Fulmar Litter Threshold Value Monitoring in Germany - 2020 & 2021

Vorhabenbezeichnung:	Monitoring von Müll in Mägen von Eissturmvögeln - Update 2020 & 2021
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Vergabe-Nr.	B34.2022-18
Laufzeit des Vorhabens:	13.06.2022 – 31.12.2022
Berichtszeitraum	01.01.2020 – 31.12.2021

Foto: Kai Borkenhagen

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Zusammenfassung

Bei der Nahrungssuche nehmen Eissturmvögel Plastikmüll von der Meeresoberfläche auf. Um den Zustand der Meeresumwelt zu bewerten, wird die Plastikmüllkonzentration in den Mägen der Eissturmvögel von OSPAR international als Indikator für die Müllbelastung im Nordost-Atlantik seit vielen Jahren genutzt. Im Jahr 2020 hat der Eissturmvogel-Schwellenwert nun formell die EcoQO ersetzt. Das langfristige Ziel verlangt, dass: **"Über einen Zeitraum von mindestens fünf aufeinanderfolgenden Jahren dürfen nicht mehr als 10 % der Eissturmvögel (*Fulmarus glacialis*) in Proben von mindestens 100 Vögeln den Wert von 0,1 g Plastikpartikeln im Magen überschreiten."**

Die Untersuchungen zur Plastikmenge in den Mägen von Eissturmvögeln laufen in Deutschland seit 2002 und wurden bisher vom Forschungs- und Technologiezentrum Westküste (FTZ, Universität Kiel) durchgeführt. Der Verein Jordsand hat das Projekt für die Jahre 2020 und 2021 übernommen. Das Projekt wurde in Anlehnung an die internationalen Standardprotokolle und in Zusammenarbeit mit den bisherigen Projektmitgliedern bearbeitet.

In den Jahren 2020 und 2021 wurden insgesamt 42 gestrandete Eissturmvögel gesammelt und seziert, wobei nicht alle Vögel intakte Mägen aufwiesen. Insgesamt konnten 33 Vögel mit intakten Mägen untersucht und ihre Mägen analysiert werden (2020: n = 16; 2021: n = 17). Zusätzlich wurden vier Vögel aus dem Jahr 2019 analysiert und in die Datenbank aufgenommen. Die deutsche Datenbank enthält nun 861 Eissturmvogelmägen aus dem Zeitraum 2002-2021.

Die Menge an Plastik in den deutschen Mägen von Eissturmvögeln nimmt leicht ab. Obwohl die Trends statistisch nicht signifikant sind, deuten sie auf einen langfristigen Abwärtstrend seit 2002 und dem letzten 10-Jahres-Zeitraum hin.

Im aktuellen 5-Jahres-Zeitraum (2017-2021) hatten 88 % der 103 untersuchten deutschen Eissturmvögel Plastik im Magen. Die durchschnittliche Anzahl der Plastikpartikel betrug 16 pro Vogel mit einem Gewicht von 0,26 g. **Im integrierten aktuellen 5-Jahres-Zeitraum (2017-2021) überschreiten 49 % der Eissturmvögel den kritischen FTV-Wert von 0,1 g Plastik im Magen.** Das zeigt, dass die gegenwärtigen Maßnahmen nicht ausreichen oder nicht entschlossen genug implementiert werden, ggf. müssen zusätzliche ergriffen werden. Die zeitlichen Trends im 5-Jahres-Durchschnitt der in Deutschland gefundenen Eissturmvögel deuten auf eine Verbesserung hin, aber das von OSPAR gesetzte 10 % FTV-Ziel wird immer noch deutlich verfehlt.

Summary

Fulmars ingest plastic debris from the sea surface in their foraging activities. To assess the state of the marine environment, the amount of plastic in the stomachs of fulmars has been used by OSPAR international as an indicator of plastic pollution in the Northeast Atlantic for many years. In 2020 the Fulmar Threshold Value has now formally replaced the EcoQO. The long-term target requires that: **"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."**

Research on the amount of plastic in the stomachs of fulmars has been ongoing in Germany since 2002 and has so far been conducted by the Research and Technology Centre, West Coast (FTZ, University of Kiel). Verein Jordsand has taken over the project for the years 2020 and 2021. The project was worked on, accordingly to the international standard protocols and in collaboration to former project members.

In 2020 and 2021 a total of 42 beached fulmars were collected and dissected, but not all birds contained intact stomachs. Nevertheless, a total of 33 birds with intact stomachs were further examined and their stomachs were analysed (2020: n = 16; 2021: n = 17 birds). Additionally, four birds from 2019 were analysed and added to the database. The German database now holds 861 fulmar stomachs from the period 2002-2021.

The amount of plastic in the German stomachs of fulmars is slowly decreasing. Although the trends are not statistically significant, they do indicate a downward trend over the long term since 2002 and the recent 10-year period.

In the current 5-year period (2017-2021), 88 % of the 103 German fulmars examined did have plastic in their stomach. The average number of plastic particles was 16 per bird, weighing 0.26 g. **Over the integrated recent 5-year period 2017-2021, 49 % of German fulmars exceed the critical FTV level of 0.1 g of plastic in the stomach.** This shows that the current measures are not sufficient or are not sufficiently implemented; additional ones may need to be taken. The time trends in the 5-year average FTV Performance of fulmars found in Germany indicate an improvement, but still the 10 % FTV target set by OSPAR is clearly missed.

1. Introduction

Descriptor 10 (Marine Litter) of the European Marine Strategy Framework Directive (MSFD, 2008/56/EC) aims to reduce existing litter levels as well as new inputs of litter into the oceans. Monitoring criteria include litter and micro litter on the coast, in the surface layer of the water column and on the seabed (D10C1 and D10C2) as well as the uptake of litter and micro-litter by marine organisms (D10C3) and other detrimental impacts to biota such as entanglement (D10C4). For the uptake of litter and micro-litter by marine organisms (D10C3) the occurrence of plastic particles in the stomachs of fulmars has been identified as suitable indicator the wider North Sea. This indicator has already been used many years by OSPAR (OSPAR 2015). The long-term target requires that: **"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."** Furthermore, the EU Technical Group on Marine Litter recommends its use for D10C3 in areas where fulmars are distributed (Werner et al. 2020, for details see Info Box 1).

Previous studies have shown that the fulmar is well suited as an indicator species for monitoring marine litter. As a typical seabird, the fulmar preys exclusively on food in the open sea and thereby also ingests floating marine litter. Due to its stomach physiology, food and waste are kept in the stomach for some time before being excreted. In the process, fulmars accumulate plastics in their stomachs. Dead fulmars are regularly washed up on the coasts and thus represent a sufficient sample size. Data on plastic ingestion by Northern Fulmars is available for the Dutch coast since 1979 and for most other countries bordering the North Sea since 2002, when a pilot project started as part of the EU campaign “Save the North Sea” (van Franeker 2004).

