proventriculus and gizzard are now combined.
Stomach contents are carefully rinsed in a sieve with a 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. Although this was a standard component at the start of our studies, requirements for the Dutch “graadmeter” and international Fulmar TV have a focus on plastic or at best MARPOL Annex V litter types. Thus, for financial efficiency, potential chemical pollutants in the stomachs were no part of the monitoring project until 2021, but basic data are now included. 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. In 2018, an internally funded project was conducted by Wageningen Marine Research looking at paraffin- or palmoil-like substances collected from beaches and fulmar stomachs in the period 1979-2017. In over 20% of fulmar stomachs, such substances are found without obvious trend over time. Chemical analyses identified both vegetable oils and paraffins in the stomachs. Paraffins dominated the beach samples (Van Franeker et al. 2019).

Categorization of debris in stomach contents
The following categorization is ideally used for plastics and other rubbish found in the stomachs, with acronyms between parentheses. However, please note that for financial efficiency in OSPAR EcoQO/FTV monitoring, the required dataset has been restricted to just 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 (mostly from mineral oil). The raw industrial plastics are then usually transported to manufacturers that melt the granules and mix them with a variety of additives (fillers, stabilizers, colorants, anti-oxidants, softeners, biocides, etc.) that depend on the user product to be made. For the time being, included in this category are a relatively small number of very small, usually transparent spherical granules, also considered to be a raw industrial product.

1.2. **User plastics (USE)** all non-industrial remains of plastic objects may be 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 matrasses or construction foams;
   - 1.2.4. **fragments (frag)** of more or less hard plastic items as used in a huge number of applications (bottles, boxes, toys, tools, equipment housing, toothbrushes, lighters etc.);
   - 1.2.5. **other (poth)**, for example cigarette filters, rubber, elastics etc., so items that are 'plastic-like' or do not fit into a clear category.

2. RUBBISH (RUB) other than plastic:

2.1. **paper (pap)** which besides normal paper includes silver paper, aluminium foil etc., so various types of non-plastic packaging material;

2.2. **kitchenfood (kit)** for human food wastes such as fried meat, chips, vegetables, onions etc., probably mostly originating from ships' galley refuse;

2.3. **various rubbish (rubvar)** is used for e.g. pieces of timber (manufactured wood); paint chips, pieces of metals etc.;

2.4. **fish hook (hook)** from either sport-fishing or long-lining.

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.

Acronyms

In addition to the acronyms used for (sub)categories as above, further acronyms may be used to describe datasets. Logarithmic transformed data are initiated by 'ln' (natural logarithm); mass data are characterized by capital G (gram) and numerical data by N (number). For example, lnGIND refers to the dataset that uses ln-transformed data for the mass of industrial plastics in the stomachs; acronym NUSE refers to a dataset based on the number of items of user plastics.

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

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

Photo 2. Easy polymer identification in fulmar stomach contents. *Sometimes the plastic particles found in fulmar stomachs reveal their polymer composition without further analysis. In this case, a second-year female fulmar, found by Jan van Franeker and Yvonne Hermes on Texel in 2021, contained a plastic fragment labelled as 'PP' – polypropylene. Usually a more complex procedure is necessary to identify the polymer type. In 2021, Kühn et al. (2021b) published a paper where plastic items, ingested by fulmar from the Netherlands, the Faroe Islands and Svalbard were compared: most items were made of polyethylene and polypropylene, reflecting the globally most commonly produced plastic types.*

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. An alternative to reduce influence of outliers is by logarithmic transformation of data. In Fig. 2A, the median value has been indicated: the median is the value of the mid sample of all samples. Medians can be confusing in skewed distributions as are common in our type of data.

Geometric Mean

Sample sizes may not be large enough to average out the impact of occasional extreme outliers. Therefore, data are often additionally presented as geometric means. Geometric mean is calculated as the average of logarithmically transformed data values, which is then back calculated to the normal arithmetic equivalent. Logarithmic transformation reduces the role of the higher values, but 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. 0.001g in mass data) to all data-points, and then subtracting this again when the mean of log values is back-calculated to normal value. This however implies that geometric means become less reliable with an increasing number of zero values in a dataset. The natural logarithm (ln) is used to run calculations for geometric means. Starting with the 2016 update, medians are included in some of the more detailed data sections of the report, as a different additional view on the strongly skewed data distributions that have to be handled.

Fulmar Threshold Value Performance (FTV%)

For early Dutch reports, the analyses focused on trends in average or mean mass data for different categories.
Recently, the former EcoQO has been replaced by OSPAR and MSFD (OSPAR 2020, EC 2022), now using the Fulmar Threshold Value (Fulmar-TV or FTV). The definition however remained unchanged to the previous OSPAR EcoQO target. The new Fulmar Threshold Value definition states:

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

The similar definition 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.
With the latest report (Kühn et al. 2021a), it has been agreed with RWS, that the new terminology is now consistently used within the reports. Thus, the information requested for OSPAR and the Fulmar-TV focuses on the category of 'total plastic' and pooled data for 5-year periods over larger areas, and a simple decision rule for each stomach if the plastics in it weigh more than 0.1 gram or less, including zero.
Fulmar TV compliance or performance is defined as the percentage of birds in a sample that has 0.1 g or more plastic mass in the stomach (FTV%). The OSPAR (and later EU MSFD) target is thus to reduce the FTV% to under 10%. The former EcoQO and now FTV format are 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, not the figures for the recent single year! Time related changes are illustrated in graphs by running 5-year averages, each time shifting one year and thus overlapping for four years. Such graphs are useful to visualize patterns, which in annual data would be obscured by annual variability and smaller sizes. However, they do not represent statistical evidence. 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 19^{th} Edition was used for statistical tests. As concluded in the pilot study (Van Franeker & Meijboom 2002) and later reports, statistical trend analysis is conducted using mass-data. Tests for trends over time are based on linear regressions fitting ln-transformed plastic mass values for individual birds on the year of collection. Logarithmic transformation is needed because the original data are strongly skewed and need to be normalized for the statistical procedures. The natural logarithm (Ln) is used. Tests for '**long-term' trends** use the full dataset; **'recent' trends** only use the past 10 years of data. This 10-year period was derived from the pilot study (Van Franeker & Meijboom 2002) which found that in the Dutch situation a series of about eight years was needed to have the potential to detect significant change. To be on the safe side in our approach, this period was arbitrarily increased to a standard period of 10 years for tests of current time related trends.

Starting with the 2017 update report, a new additional approach was developed to directly evaluate the progress towards the OSPAR long-term target in which the EcoQ% should be reduced to under 10%. The new approach now uses annual figures of the Fulmar-TV Performance (the former EcoQ Performance). Simplified data as percentages above or below a threshold do have the problem that the dataset is reduced to periodic (annual) average performance. In our approach of evaluating trends over a period of the most recent 10 years, the statistical procedure then has only ten data-points available for statistical tests and modelling. Simple linear regression cannot be applied to this type of data. The 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) for this update (data year 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 2021 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.

4 Results and Discussion

This chapter follows the original format of our earlier reports, which uses the approach recommended in 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 earlier reports, in a final section, these data were also viewed, but not statistically tested in terms of EcoQ Performance, which is the proportion of birds having more than 0.1 g of plastic in the stomach. As the FTV% (former EcoQ%) is the most relevant for policy makers, starting with the 2017 update (Van Franeker & Kühn 2018), a statistical analysis of annual FTV%'s is included, which, if significant, can be used to predict future developments. The original detailed analyses remain essential to properly understand the Fulmar-TV Performance model as a basis for policy decisions. The abstract of the current report now strongly focuses on the most policy relevant FTV Performance; underlying details and analyses are largely restricted to within this 'Results and Discussion' chapter.

4.1 The year 2021

In 2021, the loyal surveyor network managed to collect 81 fulmar corpses, of which 71 were suitable for analysis of the stomach contents. Six birds did not have a(n intact) stomach and therefore had to be excluded from further analysis. Several birds had been treated in a rehabilitation centre, but four birds exceeded the maximum care time of 3 days. For our monitoring purposes, we do not use birds that have been alive in rehabilitation for more than 3 days, because during treatment plastic particles break and wear down in the muscular stomach of the bird (Van Franeker & Law 2015). Therefore a total of 71 fulmars were available for the year 2021. In 2021, no additional 'late-delivered' stomachs of fulmars were analysed. Late additions can cause minor changes to earlier reports. The desired annual sample size in our monitoring program is ±40 birds or more (Van Franeker & Meijboom 2002).

The 2021 sample (Table 1A; Table 2) doubles the desired annual sample size, which compensates lower samples sizes in some previous years. Compared to 2020, the results for 2021 (Table 2A) show a higher average mass of plastic in the stomachs (0.33±0.06 g) and an exceptionally high proportion of fulmars that exceeded 0.1 g plastic in the stomach (FTV% 72%). Out of 71 birds, 67 birds did have plastic in the stomach (94%), and the average fulmar had 36 plastic particles. Out of 71 birds, 27% (19 birds) contained paraffin-like material in their stomachs. In 2020, 21% of 15 birds contained paraffin-like substances, but annual data seems to be more variable in these substances than in plastics (Van Franeker et al. 2019).

