# Fulmar Litter Monitoring in the Netherlands – Update 2022

Authors: Susanne Kühn, André Meijboom, Oliver Bittner & Jan Andries van Franeker

Wageningen Marine Research report C039/23
RWS Centrale Informatievoorziening BM 23.14

# Fulmar Litter Monitoring in the Netherlands – Update 2022

Authors: Susanne Kühn, André Meijboom, Oliver Bittner & Jan Andries van Franeker

Wageningen Marine Research
Den Helder, September 2023

Wageningen Marine Research report C039/23
RWS Centrale Informatievoorziening BM 23.14

**Keywords:**
OSPAR EcoQO; MSFD-GES; Fulmar Threshold Value (FTV); *Fulmarus glacialis*; monitoring; marine litter; plastic ingestion

**Citation:**
Kühn S., Meijboom A., Bittner O., & Van Franeker J.A. (2023). Fulmar Litter Monitoring in the Netherlands – Update 2022. Wageningen Marine Research Report C039/23 and RWS Centrale Informatievoorziening BM 23.14; pp 51 doi: https://doi.org/10.18174/633324

**Client:** Rijkswaterstaat Water, Traffic and Living Environment RWS-WVL (RWS-VWL)
Attn.: Mervyn Roos
E: Mervyn.roos@rws.nl
T: +31612218134

This report can be downloaded for free from https://doi.org/10.18174/633324
Wageningen Marine Research provides no printed copies of reports.

Wageningen Marine Research is ISO 9001:2015 certified.

Photo cover: Northern fulmar searching for food in front of a fish factory in Húsavík, Iceland.
Photo: S. Kühn

© Wageningen Marine Research

Wageningen Marine Research, an institute within the legal entity Stichting Wageningen Research (a foundation under Dutch private law) represented by Drs.ir. M.T. van Manen, Director Operations

Wageningen Marine Research accepts no liability for consequential damage, nor for damage resulting from applications of the results of work or other data obtained from Wageningen Marine Research. Client indemnifies Wageningen Marine Research from claims of third parties in connection with this application.

**©2023 Wageningen Marine Research.** This work is licensed under the Creative Commons CC-BY-NC-SA license. For license conditions see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

KvK nr. 09098104,
WMR BTW nr. NL 8113.83.696.B16.
Code BIC/SWIFT address: RABONL2U
IBAN code: NL 73 RABO 0373599285

# Contents

# Summary


## Fulmar Litter monitoring in the Netherlands - Update 2022

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 (EcoQO's) (North Sea Ministerial Conference 2002). At that time, in the Netherlands, marine litter was already monitored by the abundance of plastic debris in stomachs of a seabird species, the Northern Fulmar *(Fulmarus glacialis)*. In 2020 the fulmar EcoQO was formally replaced and is now called Fulmar Threshold Value (Fulmar-TV or FTV; for more details see Van Franeker et al. (2021) and Kühn et al. (2021)).

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 2 to 3 mm) to pass into the intestines (Bravo Rebolledo 2011). During this process, plastics accumulate in the stomach to a level that integrates litter levels encountered in their foraging area for a period of probably up to a few weeks (van Franeker and Law 2015). The monitoring system uses fulmars found dead on beaches, often slowly starved but also accidentally killed e.g. as in fisheries bycatch. In a pilot study, it has been shown that the amount of plastic in stomachs of slowly starved beached birds was not statistically different from that of healthy birds killed in instantaneous accidents in the same area (van Franeker and Meijboom 2002).

**The 2022 update of monitoring data for the Netherlands**
This report adds new data for year 2022 to the previous report (Kühn et al. 2022a). A total of 76 fulmar corpses were collected, of which 66 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 in rehabilitation, because particles break and wear down in the muscular stomach and disappear through the intestines (Van Franeker & Law 2015) and are not replaced by new plastics from the marine environment. In 2022, we did receive two fulmars from rehabilitation centres, both were less than three days in care, so both birds could be included to the standard monitoring. Occasionally birds from earlier years are added to the current dataset. This does not hamper the data analysis, but slight differences with previous reports may occur. In 2022, seven additional birds from 2021 were analysed of which five birds had an intact stomach. The desired annual sample size is ±40 birds or more (Van Franeker & Meijboom 2002). In 2022 the number was exceeded with 66 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 (2018-2022), in a sample of 212 birds, 50% of the fulmars contained more than 0.1 g plastic (FTV%). This is an increase compared to earlier 5-year periods and substantially exceeds the Fulmar-Threshold Value (*Fig. i*). Over the past five years, 95% of fulmars contained some plastic, with an average over all birds of 23.5 plastic particles per stomach, weighing 0.26 gram.
Looking at annual samples, the years 2020 and 2021 (together 90 individuals) showed a relatively high number and mass of plastics compared to the remarkably low figures in 2018 and 2019, for unclear reasons. The new sample from 2022 exceeds the quantity of plastics seen in preceding years, but the change is not substantial.

This report includes data on chemical stomach contents, specifically paraffin- or palmfat-like substances. In 2022, 20% of the analysed fulmars contained some paraffin- or palmfat-like substances. For the 2018-2022 period, the average mass was 1.6 gram per bird showing an increase in comparison with earlier years, caused by a few stomachs with exceptional high loads of paraffine-like materials in 2021.

***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 |
|---|---|---|---|---|---|
| **2022** | *(66)* | **48%** | 94% | 18.6 | 0.29 |
| period | | | | | |
| **2018_22** | *(212)* | **50%** | 95% | 23.5 | 0.26 |


***Photo 1 Representative fulmar stomach contents for the year 2022.*** *On average, fulmars from the Dutch coast in 2022 contained about 19 plastic particles weighing 0.29 gram (Table i). Two stomachs were fairly representative for the average mass. The left photo shows stomach contents for fulmar nr NET-2022-056, containing 116 plastic particles (1 industrial pellet, 1 thread, 100 foam pieces and 14 fragments) with a combined mass of 0.2932 gram. The photo on the right for fulmar nr NET-2022-076 shows 24 pieces of plastic (2 pellets, 22 fragments), weighing 0.3089 gram, so slightly above the year average. This stomach also contained some paraffin- or palmfat-like material, not shown on the photo. Although the mass of these two stomachs is very similar, the number of plastic pieces varies considerably. For the plastic monitoring in fulmars, the relevant metric is plastic mass, as volume and included additives may contribute to the potential effects of plastics on organisms.*

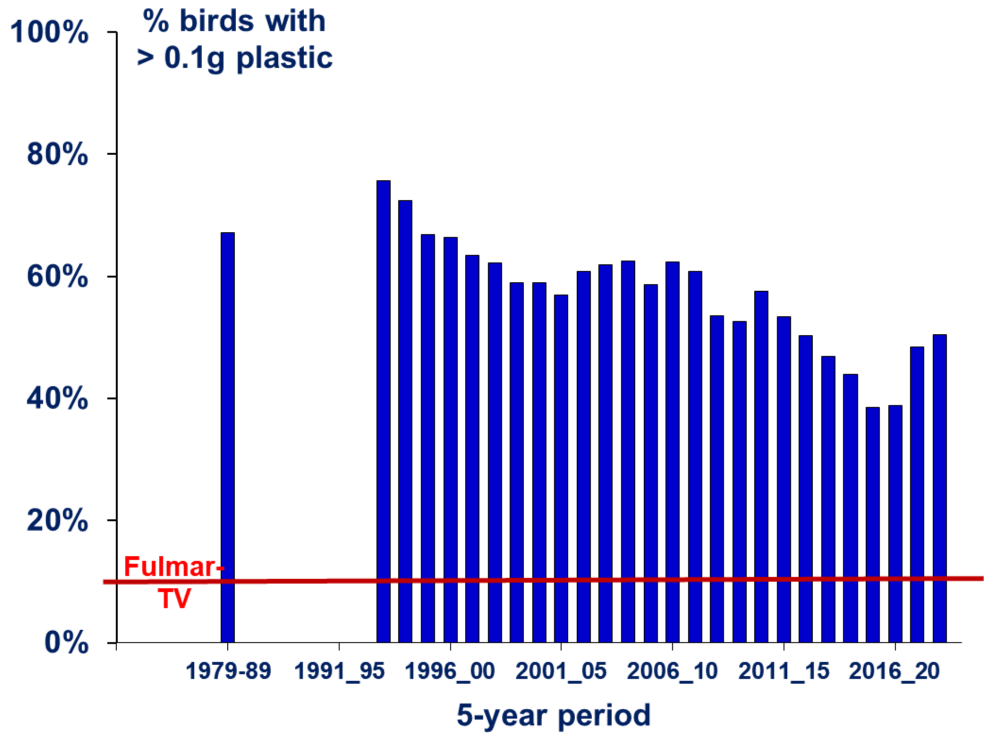


*__Figure i__ __Fulmar-TV Performance of fulmars in the Netherlands over running 5-year periods up to 2022.__ Data for the 1980s were combined due to relatively small sample size. The red line illustrates the Fulmar-Threshold Value. This graphic visualization does not represent a statistical trend analysis.*

**Trends and predictions**

In order to provide policy makers with simple straightforward information, this summary report focuses on the new predictive model to estimate when in future the Fulmar-TV may be reached if the trend observed in the 2002-2022 period 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) to define a trend in the observed data. If statistically significant that trend may 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. Since the FTV% is a figure for frequency of occurrence within a group of fulmars, the choice for 'year' to define the group size is the minimum possible. Calculating the trend over just 10 years (datapoints) is a too small number of datapoints to obtain a GLM model with sufficient power. Therefore, a longer time series is required, for which we chose annual data since the start of international fulmar monitoring in 2002 in the Save the North Sea project (Save the North Sea 2004).

GLM analysis over the 21-year period 2002-2022 for the Netherlands indicated a significant improvement in Fulmar-TV Performance (FTV% decreased significantly at $p<0.017$ *Fig. ii*). 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 MSFD long-term target may be reached in year 2074. This predicted year is later than the year 2066 calculated in the previous report. This is a consequence of an increased percentage of birds with more than 0.1 g plastic in their stomach over the period 2020-2022 compared to the low values seen in 2018 and 2019.

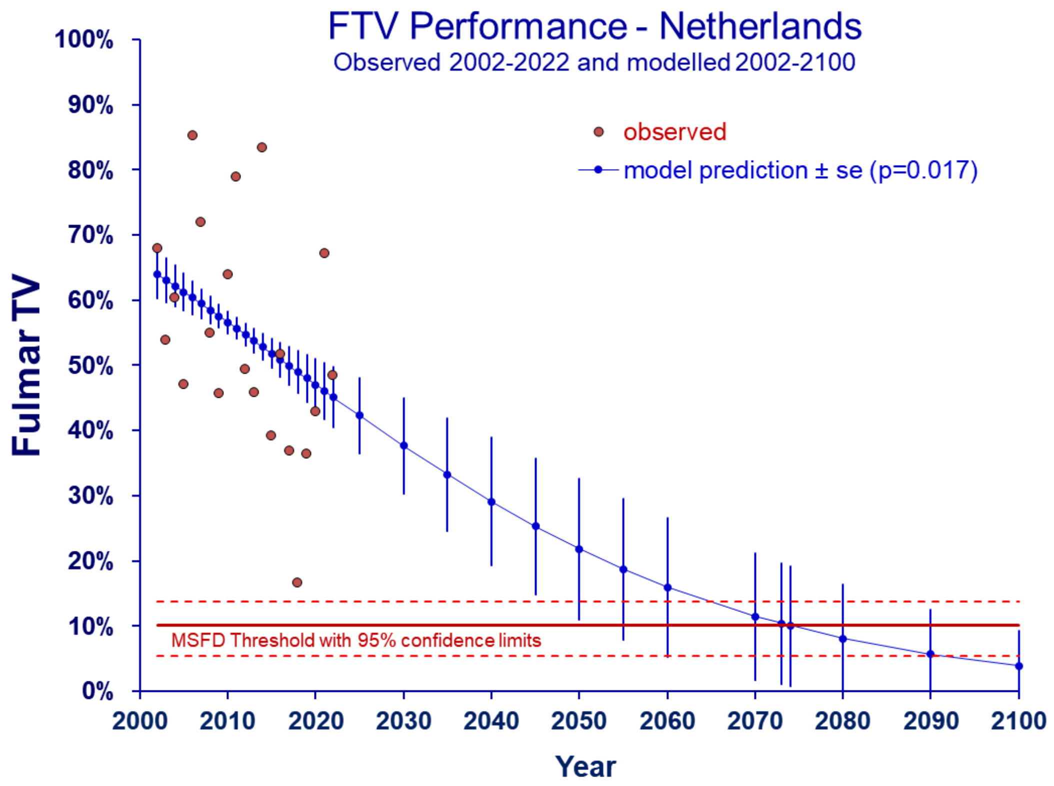


***Figure ii GLM model analysis of annual Fulmar-TV Performance using 21 years of fulmar data (2002-2022).*** *Observed data are the red closed circles. Since the modelled trend is significant (p=0.017), the predicted annual values and standard errors (vertical lines) are shown by blue dots and a solid trendline.*

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

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 2013-2022, 340 birds were available. Currently, this 10-year mass trend is not significant (p=0.440). However, over the 2002-2022 period as used in the GLM procedure, the FTV test is significant (932 birds: p=0.042), indicating a decrease of plastic mass over this period.

A non-statistical way to illustrate and check the trends in plastic ingestion over time is by comparing separate age classes. Monitoring results are mostly presented for birds of all ages together, but the pilot study for the fulmar monitoring project (Van Franeker & Meijboom 2002) showed that younger birds on average carry a higher load of ingested plastic than adult birds. As long as age composition shows no substantial persistent change, age groups may be combined. The difference between age groups should also be reflected in the respective FTV% data. *Fig. iii* illustrates Threshold Performance for separate adult and non-adult age groups. This is done by means of running 5-year data-points because annual figures are often too variable (see the red data-points for observed data in *Fig. ii*), and certainly so when sample size is reduced by splitting into subgroups. Data for the 1980's 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.

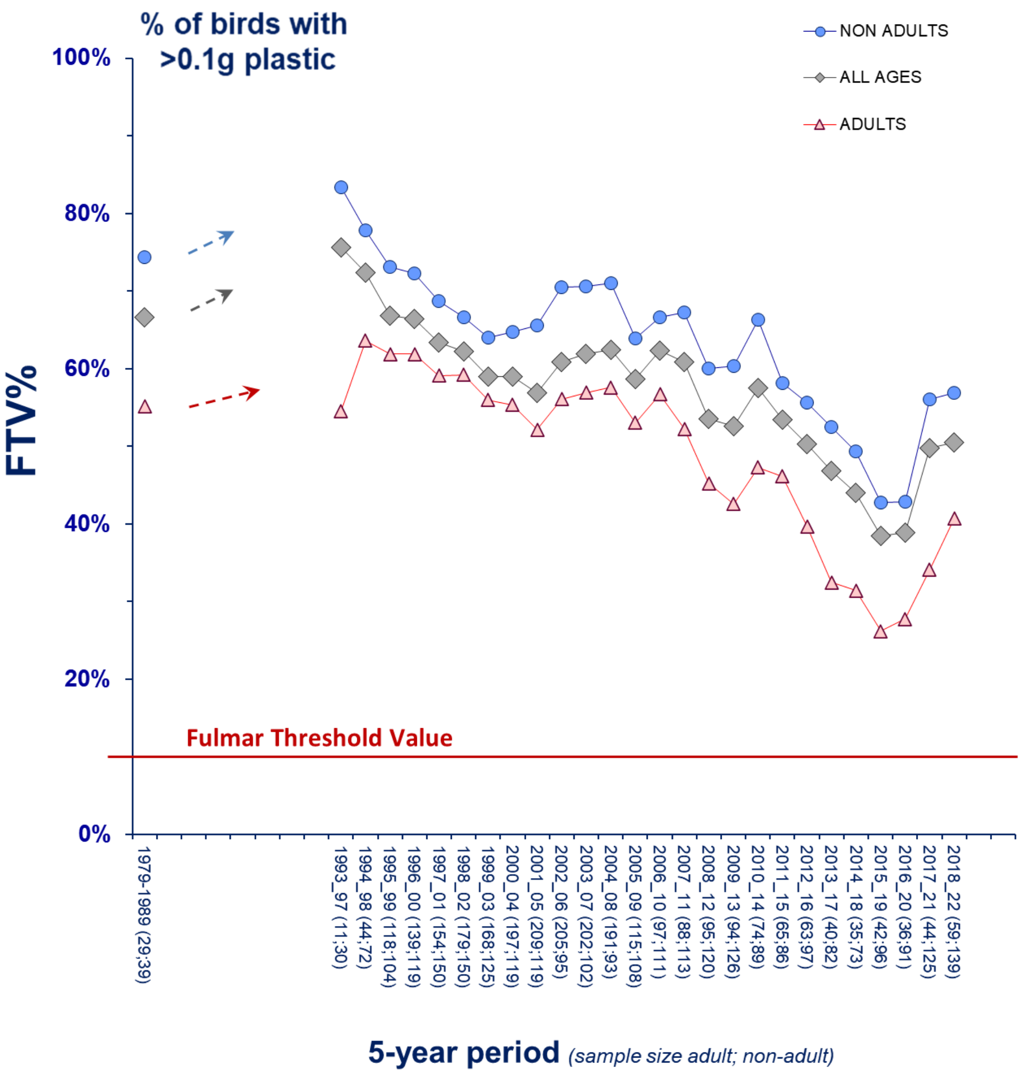


***Figure iii Visualisation of Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2022.*** *Trendlines for all birds combined (grey diamonds, including birds of unknown age), for adult birds (red triangles) and for non-adults (blue circles). This graphic visualization is based on a single data-point for the 1980s and overlapping running 5-year averages in later periods. Periods with less than 10 birds in the sample during the late 1980's and early 1990s are not shown in the graph. This visualization in itself does not represent a statistical trend analysis*

It is difficult to pinpoint specific events that may have triggered increases in ingested plastics from the 1980s into the 1990s, subsequent decreases and the very recent increase. Different trends for industrial plastics and consumer waste further complicate the issue. Since the start of the Save the North Sea project in 2002 and up to 2014, no significant trends were detected in the ingested mass of plastics over 10-year time series. However, starting with 10-year period 2006-2015 an in absolute terms moderate, but statistically significant decrease in ingested plastic mass was observed. This slow change has persisted over later 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 recent 2011-2020 period already showed a less prominent significant reduction in combined plastic mass, the periods 2012-2021 and 2013-2022 were not significant anymore.