The German program is part of the international Fulmar-Litter -Study, coordinated by OSPAR (see Info Box 1). From 2002-2004, the German contribution was financed in the scope of the EU Interreg IIIB Programme “Save the North Sea” (Guse et al. 2005, van Franeker et al. 2005). From 2005 to 2010 the FTZ continued the national work on a voluntary basis to ensure an unbroken dataset. During this period, stomach analyses were conducted by Dutch colleagues from Wageningen Marine Research without additional funding. In 2011 funds from the Federal Agency of Nature Conservation (BfN) enabled the continuation of the German contribution. For the years 2011-2019 the monitoring of plastic particles in fulmar stomach was carried out as part of research & development projects of the Federal Environmental Agency (UBA). The data was regularly compiled by the FTZ and forwarded to UBA to meet the requirements of OSPAR. For the last two years (2020 and 2021), the nature conservation association Jordsand e.V. was retrospectively coordinating the German OSPAR monitoring program on behalf of NLWKN (“Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz”) within the framework of BLANO (“Bund/Länder-Arbeitsgemeinsaft Nord- und Ostsee”).

Info Box 1

The Fulmar Threshold Value

The amount of plastic in fulmar stomachs as an indicator of plastic pollution in the North Sea has been agreed on by Contracting Parties of OSPAR. The Ecological Quality Objective (EcoQO) requested that not more than 10 % of the fulmars should have more than 0.1 gram of plastics in their stomach. However, this EcoQO was based on arbitrary values. The current OSPAR long-term goal ("Fulmar Threshold Value"; FTV) demands (in absence of a definition of harm) a value that is based on the cleanest known area. For fulmars, this is based on the litter load of fulmars in the Canadian Arctic and this value proofed to be similar to the OSPAR EcoQO. Therefore, the FTV has now formally replaced the EcoQO in 2020 (OSPAR 2020; EC 2022; see also van Franeker et al. 2021). It still reads **"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."** For more details see van Franeker et al. (2021a) and Kühn et al. (2021).

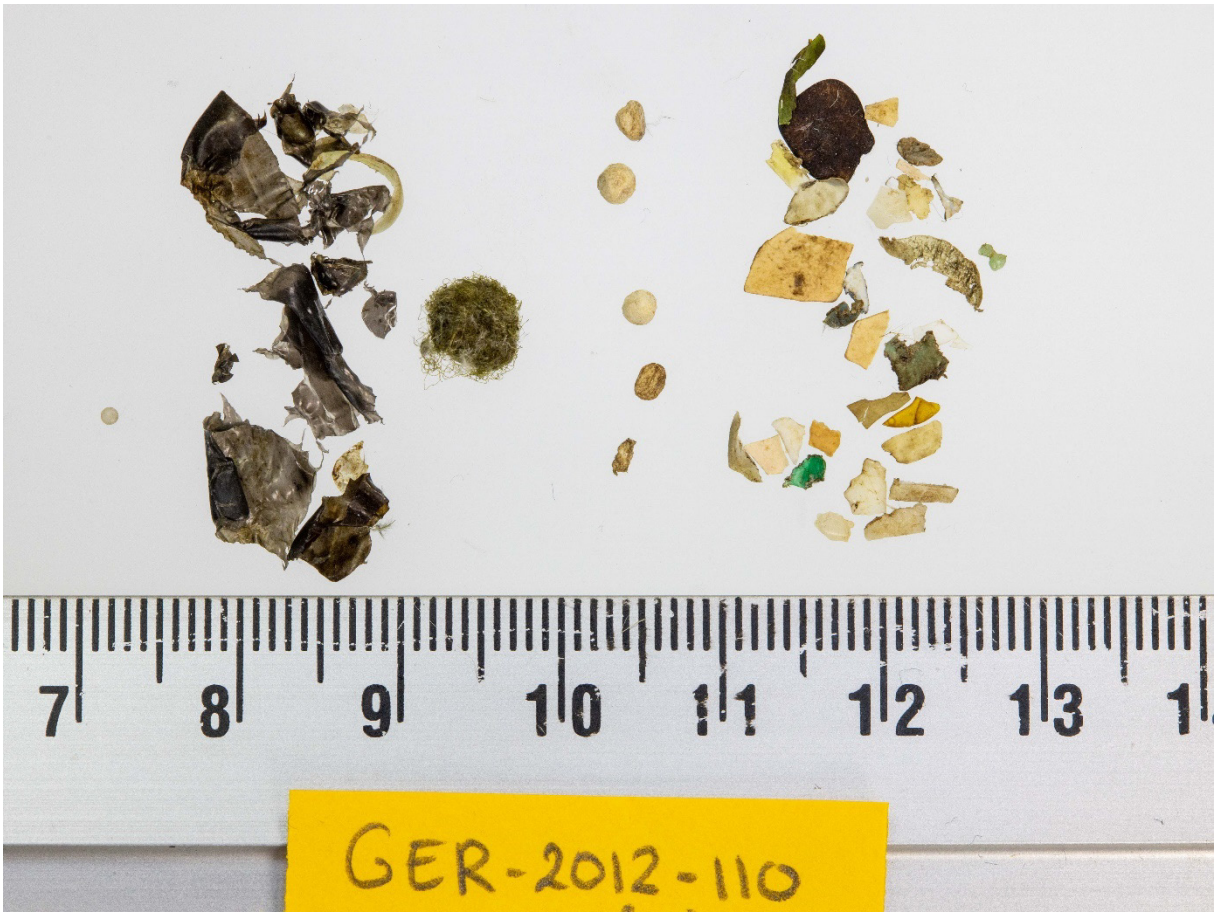

Photo 1: This photo shows plastics ingested by a Northern Fulmar collected on a German beach in 2012. The total mass of the plastic is 0.105 gram, so just above the FTV of 0.1 gram. According to the MSFD requirements only 10 % of the fulmars should have this amount of plastics or more in their stomach. Photo: Jan van Franeker, Wageningen Marine Research)

2. Materials and Methods

Research on the amount of plastic in the stomachs of fulmars has been ongoing in Germany since 2002 and has so far been conducted by the Research and Technology Centre, West Coast (FTZ, University of Kiel). Verein Jordsand has taken over the project for the years 2020 and 2021. The project was worked on, accordingly to the international standard protocols and in collaboration to former project members.

In October 2022 the latest international Fulmar Workshop took place in the Netherlands at Wageningen Marine Research. A member of Jordsand (Leonie Enners) attended this workshop and was trained in dissection and stomach analysis of Northern Fulmars by Dr. Jan van Franeker and Dr. Susanne Kühn (Wageningen Marine Research). Participants from all over Europe were attending this workshop for training and for calibrating data collection to ensure comparability across the international network. During the workshop and the days after it, all German fulmars were dissected, and stomach content analysis conducted, supervised by the Dutch colleagues. The data were entered to standard spreadsheets. Statistical tests were performed by our partners at Wageningen Marine Research.

Info Box 2

Old carcasses of good use

In February 2020 an old and decayed fulmar was collected by Fee Winkler (Schutzstation Wattenmeer) in Büsum. On the first sight the bird looked extremely old and incomplete, however at close inspection this juvenile female bird still had a complete stomach that could be used for the plastic monitoring project. This is a good reminder that old and smelly corpses should still be collected as long as there is a small chance that a stomach may be available. We rather prefer having an ‚empty' bird on the table once in a while than leaving a suitable bird on the beach.