Info Box

Beached Fulmars in 2021 – an unusual year

From the data above it appears that 2021 has been an unusual year in many regards. The number of dead birds was high and has not been as high since 2012, when 81 suitable fulmars were found.

The reason for the high number of fatalities is unclear and cannot be studied in further detail. In Germany the collection of fulmars was restricted due to avian flu mitigation rules in 2021. Therefore it is unclear if Germany, experienced similar high numbers of dead fulmars. In other neighbouring countries, no unusual number of collected birds has been reported. Also the timing of stranding was unusual. Normally the majority of birds beaches in the winter months. In 2021 however, most birds (45 individuals) were collected in April and another 14 were found in May 2021. It is not clear if the high number of mortalities and their seasonal timing was related to the relatively high level of plastics. Such uncertainty in annual samples emphasizes the importance of evaluating monitoring results over 5-year periods.

Photo 3. A dead fulmar found on 8 May 2021 on the beach of Texel.

4.2 Current levels for the Netherlands (2017-2021)

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 (2017-2021) (Table 1B, Table 3), in a sample of 179 birds, 50% of stomachs contained more than 0.1 g plastic (FTV%). This number is considerably higher than in the previous running 5-year average (2016-2020; 39%) and therefore achievement of the OSPAR/MSFD long-term target seems further away than in previous 5-year periods.

In the 2017-2021 sample, 94% of fulmars contained some plastic which is a similarly high value as in the previous period (2016-2020) when the frequency of occurrence was 93%. The average number of particles was 26.5 plastic particles per stomach, weighing 0.25 gram. Industrial plastics were rare compared to consumer debris plastics.

In the period of 2017-2021, 24% of the birds had paraffin-like substances, on average 1.8 gram per bird. The mass is almost one gram heavier than in the previous 5-year period (2016-2020; 0.9 g), which may be influenced by a few individuals with particular high paraffin-like mass in 2021 and an extreme outlier of an individual with 70 gram 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 will likely influence also the 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 over the consequences of the ingestion of either paraffin or natural fatty substances on 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 (e.g. see photos 5 and 6), however evidence for the harmfulness is currently lacking.

Photo 4 A northern fulmar (NET-2021-016) collected by Cees van Hoven in Ouddorp. *The stomach was filled with ca. 50 gram of yellowish paraffin-like substance. In this exceptional case, the cause of death was assigned to the ingestion of this large amount of non-natural food.*

Photo 5. *A northern fulmar with paraffin-like substance in its beak.* *This fulmar was found dead on the beach of Texel. The substance filled the entire beak and throat. However, the animal was heavily scavenged and no stomach or other organs were present. Therefore this individual could not be used for the plastic monitoring scheme.*

Table 1. Summary of sample characteristics and stomach contents of fulmars collected for Dutch marine litter monitoring in A) the year 2021 and B) the current 5-year period 2017-2021. *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; Van Franeker 2004). 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 ± standard error; average mass of plastic ± standard error per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-transformed values as used in trend-analyses.*

Table 1A

	The Netherlands	nr of birds	% adult	% male	% LL colour	death oil	avg condition	
	2021	**71**	**19%**	**40%**	**89%**	**0%**	**1.7**	

		incidence	average number of items (n/bird)	± se	average mass of litter (g/bird)	± se	max. mass recorded	geometric mean mass (g/bird)
1	**ALL PLASTICS**	**94%**	**36.7**	**± 7.378**	**0.335**	**± 0.058**	**3.4**	**0.1406**
1.1	**INDUSTRIAL PLASTIC**	**65%**	**2.3**	**± 0.587**	**0.051**	**± 0.011**	**0.6**	**0.0106**
1.2	**USER PLASTIC**	**94%**	**34.4**	**± 7.006**	**0.284**	**± 0.053**	**3.1**	**0.1126**
1.2.1	sheets	72%	4.6	± 1.505	0.010	± 0.003	0.2	0.0027
1.2.2	threads	38%	1.2	± 0.303	0.006	± 0.002	0.1	0.0012
1.2.3	foamed	69%	5.6	± 0.927	0.019	± 0.006	0.3	0.0040
1.2.4	fragments	90%	21.7	± 4.590	0.204	± 0.041	2.2	0.0659
1.2.5	other plastic	38%	1.3	± 0.801	0.046	± 0.016	0.8	0.0028
2	**OTHER RUBBISH**	**24%**	**1.6**	**± 0.723**	**0.036**	**± 0.019**	**1.3**	**0.0013**
2.1	paper	3%	0.3	± 0.222	0.003	± 0.002	0.2	0.0001
2.2	kitchenwaste (food)	15%	1.3	± 0.688	0.030	± 0.019	1.3	0.0007
2.3	rubbish various	8%	0.1	± 0.047	0.004	± 0.003	0.2	0.0003
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
3	**POLLUTANTS**							
3.3	paraffin-like substances	27%	3.5	± 2.817	3.134	± 1.545	70.0	0.0022

Table 1B

	The Netherlands	nr of birds	% adult	% male	% LL colour	death oil	avg condition	
	2017_21	**179**	**26%**	**43%**	**91%**	**0%**	**1.9**	

		incidence	average number of items (n/bird)	± se	average mass of litter (g/bird)	± se	max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**94%**	**26.5**	**± 4.525**	**0.247**	**± 0.037**	**4.3**	**0.0761**
1.1	**INDUSTRIAL PLASTIC**	**51%**	**1.8**	**± 0.369**	**0.040**	**± 0.007**	**1.0**	**0.0058**
1.2	**USER PLASTIC**	**94%**	**24.7**	**± 4.261**	**0.207**	**± 0.032**	**3.3**	**0.0602**
1.2.1	sheets	58%	3.3	± 0.708	0.009	± 0.002	0.3	0.0020
1.2.2	threads	39%	1.2	± 0.209	0.008	± 0.003	0.4	0.0012
1.2.3	foamed	49%	3.9	± 0.622	0.015	± 0.004	0.4	0.0020
1.2.4	fragments	87%	15.6	± 3.319	0.126	± 0.019	2.2	0.0320
1.2.5	other plastic	26%	0.8	± 0.326	0.050	± 0.018	2.3	0.0016
2.0	**OTHER RUBBISH**	**21%**	**3.7**	**± 2.805**	**0.101**	**± 0.082**	**14.7**	**0.0009**
2.1	paper	3%	0.2	± 0.133	0.001	± 0.001	0.2	0.0001
2.2	kitchenwaste (food)	16%	3.4	± 2.804	0.096	± 0.082	14.7	0.0006
2.3	rubbish various	5%	0.1	± 0.026	0.004	± 0.003	0.4	0.0002
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
3.0	**POLLUTANTS**							
3.3	paraffin-like substances	24%	2.3	± 1.209	1.805	± 0.706	70.0	0.0022

Table 2. Annual details for plastic abundance in fulmars from the Netherlands in the period 1979-2021. *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±SE) gives the abundance by number of plastic particles per bird with standard error, and average mass (g±SE) the weight of plastic per bird in grams with standard error. Total plastics mass is also shown in terms of medians and geometric mean mass (for comparative purposes reducing the influence of outliers) and as level of performance in relation to the OSPAR/ EU MSFD Fulmar Threshold Value, viz. the percentage of birds having more than the threshold of 0.1 gram of plastic in the stomach (former EcoQO). 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*

