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New tools to evaluate plastic ingestion by northern fulmars applied to North Sea monitoring data 2002–2018

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ABSTRACT

Monitoring plastic in stomachs of beached northern fulmars for OSPAR's Ecological Quality Objectives (EcoQOs) has been incorporated into the European Marine Strategy Framework Directive (MSFD). This paper aims to provide the appropriate tools to interpret the monitoring results. 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%. The MSFD approach was evaluated for 2661 North Sea fulmars in 2002–2018. Between 2014 and 2018, 51% of 393 fulmars exceeded 0.1 g plastic, significantly above the proposed Fulmar-TV. Linear regression of individual ingested plastic mass over the 2009–2018 period indicates a significant decrease. Over the longer term 2002–2018, logistic regression of annual EcoQ% shows a significant decline and predicts compliance with the Fulmar-TV by 2054.

1. Introduction

In 2002, monitoring the abundance of plastic marine litter in stomachs of beached northern fulmars (*Fulmarus glacialis;* hereafter 'fulmar') in the Netherlands (Van Franeker and Meijboom, 2002) developed into an international North Sea wide study. The abundance of marine litter ingested by seabirds like the fulmar reflects the quality of their environment. The international expansion of the project was part of the European Union's Interreg-funded campaign Save the North Sea (SNS) which aimed to reduce marine litter in the North Sea by creating awareness (Save the North Sea, 2004).

After 2004, the SNS fulmar study group continued to co-operate informally. The monitoring became part of the OSPAR system of Ecological Quality Objectives (EcoQOs) for the North Sea (OSPAR, 2008, 2009, 2010a,b; OSPAR is the acronym for the 'Convention for the Protection of the Marine Environment of the North-East Atlantic'; see Supplementary material Section 8 for details on international agreements and terms and acronyms used in their monitoring approaches of

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marine litter). Guidelines on methods for dissection and data analysis (OSPAR, 2015) were implemented in regular 'Intermediate Assessments'. The EcoQO approach has been applied both in the North Sea context (Van Franeker et al., 2011; Van Franeker and Law, 2015; OSPAR, 2017, 2019) and more widely across the Atlantic (Provencher et al., 2009; Kühn and Van Franeker, 2012; Bond et al., 2014; Trevail et al., 2015; Acampora et al., 2016; Herzke et al., 2016; Poon et al., 2017; Avery-Gomm et al., 2018; Baak et al., 2020; Environment Canada, 2020) and Pacific (Avery-Gomm et al., 2012; Nevins et al., 2011; Donnelly-Greenan et al., 2014; Terepocki et al., 2017).

OSPAR's fulmar monitoring approach has also been implemented as an indicator for 'Good Environmental Status (GES)' in the EU Marine Strategy Framework Directive (MSFD) (Galgani et al., 2010; EC, 2008, 2010, 2017). Although the monitoring method is the same, OSPAR and EU MSFD have worded their aims differently.

OSPAR (2008, 2009) has defined a (undated) long-term goal for the fulmar EcoQO in the North Sea as:

*"There should be less than 10% of northern fulmars (*Fulmarus glacialis*) having more than 0.1 g plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 areas of the North Sea over a period of at least five years".*

There was no scientific background for this target definition other than the fact that zero plastics was considered an impossible policy aim, but that reduction should be substantial. The line of thought followed the earlier OSPAR EcoQO on oil pollution, which required that the proportion of beached common guillemots (*Uria aalge*) with traces of mineral oil in the feathers should be reduced to under 10% (OSPAR, 2005).

In a different approach, the European Commission (EC, 2017) worded the aim of its marine litter descriptor D10 for Good Environmental Status (MSFD-GES) as "that no harm may be caused to the coastal and marine environment". Criterion D10C3 specifies for any marine species that:

"The amount of litter and micro-litter ingested by marine animals is at a level that does not adversely affect the health of the species concerned. Member States shall establish threshold values for these levels through regional or subregional cooperation".

Thus, where OSPAR views the fulmar as a general indicator for wider ecosystem health in terms of marine litter, with a subjectively quantified long-term EcoQO, the MSFD target requires that the fulmar species, among a broader range of indicator species, may not be negatively affected by plastic ingestion. The European MSFD covers a very wide range of ecological and environmental issues, and has an overarching target date for GES in year 2020, with specific indicator targets to be established on a regional basis.