Photo 2: A juvenile female fulmar found on 27 February 2020 in Büsum (left). The body is heavily decayed and incomplete, but nevertheless an intact stomach was retrieved (right). Photo's: Jan van Franeker, Wageningen Marine Research

Photo 3. Stomach content of the same old corpse. As the stomach was intact the data of this bird could be included in the OSPAR/MSFD plastic monitoring. This stomach contained: eight fragments of which one a large red part of a bottle cap (top), nine pieces of foam (right) and one piece of sheet (bottom right). The total mass of the plastic is 0.5005 gram, almost twice the average mass in fulmars collected between 2017 and 2021. Photo: Leonie Enners, Verein Jordsand

2.1. Collection and transport of beached fulmars

The collection of beached birds on the coast of the German North Sea is the basis of the project and is supported by volunteers, public agencies, and conservation organisations. A permanent attendance and regular information of all persons and institutions is essential. Especially because many members of the network are changing every year (participants of voluntary year), regular presentations and information about the project are important. To continue the national OSPAR/MSFD Fulmar-Litter work in Germany this network was reactivated and updated. This included the organisation of transport of birds found in 2020 and 2021 from different locations of the German North Sea coast to the FTZ. Some birds were found and stored in remote locations. Members of the network helped to take these birds to the mainland, where they were transported to Büsum by employees of Jordsand or FTZ.

A total of 42 fulmars were collected (2020: n = 22; 2021: n = 20). For sound statistical analysis, Van Franeker and Meijboom (2002) recommended a sample size of at least 40 individuals. Sample sizes are variable and sometimes less birds are found. Occasional years with smaller sample sizes are not problematic but can lengthen the period of time that is necessary to draw conclusions on trends or changes in plastic abundances. Due to avian flu in waterfowl, in some areas the collection of beached birds was not allowed or limited. More importantly, due to the interruption of funding, regular information for potential collectors was missing. Consequently, many birds were not collected, or the collected birds were not adequately labelled (n = 7). Unfortunately, these unlabelled birds could not be used for the monitoring program as sampling year and date are standard requirements by OSPAR/MSFD.

In addition, 4 fulmars from 2019 were collected and processed. Reporting data to the OSPAR secretariate for birds from previous years is possible, they can be added to the according data year. Therefore an ‘annual’ table, at submission, may include older records from earlier years.

2.2. Dissection and stomach analysis

All collected fulmars from 2020 and 2021, which were adequately labelled were dissected, as well as some birds from previous years (2019: n = 4). The performance of the dissection and subsequent stomach content analysis was carried out according to the detailed standard protocols (Van Franeker 2004, Van Franeker et al. 2011, Van Franeker & Law 2015, OSPAR 2015a,b). This included external inspection, measurement and collection of standard biological parameters, and data on condition and organ health 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 based on development of sexual organs (size and shape) and presence of *Bursa of Fabricius*. This gland is well developed in chicks but disappears within the first year of life or shortly after.

Photo 4: Northern Fulmars from Germany are thawed to be processed. The rope on the right bottom corner was only loosely attached to the bird, likely on the beach after death and did not cause the death of the fulmar. Photo: Leonie Enners

The stomach of fulmar consists of two parts. The received food is first stored in a large glandular stomach (*proventriculus*), where it begins to digest before moving to a small muscular stomach (*gizzard*), where harder prey remains can be processed by mechanical grinding. The contents of both stomach parts were analysed together. Therefore, the extracted stomach sections (proventriculus and gizzard) were cut open and carefully rinsed (sieve: 1 mm mesh size). Stomach contents were transferred to a petri dish for sorting under a binocular microscope and categorized. The contents were sorted into the main categories of plastics (industrial and user plastics), non-plastic rubbish, pollutants (e.g., slag and coal particles or paraffine-like substances), natural food remains, and natural non-food remains. Each of these categories has several subcategories of specific items. For financial efficiency in OSPAR EcoQO/FTV monitoring, the required dataset has been restricted to the main categories 'industrial plastics' and 'user plastics'. Industrial plastics are small cylindrical granules (~4-5 mm) that are regarded as the 'raw' material plastics are produced. During the production process additives such as flame retardants, colourants, UV-blockers, or plasticisers can be added. User plastics describe a large group of different (non-industrial) plastic types such as sheets, threads, foams and (often unrecognizable) fragments of larger plastic items. For each bird and each plastic (sub)category the number of particles and the mass (in grams) were recorded using Sartorius electronic weighing scale after air drying at laboratory temperatures. Weights were expressed in grams with an accuracy of 4 decimal places (= tenth of milligram).

2.3. Data preparation and statistical tests

Data from dissections and stomach content analysis were recorded in Excel spreadsheets. All data were converted to the international standardized data format according to OSPAR. In addition, the data set was sent to our partners at Wageningen Marine Research for quality control and added to the German Fulmar database. Statistical tests were performed by our partners at Wageningen Marine Research. The results are presented both annually and pooled for different time periods. To avoid short-term fluctuations, data are mostly pooled into 5-year periods. Such pooled data for 5-year periods are not derived from annual averages but are calculated from all individual birds over the entire 5-year period.

Basic data presentation includes the frequency of occurrence (%FO, percentage of birds with plastic in their stomach), the average number and mass of plastic particles (total and per (sub-)category) per bird (including all zero-accounts) and the percentage of birds with more than 0.1 gram of plastics (Fulmar-TV performance).

For trend analyses, GENSTAT 19th Edition was used for statistical tests. Tests for trends over time are based on linear regressions that fit ln-transformed plastic mass values for individual birds to the year of collection. The logarithmic transformation is necessary because the original data are strongly skewed and need to be normalized for the statistical procedures. The natural logarithm (Ln) is used. For tests of 'long-term' trends, the entire dataset is used (2002-2021), for the 'recent' trends, only data from the last 10 years are used (2012-2021). For more information see also Kühn et al. (2022).

3. Results and Discussion

In 2020 and 2021 a total of 42 beached fulmars were collected and dissected, but not all birds contained intact stomachs. Nevertheless, a total of 33 birds with intact stomachs were further examined and their stomachs were analysed (2020: n = 16; 2021: n = 17 birds). Additionally, four birds from 2019 were analysed and added to the database. The German database now holds 861 fulmar stomachs from the period 2002-2021.

In the following the results for the years 2020 and 2021 are shown respectively as well as for the current 5-year period (2017-2021; see Table 1). Trends are calculated over the recent period (2012-2021) and the long-term period (2002-2021). The desired annual sample size of ± 40 birds was not achieved in the 2020 or 2021. Smaller annual samples, like in 2020 and 2021, are not a problem for the monitoring system, but may delay the detection of significant trends.

Table 1: Data summary for the years 2020 and 2021, as well as the current 5-year period (2017-2021). The table presents the sample size, the percentage of birds that exceeds the 0.1 g level (FTV %), the proportion of birds with any plastic particles (Frequency of Occurrence; %FO), the average number of plastic items per bird, and the average mass of plastic per bird stomach in gram (g).