**MAIN POINTS**

1. North Sea governments and the EU aim at a long-term threshold value in which for at least 5 consecutive years, the proportion of fulmars with more than 0.1 gram of plastic in the stomach (FTV%) remains under 10%.

2. Over the 5-year period 2018-2022, among 212 fulmars beached in the Netherlands, the FTV% was 50%. In this period, 95% of fulmars had ingested some plastic, with an average over all birds of 23.5 particles per stomach, weighing 0.26 gram.

3. After an unusual year 2021 with high plastic abundances in fulmars, the year 2022 shows slightly less average plastic mass than 2021. However, the linear regression trend of the mass data over the recent 10 years 2013-2022 indicates no significant change.

4. Logistic trend analyses of annual FTV% over the longer period 2002-2022 do still indicate a significant overall decrease since 2002 and suggest that the Fulmar Threshold-Value may be reached in the year 2074. This is 8 years later than the previous prediction (2002-2021; to be reached in 2066) and reflects increased ingested plastic mass in the years 2020 and 2021 in comparison to low values observed earlier.

5. The model prediction of expected FTV compliance in 2074 is not based on a status-quo, but on the current rate of change, which is assumed to reflect intensified (national and regional) policy measures and improved awareness and behaviour. This implies that the predicted future change will require further policy measures and further changes in stakeholder awareness and behaviour. Without extra effort, it is unlikely that the Fulmar Threshold Value will be reached in the predicted time period.

6. It is not possible to pinpoint single clear causes for the observed changes. Gradual improvement since the early 2000s may be linked to media attention for oceanic garbage patches and plastic soup. Increased awareness among all stakeholders may slowly lead to gradually improved policy measures and implementation by marine industries and general public. The 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 2018-2022, 25% of the birds had ingested paraffin-like substances, with an average mass of 1.6 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 2074. Within 10-year evaluation periods the trend is not consistent and showed no significant change over the most recent 2013-2022 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). A growing body of literature reports mechanic effects or lesions to organs associated with plastic uptake. For example Rivers-Auty et al. (2023) and Charlton-Howard et al. (2023) report inflammatory response in seabird organs that were in contact with ingested plastics. Plastics may also impact the gut microbiome of northern fulmars (*Fulmarus glacialis*) and Cory's shearwaters (*Calonectris borealis*) as shown by Fackelmann et al. (2023). Leaching of toxic additives from ingested plastics to seabirds has been shown by Tanaka et al. (2013, 2015, 2019, 2020), Yamashita et al. (2018), Kühn et al. (2020a) and 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; Sørensen et al. 2020). Thus, in addition to the toxic substances incorporated into plastics in the manufacturing process, plastics may concentrate pollutants from the environment and act as a pathway adding to their accumulation in marine organisms. Evidently, this same mechanism operates at all levels of organisms and sizes of ingested plastic material, from small zooplankton filter-feeders to large marine birds and mammals. However, it is especially the ingestion of microplastics by small filter-feeders that has emphasized the potential scale and urgency of the problem of marine plastic litter, as it may ultimately affect human food quality and safety as well (Hauser et al. 2015; Hunt et al. 2016).

Concerns have also been expressed for the even smaller particles, those in the nano-size range (<1 μm), which might penetrate into tissues and cells with potential chemical and mechanical damage to e.g. DNA, but presence and impact of these nanometer sized particles 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). Currently, international discussions are underway to prepare a UN Convention that aims at a global reduction of plastics (https://www.unep.org/about-un-environment/inc-plastic-pollution).

Policy initiatives have recognized the need to use quantifiable and measurable aims. Therefore, the North Sea Ministers in the 2002 Bergen Declaration decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQO's) (North Sea Ministerial Conference 2002). For example, the oil pollution situation in the North Sea is measured by the rate of oil-fouling among beached Guillemots (*Uria aalge*) with an EcoQO of less than 10% of beached Guillemots having oil on the plumage (OSPAR 2005). Similarly, as proposed by ICES Working Group on Seabird Ecology (ICES-WGSE 2003), OSPAR decided to use the abundance of plastic in stomachs of seabirds, *in casu* the northern fulmar to measure quality objectives for marine litter (OSPAR 2008, 2009, 2010a, 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. (2022b). 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 also used to promote fulmar work in other areas of the world such as Ireland (Acampora et al. 2016), the Faroe Islands (Van Franeker 2012; Collard et al. 2022a), Iceland (Kühn & Van Franeker 2012; Snaethorsson & Brynjólfsson 2021), Svalbard (Trevail et al. 2015; Collard et al. 2022b; Tulatz et al. 2023), 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; Shugart & Nania 2021) and has been promoted as plastic monitoring species in the Arctic Ocean (AMAP 2021) and the North Pacific (Savoca et al. 2022).
The 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 2018 (Third Intermediate Assessment, Kühn et al. 2022c). 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 2022.
- Continued coordination of the beached fulmar sampling in the Netherlands in 2023.
- 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 its 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 surface pollution levels over a foraging space and time span that avoids bias from local pollution incidents.
- Historical data are available in the form of a Dutch data series since 1982 (one earlier 1979 specimen); and literature is available on other locations and related species worldwide (Van Franeker 1985; Van Franeker & Bell 1988; Kühn & van Franeker 2020).
- Other North Sea species that ingest litter either do not accumulate plastics (they regurgitate indigestible remains); are coastal only and/or find part of their food on land (e.g. *Larus* gulls); ingest litter only incidentally (e.g. North Sea alcids) or are too infrequent in beached bird surveys for the required sample size or spatial coverage (e.g. other tubenoses or kittiwakes *Rissa tridactyla*).

Beached fulmars may have died for a variety of reasons. For some birds, plastic accumulation in the stomach appears to be the direct cause of death, e.g. by plastic sheets blocking food passage. More often the effects of litter ingestion act at sub-lethal levels, except maybe in cases of ingestion of chemical substances. For other birds, fouling of the plumage with oil or other pollutants (Camphuysen 2022), collisions with ships or other structures, drowning in nets, extremely poor weather or food-shortage may have been direct or indirect causes of mortality. For the time being, avian influenza that led to mass mortalities in other seabird species (Camphuysen et al. 2022; Rijks et al. 2022), seems to have been relatively unimportant for the northern fulmar.

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 report.

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

A very important finding of the same pilot study was that no statistical difference was found in litter in the stomach between birds that had slowly starved to death and 'healthy' birds that had died instantly (e.g. because of collision or drowning). This means that our results, which are largely based on beached starved birds, are representative also for the 'average' healthy fulmar living in the southern North Sea.

Only age was found to have an effect on average quantities of ingested litter, adults having less plastic in their stomach than younger birds. Possibly, adults 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.

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 indicated a trend of slow decreases, but a tendency to increases over the past three years.

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

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

The pilot study (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. 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 (OSPAR 2017, 2019 and Kühn et al. 2022c) published three Intermediate Assessments of data up to 2018 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 from 2009 to 2018.

# 3 Materials and Methods

Wageningen Marine Research continues the collection of beached fulmars from Dutch beaches with the assistance of the Dutch Seabird Group (Nederlandse Zeevogelgroep - NZG) through its Working Group on Beached Bird Surveys (Nederlands Stookolieslachtoffer Onderzoek - NSO). Beached fulmars are collected by volunteers along the Dutch coast. These volunteers consist of regular beach-walkers, whereby some of them combine the collection of dead fulmars with the beached bird surveys. These regular beach bird surveys give the opportunity to continuously monitor the amount and species distribution of beached birds and can give early indications of larger bird mortalities (e.g. in Atlantic puffins (*Fratercula arctica*) and common guillemots (*Uria aalge);* Camphuysen 2022). Other beached fulmars are occasionally recorded on waarneming.nl. These birds are then retrieved by volunteers if possible (see Info Box 3). 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 Kühn et al. 2022) and in a peer-reviewed scientific 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 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 while 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.

**Info Box 1: Recognizing items found in fulmar stomachs**

Often the material in fulmar stomachs is too small or too degraded to identify the source. However, in some cases, fulmars ingest recognizable items.


***Photo 2*** *The photo on the left shows the stomach content of fulmar NET-2022-064. This bird was found on the beach of Schouwen and was collected by RTZ Kop van Goeree (via Jaap van der Hiele). This emaciated juvenile female had ingested one sheet-like particle, two threads, five fragments, a rubbery sheet, and a large amount of dark foamed plastics. Thorough rinsing revealed a whitish colour suggesting that these were broken up remains of protective foam netting in which vulnerable fruit (e.g. mangos or papayas) or liquor bottles are sometimes stored.*

*Fulmar nr NET-2022-019 on the right photo was an adult male, found by Mariette Verdaasdonk and collected by Ruud Costers on the Hondsbossche Zeewering. This bird kindly sent a flower to us.*

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

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

<u>Frequency of Occurrence (%FO)</u>
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.

<u>Arithmetic Average</u>
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.

<u>Geometric Mean</u>
Starting with the current report, medians and geometric means were removed from most tables and graphs to simplify the data presentation. Only for Figure 4, the age-dependent plastic mass presentation, the use of geometric means remained convenient. The geometric mean is calculated as the average of logarithmically transformed data values, which is then back calculated to the normal arithmetic equivalent. Logarithmic transformation reduces the role of the higher values, but consequently the geometric mean is usually considerably lower than the arithmetic average for the same data. In mass data for plastics in the fulmar stomachs, geometric means are only about one third to half of the arithmetic averages. Geometric means are useful for comparative purposes between smaller sample sizes, for example when looking at annual data rather than at 5-year-periods. Logarithmic transformation cannot deal with the value zero, and thus the common approach chosen is to add a small value (e.g. 0.001g 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.

<u>Fulmar Threshold Value Performance (FTV%)</u>
For early Dutch reports, the analyses focused on trends in average or mean mass data for different categories. Recently, the former EcoQO was replaced by OSPAR and MSFD (OSPAR 2020, EC 2022), as the Fulmar Threshold Value (Fulmar-TV or FTV). The definition however remained unchanged to the previous OSPAR EcoQO target (van Franeker et al. 2021). 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 report by Kühn et al. (2021), it has been agreed with RWS, that the new terminology is now consistently used within the annual 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 plastics.
Fulmar TV compliance or performance is defined as the percentage of birds in a sample that has 0.1 g or more plastic mass in the stomach (FTV%). The 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 22nd Edition was used for statistical tests. As concluded in the pilot study (Van Franeker & Meijboom 2002) and later reports, statistical trend analysis is conducted using 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 (Van Franeker & Kühn 2018), 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 annual data are therefore 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 2022) 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 2022 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 approach recommended in the OSPAR Guidelines (OSPAR 2015a). That approach has its focus on detailed analyses and statistics of the data on mass of plastics found in individual birds, taking into account the details of different plastic categories (industrial versus user plastics) and the differences between adult and non-adult birds. In addition, a statistical analysis of annual FTV%'s is included, which, if significant, can be used to predict future developments, as the FTV% (former EcoQ%) is the most relevant for policy makers.
The detailed analyses remain essential to properly understand the Fulmar-TV Performance model as a basis for policy decisions. 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 2022

In 2022, the loyal surveyor network collected 76 fulmar corpses, of which 66 were suitable for analysis of the stomach contents. Ten birds did not have a stomach or had an incomplete stomach, and therefore had to be excluded from further analyses. No birds had been treated in a rehabilitation centre for more than three 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 66 fulmars were available for the year 2022. In 2022, seven additional fulmar stomachs from 2021 (of which five individuals with an intact stomach) 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 2022 sample (Table 1A; Table 2) again exceeds the desired annual sample size, which compensates lower samples sizes in some previous years.

Compared to 2021, the results for 2022 (Table 2A) show a similar average mass of plastic in the stomachs (0.0.29±0.11 g). In 2021 an exceptionally high proportion of fulmars exceeded the 0.1 g threshold of plastic in the stomach, however, 2022 is lower (FTV% 48%) and therefore closer to previous years. Out of 66 birds, 62 birds did have plastic in the stomach (94%), and the average fulmar had 18.6 plastic particles. Out of 66 birds, 20% (13 birds) contained paraffin-like material in their stomachs. In 2021, 27% of 71 birds contained paraffin-like substances, but annual data seem to be even more variable in these substances than in plastics (Van Franeker et al. 2019).

## **Info Box 2:** Retrieving ringed Fulmars: valuable additional information

***Photo 3 Ringed fulmar found in February 2023 on the beach of Texel.***

Some northern fulmars are banded with a metal ring around their leg. By marking these birds individually additional data on e.g. origin, age, and distribution can be retrieved. Ringed fulmars are uncommon encounters along the Dutch coast, however in 2022 and 2023 four ringed birds were retrieved for the plastic monitoring program. For this reason, we took a closer look at ringed fulmars found in the Netherlands.

Including these birds, information on fourteen ringed fulmars is available within the fulmar plastic monitoring project. Most fulmars were ringed in the UK, only one individual had a Dutch ring and was found dead in 1982, likely a bird that has been treated in a Dutch rehabilitation facility for oil pollution.

The youngest bird in our dataset was a recently fledged chick of 1.5 months old, found in 1997 while the oldest bird was 42 years old, also the oldest record for the Netherlands. This bird was ringed in 1980 on the Orkney Islands and was found dead in 's Gravenzande by Bianca Tiegelaar in September 2022 (Photo 4). The second bird of 2022 was found by Ruud Costers on the Hondsbossche Zeewering in January (Costers 2022). This bird was ringed in 2012 on the Orkney Islands (9.5 years). In 2023, one ringed fulmar was found in February on the beach of Texel by Pascalle Jacobs (Photo 3). This bird was ringed as chick 20 years before in July 2003, in the Firth of Fourth (UK). Another bird found on Ameland in February 2023 was collected by Johan Krol. The bird was ringed as chick on the Orkney Islands in 2002.

In the Netherlands within the last decades many more ringed fulmars were found, but not collected for plastic monitoring. An interactive map of all rings retrieved in the Netherlands can be found here: https://www.vogeltrekatlas.nl/advanced.html?filter1=alles&filter2=alles. Unfortunately this map does not allow deeper analysis of the underlying data. As in the fulmar plastic monitoring data, most birds had rings from the UK.


***Photo 4 Bianca Tiegelaar (photo right) found this ringed fulmar in 2022 in 's Gravenzande.*** *The picture shows the bird after the stomach was removed during the dissection.*

## 4.2 Current levels for the Netherlands (2018-2022)

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 (2018-2022) (Table 1B, Table 3), in a sample of 212 birds, 50% of stomachs contained more than 0.1 g plastic (FTV%). This number is similar to the previous period, but higher than earlier running 5-year averages (e.g. 2016-2020: 39%) and therefore the achievement of the OSPAR/MSFD long-term target remains far away.

In the 2018-2022 sample, 95% of fulmars contained some plastic which is the same value as in the previous period (2017-2021). The average number of particles was 23.5 plastic particles per stomach, weighing 0.29 gram. Industrial plastics were rare compared to consumer debris plastics.

In the period of 2018-2022, 25% of the birds had paraffin-like substances, on average 1.6 gram per bird. The mass remains high, 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 about the consequences of the ingestion of either paraffin or natural fatty substances for the organism. Chemicals added during production or cleaning of ship tanks may be harmful and sometimes the pure volume or mass of the substances may block the stomach or diminish its functioning, however evidence for the harmfulness is currently lacking. Aesthetical and economic effects have been recorded by KIMO (2017) and calculated that 91 reported spills between 2012 and 2019 in the North Sea have caused costs of 1.4 million Euro, with a high uncertainty regarding all unnoticed smaller spills.