Table 2A

Netherlands			Total plastics					
YEAR	*sample n*	*(% ad)*	% FO	average number n ± se	average mass g ± se	median mass	geometric mean mass	FTV% (over 0.1g)
1979	*1*	*(0%)*	100%	5.0	0.24			
1980	*0*							
1981	*0*							
1982	*3*	*(0%)*	100%	11.0 ± 4.0	0.61 ± 0.34			
1983	***19***	*(41%)*	**100%**	**16.0 ± 2.5**	**0.49 ± 0.13**	**0.302**	**0.284**	**89%**
1984	***20***	*(40%)*	**90%**	**17.9 ± 5.5**	**0.35 ± 0.13**	**0.160**	**0.073**	**55%**
1985	*3*	*(33%)*	100%	10.3 ± 1.5	0.28 ± 0.07			
1986	*4*	*(25%)*	75%	5.5 ± 1.8	0.08 ± 0.05			
1987	***17***	*(59%)*	**82%**	**13.6 ± 4.0**	**0.19 ± 0.08**	**0.112**	**0.056**	**59%**
1988	*1*	*(0%)*	100%	2.0	0.04			
1989	*2*	*(100%)*	100%	12.5 ± 9.5	0.43 ± 0.40			
1990	*0*							
1991	*1*	*(0%)*	100%	11.0	0.14			
1992	*0*							
1993	*0*							
1994	*0*							
1995	*2*	*(50%)*	100%	5.0 ± 1.0	0.06 ± 0.02			
1996	*8*	*(62%)*	100%	27.4 ± 13.7	0.26 ± 0.11			
1997	***31***	*(16%)*	**97%**	**35.8 ± 7.3**	**0.73 ± 0.17**	**0.325**	**0.298**	**84%**
1998	***75***	*(44%)*	**95%**	**28.6 ± 5.2**	**0.94 ± 0.35**	**0.186**	**0.156**	**71%**
1999	***107***	*(70%)*	**98%**	**35.3 ± 6.2**	**0.44 ± 0.11**	**0.138**	**0.123**	**61%**
2000	***38***	*(58%)*	**100%**	**22.0 ± 5.2**	**0.35 ± 0.13**	**0.160**	**0.129**	**61%**
2001	***55***	*(37%)*	**96%**	**22.7 ± 4.2**	**0.24 ± 0.05**	**0.094**	**0.088**	**49%**
2002	***56***	*(54%)*	**98%**	**51.8 ± 12.5**	**0.50 ± 0.20**	**0.227**	**0.154**	**68%**
2003	***39***	*(56%)*	**95%**	**28.5 ± 7.2**	**0.17 ± 0.03**	**0.135**	**0.068**	**54%**
2004	***131***	*(80%)*	**91%**	**23.4 ± 3.0**	**0.27 ± 0.04**	**0.140**	**0.081**	**60%**
2005	***51***	*(68%)*	**98%**	**17.8 ± 2.8**	**0.27 ± 0.06**	**0.094**	**0.089**	**47%**
2006	***27***	*(62%)*	**93%**	**33.9 ± 7.6**	**0.30 ± 0.08**	**0.199**	**0.131**	**85%**
2007	***64***	*(45%)*	**92%**	**35.9 ± 5.5**	**0.37 ± 0.05**	**0.298**	**0.137**	**72%**
2008	***20***	*(58%)*	**95%**	**44.5 ± 12.3**	**0.31 ± 0.10**	**0.196**	**0.104**	**55%**
2009	***68***	*(40%)*	**97%**	**19.3 ± 3.6**	**0.22 ± 0.04**	**0.075**	**0.084**	**46%**
2010	***36***	*(46%)*	**94%**	**56.4 ± 16.3**	**0.46 ± 0.20**	**0.127**	**0.112**	**64%**
2011	***19***	*(37%)*	**100%**	**43.6 ± 13.1**	**0.43 ± 0.19**	**0.214**	**0.183**	**79%**
2012	***81***	*(46%)*	**90%**	**20.6 ± 3.4**	**0.30 ± 0.09**	**0.098**	**0.075**	**49%**
2013	***24***	*(42%)*	**92%**	**26.8 ± 8.3**	**0.18 ± 0.04**	**0.083**	**0.067**	**46%**
2014	***12***	*(64%)*	**100%**	**21.4 ± 3.9**	**0.36 ± 0.14**	**0.176**	**0.184**	**83%**
2015	***23***	*(30%)*	**96%**	**12.1 ± 3.2**	**0.26 ± 0.15**	**0.064**	**0.060**	**39%**
2016	***31***	*(18%)*	**87%**	**31.7 ± 12.9**	**0.29 ± 0.10**	**0.133**	**0.059**	**52%**
2017	***38***	*(31%)*	**92%**	**26.8 ± 14.1**	**0.24 ± 0.07**	**0.073**	**0.060**	**37%**
2018	***12***	*(50%)*	**100%**	**15.8 ± 7.8**	**0.12 ± 0.06**	**0.048**	**0.052**	**17%**
2019	***44***	*(34%)*	**95%**	**11.4 ± 2.2**	**0.09 ± 0.02**	**0.059**	**0.036**	**36%**
2020	***14***	*(8%)*	**93%**	**30.9 ± 18.9**	**0.42 ± 0.30**	**0.093**	**0.089**	**43%**
2021	***71***	*(19%)*	**94%**	**36.7 ± 7.4**	**0.33 ± 0.06**	**0.193**	**0.141**	**72%**

Table 2B

Netherlands		**Industrial granules**			**User plastics**		
YEAR	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
1979	*1*	100%	2.0	0.07	100%	3.0	0.17
1980	*0*						
1981	*0*						
1982	*3*	100%	5.0 ± 2.1	0.11 ± 0.04	67%	6.0 ± 3.2	0.50 ± 0.33
1983	***19***	**84%**	**8.8 ± 2.2**	**0.19 ± 0.04**	**89%**	**7.2 ± 1.8**	**0.31 ± 0.12**
1984	***20***	**70%**	**9.6 ± 2.6**	**0.19 ± 0.05**	**90%**	**8.4 ± 3.1**	**0.17 ± 0.09**
1985	*3*	100%	5.3 ± 1.2	0.14 ± 0.05	100%	5.0 ± 2.5	0.14 ± 0.08
1986	*4*	50%	0.8 ± 0.5	0.02 ± 0.01	75%	4.8 ± 1.7	0.06 ± 0.04
1987	***17***	**82%**	**3.9 ± 1.8**	**0.11 ± 0.05**	**71%**	**9.7 ± 2.7**	**0.09 ± 0.04**
1988	*1*	0%	0.0	0.00	100%	2.0	0.04
1989	*2*	50%	6.5 ± 6.5	0.17 ± 0.17	100%	6.0 ± 3.0	0.25 ± 0.23
1990	*0*						
1991	*1*	0%	0.0	0.00	100%	11.0	0.14
1992	*0*						
1993	*0*						
1994	*0*						
1995	*2*	100%	1.5 ± 0.5	0.02 ± 0.01	100%	3.5 ± 0.5	0.03 ± 0.01
1996	*8*	75%	2.9 ± 1.2	0.07 ± 0.03	100%	24.5 ± 13.7	0.19 ± 0.10
1997	***31***	**74%**	**5.9 ± 1.9**	**0.13 ± 0.04**	**97%**	**29.8 ± 6.8**	**0.60 ± 0.17**
1998	***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	***71***	**65%**	**2.3 ± 0.6**	**0.05 ± 0.01**	**94%**	**34.4 ± 7.0**	**0.28 ± 0.05**

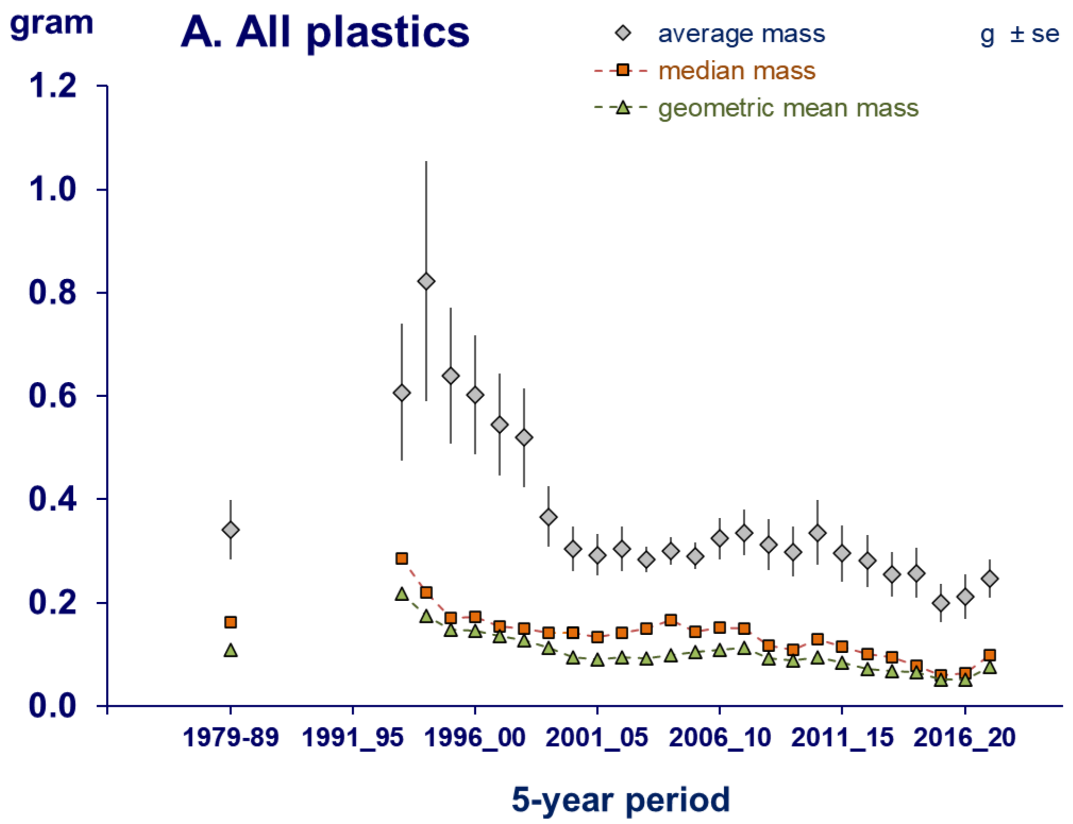
Table 3. Running averages by 5-year period for plastic abundance in fulmars from the Netherlands in the period 1979-2021. *A. all plastic categories combined; B. separate data for industrial and user plastic categories. Sample size is given with the proportion of adult birds in brackets. Frequency of Occurrence (%FO) represents the proportion of birds with one or more items of that litter present. Average number (n±SE) gives the abundance by number of plastic particles per bird with standard error, and average mass (g±SE) the weight of plastic per bird in grams with standard error. Total plastics mass is also shown in terms of medians and geometric mean mass (for comparative purposes reducing the influence of outliers) and as level of performance in relation to the OSPAR EcoQO, now Fulmar-TV, viz. the percentage of birds having more than the threshold of 0.1 gram of plastic in the stomach. Note sample sizes (n) to be very low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures.*