Year	Sample size	FTV%	% FO	average number of items (n/bird)	average mass of litter (g/bird)
2020	16	**50**	94	21.4	0.37
2021	17	**59**	94	15.5	0.21
2017-2021	103	**49**	88	16.3	0.26

3.1. The Year 2020

A total of 22 beached fulmar corpses were collected in 2020, of which 16 had an intact stomach suitable for analysis of the contents (Table 2). Out of 16 birds, 15 birds contained plastic in the stomach (frequency of occurrence = 94 %). The average number of plastic items per bird was 21 pieces, weighing 0.37 g in average. In 2020, 50 % of the collected fulmars exceeded the 0.1 g level (Table 1). Industrial plastic was found in 63 % of the stomachs with an average mass of 0.09 g (3 items per birds in average) (Table 2). Out of 16 birds, 14 birds contained user plastic (88 %; average mass = 0.28 g) with the highest incidence in the category of fragments (88 %) (Table 2).

Table 2: Summary of sample characteristics and stomach contents of fulmars collected for German marine litter monitoring in the year 2020. The top line shows 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). The table lists for each litter (sub) category: Incidence, representing the proportion of birds with one or more items of the litter category present; average number of plastic items per bird stomach ± standard error; average mass of plastic ± standard error per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-transformed values as used in trend-analyses.

Germany 2020	**nr of birds**	**% adult**	**% male**	**% LL colour**	**% death oil**	**avg condition**
	16	6	44	87	0	0.7

	incidence	**average number of items (n/bird)**	**± se**	**average mass of litter (g/bird)**	**± se**	**max. mass recorded**	**geometric mean mass (g/bird)**
ALL PLASTICS	94 %	21.4	± 10.0	0.365	± 0.192	3.1	0.0987
INDUSTRIAL PLASTIC	63 %	3.2	± 1.5	0.087	± 0.046	0.7	0.0130
USER PLASTIC	88 %	18.3	± 9.5	0.278	± 0.181	2.9	0.0486
sheets	38 %	2.4	± 1.7	0.005	± 0.003	0.1	0.0012
threads	31 %	1.4	± 0.8	0.014	± 0.009	0.1	0.0015
foamed	38 %	2.8	± 1.8	0.019	± 0.018	0.3	0.0009
fragments	88 %	11.6	± 5.6	0.240	± 0.158	2.6	0.0427
other plastic	6 %	0.1	± 0.1	0.001	± 0.001	0.0	0.0002

3.2. The Year 2021

A total of 20 beached fulmar corpses were collected in 2021, of which 17 had an intact stomach suitable for analysis of the contents (Table 3). Out of 17 birds, 16 birds contained plastic in the stomach (frequency of occurrence = 94 %). The average number of plastic items per bird was 16 weighing 0.21 g in average. In 2021, 59 % of the collected fulmars exceeded the 0.1 g level (Table 1). Industrial plastic was found in 53 % of the stomachs with an average mass of 0.05 g (2 items per birds in average) (Table 3). Out of 17 birds, 15 birds contained user plastic (88 %; average mass = 0.15 g) with the highest incidence in the category of fragments (88 %) (Table 3).

Table 3: Summary of sample characteristics and stomach contents of fulmars collected for German marine litter monitoring in the year 2021. The top line shows 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). The table lists for each litter (sub) category: Incidence, representing the proportion of birds with one or more items of the litter category present; average number of plastic items per bird stomach ± standard error; average mass of plastic ± standard error per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-transformed values as used in trend-analyses.

Germany 2021	**nr of birds**	**% adult**	**% male**	**% LL colour**	**% death oil**	**avg condition**
	17	6	41	100	0	0.9

	incidence	**average number of items (n/bird)**	**± se**	**average mass of litter (g/bird)**	**± se**	**max. mass recorded**	**geometric mean mass (g/bird)**
ALL PLASTICS	94 %	15.5	± 4.1	0.206	± 0.039	0.5	0.1131
INDUSTRIAL PLASTIC	53 %	2.4	± 0.9	0.054	± 0.019	0.3	0.0090
USER PLASTIC	88 %	13.1	± 3.3	0.152	± 0.029	0.4	0.0743
sheets	59 %	2.6	± 0.9	0.015	± 0.009	0.1	0.0029
threads	12 %	0.1	± 0.1	0.001	± 0.001	0.0	0.0003
foamed	41 %	1.2	± 0.4	0.006	± 0.004	0.1	0.0013
fragments	88 %	8.9	± 2.6	0.093	± 0.019	0.3	0.0453
other plastic	24 %	0.4	± 0.2	0.036	± 0.017	0.2	0.0023

3.3. Current levels for Germany (2017-2021)

The OSPAR long-term target requires an FTV % under 10 % for at least 5 consecutive years. Therefore, data are pooled in 5-year periods. In the recent 5-year period (2017-2021), 49 % of the analysed stomachs exceeded the 0.1 g level (FTV %). Although this remains the best FTV performance in the German monitoring program, the OSPAR long-term target is still far off and was clearly missed (Figure 1).

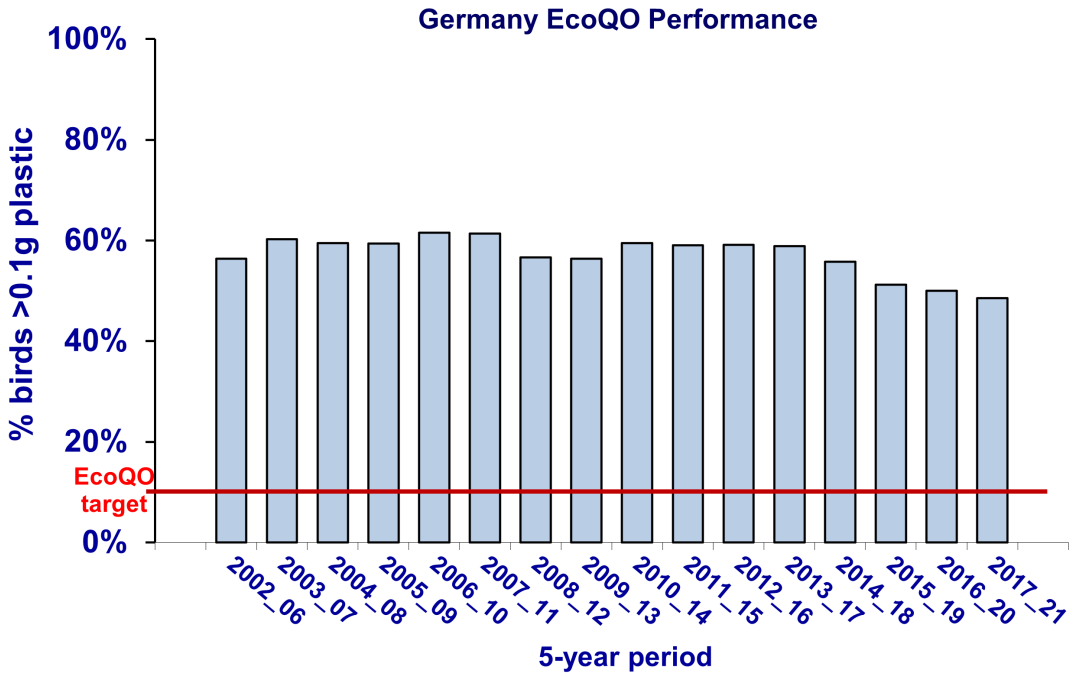

Figure 1: Fulmar-TV performance of fulmars in Germany over running 5-year periods from 2002 up to 2021. The red line illustrates the OSPAR Fulmar-TV to reduce the percentage of birds with more than 0.1 gram of plastic in the stomach to below 10 %. This graphic visualisation does not represent a statistical trend analysis.