In 2022, a German report was published, summarizing the results of several approaches to monitor paraffin-like substances in the German part of the North and Baltic Sea (Dau et al. 2022). The authors conclude that a mixture of different methods should be combined, including systematic records of larger accidents/spills, central documentation of smaller spills, structural monitoring of material on the water surface and on beaches and also monitoring the occurrence in fulmar stomachs. In the most recent available 5-year period (2015-2019), 20% of 117 fulmars had some paraffin-like substances ingested, with an average mass of 0.19 gram (Kühn & Van Franeker 2022). These numbers are very similar to those in the Netherlands during the same period (20% of 148 birds, average mass 1.15 gram).

***Table 1 Summary of sample characteristics and stomach contents of fulmars collected for Dutch marine litter monitoring in A) the year 2022 and B) the current 5-year period 2018-2022.*** *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.*

**Table 1A**

| The Netherlands | nr of birds | % adult | % male | % LL colour | death oil | avg condition |
|---|---|---|---|---|---|---|
| **2022** | **66** | **39%** | **48%** | **94%** | **2%** | **2.4** |

| | | incidence | average number of items (n/bird) ± se | average mass of litter (g/bird) ± se | max. mass recorded |
|---|---|---|---|---|---|
| **1** | **ALL PLASTICS** | **94%** | **18.6 ± 4.177** | **0.293 ± 0.110** | **7.1** |
| **1.1** | **INDUSTRIAL PLASTIC** | **42%** | **1.1 ± 0.254** | **0.026 ± 0.005** | **0.2** |
| **1.2** | **USER PLASTIC** | **94%** | **17.6 ± 3.999** | **0.268 ± 0.109** | **7.1** |
| 1.2.1 | sheets | 36% | 2.0 ± 0.921 | 0.011 ± 0.007 | 0.4 |
| 1.2.2 | threads | 39% | 1.2 ± 0.264 | 0.006 ± 0.002 | 0.1 |
| 1.2.3 | foamed | 47% | 3.7 ± 1.585 | 0.012 ± 0.005 | 0.3 |
| 1.2.4 | fragments | 88% | 10.5 ± 2.689 | 0.195 ± 0.102 | 6.7 |
| 1.2.5 | other plastic | 18% | 0.2 ± 0.059 | 0.045 ± 0.020 | 0.9 |
| **2** | **OTHER RUBBISH** | **17%** | **0.7 ± 0.546** | **0.009 ± 0.005** | **0.3** |
| 2.1 | paper | 0% | 0.0 ± 0.000 | 0.000 ± 0.000 | 0.0 |
| 2.2 | kitchenwaste (food) | 11% | 0.1 ± 0.052 | 0.005 ± 0.004 | 0.3 |
| 2.3 | rubbish various | 6% | 0.6 ± 0.545 | 0.004 ± 0.003 | 0.2 |
| 2.4 | fishhook | 0% | 0.0 ± 0.000 | 0.000 ± 0.000 | 0.0 |
| **3** | **POLLUTANTS** | **26%** | **0.7 ± 0.294** | **0.489 ± 0.313** | **17.0** |
| 3.3 | paraffin-like substances | 20% | 0.3 ± 0.079 | 0.486 ± 0.313 | 17.0 |

**Table 1B**

| The Netherlands | nr of birds | % adult | % male | % LL colour | death oil | avg condition |
|---|---|---|---|---|---|---|
| **2018_22** | **212** | **30%** | **47%** | **91%** | **0%** | **2.0** |

| | | incidence | average number of items (n/bird) ± se | average mass of litter (g/bird) ± se | max. mass recorded |
|---|---|---|---|---|---|
| **1.0** | **ALL PLASTICS** | **95%** | **23.5 ± 3.176** | **0.258 ± 0.044** | **7.1** |
| **1.1** | **INDUSTRIAL PLASTIC** | **51%** | **1.6 ± 0.300** | **0.037 ± 0.006** | **1.0** |
| **1.2** | **USER PLASTIC** | **94%** | **21.9 ± 2.970** | **0.221 ± 0.042** | **7.1** |
| 1.2.1 | sheets | 53% | 2.7 ± 0.592 | 0.009 ± 0.002 | 0.4 |
| 1.2.2 | threads | 40% | 1.3 ± 0.191 | 0.006 ± 0.001 | 0.1 |
| 1.2.3 | foamed | 50% | 4.0 ± 0.691 | 0.013 ± 0.003 | 0.3 |
| 1.2.4 | fragments | 88% | 13.3 ± 1.981 | 0.150 ± 0.035 | 6.7 |
| 1.2.5 | other plastic | 25% | 0.6 ± 0.273 | 0.044 ± 0.014 | 2.3 |
| **2.0** | **OTHER RUBBISH** | **22%** | **1.0 ± 0.312** | **0.020 ± 0.007** | **1.3** |
| 2.1 | paper | 2% | 0.2 ± 0.113 | 0.001 ± 0.001 | 0.2 |
| 2.2 | kitchenwaste (food) | 16% | 0.6 ± 0.236 | 0.014 ± 0.007 | 1.3 |
| 2.3 | rubbish various | 7% | 0.3 ± 0.171 | 0.005 ± 0.002 | 0.4 |
| 2.4 | fishhook | 0% | 0.0 ± 0.000 | 0.000 ± 0.000 | 0.0 |
| **3.0** | **POLLUTANTS** | **32%** | **2.5 ± 1.070** | **1.646 ± 0.603** | **70.0** |
| 3.3 | paraffin-like substances | 25% | 1.9 ± 1.017 | 1.641 ± 0.603 | 70.0 |

***Table 2*** ***Annual details for plastic abundance in fulmars from the Netherlands in the period 1979-2022. 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. FTV% shows 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 printed in bold).*

**Table 2A**

| Netherlands | | | Total plastics | | | | | |
|---|---|---|---|---|---|---|---|---|
| YEAR | *sample n* | *(% ad)* | %FO | average number n | ± se | average mass g | ± se | FTV% (over 0.1 g) |
| 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** | **89%** |
| **1984** | ***20*** | *(40%)* | **90%** | **17.9** | **± 5.5** | **0.35** | **± 0.13** | **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** | **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** | **84%** |
| **1998** | ***75*** | *(44%)* | **95%** | **28.6** | **± 5.2** | **0.94** | **± 0.35** | **71%** |
| **1999** | ***107*** | *(70%)* | **98%** | **35.3** | **± 6.2** | **0.44** | **± 0.11** | **61%** |
| **2000** | ***38*** | *(58%)* | **100%** | **22.0** | **± 5.2** | **0.35** | **± 0.13** | **61%** |
| **2001** | ***55*** | *(37%)* | **96%** | **22.7** | **± 4.2** | **0.24** | **± 0.05** | **49%** |
| **2002** | ***56*** | *(54%)* | **98%** | **51.8** | **± 12.5** | **0.50** | **± 0.20** | **68%** |
| **2003** | ***39*** | *(56%)* | **95%** | **28.5** | **± 7.2** | **0.17** | **± 0.03** | **54%** |
| **2004** | ***131*** | *(80%)* | **91%** | **23.4** | **± 3.0** | **0.27** | **± 0.04** | **60%** |
| **2005** | ***51*** | *(68%)* | **98%** | **17.8** | **± 2.8** | **0.27** | **± 0.06** | **47%** |
| **2006** | ***27*** | *(62%)* | **93%** | **33.9** | **± 7.6** | **0.30** | **± 0.08** | **85%** |
| **2007** | ***64*** | *(45%)* | **92%** | **35.9** | **± 5.5** | **0.37** | **± 0.05** | **72%** |
| **2008** | ***20*** | *(58%)* | **95%** | **44.5** | **± 12.3** | **0.31** | **± 0.10** | **55%** |
| **2009** | ***68*** | *(40%)* | **97%** | **19.3** | **± 3.6** | **0.22** | **± 0.04** | **46%** |
| **2010** | ***36*** | *(46%)* | **94%** | **56.4** | **± 16.3** | **0.46** | **± 0.20** | **64%** |
| **2011** | ***19*** | *(37%)* | **100%** | **43.6** | **± 13.1** | **0.43** | **± 0.19** | **79%** |
| **2012** | ***81*** | *(46%)* | **90%** | **20.6** | **± 3.4** | **0.30** | **± 0.09** | **49%** |
| **2013** | ***24*** | *(42%)* | **92%** | **26.8** | **± 8.3** | **0.18** | **± 0.04** | **46%** |
| **2014** | ***12*** | *(64%)* | **100%** | **21.4** | **± 3.9** | **0.36** | **± 0.14** | **83%** |
| **2015** | ***23*** | *(30%)* | **96%** | **12.1** | **± 3.2** | **0.26** | **± 0.15** | **39%** |
| **2016** | ***31*** | *(18%)* | **87%** | **31.7** | **± 12.9** | **0.29** | **± 0.10** | **52%** |
| **2017** | ***38*** | *(31%)* | **92%** | **26.8** | **± 14.1** | **0.24** | **± 0.07** | **37%** |
| **2018** | ***12*** | *(50%)* | **100%** | **15.8** | **± 7.8** | **0.12** | **± 0.06** | **17%** |
| **2019** | ***44*** | *(34%)* | **95%** | **11.4** | **± 2.2** | **0.09** | **± 0.02** | **36%** |
| **2020** | ***14*** | *(8%)* | **93%** | **30.9** | **± 18.9** | **0.42** | **± 0.30** | **43%** |
| **2021** | ***76*** | *(20%)* | **95%** | **34.7** | **± 6.9** | **0.32** | **± 0.06** | **67%** |
| **2022** | ***66*** | *(39%)* | **94%** | **18.6** | **± 4.2** | **0.29** | **± 0.11** | **48%** |

**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** | ***76*** | **63%** | **2.2 ±0.6** | **0.05 ±0.01** | **93%** | **32.5 ±6.6** | **0.27 ±0.05** |
| **2022** | ***66*** | **42%** | **1.1 ±0.3** | **0.03 ±0.01** | **94%** | **17.6 ±4.0** | **0.27 ±0.11** |

***Table 3*** **Running averages by 5-year period for plastic abundance in fulmars from the Netherlands in the period 1979-2022.** *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. FTV% shows 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.*

**Table 3A**

| Netherlands | | | Total plastics | | | | | |
|---|---|---|---|---|---|---|---|---|
| YEAR | *sample n* | *(% ad)* | %FO | average number n ± se | | average mass g ± se | | FTV% (over 0.1g) |
| 1979-89 | *70* | *(43%)* | 91% | 14.4 | ± 2.0 | 0.34 | ± 0.06 | 67% |
| 1990_94 | *1* | | | | | | | |
| 1991_95 | *3* | | | | | | | |
| 1992_96 | *10* | | | | | | | |
| 1993_97 | *41* | *(27%)* | 98% | 32.6 | ± 6.1 | 0.61 | ± 0.13 | 76% |
| 1994_98 | *116* | *(38%)* | 96% | 30.0 | ± 4.0 | 0.82 | ± 0.23 | 72% |
| 1995_99 | *223* | *(53%)* | 97% | 32.5 | ± 3.6 | 0.64 | ± 0.13 | 67% |
| 1996_00 | *259* | *(54%)* | 97% | 31.2 | ± 3.2 | 0.60 | ± 0.12 | 66% |
| 1997_01 | *306* | *(51%)* | 97% | 29.8 | ± 2.8 | 0.54 | ± 0.10 | 63% |
| 1998_02 | *331* | *(54%)* | 97% | 32.9 | ± 3.3 | 0.52 | ± 0.10 | 62% |
| 1999_03 | *295* | *(57%)* | 98% | 33.5 | ± 3.6 | 0.37 | ± 0.06 | 59% |
| 2000_04 | *319* | *(62%)* | 95% | 28.7 | ± 2.9 | 0.30 | ± 0.04 | 59% |
| 2001_05 | *332* | *(64%)* | 95% | 27.8 | ± 2.7 | 0.29 | ± 0.04 | 57% |
| 2002_06 | *304* | *(68%)* | 94% | 29.3 | ± 3.0 | 0.30 | ± 0.04 | 61% |
| 2003_07 | *312* | *(66%)* | 93% | 26.6 | ± 2.1 | 0.28 | ± 0.02 | 62% |
| 2004_08 | *293* | *(67%)* | 93% | 27.6 | ± 2.2 | 0.30 | ± 0.03 | 62% |
| 2005_09 | *230* | *(52%)* | 95% | 27.5 | ± 2.5 | 0.29 | ± 0.03 | 59% |
| 2006_10 | *215* | *(47%)* | 94% | 34.6 | ± 3.8 | 0.32 | ± 0.04 | 62% |
| 2007_11 | *207* | *(44%)* | 95% | 35.6 | ± 4.0 | 0.34 | ± 0.04 | 61% |
| 2008_12 | *224* | *(44%)* | 94% | 30.0 | ± 3.6 | 0.31 | ± 0.05 | 54% |
| 2009_13 | *228* | *(43%)* | 94% | 28.4 | ± 3.4 | 0.30 | ± 0.05 | 53% |
| 2010_14 | *172* | *(45%)* | 93% | 31.5 | ± 4.3 | 0.34 | ± 0.06 | 58% |
| 2011_15 | *159* | *(43%)* | 93% | 23.1 | ± 2.8 | 0.30 | ± 0.05 | 53% |
| 2012_16 | *171* | *(39%)* | 91% | 22.4 | ± 3.1 | 0.28 | ± 0.05 | 50% |
| 2013_17 | *128* | *(33%)* | 92% | 24.9 | ± 5.5 | 0.26 | ± 0.04 | 47% |
| 2014_18 | *116* | *(32%)* | 93% | 23.5 | ± 5.9 | 0.26 | ± 0.05 | 44% |
| 2015_19 | *148* | *(30%)* | 93% | 20.1 | ± 4.6 | 0.20 | ± 0.04 | 39% |
| 2016_20 | *139* | *(28%)* | 93% | 22.5 | ± 5.2 | 0.21 | ± 0.04 | 39% |
| 2017_21 | *184* | *(27%)* | 95% | 26.0 | ± 4.4 | 0.24 | ± 0.04 | 48% |
| 2018_22 | *212* | *(30%)* | 95% | 23.5 | ± 3.2 | 0.26 | ± 0.04 | 50% |

**Table 3B**

| 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** | *184* | 51% | 1.8 | ± 0.4 | 0.04 | ± 0.01 | 94% | 24.2 | ± 4.2 | 0.20 | ± 0.03 |
| **2018_22** | *212* | 51% | 1.6 | ± 0.3 | 0.04 | ± 0.01 | 94% | 21.9 | ± 3.0 | 0.22 | ± 0.04 |