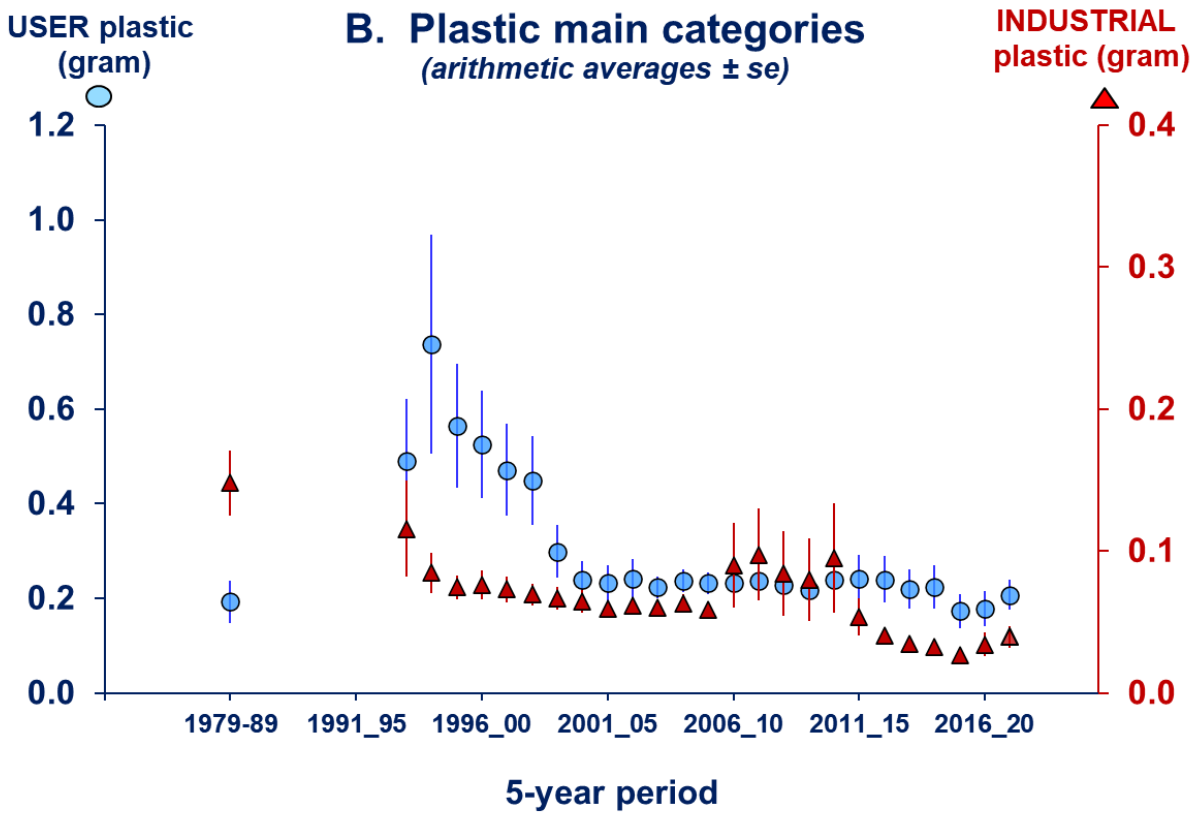
Table 3A

Netherlands			Total plastics					
YEAR	*sample n*	*(% ad)*	% FO	average number n ± se	average mass g ± se	median mass	geometric mean mass	FTV% (over 0.1g)
1979-89	*70*	*(43%)*	91%	14.4 ± 2.0	0.34 ± 0.06	0.162	0.109	67%
1990_94	*1*							
1991_95	*3*							
1992_96	*10*							
1993_97	*41*	*(27%)*	98%	32.6 ± 6.1	0.61 ± 0.13	0.286	0.217	76%
1994_98	*116*	*(38%)*	96%	30.0 ± 4.0	0.82 ± 0.23	0.220	0.176	72%
1995_99	*223*	*(53%)*	97%	32.5 ± 3.6	0.64 ± 0.13	0.170	0.148	67%
1996_00	*259*	*(54%)*	97%	31.2 ± 3.2	0.60 ± 0.12	0.174	0.146	66%
1997_01	*306*	*(51%)*	97%	29.8 ± 2.8	0.54 ± 0.10	0.154	0.135	63%
1998_02	*331*	*(54%)*	97%	32.9 ± 3.3	0.52 ± 0.10	0.151	0.128	62%
1999_03	*295*	*(57%)*	98%	33.5 ± 3.6	0.37 ± 0.06	0.141	0.112	59%
2000_04	*319*	*(62%)*	95%	28.7 ± 2.9	0.30 ± 0.04	0.141	0.095	59%
2001_05	*332*	*(64%)*	95%	27.8 ± 2.7	0.29 ± 0.04	0.134	0.091	57%
2002_06	*304*	*(68%)*	94%	29.3 ± 3.0	0.30 ± 0.04	0.142	0.094	61%
2003_07	*312*	*(66%)*	93%	26.6 ± 2.1	0.28 ± 0.02	0.151	0.093	62%
2004_08	*293*	*(67%)*	93%	27.6 ± 2.2	0.30 ± 0.03	0.166	0.098	62%
2005_09	*230*	*(52%)*	95%	27.5 ± 2.5	0.29 ± 0.03	0.144	0.104	59%
2006_10	*215*	*(47%)*	94%	34.6 ± 3.8	0.32 ± 0.04	0.153	0.110	62%
2007_11	*207*	*(44%)*	95%	35.6 ± 4.0	0.34 ± 0.04	0.150	0.112	61%
2008_12	*224*	*(44%)*	94%	30.0 ± 3.6	0.31 ± 0.05	0.116	0.092	54%
2009_13	*228*	*(43%)*	94%	28.4 ± 3.4	0.30 ± 0.05	0.109	0.088	53%
2010_14	*172*	*(45%)*	93%	31.5 ± 4.3	0.34 ± 0.06	0.129	0.094	58%
2011_15	*159*	*(43%)*	93%	23.1 ± 2.8	0.30 ± 0.05	0.116	0.085	53%
2012_16	*171*	*(39%)*	91%	22.4 ± 3.1	0.28 ± 0.05	0.102	0.073	50%
2013_17	*128*	*(33%)*	92%	24.9 ± 5.5	0.26 ± 0.04	0.095	0.068	47%
2014_18	*116*	*(32%)*	93%	23.5 ± 5.9	0.26 ± 0.05	0.078	0.066	44%
2015_19	*148*	*(30%)*	93%	20.1 ± 4.6	0.20 ± 0.04	0.059	0.051	39%
2016_20	*139*	*(28%)*	93%	22.5 ± 5.2	0.21 ± 0.04	0.064	0.052	39%
2017_21	*179*	*(26%)*	94%	26.5 ± 4.5	0.25 ± 0.04	0.100	0.076	50%

Table 3B. For caption see Table 3A.