In the recent 5-year period (2017-2021), 88 % of the 103 German fulmars examined did have plastic in their stomach (Table 4). On average 16 plastic particles per stomach with a mass of 0.26 g were found. According to the age and sex analysis, 24 % of the birds were adult and 51 % male. For all birds a body condition-index was calculated based on the status of the breast muscle, subcutaneous fat, and intestinal fat. With an average condition-index of 1.1 most of the analysed birds showed a very poor body condition. All plastic items were distinguished into the categories industrial and user plastic (Figure 2). In the current years (2017-2021), 50 % of the fulmar stomachs contained industrial plastics while user plastics were found in 86 % of the birds. The category user plastic is separated into five subcategories: sheet-like plastic, threads, foamed plastic, plastic fragments, and other plastics. In the current period (2017-2021) plastic fragments show the highest incidence with 80 % in German samples (Table 4).

Table 4: Summary of sample characteristics and stomach contents of fulmars collected for German marine litter monitoring in the current 5-year period 2017-2021. The top line shows 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). The table lists for each litter (sub) category: Incidence, representing the proportion of birds with one or more items of the litter category present; average number of plastic items per bird stomach ± standard error; average mass of plastic ± standard error per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-transformed values as used in trend-analyses.

Germany 2017-2021	**nr of birds**	**% adult**	**% male**	**% LL colour**	**% death oil**	**avg condition**
	103	24	51	90	0	1.1

	incidence	**average number of items (n/bird)**	**± se**	**average mass of litter (g/bird)**	**± se**	**max. mass recorded**	**geometric mean mass (g/bird)**
ALL PLASTICS	88 %	16.3	± 2.2	0.261	± 0.053	3.1	0.0638
INDUSTRIAL PLASTIC	50 %	2.5	± 0.7	0.064	± 0.018	1.7	0.0074
USER PLASTIC	86 %	13.8	± 1.9	0.196	± 0.046	2.9	0.0441
sheets	51 %	2.5	± 0.7	0.008	± 0.002	0.1	0.0016
threads	35 %	0.9	± 0.2	0.010	± 0.003	0.2	0.0012
foamed	49 %	2.3	± 0.5	0.011	± 0.004	0.3	0.0018
fragments	80 %	7.7	± 1.2	0.092	± 0.026	2.6	0.0220
other plastic	20 %	0.3	± 0.1	0.076	± 0.034	2.9	0.0015

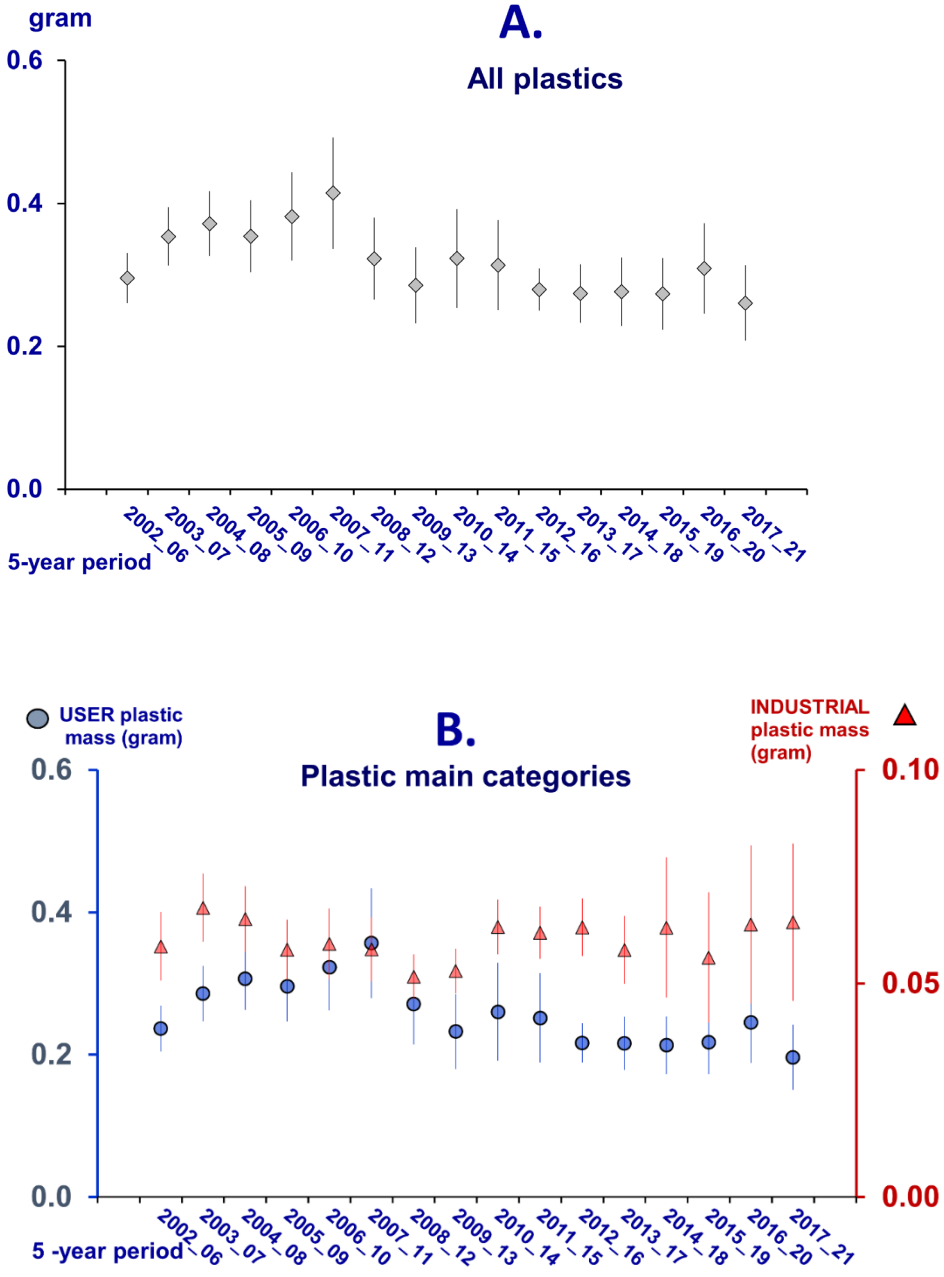

Figure 2: Plastic in stomachs of fulmars from Germany 2002-2021. Shown by 5-year running averages A: Data for all plastics combined visualising changes in arithmetic average mass ± se. B: Arithmetic mass data, split into user plastic (blue circles, left y-axis) and industrial plastic (red triangles, right y-axis).

3.4. Trends

Within the Fulmar Threshold Value approach, detailed trend analyses focus on the mass of plastics in stomachs of beached fulmars rather than on the incidence or number of plastic particles. The following trend discussions distinguish between the long-term trends (2002-2021) and the recent trends (2012-2021).