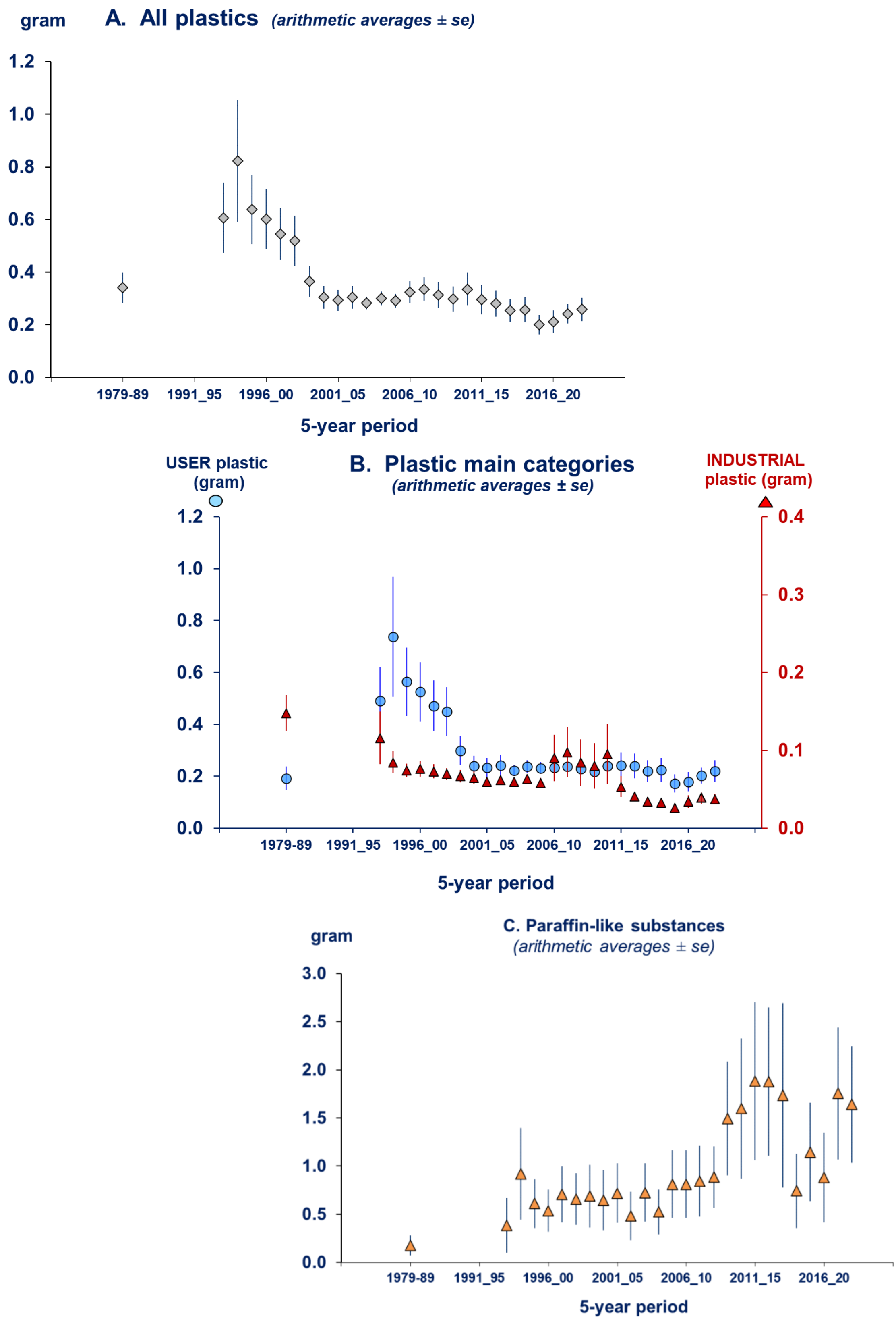


**Figure 2** ***Plastic and paraffin-like substance mass in stomachs of fulmars from the Netherlands in the period 1979-2022.*** *Shown by 5-year running averages, except all data combined for the early period 1979-1989. Data only shown where sample size over 40 stomachs. A: Data for all plastics combined visualising changes in arithmetic average mass ± SE. B: Arithmetic mass data, split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis). Please note the different scales for user and industrial plastics. C: Arithmetic mass ± 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 3: Additional birds from www.waarneming.nl**
In the Netherlands, live and dead bird observations can be recorded at the digital platform www.waarneming.nl (international version: www.observation.org). The program also alerts on certain records, such as 'dead fulmar' and therefore is a valuable source of information for us to survey beached fulmars and, if applicable, contact the finders.
Several dead fulmars were recorded in 2022, not all of them were suitable for our monitoring program (e.g. clearly scavenged, or at a place where storage was impossible). The picture below shows a typical example of a dead fulmar record from January 2023 with clear pictures of the specimen (well visible that the bird was intact) and a note written by the finder Jorg Schagen that this bird was collected for the plastic monitoring scheme ('meegenomen WMR').
It is also an important way to contact people not aware of the fulmar monitoring program, in order to collect birds in the future. Waarneming.nl contributed considerably to the increased numbers of dead fulmars collected in recent years. Therefore we want to thank the program builders and all people recording their finds online.

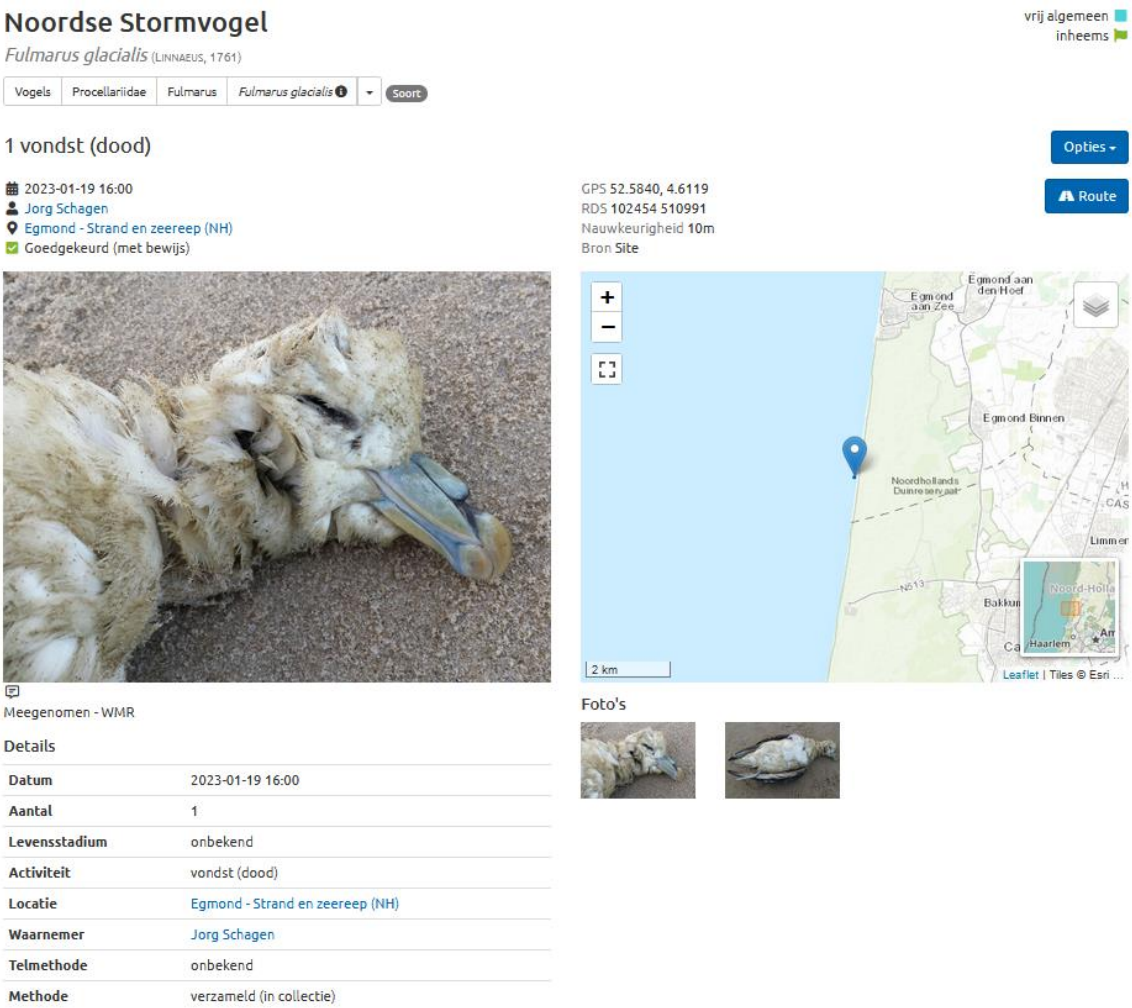


***Photo 5*** ***Screenshot of a reported dead fulmar on www.waarneming.nl****. See original observation here: https://waarneming.nl/observation/262351248/*

## 4.3 Trends

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

### 4.3.1 Long-term trends

The **'long-term trend'** is defined as the trend over all years in the dataset (now 1979-2022). The current dataset holds records for 1319 fulmars, with 615 adult birds and 663 non-adults, which are juveniles to immatures several years of age. For 41 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 44 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 being non-significant.
Trends in different age groups (adults/non-adults) are decreasing similarly in industrial plastics. For user plastics the mass is decreasing in both adults and non-adults, but for the non-adults the decrease is less prominent. For all plastics combined, the opposite is the case: Although total plastic mass is decreasing significantly, it is the adults where the decrease is less obvious. Nevertheless, combined for industrial and user plastics the trend is a highly significant decrease ($p<0.001$) over the entire sampling period.

### 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: 2013-2022 (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 strength of the 10-year trends has 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 (2013-2022) the signs of the regression slopes have even reverted suggesting a potential although non-significant increase ($p=0.440$) of user and industrial plastics combined. This is also true for user plastics and for adults and non-adults respectively. This change is driven by an increase in user plastic mass ingested by fulmars since 2020(Table 4C).

The 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 show a strongly significant decrease over the 2002-2022 period ($p<.001$), also for separate age groups. User plastics do not show a significant decline ($p=0.24$) anymore. However, combined for all plastics and both age groups, the 2002-2022 decrease is still significant ($p=0.042$).

**Table 4 *Details of linear regression analyses for time related trends in plastic abundance by mass in stomachs of fulmars in the Netherlands.*** *Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over A. full time period of data, B. the period since start of the Save the North Sea project in 2002, and C. the most recent 10 years of data, which is the recommended period in OSPAR guidelines for testing in the Fulmar-TV. D. significance of sequential decadal trends for 1980s and 10-year periods starting 1997. The regression line ('trend') is described by y = 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 1979-2022***
**for plastics in Fulmar stomachs, the Netherlands**

| Industrial plastics (lnGIND) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *1319* | 83.2 | -0.0437 | 0.0064 | -6.81 | <.001 | ↓ - - - |
| adults | *615* | 84.6 | -0.0446 | 0.0107 | -4.15 | <.001 | ↓ - - - |
| non adults | *663* | 96.4 | -0.0501 | 0.0083 | -6.07 | <.001 | ↓ - - - |

| User plastics (lnGUSE) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *1319* | 8.7 | -0.0057 | 0.0056 | -1.01 | 0.315 | *n.s.* |
| adults | *615* | 28.2 | -0.0155 | 0.0098 | -1.58 | 0.115 | *n.s.* |
| non adults | *663* | 3.7 | -0.0031 | 0.0069 | -0.44 | 0.660 | *n.s.* |

| All plastics combined (lnGPLA) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *1319* | 39.2 | -0.0207 | 0.0055 | -3.75 | <.001 | ↓ - - - |
| adults | *615* | 47.0 | -0.0247 | 0.0097 | -2.54 | 0.011 | ↓ - |
| non adults | *663* | 43.2 | -0.0226 | 0.0066 | -3.41 | <.001 | ↓ - - - |

| SUSPECTED CHEMICALS (lnGCHE) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *1319* | -16.9 | 0.0055 | 0.0074 | 0.75 | 0.452 | *n.s.* |
| adults | *615* | 8.3 | -0.0071 | 0.0117 | -0.61 | 0.545 | *n.s.* |
| non adults | *663* | -31.9 | 0.0130 | 0.0101 | 1.29 | 0.198 | *n.s.* |

**B.**

***TRENDS 2002-2022 since start SNS project***
**for plastics in Fulmar stomachs, the Netherlands**

| Industrial plastics (lnGIND) | *n* | Constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *932* | 72.7 | -0.0385 | 0.0106 | -3.62 | <.001 | ↓ - - - |
| adults | *426* | 102.1 | -0.0532 | 0.0168 | -3.17 | 0.002 | ↓ - - |
| non adults | *469* | 91.7 | -0.0478 | 0.0152 | -3.15 | 0.002 | ↓ - - |

| User plastics (lnGUSE) | *n* | Constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *932* | 19.3 | -0.0110 | 0.0093 | -1.18 | 0.240 | *n.s.* |
| adults | *426* | 47.4 | -0.0251 | 0.0158 | -1.58 | 0.114 | *n.s.* |
| non adults | *469* | 33.7 | -0.0180 | 0.0123 | -1.46 | 0.144 | *n.s.* |

| All plastics combined (lnGPLA) | *n* | Constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *932* | 35.4 | -0.0188 | 0.0093 | -2.03 | 0.042 | ↓ - |
| adults | *426* | 62.5 | -0.0325 | 0.0157 | -2.07 | 0.040 | ↓ - |
| non adults | *469* | 50.6 | -0.0262 | 0.0121 | -2.16 | 0.031 | ↓ - |

| SUSPECTED CHEMICALS (lnGCHE) | *n* | Constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *932* | -16.6 | 0.0054 | 0.0123 | 0.43 | 0.665 | *n.s.* |
| adults | *426* | -4.8 | -0.0006 | 0.0174 | -0.03 | 0.973 | *n.s.* |
| non adults | *469* | -11.7 | 0.0030 | 0.0194 | 0.15 | 0.879 | *n.s.* |

## C. *RECENT 10-YEAR TRENDS 2013-2022*

**for plastics in Fulmar stomachs, the Netherlands**

| Industrial plastics (lnGIND) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *340* | 22.6 | -0.0137 | 0.0380 | -0.36 | 0.719 | *n.s.* |
| adults | *99* | 97.0 | -0.0509 | 0.0599 | -0.85 | 0.398 | *n.s.* |
| non adults | *221* | -38.0 | 0.0165 | 0.0497 | 0.33 | 0.740 | *n.s.* |

| User plastics (lnGUSE) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *340* | -76.2 | 0.0363 | 0.0350 | 1.04 | 0.300 | *n.s.* |
| adults | *99* | -99.0 | 0.0474 | 0.0604 | 0.78 | 0.434 | *n.s.* |
| non adults | *221* | -83.5 | 0.0401 | 0.0437 | 0.92 | 0.360 | *n.s.* |

| All plastics combined (lnGPLA) | *n* | constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| **all ages** | ***340*** | **-57.0** | **0.0269** | **0.0349** | **0.77** | **0.440** | *n.s.* |
| adults | *99* | -65.0 | 0.0307 | 0.0610 | 0.50 | 0.616 | *n.s.* |
| non adults | *221* | -74.6 | 0.0358 | 0.0430 | 0.83 | 0.407 | *n.s.* |

| SUSPECTED CHEMICALS (lnGCHE) | *n* | Constant | slope | s.e. | t | p | |
|---|---|---|---|---|---|---|---|
| all ages | *340* | 20.4 | -0.0130 | 0.0489 | -0.27 | 0.790 | *n.s.* |
| adults | *99* | 66.0 | -0.0355 | 0.0740 | -0.48 | 0.633 | *n.s.* |
| non adults | *221* | 8.0 | -0.0067 | 0.0677 | -0.10 | 0.921 | *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. |
| **2013-2022** | *(340)* | 0.719 | n.s. | 0.300 | n.s. | 0.440 | n.s. |

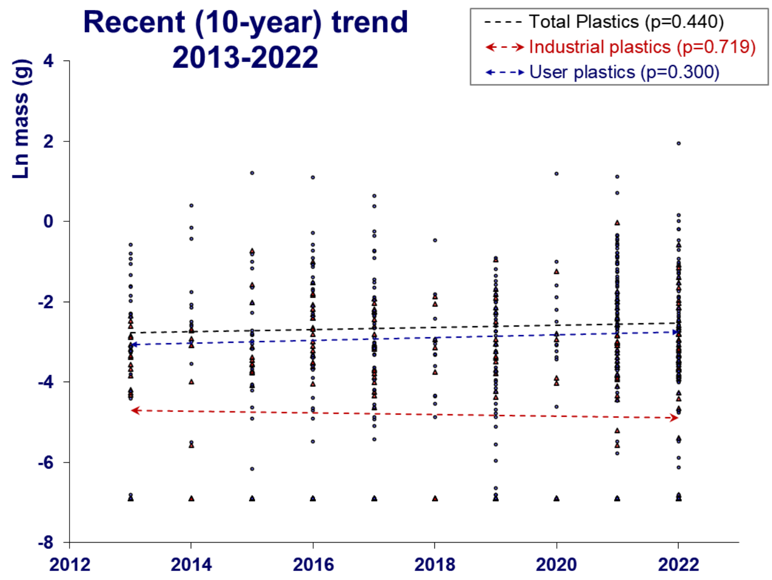


***Figure 3*** ***Statistical trend in plastic mass in stomachs of fulmars from the Netherlands 2013-2022.*** *The graph, as an example of the statistical approach, shows plotted ln-transformed mass data for industrial plastic and user plastic in stomachs of individual fulmars, plotted against year, and linear trendlines for industrial (lower, red line), user (middle blue line) and total plastics (top black line). Full details for results of statistical tests for trends are available in Table 4C. Trendlines are shown as solid line when significant and dashed when non-significant.*

Younger fulmars (the 'non-adult' category which includes first year juveniles, second year birds and immatures up to several years of age), have consistently higher levels of ingested plastics than adult birds. Nevertheless, in Fulmar-TV monitoring, all age groups are combined on the assumption that in the long-term, there will be no major directional change in the age-composition of beached birds. Fig. 4 illustrates age-related variations in our monitoring data: in geometric means, the persistent difference in plastic loads between adults and non-adults is very clear. However, both age groups follow, at a different level, a very similar pattern, which strengthens the validity of the monitoring approach combining data for all birds.