Netherlands		Industrial granules			User plastics		
YEAR	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± 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	*179*	51%	1.8 ± 0.4	0.04 ± 0.01	94%	24.7 ± 4.3	0.21 ± 0.03


gram
A. All plastics
average mass
g ± se
median mass
geometric mean mass
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1979-89
1991_95
1996_00
2001_05
2006_10
2011_15
2016_20
5-year period


USER plastic (gram)
B. Plastic main categories
(arithmetic averages ± se)
INDUSTRIAL plastic (gram)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.4
0.3
0.2
0.1
0.0
1979-89
1991_95
1996_00
2001_05
2006_10
2011_15
2016_20
5-year period

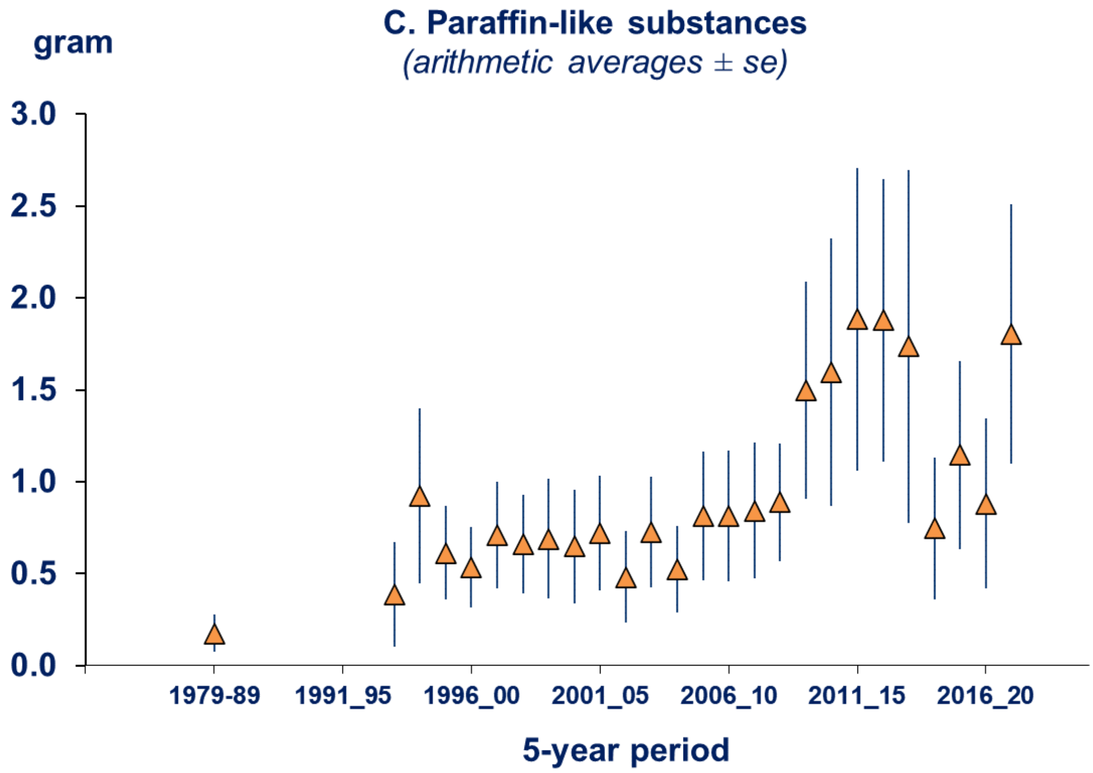


Figure 1. ***Plastic and paraffin-like substance mass in stomachs of fulmars from the Netherlands in the period 1979-2021.*** *Shown by 5-year running averages, except all data combined for the early period 1979-1989. Data only shown where sample size over 40 stomachs. A: Data for all plastics combined visualising changes in arithmetic average mass ± SE (grey diamonds), median mass (oranges squares) and geometric mean mass (green triangles). B: Arithmetic mass data, split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). C: Arithmetic mass ± 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.*

Info Box: Inland Fulmars in the Netherlands

Photo 6. Fulmars are true seabirds. *They avoid land and only return to cliffs to breed. Most dead fulmars in the Netherlands, are therefore collected along the coastlines. However, there are a few exceptional cases in which fulmars are reported more inland. The depicted bird above, was found in April 2021 at the entry of Den Burg on Texel, several kilometres from the coastline of the island. The finder, Job Schepers, works for the local newspaper 'Texelse Courant'. A short article on his special find can be found here (in Dutch): www.texelsecourant.nl/nieuws/natuur/198711/de-noordse-stormvogel*

Earlier inland records of fulmars that were used for Dutch plastic monitoring show several examples of birds found inland, e.g. in Leeuwarden (1980; 13 km from the coast), in Dordrecht (1981; 43 km), along the IJsselmeer coast (Waterland, 1986; 32 km to the North Sea coast) and in a central city park in Groningen (2017; 22 km). The reason for such inland visits can be related to bad weather conditions and potentially a bad health of those fulmars.

Other fulmars, which were seen alive or dead but not collected for the plastic monitoring project are documented on www.waarneming.nl. In 2021, another fulmar was found far inland, emaciated between Utrecht and Hilversum, about 40 km from the North Sea coast. This bird was brought to a rehabilitation centre and was later released in good condition. In the Dutch province of Flevoland, five birds were reported close to the IJsselmeer between 1982 and 2017. In Gelderland, one bird was found in 2015, 80 km from the North Sea coast (and still 50 km from the IJsselmeer).

4.3 Trends

In the EcoQO 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

The **'long-term trend'** is defined as the trend over all years in the dataset (now 1979-2021). The current dataset holds records for 1248 fulmars, with 589 adult birds and 624 non-adults, which are juveniles to immatures several years of age. For 35 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 43 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 et al. 2011; Van Franeker & Law 2015). For user plastics, the initial increase from the 1980s to mid-1990s was largely ‘compensated’ by a rapid decrease from late 1990s to around 2003, and relatively small changes after that. Combined for industrial and user plastics the trend is a highly significant decrease ($p=0.001$). Trends in different age groups (adults/non-adults) are decreasing similarly, except for user plastics, where no evident change is seen in non-adult birds with even a positive slope value. This result is influenced by the 2021 sample, as in the previous year, all long-term trends were downwards (Kühn et al. 2021a). However the effect is not reflected in the overall plastic mass, which continues to decrease significantly for adults and non-adults alike.

4.3.2 Recent trends

The **'recent trend'** is defined as the trend in plastic mass in fulmar stomachs over the past 10 years, so in this report: 2012-2021 (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 debris ($p=0.036$) and industrial plastics ($p=0.035$). Since then, the 10-year trends have been decreasing, either close to significance or decreased significantly.
The shorter the assigned time period, the more likely extreme years can influence the data. In the current 10-year period (2012-2021) the signs of the regression slopes have even reverted suggesting a potential although non-significant increase ($p=0.347$). This is also true for non-adults and for user and industrial pellets separately. This change is driven by an increase in user plastic mass ingested by non-adult fulmars in 2021 (Table 4C).

The new policy relevant addition of FTV Performance, has led to an added 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 are evaluated. Trends in ingested mass of plastics over the 20-year period (since the start of the SNS fulmar project in 2002; Table 4B) are clearer than over the recent 10 years (Table 4C). Industrial plastics still show a significant decrease over the 2002-2021 period ($p=0.007$) also for separate age groups. User plastics do not show a significant decline ($p=0.477$) anymore, mainly due to the non-adult birds. Combined for all plastics and both age groups, no significant change is present ($p=0.136$); in this, adult birds do show a significant downward trend ($p=0.014$), but are overruled by the non-adult birds ($p=0.104$, not significant).

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 former Fulmar EcoQO, now Fulmar-TV. D. significance of sequential decadal trends for 1980s and 10-year periods starting 1997. The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x. 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 1979-2021***

for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	*n*	constant	slope	s.e.	t	p	
all ages	*1248*	80.1	-0.0421	0.0070	-6.00	<0.001	↓ - - -
adults	*589*	85.4	-0.0450	0.0120	-3.74	<0.001	↓ - - -
non adults	*624*	93.9	-0.0489	0.0089	-5.52	<0.001	↓ - - -

User plastics (lnGUSE)	*n*	constant	slope	s.e.	t	p	
all ages	*1248*	3.4	0.0030	0.0061	-0.49	0.623	*n.s.*
adults	*589*	36.8	-0.0198	0.0110	-1.80	0.072	↓ *n.s.*
non adults	*624*	-4.6	0.0011	0.0074	0.14	0.885	*n.s.*

All plastics combined (lnGPLA)	*n*	constant	slope	s.e.	t	p	
all ages	*1248*	36.2	-0.0192	0.0060	-3.21	0.001	↓ - -
adults	*589*	56.0	-0.0292	0.0109	-2.69	0.007	↓ - -
non adults	*624*	38.3	-0.0201	0.0070	-2.86	0.004	↓ - -

SUSPECTED CHEMICALS (lnGCHE)	*n*	constant	slope	s.e.	t	p	
all ages	*1248*	-24.7	0.0094	0.0081	1.17	0.243	*n.s.*
adults	*589*	0.0	-0.0029	0.0131	-0.02	0.825	*n.s.*
non adults	*624*	-37.2	0.0157	0.0108	1.45	0.148	*n.s.*

B. ***TRENDS 2002-2021 since start SNS project***

for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	*n*	Constant	slope	s.e.	t	p	
all ages	*861*	61.7	-0.0330	0.0122	-2.71	0.007	↓ - -
adults	*400*	108.9	-0.0566	0.0202	-2.80	0.005	↓ - -
non adults	*430*	84.0	-0.0439	0.0168	-2.61	0.009	↓ - -