3.4.1. Long-term trend (2002-2021)

The 'long-term trend' is defined as the trend among all years in the dataset (2002-2021). The current dataset contains records of 861 fulmars, with 348 adult birds and 488 non-adults, which are juveniles to immatures several years of age. For 25 birds, there was insufficient information to determine the age group. The slopes of the regression lines for industrial plastics over the 2002-2021 period are negative, indicating a decline, but are only significant for adults (p = 0.033) (Table 5). The status is similar for consumer plastics. Except for non-adults, both for adults and for the combined age group, the slopes of the regression lines are negative, but also not significant (Table 5). Combining industrial and user plastics, the trend of all plastic particles in the stomachs of fulmars in German samples shows negative slopes of the regression lines, which are only significant for adult birds (p<0.05). Overall, the trends in the different age groups are similar, but do not reach the same significance level due to smaller sample sizes.

*Table 5: Trends 2002-2021 since start SNS project for plastics in Fulmar stomachs, Germany. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x. 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.*

Industrial plastics (lnGIND)	**n**	**Constant**	**slope**	**s.e.**	**t**	**p**	
all ages	861	25.6	-0.0150	-0.0150	-1.00	0.317	n.s.
adults	348	104.7	-0.0546	0.0255	-2.14	0.033	↓ -
non adults	488	45.9	-0.0249	0.0197	1.16	0.206	n.s.

User plastics (lnGUSE)	n	Constant	slope	s.e.	t	p	
all ages	861	8.8	-0.0057	0.0128	-0.05	0.654	n.s.
adults	348	86.6	-0.0446	0.2340	-1.91	0.057	n.s.
non adults	488	-6.6	0.0020	0.0163	0.12	0.902	n.s.

All plastics combined (lnGPLA)	n	Constant	slope	s.e.	t	p	
all ages	861	16.3	-0.0093	0.0128	-0.73	0.467	n.s.
adults	348	114.7	-0.0584	0.0236	-2.49	0.013	↓ -
non adults	488	-1.3	-0.0004	0.0161	-0.03	0.978	n.s.

3.4.2. Recent trends (2012-2021)

The 'recent trend' is defined as the trend in plastic mass in fulmar stomachs over the last 10 years (2012-2021). The shorter the assigned period, the more likely extreme years can influence the data. The current dataset contains records of 323 fulmars, with 79 adult birds and 240 non-adults, which are juveniles to immatures several years of age. For four birds, there was insufficient information to determine the age group. In the current 10-year period (2012-2021), the signs of the regression slopes indicate a downward trend (Table 6). Thereby, the samples of adults show a clear significant decrease ($p < 0.001$) for all plastic types (Table 6).

*Table 6: Recent 10-year trends 2012-2021 plastics in Fulmar stomachs, Germany. Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x. 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.*

Industrial plastics (lnGIND)	**n**	**constant**	**slope**	**s.e.**	**t**	**p**	
all ages	323	93.8	-0.0488	0.0406	-1.20	0.230	n.s.
adults	79	654.0	-0.3270	0.0885	-3.69	<0.001	↓ - - -
non adults	240	-31.0	0.0132	0.0447	0.30	0.767	n.s.

User plastics (lnGUSE)	n	constant	slope	s.e.	t	p	
all ages	323	94.9	-0.0485	0.0329	-1.47	0.141	n.s.
adults	79	607.0	-0.3028	0.0803	-3.77	<0.001	↓ - - -
non adults	240	-23.5	0.0104	0.0340	0.30	0.761	n.s.

All plastics combined (lnGPLA)	n	constant	slope	s.e.	t	p	
all ages	323	86.0	-0.0439	0.0335	-1.31	0.191	n.s.
adults	79	657.0	-0.3276	0.0850	-3.85	<0.001	↓ - - -
non adults	240	-42.9	0.0202	0.0336	0.60	0.548	n.s.

3.4.3. Germany in relation to other European countries

The OSPAR/MSFD monitoring program obliges all North Sea countries to annually report on plastics in fulmars. The latest international overview was published by Van Franeker et al. (2021) and reports data up to the year 2018. The latest OSPAR Intermediate Assessment has been published in 2019 and includes data until 2016 (OSPAR 2019). A third Intermediate Assessment up to 2018 has been prepared but is awaiting publication by OSPAR until now. Data from Germany is within the average for the OSPAR region South Eastern North Sea (a region that includes Germany, the Netherlands and Belgium) as well as in comparison the broader North Sea area. For the current 5-year period (2017-2021), data is publicly available for the Netherlands and the Skagerrak region. For the UK data for the previous 5-year period (2016-2020) is published so far. The basic data for all these countries are summarized in Table 7. Trends over the recent 10 years and over the entire sampling period since 2002 are similar. All countries observe a decrease in plastic mass, sometimes significant, sometimes not. All countries however are still far off the Threshold of not more than 10 % of the birds having 0.1 gram or more in their stomach.

Table 7: Overview of 5-year period data available from other countries around the North Sea. Given are the location (with sampling years), the number of available birds, the frequency of occurrence (%FO), average number and mass of plastics per bird and the percentage of birds above the 0.1-gram Fulmar Threshold (Fulmar-TV).

Location	**Sample size**	**%FO**	**Avg n**	**Avg g**	**Fulmar-TV (% > 0.1 g)**	**Reference**
Skagerrak (DEN+NOR) (2017-21)	14	100	20.4	0.11	29	Van Franeker et al. 2021b
UK North Sea (2016-20)	98	85	22.7	0.16	45	Kühn & van Franeker 2022
Netherlands (2017-21)	179	94	26.5	0.25	50	Kühn et al. 2022
Germany (2017-21)	**103**	**88**	**16.3**	**0.26**	**49**	**This report**

In the Netherlands, the slopes of the regression lines for industrial plastics, consumer plastics, and the combination of user and industrial plastics are negative over the 2002-2021 period, but significant for industrial plastics ($p < 0.01$) and for adults within user plastics ($p < 0.05$) and for all plastics ($p < 0.05$). Over the 1979-2021 period, long-term trends for all plastics (industrial and user plastics combined) in fulmar stomachs in the Netherlands show a highly significant decrease ($p < 0.01$) (Kühn et al. 2022).

For the years 2017-2021, 94 % of Dutch samples contained plastic particles with a slightly lower average mass of 0.25 g (Kühn et al. 2022) compared to German samples (Germany: 0.26 g; Table 4). The incidence of industrial plastics found in Dutch and German samples was 51 % and 50 %, respectively. The average mass of industrial plastic particles slightly exceeds Dutch levels in recent years (Germany: 0.06 g; Netherlands: 0.04 g). While in Dutch samples the incidence of user plastics was higher (94 %) than the German birds (86 %; Figure 2), the average mass of user plastics was similar for both countries (Germany: 0.20 g; Netherlands: 0.21 g).

4. Concluding remarks

The amount of plastic in the stomachs of fulmars is slowly decreasing. Although the trends are not statistically significant, they do indicate a downward trend over the long term since 2002 and the recent 10-year period.

In the current 5-year period (2017-2021), 88 % of the 103 German fulmars examined did have plastic in their stomach. The average number of plastic particles was 16 per bird, weighing 0.26 g. Over the integrated recent 5-year period 2017-2021, 49 % of German fulmars exceed the critical FTV level of 0.1 g of plastic in the stomach indicating, that current measures are not sufficient or not sufficiently implemented and as the case may be additional ones need to be taken. The time trends in the 5-year average FTV Performance of fulmars found in Germany indicate an improvement, but still the 10 % FTV target set by OSPAR is clearly missed.