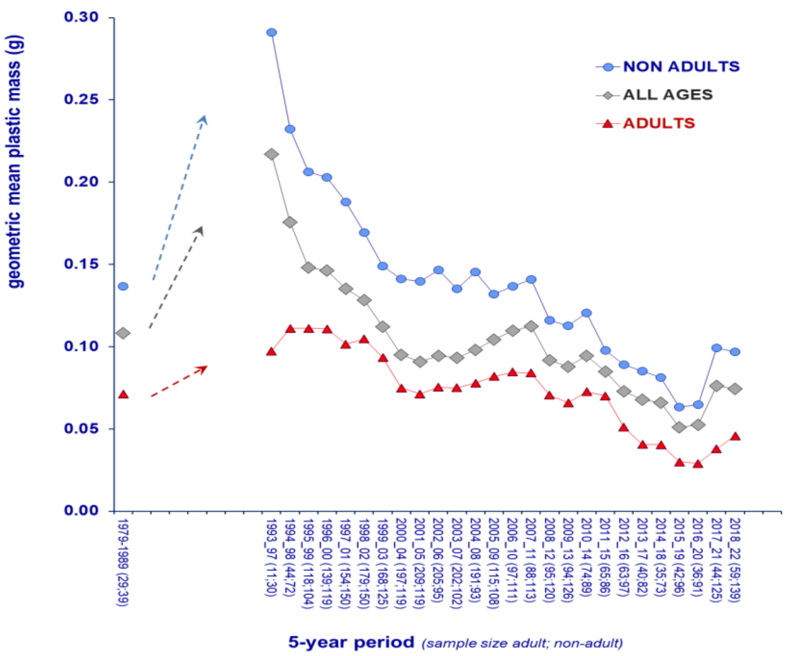


***Figure 4*** ***Geometric mean mass of plastics in stomachs of beached fulmars from the Netherlands 1979-2022*** *for all age groups combined (grey diamonds; including birds of unknown age), adult birds (red triangles) and non-adults (blue circles), with respective sample sizes in brackets in the x-axis labels. 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 Ecological Quality Objective (EcoQ) 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 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 such problems are largely overcome by logarithmic transformation of data. This is a standard statistical procedure. 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 on the long-term, it also emphasizes the distance from the 10% FTV target set by OSPAR. Over the integrated recent 5-year period 2018-2022, 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 39%). The exceptional high plastic mass in 2021 fulmars caused this high value and will likely influence the 5-year periods for the upcoming years.

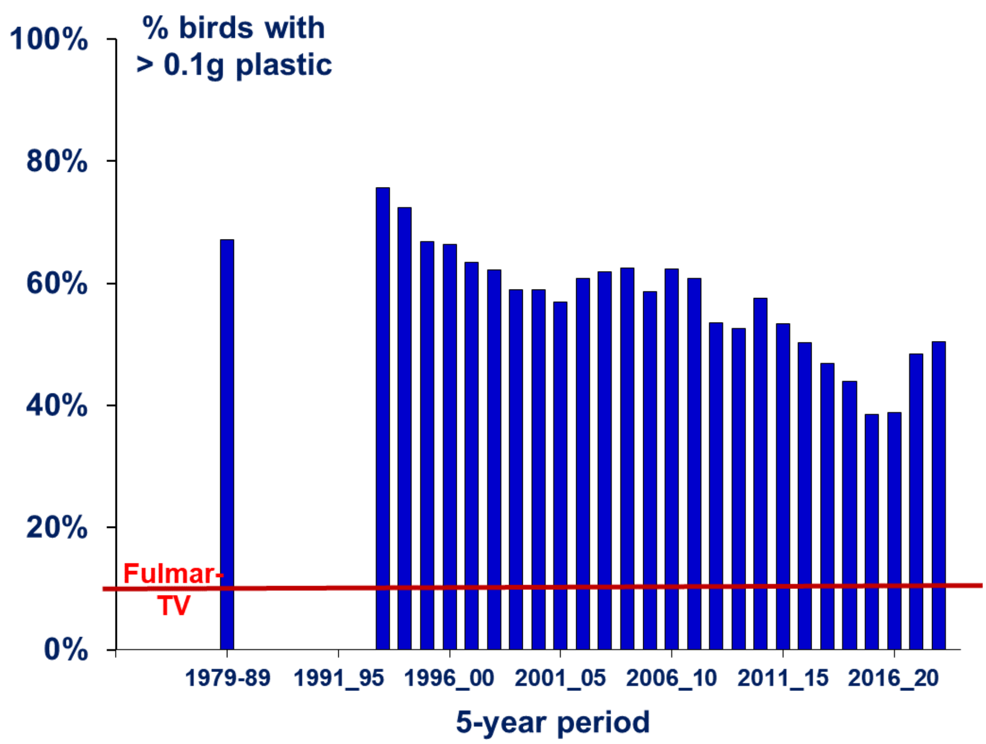


***Figure 5*** ***Fulmar-TV Performance of fulmars in the Netherlands over running 5-year periods up to 2022.*** *Data for the 1980s were combined due to relatively small sample size. The red line illustrates the Fulmar-Threshold Value. This graphic visualization does not represent a statistical trend analysis.*

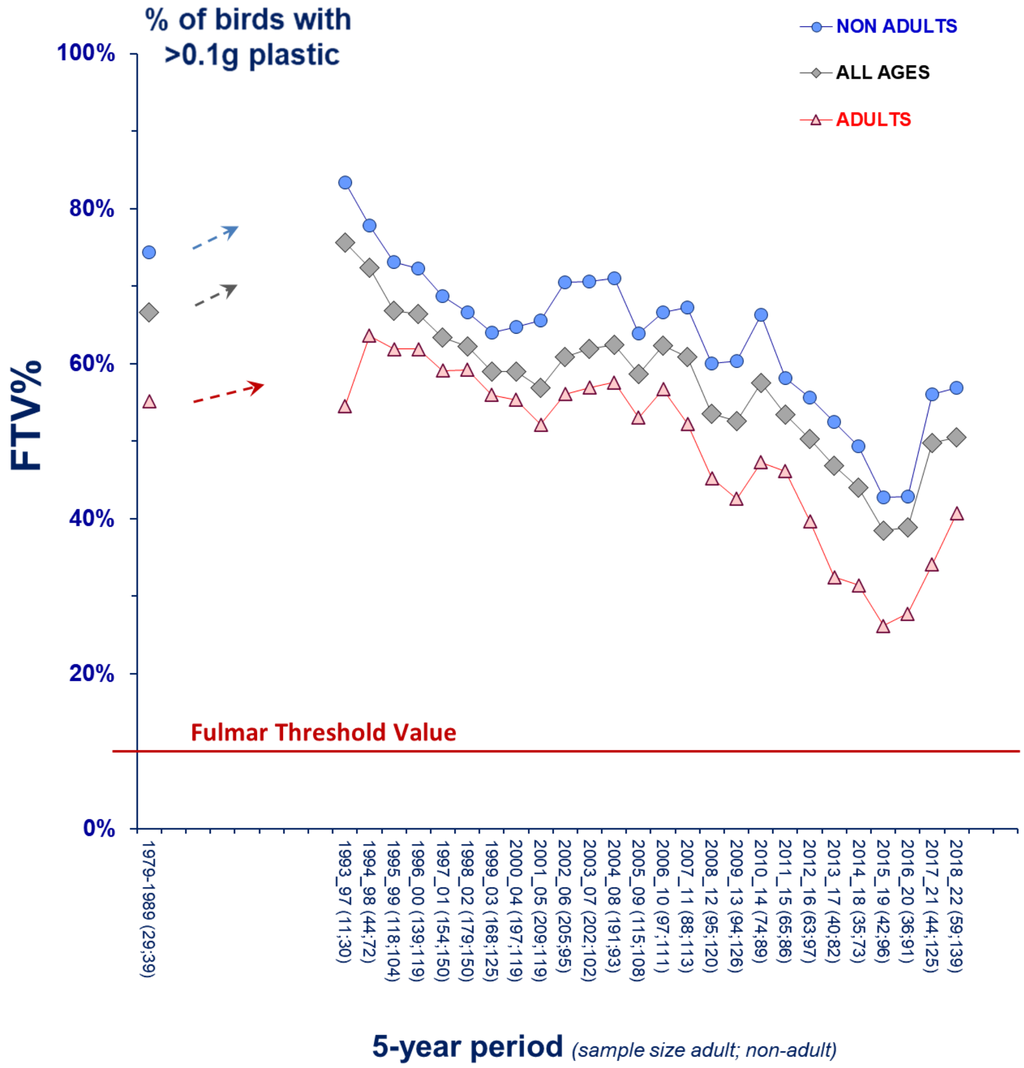


***Figure 6 Trend in Fulmar-TV Performance of different age classes of beached fulmars from the Netherlands 1979-2022.*** *Trendlines for all birds combined (grey diamonds, including birds of unknown age), for adult birds (red triangles) and for non-adults (blue circles). This graphic visualization is 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 logistic 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. 2021). Since 2021, the factor age is included as covariate to this model, as recommended by Van Franeker et al. (2021). The 2021 model predicted 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. The recent data for 2022 imply a further delay in the year when the FTV may be reached. Currently it is predicted that the Fulmar-TV will be reached in the year 2074.

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

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

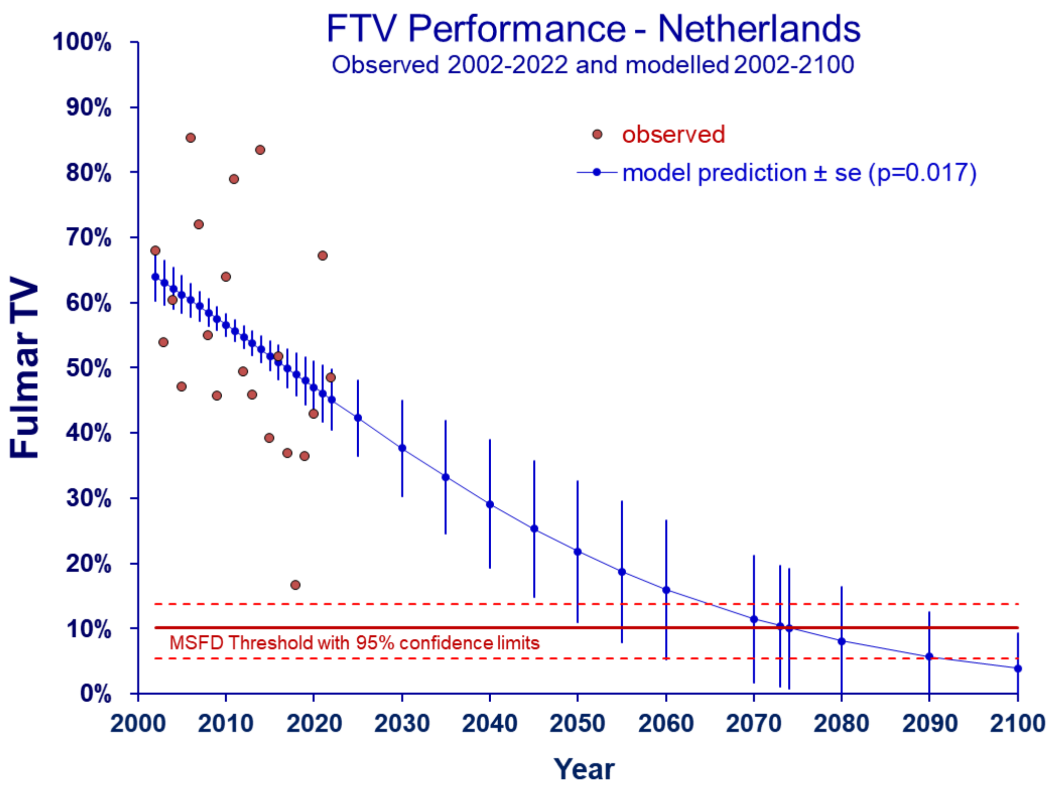


***Figure 7*** ***Predicted trajectory to the OSPAR long-term Fulmar-TV target for plastics ingested by Fulmars in Dutch offshore waters,*** *based on a logistic binomial model from annual Fulmar-TV Performances. This model is based on observed FTV Performance over the 21-year period 2002-2022 (p<0.017) 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 21-year Save the North Sea period 2002-2022 (p<0.017).*** *This table is the source for Figure 7.*

| SOURCE DATA FOR LOGISTIC REGRESSION | | | | | | Modelled and observed proportions of birds having > 0.1g of plastic | | |
|---|---|---|---|---|---|---|---|---|
| YEAR | sample size | nr with over 0.1g plastic | Fulmar TV | proportion adult birds | proportion male birds | Year | model prediction ± se (p=0.017) | observed |
| 2002 | *56* | 38 | 0.68 | 0.54 | 34% | **2002** | **0.640** ± *0.04* | **0.68** |
| 2003 | *39* | 21 | 0.54 | 0.56 | 41% | **2003** | **0.631** ± *0.03* | **0.54** |
| 2004 | *131* | 79 | 0.60 | 0.80 | 22% | **2004** | **0.622** ± *0.03* | **0.60** |
| 2005 | *51* | 24 | 0.47 | 0.68 | 52% | **2005** | **0.613** ± *0.03* | **0.47** |
| 2006 | *27* | 23 | 0.85 | 0.62 | 42% | **2006** | **0.603** ± *0.03* | **0.85** |
| 2007 | *64* | 46 | 0.72 | 0.45 | 47% | **2007** | **0.594** ± *0.02* | **0.72** |
| 2008 | *20* | 11 | 0.55 | 0.58 | 32% | **2008** | **0.585** ± *0.02* | **0.55** |
| 2009 | *68* | 31 | 0.46 | 0.40 | 56% | **2009** | **0.575** ± *0.02* | **0.46** |
| 2010 | *36* | 23 | 0.64 | 0.46 | 56% | **2010** | **0.566** ± *0.02* | **0.64** |
| 2011 | *19* | 15 | 0.79 | 0.37 | 47% | **2011** | **0.557** ± *0.02* | **0.79** |
| 2012 | *81* | 40 | 0.49 | 0.46 | 39% | **2012** | **0.547** ± *0.02* | **0.49** |
| 2013 | *24* | 11 | 0.46 | 0.42 | 42% | **2013** | **0.537** ± *0.02* | **0.46** |
| 2014 | *12* | 10 | 0.83 | 0.64 | 36% | **2014** | **0.528** ± *0.02* | **0.83** |
| 2015 | *23* | 9 | 0.39 | 0.30 | 59% | **2015** | **0.518** ± *0.02* | **0.39** |
| 2016 | *31* | 16 | 0.52 | 0.18 | 43% | **2016** | **0.509** ± *0.03* | **0.52** |
| 2017 | *38* | 14 | 0.37 | 0.31 | 36% | **2017** | **0.499** ± *0.03* | **0.37** |
| 2018 | *12* | 2 | 0.17 | 0.50 | 30% | **2018** | **0.489** ± *0.03* | **0.17** |
| 2019 | *44* | 16 | 0.36 | 0.34 | 57% | **2019** | **0.480** ± *0.04* | **0.36** |
| 2020 | *14* | 6 | 0.43 | 0.08 | 50% | **2020** | **0.470** ± *0.04* | **0.43** |
| 2021 | *76* | 51 | 0.67 | 0.20 | 43% | **2021** | **0.461** ± *0.04* | **0.67** |
| 2022 | *66* | 32 | 0.48 | 0.39 | 48% | **2022** | **0.451** ± *0.05* | **0.48** |
| | | | | | | **2025** | 0.423 ± *0.06* | |
| | | | | | | **2030** | 0.377 ± *0.07* | |
| | | | | | | **2035** | 0.332 ± *0.09* | |
| | | | | | | **2040** | 0.291 ± *0.10* | |
| | | | | | | **2045** | 0.253 ± *0.10* | |
| | | | | | | **2050** | 0.218 ± *0.11* | |
| | | | | | | **2055** | 0.187 ± *0.11* | |
| | | | | | | **2060** | 0.160 ± *0.11* | |
| | | | | | | **2070** | 0.115 ± *0.10* | |
| | | | | | | **2080** | 0.081 ± *0.08* | |
| | | | | | | **2090** | 0.057 ± *0.07* | |
| | | | | | | **2100** | 0.039 ± *0.05* | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | **2073** | **0.1034** ± *0.09* | |
| | | | | | | **2074** | **0.0998** ± *0.09* | |

# 5 Concluding remarks

Although 2022 has not been as extreme as 2021 in terms of plastic mass, the numbers have not yet returned to the low values that were reached before the year 2021 (and to a lesser extent 2020). The sample size was again relatively high with 66 birds collected in 2022, indicating a good reliability of the recent dataset.

In February 2022 several heavy storms were recorded in the North Sea, which may explain why many fulmars (30 out of 66) were collected in February. 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 in February (Camphuysen 2022). The reasons for such influx remain unclear.
To avoid that such occasional high or low sample sizes influence the overall data too much, it has been decided to combine data over several years and to look at different time periods to better understand trends. The necessity of this approach becomes visible in the current dataset. While the recent dataset (10 years; 2013-2022) does not show a significant trend, the strongest decline becomes visible when including the data from 1979. The longer the considered period, the less affected is the data by extreme years.

Policy makers involved in the OSPAR and MSFD process have asked to provide models that might predict plastic ingestion rates by fulmars in future years. Such information could assist in focused planning of actions aiming at reaching policy targets by specific dates.
The considered 2002-2022 time period, shows a significant decrease in terms of birds above the threshold of 0.1 gram plastic in their stomachs. This significance allowed the prediction of future plastic ingestion rate in fulmars. According to the newest data, the Fulmar-TV of less than 10% of the birds having more than 0.1 g of plastic in their stomachs could be reached in 2074, which implies a further delay in comparison with earlier predictions.
It has to be emphasized that a predicted trend of reaching target by a specific year does not imply that no further action is needed. The model prediction is not based on a status-quo, but on the current rate of change. We assume the observed change to be the result of increased policy measures and improved awareness and behaviour. Consequently the predicted future change will require further new policy measures and further changes in awareness and behaviour. Without extra effort, it is unlikely that the FTV target could be reached in the predicted time period.