User plastics (lnGUSE)	*n*	Constant	slope	s.e.	t	p	
all ages	*861*	12.4	-0.0075	0.0106	-0.71	0.477	*n.s.*
adults	*400*	77.6	-0.0402	0.0190	-2.11	0.035	↓ -
non adults	*430*	21.9	-0.0121	0.0134	-0.90	0.368	*n.s.*

All plastics combined (lnGPLA)	*n*	Constant	slope	s.e.	t	p	
all ages	*861*	29.1	-0.0157	0.0105	-1.49	0.136	*n.s.*
adults	*400*	91.2	-0.0468	0.0189	-2.48	0.014	↓ -
non adults	*430*	41.3	-0.0216	0.0133	-1.63	0.104	*n.s.*

C. *RECENT 10-YEAR TRENDS 2012-2021*

for plastics in Fulmar stomachs, the Netherlands

Industrial plastics (lnGIND)	*n*	constant	slope	s.e.	t	p
all ages	*350*	29.1	-0.0168	0.0323	0.52	0.603 *n.s.*
adults	*107*	171.0	-0.0875	0.0568	-1.54	0.126 *n.s.*
non adults	*222*	8.9	-0.0067	0.0415	-0.16	0.871 *n.s.*

User plastics (lnGUSE)	*n*	constant	slope	s.e.	t	p
all ages	*350*	-77.4	0.0370	0.0300	1.23	0.219 *n.s.*
adults	*107*	143.0	-0.0728	0.0586	-1.24	0.217 *n.s.*
non adults	*222*	-126.6	0.0615	0.0364	1.69	0.093 ↑ *n.s.*

All plastics combined (lnGPLA)	*n*	constant	slope	s.e.	t	p
all ages	***350***	**-59.4**	**0.0282**	**0.0299**	**0.94**	**0.347** *n.s.*
adults	*107*	168.0	-0.0848	0.0590	-1.44	0.153 *n.s.*
non adults	*222*	-107.8	0.5230	0.0360	1.45	0.148 *n.s.*

SUSPECTED CHEMICALS (lnGCHE)	*n*	Constant	slope	s.e.	t	p
all ages	*350*	0.4	-0.0031	0.0435	-0.07	0.944 *n.s.*
adults	*107*	-135.0	0.0638	0.0715	0.89	0.374 *n.s.*
non adults	*222*	54.0	-0.2970	0.0580	-0.51	0.609 *n.s.*

D. Linear Regression tests over 10-year periods

Decade	*n*	Industrial plastic p		User plastic p		ALL PLASTICS 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.

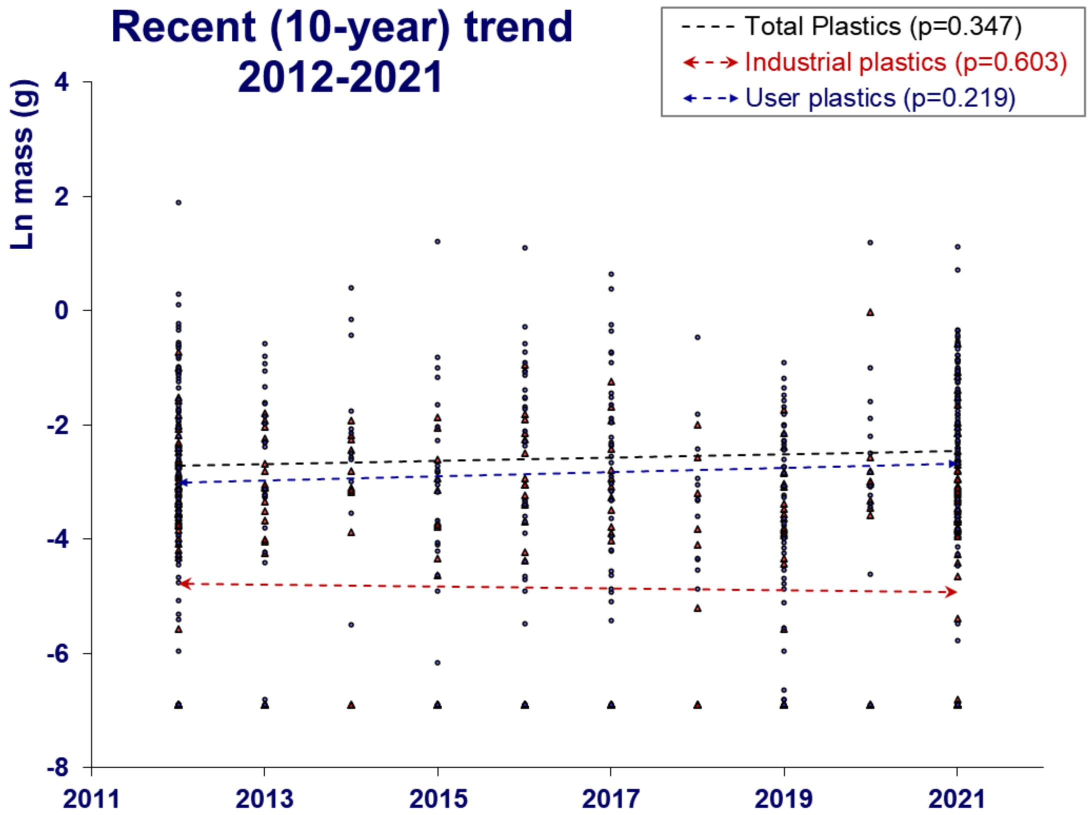


Figure 2. Statistical trend in plastic mass in stomachs of fulmars from the Netherlands 2012-2021. *The graph, as an example of the statistical approach, shows plotted ln-transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear 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, 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 very similar pattern, which strengthens the validity of the monitoring approach combining data for all birds. As seen in Figure 4, both age classes follow the upward trend in geometric mean plastic mass in 2021.

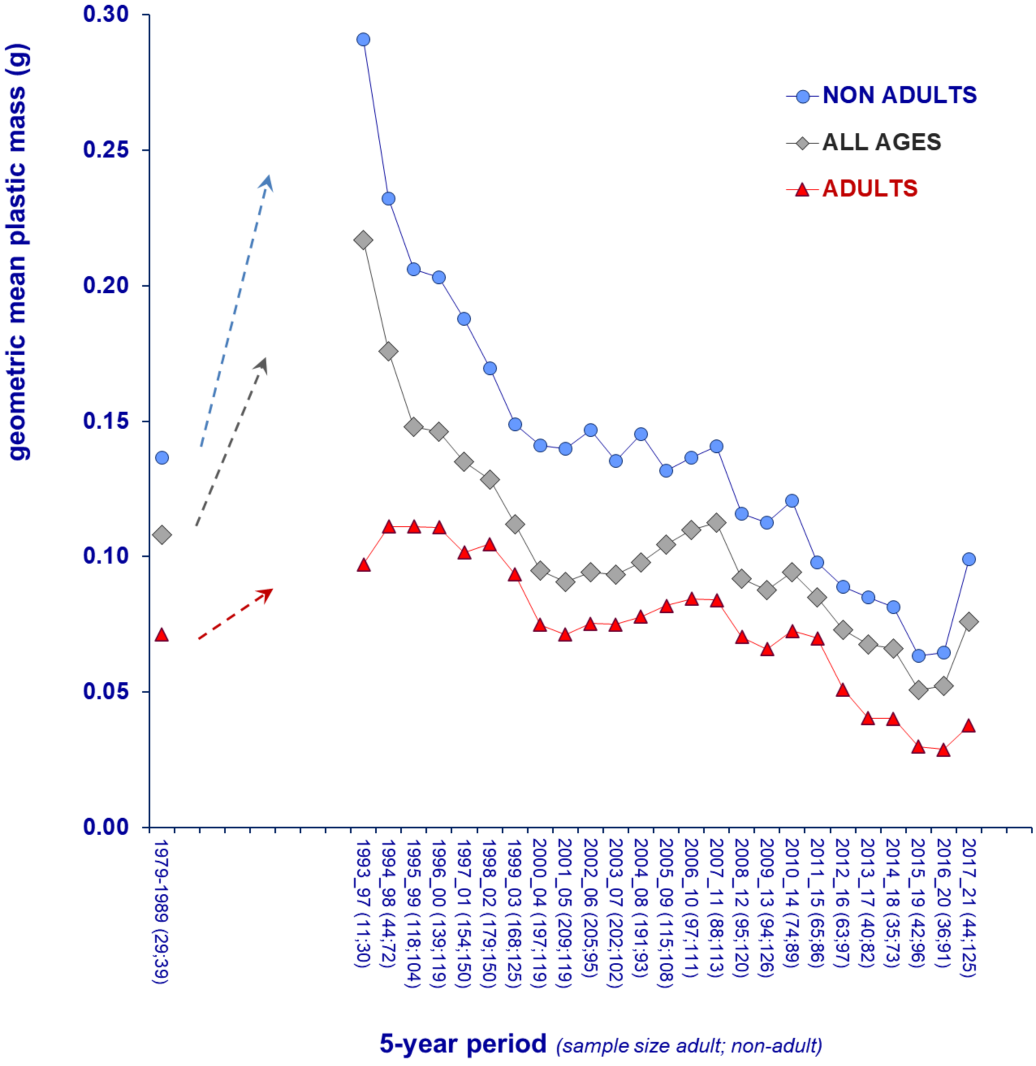


Figure 3. Geometric mean mass of plastics in stomachs of beached fulmars from the Netherlands 1979-2021 *for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults (blue circles), with respective sample sizes in brackets in the x-axis labels. 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