Info Box 3

Seabird of the Year 2022: The Northern Fulmar

The fulmar has been announced as seabird of the year 2022. To celebrate this announcement, Verein Jordsand has dedicated a Special Issue of their journal SEEVÖGEL to this bird. The publication is expected at the end of 2022. The special issue features various aspects of the fulmar distribution, population trends, biology, behaviour and potential threats. One of the chapter focuses on plastic ingestion in fulmars from German coasts. The Special Issue is written in German but provides summaries and Figure/Table captions in English.

5. Acknowledgements

We acknowledge financial support for this project by NLWKN ("Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz") within the framework of BLANO ("Bund/Länder-Arbeitsgemeinsaft Nord- und Ostsee"). We would like to thank the Federal Environmental Agency (UBA) for the coordination, support, and funding of the project during recent years. We are grateful for the good cooperation with our partners at the University Kiel (FTZ, Büsum) and at Wageningen Marine Research. We would especially like to thank Stefan Weiel for his engagement the last years!

We would like to thank all agencies, institutions and NGOs that supported our work: Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN), Nationalparkverwaltung im Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein (LKN-SH), Schutzstation Wattenmeer e.V., Der Mellumrat e.V., Landesmuseum Natur und Mensch in Oldenburg, Öömrang Ferian i.f., Seehundstation Nationalpark-Haus Norden-Norddeich, Naturschutzbund Deutschland e.V.

We are particularly grateful to the hundreds of individuals that have helped in the collection of beached fulmars along the German North Sea coast on a voluntary basis. Without their motivation and support the realisation and continuation of the Fulmar Litter monitoring programme would not be possible.

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7. Supplementary

The following photos of plastic particles found in individual bird samples originally served only as notes but are added here for completeness and general information (Photos: Leonie Enners, Verein Jordsand).

	GER-2020-002: No stomach
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	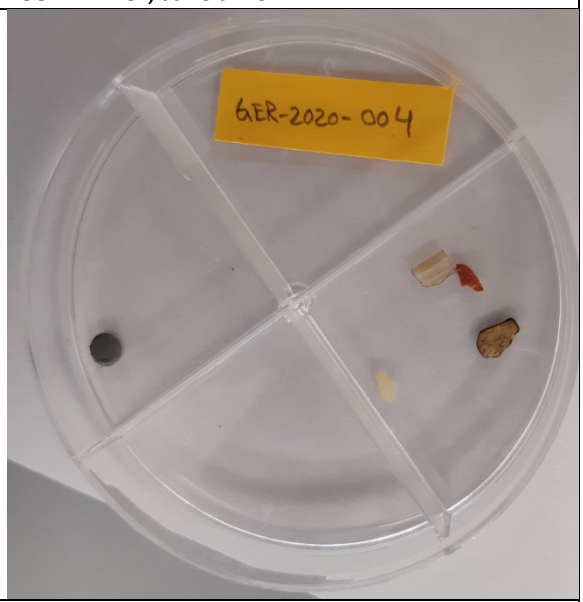
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17/05/2020:
Mellum, Mellumrat, Jonas Frey

12/12/2020:
Spiekeroog, NLWKN

17/02/2020:
Hedwigenkoog, LKN, Christian Piening

GER-2020-009: No stomach	
21/01/2020: Sylt, Schutzstation Wattenmeer, Christian Umlauf	18/04/2020: Spiekeroog, NLWKN
GER-2020-011: No stomach	**GER-2020-012: No stomach**
23/02/2020: Sylt, Schutzstation Wattenmeer, Christian Umlauf	21/07/2020: Amrum, Schutzstation Wattenmeer, Felix Grygier
GER-2020-013: No stomach	
21/07/2020: Büsum/Blauortsand, Schutzstation Wattenmeer, Maja Bernhardt	23/02/2020: Sylt, Schutzstation Wattenmeer, Christian Umlauf

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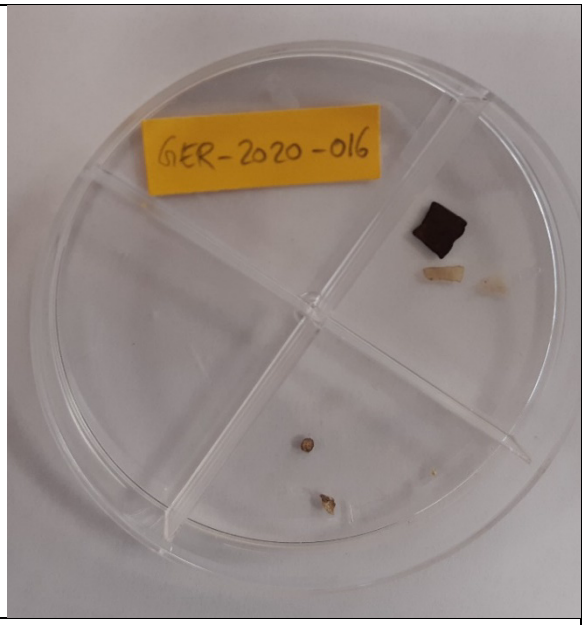
</td><td> 
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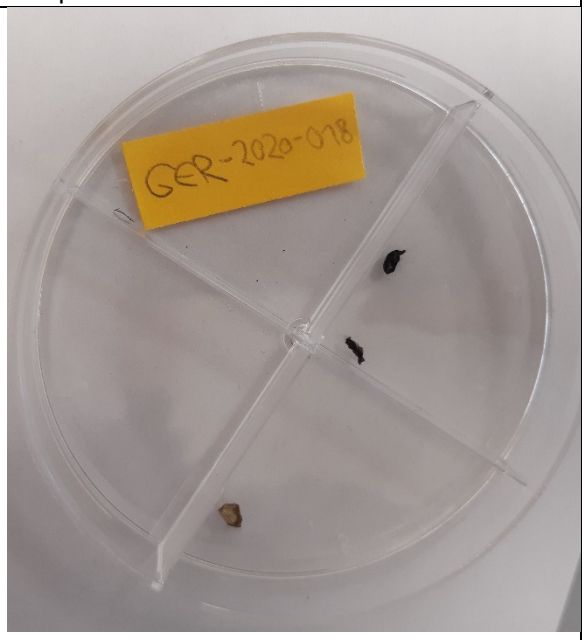
</td><td> 
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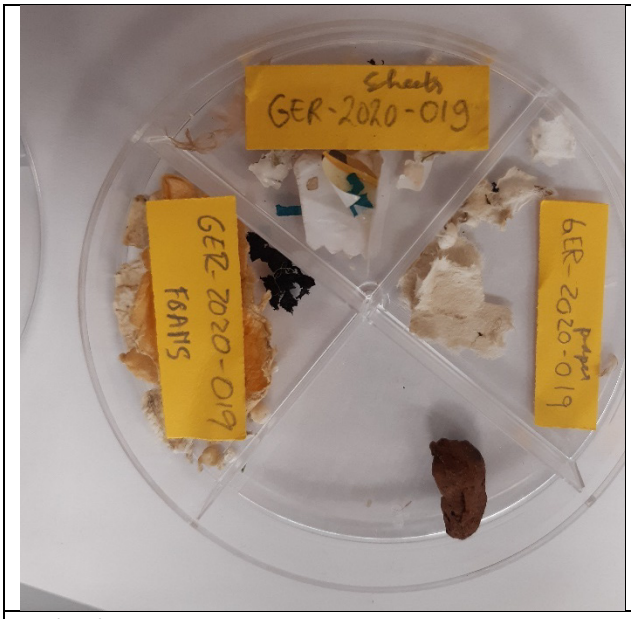