**CONCLUSION**
**On the longer term, stomach contents of fulmars beached in the Netherlands indicate that the marine litter situation off the Dutch coast 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 2074. Within 10-year evaluation periods the trend is not consistent, and showed no significant change over the most recent decade (2013-2022). Future data must reveal if this reflects a temporary deviation, or a reversal in the longer term trend. It is clear that the further reduction of marine litter is required to reach the Fulmar Threshold Value.**

# 6 Acknowledgements

Fulmar monitoring in the Netherlands is supported financially by the Netherlands Ministry of Infrastructure and Waterways (I&W). The concept an EcoQO based on the abundance of plastics in seabird stomachs was initiated by the ICES Working Group on Seabird Ecology and guided in several workgroups within ICES and OSPAR. The EU Interreg IIIB North Sea program supported the work in the 2002-2004 Save the North Sea project. The work has also been funded by the NYK Group Europe Ltd and Chevron Upstream Europe.
Beached fulmars are mainly collected by volunteers without whom a project such as this is impossible. Below is a list of beach surveyors that contributed to the collection of beached fulmars. If people find that their name or group is listed incorrectly, or worse, not at all, our sincere apologies and please take up contact.

*A van der Spoel, A Varkevisser, Ad van den Berge, Albert van den Ende, Alma de Groot, André Meijboom, Annemarie Mewe, Annet de Willigen, Anthony James, Arjen Dijkstra, Arnold Gronert, Arnoud Heikens, Arnout de Vries, Arthur Oosterbaan, Barend Kuiken, Bart Ebbinge, Ben Brugge, Bert Winters, Bezoekerscentrum Nat. Park Schiermonnikoog, Bianca Tiegelaar, BJ Bulsink, Bob Loos, Boogaart, Bram Fey, Buijtelaar, C Boele, Carl Zuhorn, Carlijn Lammers, CDI Lelystad, Cees Baart, Cees Swennen†, Cees van Hoven, Chris Braat, Chris Winter, Christine Fabricius, CJ de Graaf, Coby Kuiken, Colin Aalbers, Daphna Lavy, De Windbreker Petten, Dick Schermer, Dick Veenendaal, Dierenambulances Den Haag, Dierenambulance IJmuiden/Velsen (Gerrit van Egmond), Dirk Bruin, Dirk Kuiken†, Dirk Moerbeek, Dook Vlugt, ECOMARE, E-Connection, Eddie Douwma, Edward Soldaat†, Elisa Bravo Rebolledo, Ep van Hijum, Esther de Jong, Esther Kraaijenveld, Faunavisie, Floor Arts DPM, Florian Müller, Folkert Janssens, Frank Haven, Frank van den Ende, Frank Willems, Frits-Jan Maas, G Fuchs, GJ Bruin, Guido Keijl, Guus van Duin, H de Groot, H Horn, Hanneke Roeper, Hans Schekkerman, Hans Spoelstra, Hans Verdaat, Hauke Flores, Hein Verkade, Henk Brugge†, Henk Mellema, Henk Sandee, Hidde Batterink, Hidde Kressin, Hondenuitlaatservice/Dienrenambulance Velsen, Huib den Heijer, Ilse Kootkar, Ingrid Tulp, J Alewijn Dijkhuizen, J Appeloo, JT Kuiken, JW Vergeer, Jaap Boersma, Jaap van der Hiele, Jack van Velzen, Jacky Kuiper, Jacob de Vries, Jan den Ouden, Jan F de Jong, Jan Goedbloed, Janne Ouwehand, Jannes Heusinkveld, Jarco Havermans, Jasmijn Hulleman, Jeffrey Huizenga, Jelle van Dijk, Jeroen Reneerkens, Job Schepers, Job ten Horn, Johan Krol, Jorg Schagen, Jurgen Rotteveel, K Boele, K Post, Kees Borrius, Kees Camphuysen, Kees de Graaf, Kees Kooiker, Kees Roselaar, Kees Woutersen, Klaas de Jong, Klaas van Dijk, Kyra Leopold, Lars Gaedicke, Laurens Kikkert, Laurens van Kooten, Leon Kelder, LH Kuiken, M Janssen, Maarten Brugge, Maarten Platteeuw, Maarten Sluijter, Marc Kerkhove, Marc Plomp, Marcel Wijnalda, Marco Bakker, Mardik Leopold, Maria Elisa Hobbelink, Mariëtte Smit, Marijke Barhorst, Marion Mensink, Marjolein Postma, Mark Fonds, Mark van Veen, Martin Baptist, Martin de Jong, Martin Poot, Meinte Engelmoer, Michael Hermse, Mick Pederman, Natuurmonumenten, Nicole Janinhoff, Nina Dieters, Noordwester Vlieland, P Bison, Peter de Boer, Peter Meininger, Peter Quist, Peter Spannenburg, Peter van Horssen, Pierre Bonnet, Piet Zumkehr, Pieter Duin, Pieter van Klaveren, Pim Lollinga, Pim Wolff, REP Maan, Rinus van der Molen, Rob Dekker, Rob Mantel, Rob Strietman, Rob van Bemmelen, Rob Vink, Robert Keizer, Roel Draijer, Roeland Bom, Romke Kats, Ronald Oortwijn, Roy de Hey, RTZ Kop van Goeree, Rutger Rotscheid, Ruud Costers, Ruud van Halewijn, S Smit, Salko de Wolf. Sander Lagerveld, Sanne van den Berg-Blok, Saskia Kipp, SBB Staatsbosbeheer, SC Kipp, Sharon Lexmond, Simon de Vries, Simon Hart, Sophie Brasseur, St Damland Bergen, Stephan Gomes, Stephan Kühn, Sytske Dijksen, T. Pieters, Teun Talsma, Theo Kiewiet, Theo Ruppert, Theunis Piersma, Tim Oortwijn, Tim van Nus, Timo Roskam, Tom van Spanje, Tonny van Kooten, Toon Pop, van Eck, Vogelasiel Bergen, Vogelasiel de Groot, Vogelasiel De Wulp, Vogelasiel Fugelpits, Vogelasiel Zandvoort, Vogelopvang Terschelling, VogelRampenFonds Haarlem, VWG Steenloper, Wandelaar, Wiebe Boomsma, Willem Pompert, Wim de Winter, Wouter Vahl, Y de Jong, Yerko Hankmann, Yvonne Hermes*

# 7 Main acronyms – abbreviations

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

**OSPAR EcoQO = Ecological Quality Objective.**

At the request of ministers of North Sea states in 2002, OSPAR developed a system of measurable targets for environmental/ecological quality in the North Sea and the OSPAR area in general. There is a broad range of EcoQO's for various types of pollution (oil, fouling paints, mercury, organochlorines, litter), 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.

# References


Acampora, H., Lyashevska, O., Van Franeker, J.A., O'Connor, I. 2016. The use of beached bird surveys for marine plastic litter monitoring in Ireland. Marine Environmental Research 120: 122-129. http://dx.doi.org/10.1016/j.marenvres.2016.08.002

AMAP, 2021. AMAP Litter and Microplastics Monitoring Guidelines. Version 1.0., Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway, pp 257 doi https://litterandmicroplastics.amap.no/

Avery-Gomm, S., O'Hara, P.D., Kleine, L., Bowes, V., Wilson, L.K., Barry, K.L. 2012. Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific. Marine Pollution Bulletin 64: 1776-1781. http://dx.doi.org/10.1016/j.marpolbul.2012.04.017

Avery-Gomm, S., Provencher, J.F., Liboiron, M., Poon, F.E., Smith, P.A. 2018. Plastic pollution in the Labrador Sea: An assessment using the seabird northern fulmar *Fulmarus glacialis* as a biological monitoring species. Marine Pollution Bulletin 127: 817-822. https://doi.org/10.1016/j.marpolbul.2017.10.001

Baak, J.E., Provencher, J.F., Mallory, M.L., 2020. Plastic ingestion by four seabird species in the Canadian Arctic: Comparisons across species and time. Marine Pollution Bulletin 158: 11386. https://doi.org/10.1016/j.marpolbul.2020.111386

Baltz, D.M., Morejohn, G.V. 1976. Evidence from seabirds of plastic pollution off central California. Western Birds 7: 111-112. https://www.westernfieldornithologists.org/archive/V07/7(3)%20p0111-p0112.pdf

Beaman, J., Bergeron, C. (Eds.) 2016. State of the Science White Paper – A Summary of Literature on the Chemical Toxicity of Plastics Pollution to Aquatic Life and Aquatic-Dependent Wildlife. EPA-822-R-16-009, United States Environmental Protection Agency, Washington DC, 50pp. https://www.epa.gov/sites/production/files/2017-02/documents/tfw-trash_free_waters_plastics-aquatic-life-report-2016-12.pdf

Blight, L.K., Burger, A.E. 1997. Occurrence of plastic particles in seabirds from the eastern North Pacific. Marine Pollution Bulletin 34: 232-325. https://doi.org/10.1016/S0025-326X(96)00095-1

Bond, A.L., Provencher, J.F., Daoust, P.-Y., Lucas, Z.N. 2014. Plastic ingestion by fulmars and shearwaters at Sable Island, Nova Scotia, Canada. Marine Pollution Bulletin 87: 68-75 http://dx.doi.org/10.1016/j.marpolbul.2014.08.010

Booth, A.M., Hansen, B.H., Frenzel, M., Johnsen, H., Altin, D. 2016. Uptake and toxicity of methylmethacrylate-based nanoplastic particles in aquatic organisms. Environmental Toxicology and Chemistry 35: 1641-1649. http://dx.doi.org/10.1002/etc.3076

Bourne, W.R.P. 1976. Seabirds and Pollution. in: R. Johnston, (Ed.), Marine Pollution. Academic Press, London. pp 403-502.

Bravo Rebolledo, E.L. 2011. Threshold Levels and Size Dependent Passage of Plastic Litter in Stomachs of Fulmars. MSc thesis. Aquatic Ecology and Water Quality Management group, Wageningen, The Netherlands

Bravo Rebolledo, E.L., Van Franeker, J.A., Jansen, O.E., Brasseur, M.J.M. 2013. Plastic ingestion by harbour seals (*Phoca vitulina*) in The Netherlands. Marine Pollution Bulletin 67: 200-202. http://dx.doi.org/10.1016/j.marpolbul.2012.11.035

Brown, L.D., Cat, T.T., DasGupta, A. 2001. Interval Estimation for a proportion. Statistical Science 16:101-133. http://dx.doi.org/10.1214/ss/1009213286

Browne, M.A., Niven, S.J., Galloway, T.S., Rowland, S.J., Thompson, R.C. 2013. Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. Current Biology 23: 2388-2392 http://dx.doi.org/10.1016/j.cub.2013.10.012

Browne, M.A., Underwood, A.J., Chapman, M.G., Williams, R., Thompson, R.C., Van Franeker, J.A. 2015. Linking effects of anthropogenic debris to ecological impacts. Proceedings Royal Society B 282: 20142929 (11pp). http://dx.doi.org/10.1098/rspb.2014.2929

Camphuysen, C.J., 2022. Beached bird surveys in The Netherlands autumn 2021 & winter 2021/22. Royal Netherlands Institute for Sea Research (NIOZ), NIOZ Report - RWS Centrale Informatievoorziening BM 2218, pp 33

Camphuysen, C., Gear, S., Furness, R., 2022. Avian influenza leads to mass mortality of adult Great Skuas in Foula in summer 2022. Scottish Birds 4: 312-323

CBD 2016. Marine debris: understanding, preventing and mitigating the significant adverse impacts on marine and coastal biodiversity. Technical Series No.83. Secretariat of the Convention on Biological Diversity, Montreal, 78 pages. https://www.cbd.int/doc/publications/cbd-ts-83-en.pdf

Charlton-Howard, H.S., Bond, A.L., Rivers-Auty, J., Lavers, J.L., 2023. 'Plasticosis': Characterising macro- and microplastic-associated fibrosis in seabird tissues. Journal of Hazardous Materials 450: 131090 https://doi.org/10.1016/j.jhazmat.2023.131090

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Galloway, T.S. 2015. The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod *Calanus helgolandicus*. Environmental Science and Technology 49: 1130-1137 http://dx.doi.org/10.1021/es504525u.

Collard, F., Leconte, S., Danielsen, J., Halsband, C., Herzke, D., Harju, M., Tulatz, F., Gabrielsen, G.W., Tarroux, A., 2022a. Plastic ingestion and associated additives in Faroe Islands chicks of the Northern Fulmar *Fulmarus glacialis*. Water Biology and Security: 100079 https://doi.org/10.1016/j.watbs.2022.100079

Collard, F., Bangjord, G., Herzke, D., Gabrielsen, G.W., 2022. Plastic burdens in northern fulmars from Svalbard: Looking back 25 years. Marine Pollution Bulletin 185: 114333

Costers, R., 2022. Opmerkingen bij de vondst van een geringde Noordse Stormvogel. De Kleine Alk 40: 4-7

Danielsen, J., Van Franeker, J.A., Olsen, B., Bengtson, S.-A. 2010. Preponderance of mesopelagic fish in the diet of the Northern Fulmar (*Fulmarus glacialis*) around the Faroe Islands. Seabird 23: 66-75. http://www.seabirdgroup.org.uk/journals/seabird-23/seabird-23-66.pdf

Dau, K., Gräwe, D., Brockmeyer, B., Fitz, N., Fleet, D., Schuchardt, B., Schulze-Dieckhoff, M., 2022. Paraffine und andere persistente aufschwimmende Stoffe in der deutschen Nord- und Ostsee. Pilotstudie zur Entwicklung und Erprobung eines Monitorings. Erstellt in Zusammenarbeit mit der Bund/Länder-Arbeitsgemeinschaft Nord- und Ostsee (BLANO), gefördert durch den Bund/Länder-Koordinierungsausschuss Schadstoff-Unfallbekämpfung (KOA-SUB). pp 181 https://www.havariekommando.de/SharedDocs/Downloads/DE/UEGStellungenahmen/PilotstudieMonitoring_persistenteStoffe.html

Day, R.H., Wehle, D.H.S., Coleman, F.C. 1985. Ingestion of plastic pollutants by marine birds. pp 344-386 *in:* R.S. Shomura and H.O. Yoshida (Eds.), Proceedings of the workshop on the fate and impact of Marine debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54. http://www.st.nmfs.noaa.gov/tm/swfc/swfc054.pdf

Donnelly-Greenan, E.L., Harvey, J.T., Nevins, H.M., Hester, M.M., Walker, W.A. 2014. Prey and plastic ingestion of Pacific Northern Fulmars (*Fulmarus glacialis rodgersii*) from Monterey Bay, California. Marine Pollution Bulletin 85: 214-224. http://dx.doi.org/10.1016/j.marpolbul.2014.05.046.

EC 2000. Directive 2000/59/EC of the European Parliament and of the Council of 27 November 2000 on port reception facilities for ship-generated waste and cargo residues. Official Journal of the European Communities L 332: 81-90 (28 Dec 2000). http://eur-lex.europa.eu/resource.html?uri=cellar:15945efb-a7e8-4840-ab4d-0535f12692a8.0004.02/DOC_1&format=PDF

EC 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union L 164: 19-40 (25 Jun 2008). http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0056&from=EN

EC 2010. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (notified under document C(2010) 5956) (Text with EEA Relevance) (2010/477/EU). Official Journal of the European Union L232:14-24. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010D0477(01)&from=EN

EC 2017. Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU. Official Journal of the European Union L125: 43-74 (18 May 2017) https://publications.europa.eu/en/publication-detail/-/publication/a7523a58-3b91-11e7-a08e-01aa75ed71a1/language-en

EC 2022. MSFD CIS Guidance Document No. 19, Article 8 MSFD. European Commission, Brussels, pp 193 *https://www.researchgate.net/publication/361461227*

Edwards, R. 2005. Litter at sea means a bellyful of plastic. New Scientist 185(2481): 11. http://www.lexisnexis.com.ezproxy.library.wur.nl/hottopics/lnacademic/?verb=sr&csi=158275&sr=BYLINE(edwards)+AND+HLEAD(Litter+at+sea+means+a+bellyful+of+plastic)+AND+DATE+IS+2005

Endo, S., Takizawa, R., Okuda, K., Takada, H., Chiba, K., Kanehiro, H., Ogi, H., Yamashita, R., Date, T. 2005. Concentration of polychlorinated biphenyls (PCBs) in beached resin pellets: Variability among individual particles and regional differences. Marine Pollution Bulletin 50: 1103-1114. http://dx.doi.org/10.1016/j.marpolbul.2005.04.030

Endo, D., Yuyama, M., Takada, H. 2013. Desorption kinetics of hydrophobic organic contaminants from marine plastic pellets. Marine Pollution Bulletin 74: 125-131 http://dx.doi.org/10.1016/j.marpolbul.2013.07.018

EU 2019. Directive (EU) 2019/883 of the European Parliament and of the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC. Official Journal of the European Union L 151: 116-142 (7.6.2019). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0883&from=EN.