ICES working groups (e.g. ICES-WGSE 2001, 2003), followed by OSPAR (2008, 2009), have initiated the approach in which the EcoQO metric for marine litter is expressed in terms of a percentage of birds exceeding a threshold value of plastic in the stomach. This approach is now to be replaced by the OSPAR/ EU MSFD Fulmar Threshold Value (Fulmar-TV). 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, whether intentional or not, the 'percentage above threshold value' definition represents a simplified procedure to avoid the mathematical problems caused by a few excessive stomach contents that distort comparative analyses and averaged values. In our standard statistical testing procedures and calculations of geometric means, such problems are largely overcome by logarithmic transformation of data. This is a standard statistical procedure. However, it is not always easily conveyed to the general public, and differences between arithmetic averages versus geometric means can be confusing. 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."*

This Fulmar-TV target replaces the very similar earlier OSPAR EcoQO targets. 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, it also emphasizes the distance from the 10% FTV target set by OSPAR. Over the integrated recent 5-year period 2017-2021, 50% of Dutch fulmars exceed 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 in the period 2016-20, this percentage was at 39%). The exceptional high mass of plastic in 2021 fulmars causes this high value and will likely influence the 5-year periods for the upcoming years.

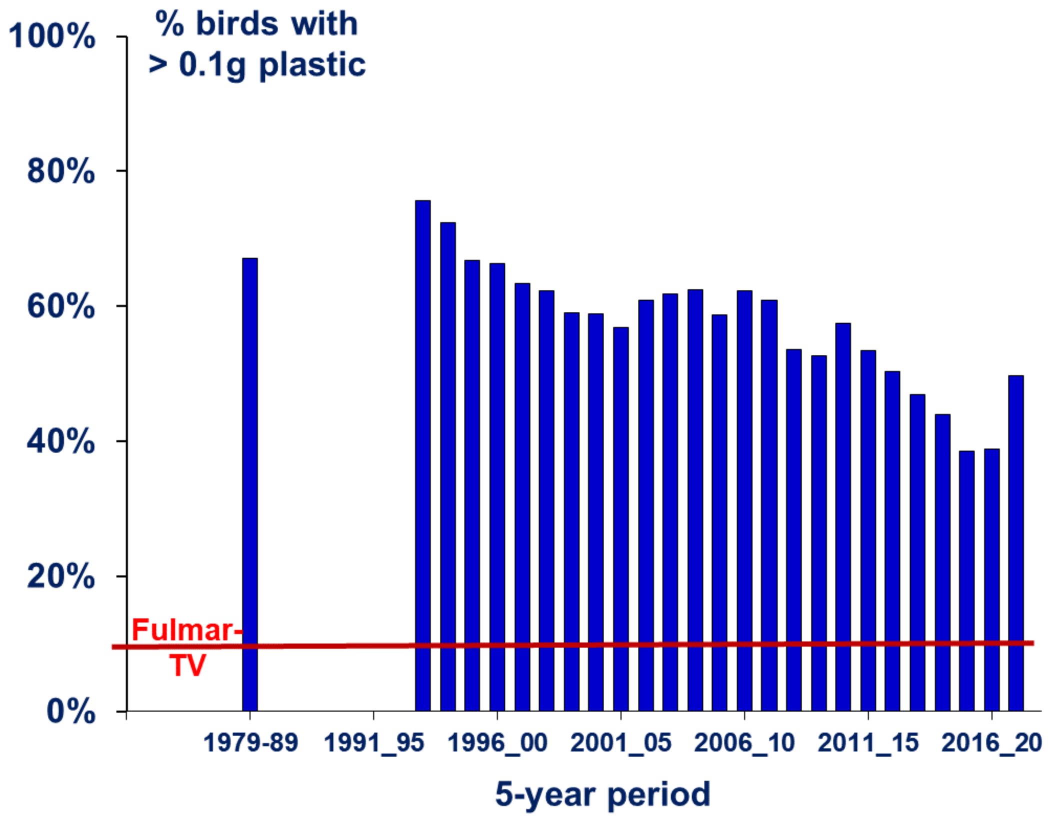


Figure 4. ***Fulmar-TV Performance of fulmars in the Netherlands over running 5-year periods up to 2021.*** *Data for the 1980s were combined due to relatively small sample size. The red line illustrates the OSPAR Fulmar-TV to reduce the percentage of birds with more than 0.1 gram of plastic in the stomach to below 10%. This graphic visualization does not represent a statistical trend analysis.*

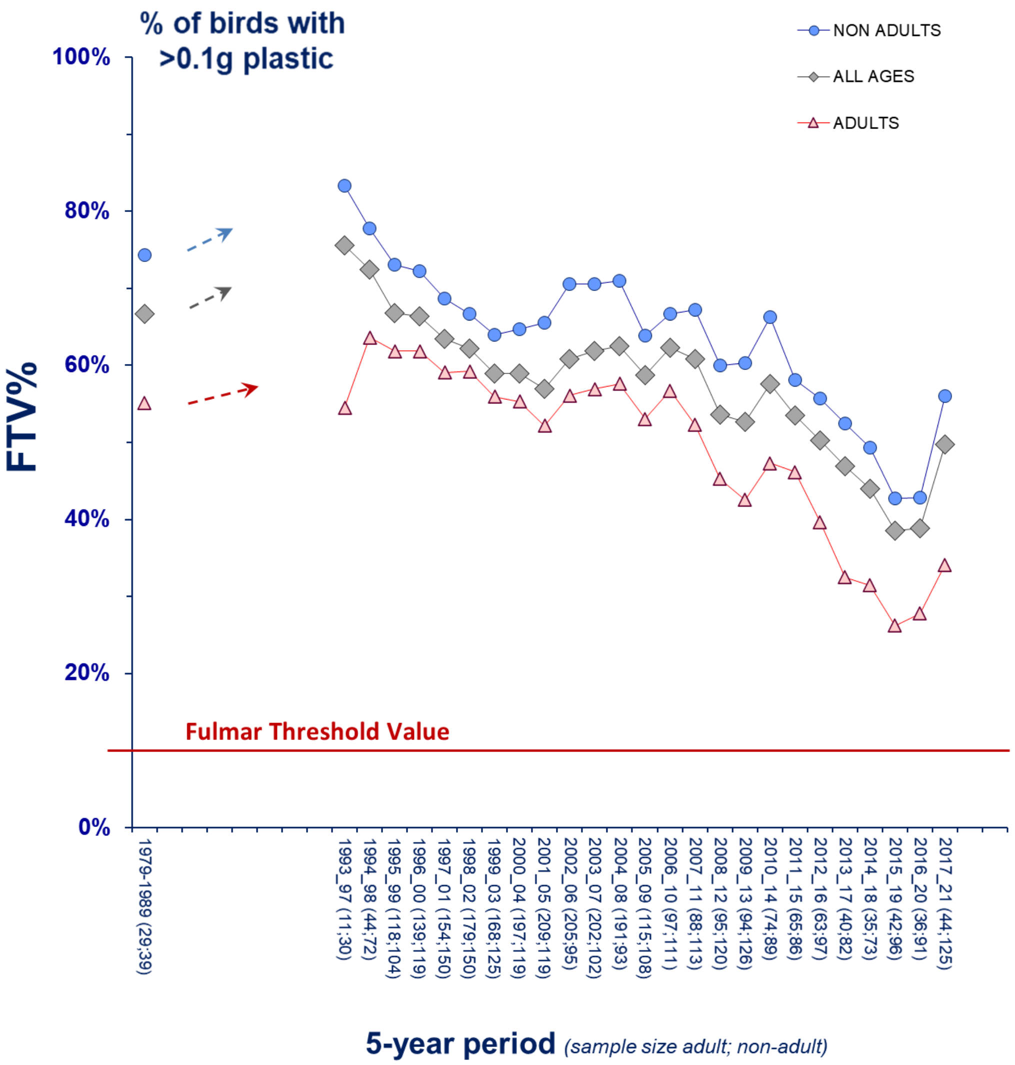


Figure 5. *Trend in Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2021.* *Trendlines for all birds combined (grey diamonds, including birds of unknown age), for adult birds (red triangles) and for non-adults (blue circles). This graphic visualization is based 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 1980s 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.
In our approach of evaluating trends over a period of the most recent ten years, the statistical procedure then has only ten data-points available for statistical tests and modelling. Simple linear regression cannot be applied to this type of data. The data need to be considered in a GLM approach *(Generalized Linear Modelling)*, more specifically in a logistic analysis dedicated for binomial distributions (birds yes or no above threshold) and using logit transformed data.