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11/03/2020:
Pellworm, Schutzstation Wattenmeer,
Theresa Wittig

16/09/2020:
Süderoogsand, Schutzstation Wattenmeer,
Linda Reichel

08/04/2021: Norderney, NLWKN	15/04/2021: Norderney, NLWKN
12/04/2021: Beltringharder Koog, LKN, Rainer Rehm	13/04/2021: Hamburger Hallig, LKN, Rainer Rehm

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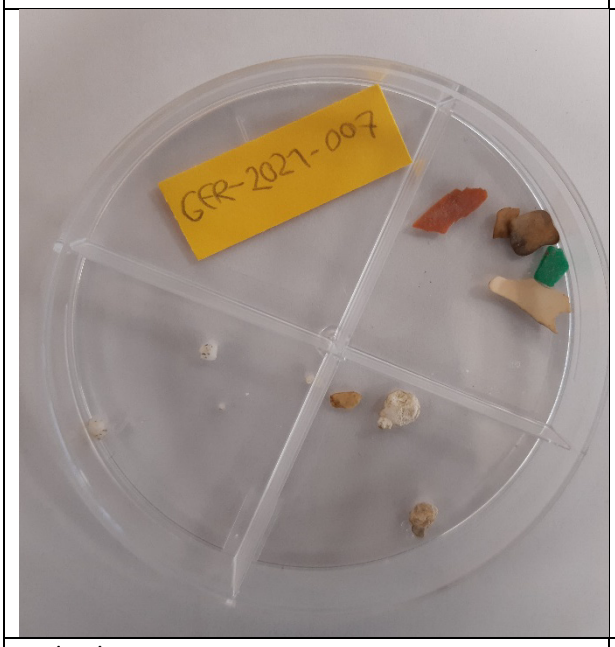

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Beltringharder Koog, LKN, Rainer Rehm

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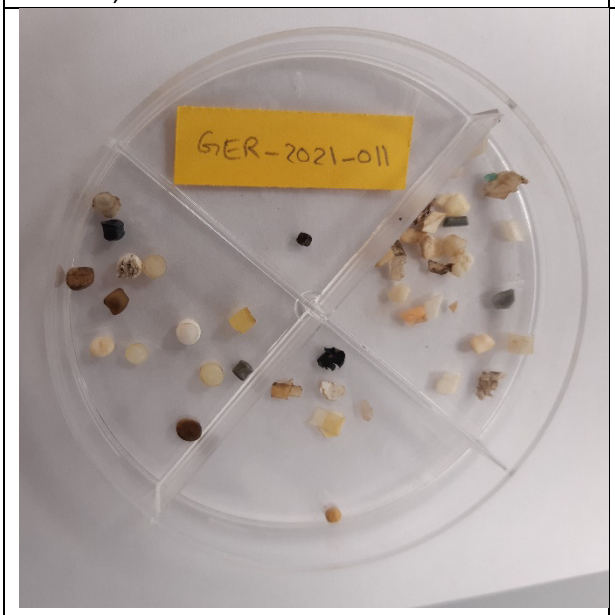	
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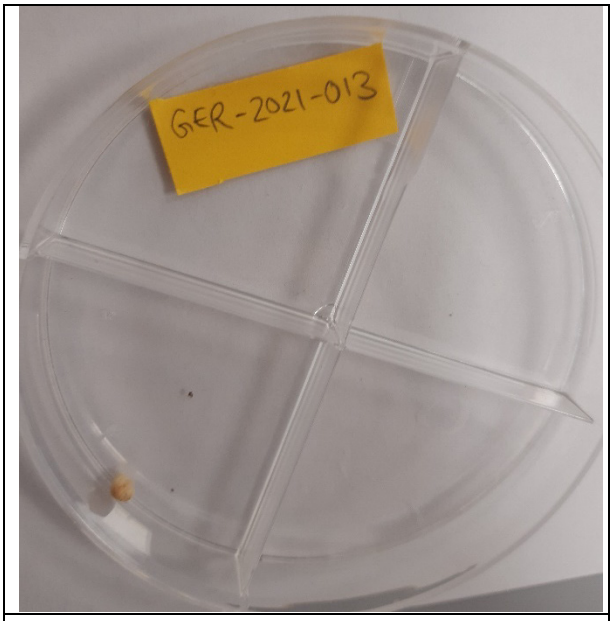	
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	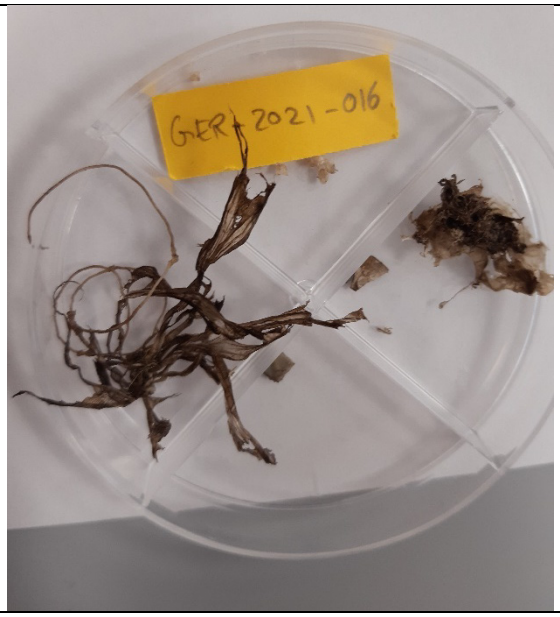
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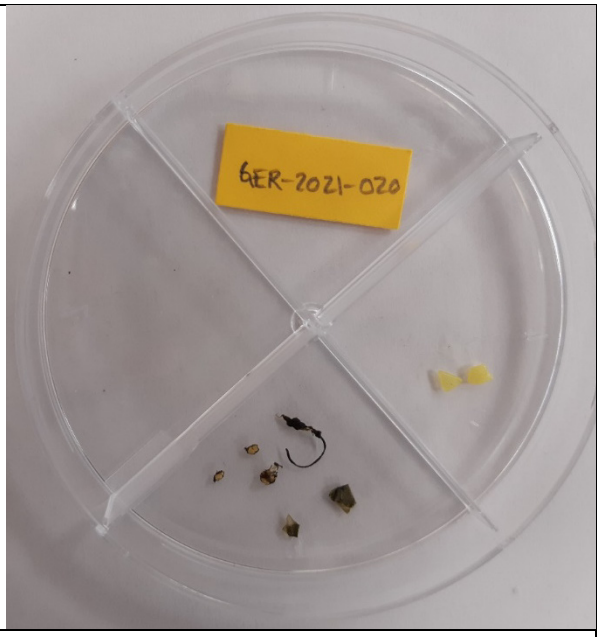
GER-2021-019: No stomach	
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