Fackelmann, G., Pham, C.K., Rodríguez, Y., Mallory, M.L., Provencher, J.F., Baak, J.E., Sommer, S., 2023. Current levels of microplastic pollution impact wild seabird gut microbiomes. Nature Ecology & Evolution: xx https://doi.org/10.1038/s41559-023-02013-z

Foekema, E.M., De Gruijter, C., Mergia, M.T., Van Franeker, J.A., Murk, T.J., Koelmans, A.A. 2013. Plastic in North Sea fish. Environmental Science & Technology 47: 8818-8824. http://dx.doi.org/10.1021/es400931b

Furness, R.W. 1985. Plastic particle pollution: accumulation by Procellariiform seabirds at Scottish colonies. Marine Pollution Bulletin 16: 103-106. https://doi.org/10.1016/0025-326X(85)90531-4

Gigault, J., Pedrono, B., Maxit, B., Ter Halle, A. 2016. Marine plastic litters: the unanalyzed nano-fraction. Environmental Science: Nano 3: 346-350 http://dx.doi.org/10.1039/C6EN00008H

Guse, N., Fleet, D., van Franeker, J., Garthe, S. 2005. Der Eissturmvogel (*Fulmarus glacialis*)- Mülleimer der Nordsee? Seevögel 26(2): 3-12.

Guse, N., Jensen, J.-K., Turner, D.M., Rebolledo, E.B., Kühn, S., van Franeker, J.A., 2020. Detonating cord found in the stomach of a northern fulmar. SULA 28: 1-5 https://edepot.wur.nl/534885

Hall, K. 2000. Impacts of marine debris and oil: economic and social costs to coastal communities. KIMO, c/o Shetland Islands Council, Lerwick. 104pp.

Hatch, S.A., Nettleship, D.N. 1998. Northern Fulmar (*Fulmarus glacialis*). No. 361 (31 pp) in: A. Poole and F. Gill, (Eds.), The Birds of North America, Inc. Philadelphia, P.A.

Hauser, R., Skakkebaek, N.E., Hass, U., Toppari, J., Juul, A., Andersson, A.M., Kortenkamp, A., Heindel, J.J., Trasande, L. 2015. Male Reproductive Disorders, Diseases, and Costs of Exposure to Endocrine-

Disrupting Chemicals in the European Union. Journal of Clinical Endocrinology & Metabolism 100: 1267-1277. http://dx.doi.org/10.1210/jc.2014-4325

Hermabessiere, L., Dehaut, A., Paul-Pont, I., Lacroix, C., Jezequel, R., Soudant, P., Duflos, G. 2017. Occurrence and effects of plastic additives on marine environments and organisms: A review. Chemosphere 182: 781-793. http://dx.doi.org/10.1016/j.chemosphere.2017.05.096

Hunt, P., Sathyanarayana, S., Fowler, P.A., Trasande, L. 2016. Female Reproductive Disorders, Diseases, and Costs of Exposure to Endocrine Disrupting Chemicals in the European Union. The Journal of Clinical Endocrinology & Metabolism 101:1562-1570. http://dx.doi.org/10.1210/jc.2015-2873

ICES-WGSE 2001. Report of the Working Group on Seabird Ecology. Ices Headquarters, 16-19 March 2001. ICES CM 2001/C:05. Copenhagen. 68pp http://www.ices.dk/sites/pub/CM%20Doccuments/2001/C/C0501.pdf

ICES-WGSE 2003. Report of the Working Group on Seabird Ecology. Ices Headquarters, 7-10 March 2003. ICES CM 2003/C:03. Copenhagen. 89pp http://www.ices.dk/sites/pub/CM%20Doccuments/2003/C/C0303.PDF

Jahnke, A., Arp, H.P.H., Escher, B.I., Gewert, B., Gorokhova, E., Kühnel, D., Ogonowski, M., Potthoff, A., Rummel, C., Schmitt-Jansen, M., Toorman, E., MacLeod, M. 2017. Reducing Uncertainty and Confronting Ignorance about the Possible Impacts of Weathering Plastic in the Marine Environment. Environmental Science and Technology Letters 4: 85-90. http://dx.doi.org/10.1021/acs.estlett.7b00008

KIMO, 2017. KIMO International Annual Report 2017, pp 19 https://www.kimointernational.org/wp/wp-content/uploads/2017/10/2017_KIMO_Annual_Report.pdf

Koelmans, A.A., Besseling, E., Wegner, A., Foekema, E.M. 2013a. Plastic as a carrier of POPs to aquatic organisms: A model analysis. Environmental Science & Technology 47: 7812-7820 http://dx.doi.org/10.1021/es401169n

Koelmans, A.A., Besseling, E., Wegner, A., Foekema, E.M. 2013b. Correction to Plastic as a Carrier of POPs to Aquatic Organisms: A Model Analysis. Environmental Science & Technology 47: 8992-8993 http://pubs.acs.org/doi/pdf/10.1021/es403018h

Koelmans, A.A., Besseling, E., Foekema, E.M. 2014. Leaching of plastic additives to marine organisms. Environmental Pollution 187: 49-54 http://dx.doi.org/10.1016/j.envpol.2013.12.013

Koelmans, A.A., Besseling, E., Shim, W.J. 2015. Nanoplastics in the aquatic environment. Critical review. pp 325-340 Chpt.12 In: Bergmann, M., Gutow, L., and Klages, M. (eds). Marine Anthropogenic Litter. Springer, Berlin. http://link.springer.com/book/10.1007%2F978-3-319-16510-3

Koelmans, A.A., Bakir, A., Burton, G.A., Janssen, C.R. 2016. Microplastic as a vector for chemicals in the aquatic environment: critical review and model-supported reinterpretation of empirical studies. Environmental Science & Technology 50: 3315-3326. http://dx.doi.org/10.1021/acs.est.5b06069

Kühn, S., Van Franeker, J.A. 2012. Plastic ingestion by the Northern Fulmar (*Fulmarus glacialis*) in Iceland. Marine Pollution Bulletin 64: 1252-1254 http://dx.doi.org/10.1016/j.marpolbul.2012.02.027

Kühn, S., Bravo Rebolledo E.L., Van Franeker, J.A. 2015. Deleterious effects of litter on marine life. Pp 75-116 in: Bergmann, M., Gutow, L., and Klages, M. (Eds). Marine Anthropogenic Litter. Springer, Berlin. http://dx.doi.org/10.1007/978-3-319-16510-3_4

Kühn, S., Van Franeker, J.A. 2020. Quantitative overview of marine debris ingested by marine megafauna. Marine Pollution Bulletin 151: 110858. https://doi.org/10.1016/j.marpolbul.2019.110858

Kühn, S., Booth, A.M., Sørensen, L., Van Oyen, A., Van Franeker, J.A. 2020a. Transfer of additive chemicals from marine plastic debris to the stomach oil of northern fulmars. Frontiers in Environmental Science 8:138 (14pp) https://doi.org/10.3389/fenvs.2020.00138

Kühn, S., van Franeker, J.A., O'Donoghue, A.M., Swiers, A., Starkenburg, M., Van Werven, B., Foekema, E., Hermsen, E., Egelkraut-Holtus, M., Lindeboom, H. 2020b. Details of plastic ingestion and fibre contamination in North Sea fishes. Environmental Pollution 257: 113569 https://doi.org/10.1016/j.envpol.2019.113569

Kühn, S., Meijboom, A., Bittner, O., Van Franeker, J.A. 2021. Fulmar Litter Threshold Value Monitoring in the Netherlands – Update 2020. Wageningen Marine Research, Den Helder, The Netherlands, pp 64 https://doi.org/10.18174/553736

Kühn, S., Van Franeker, J.A., 2022. Disperse Belastung: Mageninhalt Eissturmvogel. pp 54-63. In: Dau K., Gräwe D., Brockmeyer B., et al. (eds) Paraffine und andere persistente aufschwimmende Stoffe in der deutschen Nord- und Ostsee Pilotstudie zur Entwicklung und Erprobung eines Monitorings. https://www.havariekommando.de/SharedDocs/Downloads/DE/UEGStellungenahmen/PilotstudieMonitoring_persistenteStoffe.html

Kühn, S., Meijboom, A., Bittner, O., Van Franeker, J.A., 2022a. Fulmar Litter Monitoring in the Netherlands – Update 2021, Den Helder, The Netherlands, pp 59 https://doi.org/10.18174/575038

Kühn, S., Guse, N., Garthe, S., Enners, L., Van Franeker, J.A., 2022b. Der Eissturmvogel und das Plastik. Seevögel (Special issue in German with English summary) 43: 72-82 https://edepot.wur.nl/587760 Full issue: https://www.jordsand.de/2023/01/25/sonderheft-%C3%BCber-eissturmvogel-ver%C3%B6ffentlicht/

Kühn, S., Van Franeker, J.A., Van Loon, W., 2022c. Plastic Particles in Fulmar Stomachs in the North Sea. In: OSPAR 2023 (ed) The 2023 Quality Status Report for the Northeast Atlantic. OSPAR Commission, London, pp 25 https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/plastic-in-fulmar/

Laist, D.W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Pollution Bulletin 18(6B): 319-326. https://doi.org/10.1016/S0025-326X(87)80019-X

Laist, D.W. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. pp 99-140 in: Coe, J.M. and Rogers, D.B. (Eds.). Marine debris sources, impacts and solutions. Springer Series on Environmental Management. Springer Verlag, New York. 432pp. http://plastics.earthmind.net/files/ART_Laist_1997.pdf

Liu, L., Fokkink, R., Koelmans, A.A. 2016. Sorption of polycyclic aromatic hydrocarbons to polystyrene nanoplastic. Environmental Toxicology and Chemistry 35: 1650-1655. DOI: http://dx.doi.org/10.1002/etc.3311

Lozano, R.L., Mouat, J. 2009. Marine litter in the North-East Atlantic Region, Assessment and priorities for response. OSPAR/KIMO/UNEP. Biological Diversity and Ecosystems Nr 386. OSPAR, London, 127 pp. https://qsr2010.ospar.org/media/assessments/p00386_Marine_Litter_in_the_North-East_Atlantic_with_addendum.pdf

Mallory, M.L., Roberston, G.J., Moenting, A. 2006. Marine plastic debris in northern fulmars from Davis Strait, Nunavut, Canada. Marine Pollution Bulletin 52: 813-815. https://doi.org/10.1016/j.marpolbul.2006.04.005

Mallory, M.L. 2008. Marine plastic debris in northern fulmars from the Canadian High Arctic. Marine Pollution Bulletin 56: 1486-1512. https://doi.org/10.1016/j.marpolbul.2008.04.017

Matiddi, M., Hochsheid, S., Camedda, A., Baini, M., Cocumelli, C., Serena, F., Tomassetti, P., Travaglini, A., Marra, S., Campani, T., Scholl, F., Mancusi, M,, Amato, E., Briguglio, P., Maffucci, F., Fossi, M.C., Bentivegna, F., Andrea de Lucia, G. 2017. Loggerhead sea turtles (*Caretta caretta*): A target species for monitoring litter ingested by marine organisms in the Mediterranean Sea. Environmental Pollution 230: 199-209. http://dx.doi.org/10.1016/j.envpol.2017.06.054

MEPC 2011. Amendments to the Annex of the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973 (Revised MARPOL Annex V). RESOLUTION MEPC.201(62) IMO, London 12pp. http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Garbage/Documents/2014%20revision/RESOLUTION%20MEPC.201(62)%20Revised%20MARPOL%20Annex%20V.pdf

Mintenig, S.M., Bauerlein, P., Koelmans, A.A., Dekker, S.C., Van Wezel, A. 2018. Closing the gap between small and smaller: towards a framework to analyse nano-and microplastics in aqueous environmental samples. Environmental Science: Nano 5 1640-1649. http://dx.doi.org/10.1039/C8EN00186C

Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B. 2001. A comparison of plastic and plankton in the North Pacific Central Gyre. Marine Pollution Bulletin 42: 1297-1300. https://doi.org/10.1016/S0025-326X(01)00114-X

Moser, M.L., Lee, D.S. 1992. A fourteen-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15: 83-94. http://dx.doi.org/10.2307/1521357

Mouat, J., Lozano, R.L., Bateson, H. 2010. Economic impacts of marine litter. KIMO Report September 2010. KIMO, Shetland 105pp. https://www.noordzeeloket.nl/images/Economic%20impacts%20of%20marine%20litter_1290.pdf

MSFD-TSGML 2011. Marine Litter - Technical recommendations for the implementation of MSFD requirements. Joint Research Centre - Institute for Environment and Sustainability Report EU 25009 EN. Publications Office of the EU, Luxembourg, 91pp http://dx.doi.org/10.2788/91406

MSFD-TSGML 2013. Guidance on monitoring of marine litter in European Seas - a guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive. EUR-26113 EN. JRC Scientific and Policy Reports JRC83985. 128pp http://dx.doi.org/10.2788/99475

Nevins, H., Donnelly, E., Hester, M., Hyrenbach, D. 2011. Evidence for Increasing Plastic Ingestion in Northern Fulmars (*Fulmarus glacialis rodgersii*) in the Pacific. Fifth International Marine Debris Conference, Honolulu Hawaii 20-25 Mar 2011. Oral Presentation Extended Abstracts 4.b.3. 140-144.

Newman, S., Watkins, E., Farmer, A., Ten Brink, P., Schweitzer, J.-P. 2015. The economics of marine litter. pp 367-394 Chpt.14 In: Bergmann, M., Gutow, L., and Klages, M. (Eds). Marine Anthropogenic Litter. Springer, Berlin. http://link.springer.com/book/10.1007%2F978-3-319-16510-3

North Sea Ministerial Conference 2002. Bergen Declaration. Ministerial declaration of the Fifth International Conference on the Protection of the North Sea. Bergen, Norway, 20-21 March 2002. NSMC Secretariat, Bergen. 50pp. http://www.regjeringen.no/upload/kilde/md/rap/2002/0002/ddd/pdfv/156076-engelsk.pdf

Olsen, K. 2005. Havhesten - en flygende söppelbötte. Var Fuglefauna 28: 28-32.

OSPAR 2005. North Sea Pilot Project on Ecological Quality Objectives: Background Document on the Ecological Quality Objective on Oiled Guillemots. OSPAR Commission Biodiversity Series Publication Number: 2005/252, OSPAR, London 33pp. https://www.ospar.org/documents?d=7011

OSPAR 2008. Background Document for the EcoQO on plastic particles in stomachs of seabirds. OSPAR Commission, Biodiversity Series. ISBN 978-1-905859-94-8 Publication Number: 355/2008. https://www.ospar.org/documents?v=7109

OSPAR 2009. EcoQO Handbook - Handbook for the application of Ecological Quality Objectives in the North Sea. Second Edition - 2009. OSPAR Biodiversity Series Publication 307/2009. OSPAR Commission London, 65pp. https://www.ospar.org/documents?v=7127

OSPAR 2010a. Quality Status Report 2010. OSPAR Commission, London. 175pp. http://qsr2010.ospar.org/en/

OSPAR 2010b. The OSPAR system of Ecological Quality Objectives for the North Sea: a contribution to OSPAR's Quality Status Report 2010. OSPAR Publication 404/2009. OSPAR Commission London, en Rijkswaterstaat VenW, Rijswijk. 16pp. (Update 2010). https://qsr2010.ospar.org/media/assessments/EcoQO/EcoQO_P01-16_complete.pdf

OSPAR 2015a. Guidelines for Monitoring of plastic particles in stomachs of fulmars in the North Sea area. OSPAR Commission Agreement 2015-03e (Source: EIHA 15/5/12 Add.1). 26pp. http://www.ospar.org/convention/agreements?q=fulmar.

OSPAR 2015b. Explanatory note for the data reporting format for the OSPAR common indicator on plastic particles in fulmars' stomachs. OSPAR Commission Agreement 2015-09ef 2pp. http://www.ospar.org/convention/agreements?q=fulmar.

OSPAR 2017. OSPAR Intermediate Assessment 2017. Plastic Particles in Fulmar Stomachs in the North Sea. OSPAR Assessment Portal OAP online document: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities-v2/marine-litter/plastic-particles-fulmar-stomachs-north-sea/

OSPAR 2019. OSPAR Committee Assessment: Plastic particles in fulmar stomachs in the North Sea. OSPAR Assessment Portal (OAP) Online Document. https://oap.ospar.org/en/ospar-assessments/committee-assessments/eiha-thematic-assessments/marine-litter/plastic-particles-in-fulmar-stomachs-north-sea/

OSPAR 2020. Summary record of the meeting of the OSPAR Commission, videoconference 8-9 December 2020. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, London, UK, pp 23. https://www.ospar.org/meetings/archive/ospar-commission-17

Peda, C., Caccamo, L., Fossi, M.C., Cai, F., Andaloro, F., Genovese, L., Perdichizzi, A., Romeo, T., Maricchiolo, G. 2016. Intestinal alterations in European sea bass *Dicentrarchus labrax* (Linnaeus, 1758) exposed to microplastics: Preliminary results. Environmental pollution 212: 251-256. http://dx.doi.org/10.1016/j.envpol.2016.01.083.