The concept of 'no harm' in the EU MSFD approach has its background in toxicity testing of chemical substances where risks are assessed by lethal or no-effect doses measured in animal experiments. However, in the case of (a wide range of types and sizes of) marine litter and the impact on a specific species of wildlife, it is virtually impossible to assess when a particular variable represents 'harm' or an 'adverse effect' (Browne et al., 2015; Rochman et al., 2016; Werner et al., 2016). In the MSFD, species health is the criterion rather than individual harm, health or mortality. However, populations or species are affected by a broad range of continuously changing variables, such as habitat availability, habitat quality, food conditions, predation pressure, climate change, and a range of pollutants, including plastics (e.g. Rodríguez et al., 2019). Plastic ingestion undoubtedly has a negative effect for individual birds, but the level of impact is very hard to assess (Kühn and Van Franeker, 2020), and resultant effects on populations or species cannot be quantified (Werner et al., 2016). One scientific paper claims that harm from plastic ingestion to procellariiform seabirds in the Southern Ocean can be quantified (Roman et al., 2019). Based on proportions of beached birds judged to have died specifically from ingested litter, they constructed a model that predicts a 20% mortality risk from a single particle of ingested plastic. The northern fulmar is also a procellariiform seabird, but no data exist to construct a fulmar-specific model using a similar approach. Applying the Southern Ocean mortality risk to the fulmar would imply that after half a century of plastic pollution, the species should be extinct. However, even though the species is currently not doing very well (see Supplementary material Section 2A), it is certainly not extinct, which invalidates the Southern Ocean model for application on the fulmar in the northern hemisphere.

Recognizing the difficulty of defining harm, MSFD decided that assessing a threshold value for fulmars by referring to the situation in pristine areas is an acceptable alternative (Werner et al., 2020). In terms of plastic marine litter, the Canadian High Arctic region may be viewed as near pristine (Supplementary material Section 2B). It has a low level of human population with the Inuit inhabiting the region for generations and the current population for the entire territory of Nunavut being about 30,000 people. Additionally, the extensive coastline has only a few industrial level settlements (all of which have been developed since the 1960s), is still ice covered for most of the year, and water currents mostly flow in from the northern, ice-covered Arctic basin, rather than from polluted Atlantic waters farther south (AMAP, 1998). It must be emphasized that a (near) pristine area threshold provides no information whatsoever on individual health or harm to a population or species.

In terms of data analysis, the current fulmar monitoring guidelines (OSPAR, 2015) are derived from the early research by Van Franeker and Meijboom (2002) and prescribe:

a. an assessment of the proportion of stomachs exceeding 0.1 g of plastics over the most recent 5-year period and
b. a linear regression analysis of the trend in mass of plastic in individual stomachs over the most recent ten years of data.

These two assessments provide a simple yes or no answer to the question whether the policy target of 10% has been reached, plus a statistical indication on the direction of change under recent policies. However, they do not provide the direct analytical tools required for policy decisions in relation to either the OSPAR or MSFD target definitions. The aim of the current paper is to provide additional tools for policy makers to interpret fulmar monitoring results in a way that allows clear decision making in relation to targets in both OSPAR and MSFD. More specifically, in addition to the existing standard analysis of the monitoring data this paper aims to provide:

Addition 1. a data-based threshold value for fulmar-ingested plastics that meets the MSFD GES requirements (hereafter abbreviated 'Fulmar-TV')

Addition 2. a statistical approach to test whether plastics in stomachs of a specific sample of fulmars meet the EcoQO or threshold value

Addition 3. a statistical approach to view progress towards meeting policy targets.

In a next step we aim to implement the existing and the new analytical tools in an analysis of the SNS data for plastics in stomachs of fulmars in the North Sea over the period 2002–2018. The proposed additional assessment tools aim for more accurate and easy to understand information on marine litter monitoring to the general public, stakeholders and policy makers.

2. Materials and methods

2.1. Existing OSPAR analyses

The plastic monitoring program of OSPAR in the North Sea uses beached fulmars. The pilot study by Van Franeker and Meijboom (2002) showed that plastic contents in stomachs of slowly starved beached fulmars were not statistically different from those in fulmars that had died instantly in good body condition for example from collisions or as fisheries bycatch. Thus, results from beached birds may be considered representative for the fulmar population at sea. The only variable found to affect the quantity of ingested plastic was age, with younger birds holding on average more plastic than older ones. But as long as age composition shows no persistent change over time, monitoring data can be grouped for all ages.

Methods for dissection including the assessment of age and sex are described in Van Franeker (2004a) and the OSPAR Guidelines (OSPAR, 2015). In short: age and sex are assessed on the basis of anatomical details of the sex organs, and presence and size of the Bursa of Fabricius, a gland that is present in very young birds, but that shrinks and disappears within one to two years. Supporting evidence for age can be found in moult patterns of the plumage. OSPAR uses a simple split in adult and non-adult birds, that is whether sex organs indicate if a bird has been breeding, or not. The non-adult bird group may include immatures and sub-adults up to considerable age, as fulmars on average only start breeding at 9 years of age (Ollason and Dunnet, 1978).