In principle, significance of the model should be the decision rule to whether use the trend for calculating future predicted values. In our first analysis of data up to 2017 (Van Franeker & Kühn 2018), the ten-year binomial regression result was not significant, but the same type of analysis over a longer period of 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. The analysis for 2002-2020 predicted that the target could be reached already in 2049 (Kühn et al. 2021a). With the current year 2021, the factor age is included as covariate to this model, as recommended by Van Franeker et al. (2021). The new model predicts that the Fulmar Threshold will be reached in 2066, so later than in previous predictions. The larger standard errors in the current model (Figure 7 and Table 5) reflect the uncertainty caused by an unusual year.

Possibly the logistic 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. Logistic models for just 10 data years are strongly influenced by individual years which will cause frequent change in statistical significance and thus in variable future predictions. The present situation of an exceptional year, influencing even the longer-term predictions, highlights this effect and supports the choice for long-term approaches.

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 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.

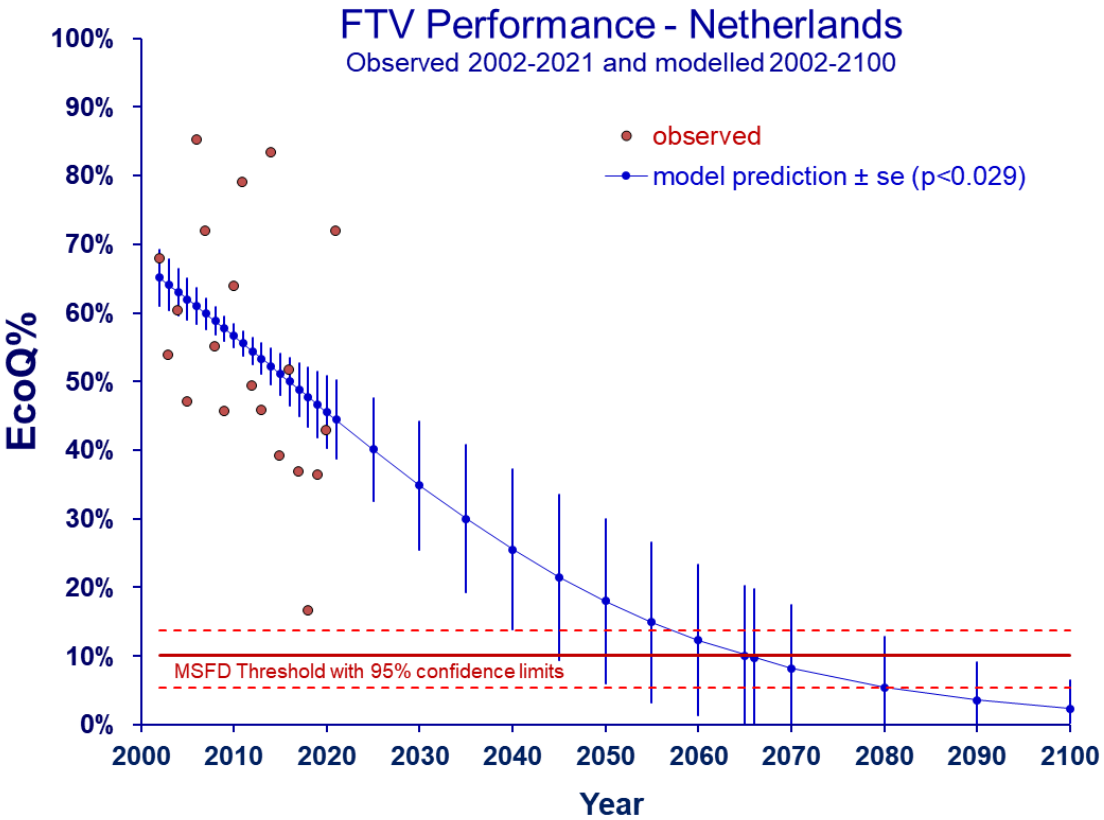


Figure 6. *Predicted trajectory to the OSPAR long-term Fulmar-TV target for plastics ingested by Fulmars in Dutch offshore waters,* *based on a logistic binomial model from annual EcoQ Performances. This model is based on observed FTV Performance over the 20-year period 2002-2021 (p<0.029) and includes age composition of the annual samples as a covariate.*

Table 5. Observed and modelled data in the logistic binomial models based on annual Fulmar-TV performances observed *over the 20-year Save the North Sea period 2002-2021 ($p<0.029$). This table is the source for Figure 7.*

Long term model period (starting with start of the SNS project in 2002)

SOURCEDATA FOR LOGISTIC REGRESSION						Modelled and observed proportion	
YEAR	sample size	nr with over 0.1g plastic	EcoQ%	proportion adult birds	proportion male birds	Year	model prediction ± se (p<0.029)
2002	56	38	0.68	0.54	34%	2002	0.651 ± 0.04
2003	39	21	0.54	0.56	41%	2003	0.641 ± 0.04
2004	131	79	0.60	0.80	22%	2004	0.631 ± 0.03
2005	51	24	0.47	0.68	52%	2005	0.620 ± 0.03
2006	27	23	0.85	0.62	42%	2006	0.610 ± 0.03
2007	64	46	0.72	0.45	47%	2007	0.599 ± 0.02
2008	20	11	0.55	0.58	32%	2008	0.588 ± 0.02
2009	68	31	0.46	0.40	56%	2009	0.577 ± 0.02
2010	36	23	0.64	0.46	56%	2010	0.566 ± 0.02
2011	19	15	0.79	0.37	47%	2011	0.555 ± 0.02
2012	81	40	0.49	0.46	39%	2012	0.544 ± 0.02
2013	24	11	0.46	0.42	42%	2013	0.533 ± 0.02
2014	12	10	0.83	0.64	36%	2014	0.522 ± 0.03
2015	23	9	0.39	0.30	59%	2015	0.511 ± 0.03
2016	31	16	0.52	0.18	43%	2016	0.500 ± 0.03
2017	38	14	0.37	0.31	36%	2017	0.489 ± 0.04
2018	12	2	0.17	0.50	30%	2018	0.478 ± 0.04
2019	44	16	0.36	0.34	57%	2019	0.466 ± 0.05
2020	14	6	0.43	0.08	50%	2020	0.455 ± 0.05
2021	71	51	0.72	0.19	40%	2021	0.444 ± 0.06
						2025	0.401 ± 0.07
						2030	0.349 ± 0.09
						2035	0.300 ± 0.11
						2040	0.255 ± 0.12
						2045	0.215 ± 0.12
						2050	0.180 ± 0.12
						2055	0.149 ± 0.12
						2060	0.123 ± 0.11
						2070	0.082 ± 0.09
						2080	0.054 ± 0.07
						2090	0.036 ± 0.06
						2100	0.023 ± 0.04
						2065	0.101 ± 0.10
						2066	0.097 ± 0.10

5 Concluding remarks

The year 2021 has been unusual, not only in terms of sample size (81 birds of which 71 were suitable for monitoring). The large sample size could derive from a fulmar-specific influx in the southern North Sea, an increase in beached birds not observed in other seabird species within the regular Beached Bird Surveys (Camphuysen 2021). The reasons for such influx remain unclear. The year 2021 was also characterized by a high average plastic mass.
To avoid that such single sample influences 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 necessity of this approach becomes visible in the current dataset. The longer the considered period, the less affected is the data by the 2021 sample. While in the previous periods (data up to 2020) all trends were significantly decreasing, in all considered time periods, the inclusion of the data year 2021 results in insignificance for the 10-year period (2012-2021) and the period since the start of the SNS project in 2002. Only the long-term data, for which fulmars since 1979 were available, continues to show a significant decrease.

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.
Although the significant plastic mass reduction did not persist within the 2002-2021 time period, it still 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 2066.
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 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 is gradually improving, but still far off the Fulmar Threshold Value. At the current rate of the trend, the Fulmar-TV might be reached around the year 2066. Within 10-year evaluation periods the trend is not consistent, and showed no significant change over the most recent decade (2012-2021). Future data must reveal if this reflects a temporary deviation, or a reversal in the longer term trend.

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Beached fulmars are mainly collected by volunteers without whom a project such as this is impossible. Below is a list of beach surveyors that contributed to the collection of beached fulmars. If people find that their name or group is listed incorrectly, or worse, not at all, our sincere apologies and please take up contact.

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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 by the 1992 OSPAR Convention.

OSPAR EcoQO = Ecological Quality Objective.
At the request of ministers of North Sea border 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), euthrophication, 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.

8 Quality Assurance

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

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Justification

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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. Ruud Jongbloed
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