Poon, F.E., Provencher, J.F., Mallory, M.L., Braune, B.M., Smith, P.A. 2017. Levels of ingested debris vary across species in Canadian Arctic seabirds. Marine Pollution Bulletin 116: 517-520. http://dx.doi.org/10.1016/j.marpolbul.2016.11.051

Provencher, J.F., Gaston, A.J., Mallory, M.L. 2009. Evidence for increased ingestion of plastics by northern fulmars *(Fulmarus glacialis*) in the Canadian Arctic. Marine Pollution Bulletin 58: 1092-1095. https://doi.org/10.1016/j.marpolbul.2009.04.002

Provencher, J.F., Bond, A.L., Avery-Gomm, S., Borrelle, S.B., Bravo Rebolledo, E.L., Hammer, S., Kühn, S., Lavers, J.L., Mallory, M.L., Trevail, A., Van Franeker, J.A. 2017. Quantifying ingested debris in marine megafauna: a review and recommendations for standardization. Analytical Methods 9: 1454-1469. http://dx.doi.org/10.1039/C6AY02419J

Ribeiro, F., Garcia, A.R., Pereira, B.P., Fonseca, M., Mestre, M.C., Fonseca, T.G., Ilharco, L.M., João Bebianno, M.J. 2017. Microplastics effects in *Scrobicularia plana*. Marine Pollution Bulletin 122: 379–391. https://doi.org/10.1016/j.marpolbul.2017.06.078

Rijks, J.M., Leopold, M.F., Kühn, S., in 't Veld, R., Schenk, F., Brenninkmeijer, A., Lilipaly, S.J., Ballmann, M.Z., Kelder, L., de Jong, J.W., Courtens, W., Slaterus, R., Kleyheeg, E., Vreman, S., Kik, M.J.L., Gröne, A., Fouchier, R.A.M., Engelsma, M., de Jong, M.C., Kuiken, T., Beerens, N., 2022. Mass Mortality Caused by Highly Pathogenic Influenza A(H5N1) Virus in Sandwich Terns, the Netherlands Emerging Infectious Diseases 28: 2538-2542 https://doi.org/10.3201/eid2812.221292

Rivers-Auty, J., Bond, A.L., Grant, M.L., Lavers, J.L., 2023. The one-two punch of plastic exposure: Macro- and micro-plastics induce multi-organ damage in seabirds. Journal of Hazardous Materials 442: 130117 https://doi.org/10.1016/j.jhazmat.2022.130117

Robards, M.D., Piatt, J.F., Wohl, K.D. 1995. Increasing frequency of plastic particles ingested by seabirds in the subarctic North Pacific. Marine Pollution Bulletin 30: 151-157 https://doi.org/10.1016/0025-326X(94)00121-O

Rochman, C.M., Hoh, E., Kurobe, T., Teh, S.J. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports 3, 3263. 7pp http://dx.doi.org/10.1038/srep03263

Rochman, C.M., Kurobe, T., Flores, I., Teh, S.J. 2014a. Early warning signs of endocrine disruption in adult fish from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. Science of the Total Environment 493: 656-661 http://dx.doi.org/10.1016/j.scitotenv.2014.06.051.

Rochman, C.M., Lewison, R.L., Eriksen, M., Allen. H., Cook, A.-M., Teh, S.J. 2014b. Polybrominated diphenyl ethers (PBDEs) in fish tissue may be an indicator of plastic contamination in marine habitats. Science of The Total Environment, Volumes 476-477: 622-633 http://dx.doi.org/10.1016/j.scitotenv.2014.01.058

Rochman, C.M., Browne, M.A., Underwood, A.J., Van Franeker, J.A., Thompson, R.C. Amaral-Zettler, L. 2016. The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived. Ecology 97: 302–312. http://www.esajournals.org/doi/pdf/10.1890/14-2070.1.

Ryan, P.G. 2008. Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans. Marine Pollution Bulletin 56: 1406-1409. https://doi.org/10.1016/j.marpolbul.2008.05.004

Ryan, P.G., Moore, C.J., Van Franeker, J.A., Moloney, C.L. 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B 364: 1999-2012. http://dx.doi.org/10.1098/rstb.2008.0207.

Save the North Sea, 2004. Reduce marine litter: 'Save the North Sea' project results. Keep Sweden Tidy Foundation, Stockholm, 17pp. https://www.researchgate.net/publication/343080543_Reduce_Marine_Litter_Save_the_North_Sea_Project_Results

Savoca, M.S., Kühn, S., Sun, C., Avery-Gomm, S., Choy, C.A., Dudas, S., Hong, S.H., Hyrenbach, K.D., Li, T.-H., Ng, C.K.-y., Provencher, J.F., Lynch, J.M., 2022. Towards a North Pacific Ocean long-term monitoring program for plastic pollution: A review and recommendations for plastic ingestion bioindicators. Environmental Pollution 310: 119861 https://doi.org/10.1016/j.envpol.2022.119861

Sergeant, E.S.G., 2019. Epitools epidemiological calculators. Ausvet Pty Ltd. http://epitools.ausvet.com.au

Shugart, G., Nania, T., 2021. Demographic Differences in the Quantity, Mass, and Anatomical Location of Ingested Plastic in Northern Fulmars (*Fulmarus glacialis*): A Review and Reconsideration of NE Pacific Ocean Samples. Advances in Environmental and Engineering Research 2: 15 *https://doi.org/10.21926/aeer.2103023*

Snæþórsson, A.Ö., Brynjólfsson, B. 2021. Plast í meltingarvegi fýla við Ísland árið 2021. Náttúrustofa Norðausturlands (Northeast Iceland Nature Research Centre), Husavik, Iceland, pp 11

Sørensen, L., Rogers, E., Altin, D., Salaberria, I., Booth, A.M., 2020. Sorption of PAHs to microplastic and their bioavailability and toxicity to marine copepods under co-exposure conditions. Environmental Pollution 258: 113844 *https://doi.org/10.1016/j.envpol.2019.113844*

Sühring, R., Baak, J.E., Letcher, R.J., Braune, B.M., de Silva, A., Dey, C., Fernie, K., Lu, Z., Mallory, M.L., Avery-Gomm, S., Provencher, J.F. 2022. Co-contaminants of microplastics in two seabird species from the Canadian Arctic. Environmental Science and Ecotechnology 12: 100189 *https://doi.org/10.1016/j.ese.2022.100189*

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., Watanuki, Y. 2013. Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Marine Pollution Bulletin 69: 219-222. *http://dx.doi.org/10.1016/j.marpolbul.2012.12.010*

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M.-A., Watanuki, Y. 2015. Facilitated leaching of additive-derived PBDEs from plastic by seabirds' stomach oil and accumulation in tissues. Environmental Science and Technology 49: 11799-11807. *http://dx.doi.org/10.1021/acs.est.5b01376*

Tanaka, K., Van Franeker, J.A., Deguchi, T., Takada, H. 2019. Piece-by-piece analysis of additives and manufacturing byproducts in plastics ingested by seabirds: implication for risk of exposure to seabirds. Marine Pollution Bulletin 145: 36-41 https://doi.org/10.1016/j.marpolbul.2019.05.028

Tanaka, K., Watanuki, Y., Takada, H., Ishizuka, M., Yamashita, R., Kazama, M., Hiki, N., Kashiwada, F., Mizukawa, K., Mizukawa, H., Hyrenbach, D., Hester, M., Ikenaka, Y., Nakayama, S.M.M. 2020. Accumulation of plastic-derived chemicals into seabird tissues. Current Biology 30: 723-728 *https://doi.org/10.1016/j.cub.2019.12.037*

Terepocki, A.K., Brush, A.T., Kleine, L.U., Shugart, G.W., Hodum, P. 2017. Size and dynamics of microplastic in gastrointestinal tracts of Northern Fulmars (*Fulmarus glacialis*) and Sooty Shearwaters (*Ardenna grisea*). Marine Pollution Bulletin 116: 143-150. *https://doi.org/10.1016/j.marpolbul.2016.12.064*

Teuten, E.L., Rowland, S.J., Galloway, T.S., Thompson, R.C. 2007. Potential for Plastics to Transport Hydrophobic Contaminants. Environmental Science and Technology 41: 7759-7764 *http://dx.doi.org/10.1021/es071737s*

Teuten, E. L., Saquing, J.M., Knappe, D.R.U., Barlaz, M.A., Jonsson, S., Björn, A., Rowland, S.J., Thompson, R.C., Galloway, T.S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P.H., Tana, T.S., Prudente, M., Boonyatumanond, R., Zakaria, M.P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, U., Imamura, A., Saha, M., Takada, H. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B 364: 2027-2045 *http://dx.doi.org/10.1098/rstb.2008.0284*

Thompson, R.C., Moore, C.J., vom Saal, F.S., Swan, S.H. (Eds.) 2009. Plastics, the environment and human health. Philosophical Transactions of the Royal Society B 364 (nr 1526 Theme Issue) pages 1969-2166. *http://rstb.royalsocietypublishing.org/content/364/1526*

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle. D., Russell, A.E. 2004. Lost at sea: Where is all the plastic? Science 304 (5672): 838-838. *http://dx.doi.org/10.1126/science.1094559*

Trevail, A.M., Gabrielsen, G.W., Kühn, S., Van Franeker, J.A. 2015. Elevated levels of ingested plastic in a high Arctic seabird, the northern fulmar (*Fulmarus glacialis*). Polar Biology 38: 975-981 *http://dx.doi.org/10.1007/s00300-015-1657-4*

Tulatz, F., Gabrielsen, G.W., Bourgeon, S., Herzke, D., Krapp, R., Langset, M., Neumann, S., Lippold, A., Collard, F., 2023. Implications of Regurgitative Feeding on Plastic Loads in Northern Fulmars (*Fulmarus glacialis*): A Study from Svalbard. Environmental Science & Technology 57: 3562–3570 *https://doi.org/10.1021/acs.est.2c05617*

Van Franeker, J.A. 1985. Plastic ingestion in the North Atlantic Fulmar. Marine Pollution Bulletin 16: 367-369. *https://doi.org/10.1016/0025-326X(85)90090-6*

Van Franeker, J.A., Bell, P.J. 1988. Plastic ingestion by petrels breeding in Antarctica. Marine Pollution Bulletin 19: 672-674. *https://doi.org/10.1016/0025-326X(88)90388-8*

Van Franeker, J.A., Meijboom, A. 2002. Litter NSV - Marine litter monitoring by Northern Fulmars: a pilot study. ALTERRA-Rapport 401. Alterra, Wageningen, 72pp. *http://edepot.wur.nl/45695*

Van Franeker, J.A. 2004. Save the North Sea - Fulmar Study Manual 1: Collection and dissection procedures. Alterra Rapport 672. Alterra, Wageningen. 38pp. *http://edepot.wur.nl/40451*

Van Franeker, J.A. 2005. Schoon strand Texel 2005: onderzoeksresultaten van de schoonmaakactie van het Texelse strand op 20 april 2005. Alterra speciale uitgave 2005/09. Alterra, Texel. 23pp. *http://edepot.wur.nl/19515*

Van Franeker, J.A., Blaize, C., Danielsen, J., Fairclough, K., Gollan, J., Guse, N., Hansen, P.L., Heubeck, M., Jensen, J.-K., Le Guillou, G., Olsen, B., Olsen, K.O., Pedersen, J., Stienen, E.W.M., Turner, D.M. 2011. Monitoring plastic ingestion by the northern fulmar *Fulmarus glacialis* in the North Sea. Environmental Pollution 159: 2609-2615. *http://dx.doi.org/10.1016/j.envpol.2011.06.008*

Van Franeker, J.A. 2012. Plastic ingestion by fulmars at the Faroe Islands (Plastic i færoske mallemukkers fodeindtagelse). pp 82-85 in: Jensen, J.-K., Mallemukken på Færoerne / The Fulmar on the Faroe Islands. Prenta, Torshavn. *http://www.wur.nl/upload_mm/e/9/f/c7466bbd-d617-4a01-943f-f6e7dfa3c7ba_2012_Faroe.pdf*

Van Franeker, J.A., the SNS Fulmar Study Group 2013. Fulmar Litter EcoQO monitoring along Dutch and North Sea coasts - Update 2010 and 2011. IMARES Report C076/13. IMARES, Texel. 61pp.

Van Franeker, J.A., Law, K.L. 2015. Seabirds, gyres and global trends in plastic pollution. Environmental Pollution 203: 89-96. *http://dx.doi.org/10.1016/j.envpol.2015.02.034*

Van Franeker, J.A., Kühn, S. 2018. Fulmar Litter EcoQO monitoring in the Netherlands - Update 2017. Wageningen Marine Research Report C060/18 & RWS Centrale Informatievoorziening BM 18.20. Den Helder, 60pp. *https://doi.org/10.18174/458857*

Van Franeker, J.A., Bravo Rebolledo, E.L., Hesse, E., IJsseldijk, L.L., Kühn, S., Leopold, M., Mielke, L. 2018. Plastic ingestion by harbour porpoises *Phocoena phocoena* in the Netherlands: establishing a standardized method. Ambio 47: 387-397. *https://doi.org/10.1007/s13280-017-1002-y*

Van Franeker, J.A., Kühn, S., Kotterman, M. Kwadijk, C. 2019 Monitoring van paraffine-achtige stoffen op Nederlandse stranden en in magen van Noordse Stormvogels. Wageningen University and Research Report C001/19. Wageningen Marine Research, Den Helder, 33pp. *https://doi.org/10.18174/467759.*

Van Franeker, J.A., Kühn, S., 2019. Fulmar Litter EcoQO monitoring in the Netherlands - Update 2018. Wageningen Marine Research Report C077/19 & RWS Centrale Informatievoorziening BM 19.16. Den Helder, 60pp. *https://doi.org/10.18174/486799*

Van Franeker, J.A., Kühn, S., Anker-Nilssen, T., Edwards, E.W.J., Gallien, F., Guse, N., Kakkonen, J.E., Mallory, M.L., Miles, W., Olsen, K.O., Pedersen, J., Provencher, J., Roos, M., Stienen, E., Turner, D.M., van Loon, W.M.G.M. 2021. New tools to evaluate plastic ingestion by northern fulmars applied to North Sea monitoring data 2002–2018. Marine Pollution Bulletin 166: 112246 *https://doi.org/10.1016/j.marpolbul.2021.112246*

Van Franeker, J.A., Jensen, J.-K., Simonsen, P.J., Bravo Rebolledo, E.L., Kühn, S. 2022. Plastics in stomachs of northern fulmars *Fulmarus glacialis* collected at sea off east Greenland: latitude, age, sex and season. Marine Biology 169: 45 *https://doi.org/10.1007/s00227-022-04029-8*

Venables, V.N., Ripley, B.D. 2002. Modern applied statistics with S, 4$^{th}$ ed. Springer, New York, 503pp. *http://www.bagualu.net/wordpress/wp-content/uploads/2015/10/Modern_Applied_Statistics_With_S.pdf*

Vlietstra, L.S., Parga, J.A. 2002. Long-term changes in the type, but not the amount, of ingested plastic particles in Shor1t-tailed Shearwaters in the southeastern Bering Sea. Marine Pollution Bulletin 44: 945-955. *https://doi.org/10.1016/S0025-326X(02)00130-3*

Werner, S., Budziak, A., Van Franeker, J., Galgani, F., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T. 2016. Harm caused by marine litter. MSFD GES TG Marine Litter - Thematic Report. JRC Technical Report EUR 28317, Publications Office of the European Union, Luxembourg, 89pp. *http://dx.doi.org/10.2788/19937*

Yamashita, R., Tanaka, K., Yeo, B.G., Takada, H., Van Franeker, J.A., Dalton, M., Dale, E. 2018. Hazardous chemicals in plastics in marine environments: International Pellet Watch. The Handbook of Environmental Chemistry Springer, Berlin, Heidelberg. (Book chapter 21pp). *https://doi.org/10.1007/698_2018_299*

# Justification

Report C039/23
Project Number: 4315100164

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

Approved: Dr. R.H. Jongbloed
Senior Researcher

Signature: 

Date: 19 September 2023

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


Signature:

Date: 19 September 2023

Wageningen Marine Research
T +31 (0)317 48 7000
E: marine-research@wur.nl
www.wur.eu/marine-research

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

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

Wageningen Marine Research is part of Wageningen University & Research. Wageningen University & Research is the collaboration between Wageningen University and the Wageningen Research Foundation and its mission is: 'To explore the potential for improving the quality of life'