Methodological details of stomach content analyses are specified in the Online Supplement to Van Franeker et al. (2011) and in annual Dutch reports (e.g. Van Franeker and Kühn, 2019). The OSPAR EcoQO is worded in terms of total plastic mass in stomachs but sometimes the presence of major categories of plastic like industrial plastic ('pellets') and user plastic (consumer debris) are considered separately (e.g. Van Franeker and Law, 2015).

In the guidelines by OSPAR (2015) for EcoQO monitoring of plastic ingestion by fulmars in the North Sea area, the choice has been made to not use a single year for describing the 'current situation', but to use data from the most recent five years. The number of years is arbitrary, but largely avoids unexplained interannual variations and occasional years of low sample size. Calculated are the frequency of occurrence (proportion of individual stomachs with any plastic), and the average number of particles and mass of plastic with standard errors. Geometric mean mass is often added as an additional figure that reduces the impact of exceptional outliers on the averages. The analyses use data from all individual birds (not the average of annual averages), including the birds without any plastic, so number and mass data represent 'population averages'. The mass data are used to calculate the required simple and single monitoring parameter: the proportion of birds in the sample exceeding 0.1 g of plastic mass. This proportion is referred to as EcoQ-Performance or EcoQ%.

The second parameter prescribed by the OSPAR (2015) guidelines concerns the 'recent trend'.

The recent trend is calculated by simple linear regression of ln-transformed data for mass of plastics in individual birds against the year of collection. The standard test-period uses data from all individuals over the most recent ten years in the dataset. The period of ten years was arbitrarily chosen from the background that Dutch long-term data had shown considerable non-linear changes over longer time-periods (Van Franeker and Meijboom, 2002; Van Franeker et al., 2011). The aim of the OSPAR trend analysis was to provide a simple indicator for the direction of change under current conditions of governmental policies and polluter behaviour (see also the OSPAR guidelines (OSPAR, 2015) and Van Franeker et al. (2011)). Linear tests over longer time periods are not directly helpful for policy decision making. The Intermediate Assessments of the monitoring system (OSPAR, 2017, 2019) often provide non-statistical visual illustrations of longer term 'trends' using graphs of running 5-year averages over all available monitoring data. Running annual averages each time re-uses data from earlier years to smooth out the noise of random outliers or years of small sample sizes.

2.2. Addition 1: establishment of the MSFD Fulmar Threshold Value

Lacking the possibility to calculate a Fulmar-TV that represents the MSFD requirement of no harm to the population or species, the threshold must be derived from the most pristine environment for which fulmar studies are available. In order to calculate such a near pristine Fulmar-TV, we used the original raw data from the following fulmar studies in the Canadian High Arctic:

1) Mallory et al. (2006) presented data for 42 fulmars retrieved by a fisheries observer aboard a Norwegian longline fishing vessel operating between 15 August and 10 September 2002 in Baffin Bay between 67°19′ to 69°32′N and 58°29′ to 65°08′W.
2) Mallory (2008) presented data for 102 fulmars collected by noose pole or shooting from the Cape Vera colony or vicinity (76°15′N, 89°15′W), northern Devon Island, Nunavut, from 26 May to 22 August 2003 and 14 May to 9 August 2004.
3) Provencher et al. (2009) presented data on ten breeders captured with a noose pole from nest sites at Prince Leopold Island, Nunavut (74°N, 90°W) on 1 August 2008, and for 15 birds shot at sea on 4 August 2008 within 5 km of the colony at Cape Searle, Nunavut (67°15′N, 62°35′W).
4) Poon et al. (2017) added nine fulmars captured by noose pole from nests at Prince Leopold Island on 3 and 5 July 2013. For our calculations a tenth bird collected at the same date and location could be added (Provencher, pers. inf.).

The combined dataset thus holds records for plastics in stomachs of 179 fulmars from Arctic Canada over 2002–2013. All sample locations are within what is usually defined as the 'High Arctic'. Because latitudinal differences in plastic burdens may exist (Mallory, 2008; Van Franeker and Law, 2015), records were grouped into either High Arctic North (north of 70°N, Cape Vera and Prince Leopold Island; n = 122) or High Arctic South (south of 70°N, the collection locations near Cape Searle or at sea; n = 57). Original data from the 179 birds are provided in Supplementary material Section 9. Methods for dissections and stomach analyses in the Canadian studies were mostly similar to those used in the OSPAR monitoring, but partly miss details for age and sex. Where accurate dates of collection were missing (Cape Vera data), the month of collection could be derived from the combination of sample numbers containing dates, and monthly totals for birds collected given in Fig. 2 of Mallory (2008). Month of collection is relevant because seasonal changes in quantities of plastics in the stomachs may occur (Mallory, 2008; Van Franeker and Law, 2015). For the northern and southern Canadian samples plus seasonally split subsamples, the analyses include:

- the number of stomachs
- the average (± standard error) and maximum number of plastic particles per stomach, including zero records (population average)
- the average (± standard error) and maximum mass (in g) of plastic per stomach, including zero records (population average)
- the proportion of stomachs containing any plastic (Frequency of Occurrence, %FO)
- the proportion of stomachs containing more than 0.1 g of plastic (EcoQ% = EcoQ-Performance). As recommended by Provencher et al. (2017) following Brown et al. (2001) the 95% confidence intervals for %FO and EcoQ% are calculated using *http://epitools.ausvet.com.au/content.php?page=CIProportion* with the Jeffreys Interval
- the 90th percentile of masses, that is the value in grams of plastic separating the 10% most polluted fulmars from the 90% cleaner birds in the sample (this percentile approach is also being used in other MSFD threshold assessments).

An EU MSFD Threshold Value could of course be based on any average, or proportion or percentile of ingested plastic in the near pristine environment. However, we focus on the 'proportion of birds with more than 0.1g of plastic in the stomach' in the pristine situation. Such wording for the new Fulmar-TV matches the wording used in the earlier OSPAR EcoQO and thereby represents consistency in international policy measures.

2.3. *Addition 2: testing sample difference from the Fulmar-TV*

The Canadian data-derived Fulmar-TV makes it straightforward to quantify the difference in plastic abundance between the Fulmar-TV and any other sample, such as those from the North Sea. Tests are available to compare proportions, using sample sizes and proportions of the samples meeting a specific condition, in this case having more than 0.1 g of plastic in the stomach. We used the 2-sample z-test to compare sample proportions, as provided by Sergeant (2019) at *http://epitools.ausvet.com.au/content.php?page=z-test-2*. In addition to the statistical probability value, this provides information about whether the test can be considered appropriate in relation to sample sizes and proportions. Similar tests to analyse binomial proportions are available in other statistical packages (e.g. Genstat, VSN International, 2017), but we recommend the 2-sample-z-test because it provides a standard and easily applied test that is freely accessible via internet.

2.4. *Addition 3: testing and predicting long term trends towards the Fulmar-TV*

In the annual updates of the fulmar monitoring program in the Netherlands, starting with the 2017 update report (Van Franeker and Kühn, 2018), an additional approach has been developed to directly evaluate the progress towards the OSPAR long-term target. This uses annual figures of EcoQ-Performance over longer time frames, for example for the Netherlands a period of 41 years since 1979 or 17 years of international North Sea monitoring since 2002 (Van Franeker and Kühn, 2019). The approach is not suitable for short periods such as the ten years used for recent linear trends because only ten datapoints will rarely lead to reliable and consistent conclusions. Longer series of annual data can be analysed in a GLM approach (Generalized Linear Modelling; VSN International, 2017), more specifically in a logistic analysis dedicated for binomial distributions (number of birds in the sample and number of birds above the Fulmar-TV) and using logit transformation. A similar type of analysis is already used for OSPAR-related analyses of long-term rates of oiling among seabirds (cf. Camphuysen, 2019). The logistic approach models a sigmoid shaped curve over longer time periods by assuming a start to end process which considers that initial reductions from highest values will be difficult and slow, intermediate changes can potentially be fast, but final changes towards the lowest values will again increase in difficulty and are expected to be slow. If the statistical trend based on observed data of annual EcoQ% is significant, as it was in the Dutch data (Van Franeker and Kühn, 2019), the logistic model can be used to predict EcoQ-Performance in future years and includes an estimated year of reaching the target. The predictive model of the trend may be used to set intermediate policy targets in relation to ultimately reaching the Fulmar-TV.

2.5. *Implementation of existing and new analytical tools in North Sea monitoring*

Since the start of the international monitoring program in 2002 (Save the North Sea, 2004) and up to 2018, data were collected on 2661 fulmars from the North Sea Region. In this figure, stomachs damaged by scavengers or decayed to the extent that part of the contents could have been lost, were excluded. Also, birds kept in rehabilitation centres for more than three days before dying, were excluded because of the gradual disappearance of plastics from stomachs under clean conditions (Van Franeker and Law, 2015; Terepocki et al., 2017).

The OSPAR (2008, 2009) EcoQO definition requires a subregional split of the North Sea region. OSPAR (2015) defined five arbitrarily bordered, subregions (Fig. 1). With their short name and number of fulmars collected over the 2002–2018 period, these are: 1) Shetland and Orkney Islands ('Scottish Islands'; n = 272); 2) the eastern coast of mainland United Kingdom ('East-Eng-Sco'; n = 170); 3) the Channel

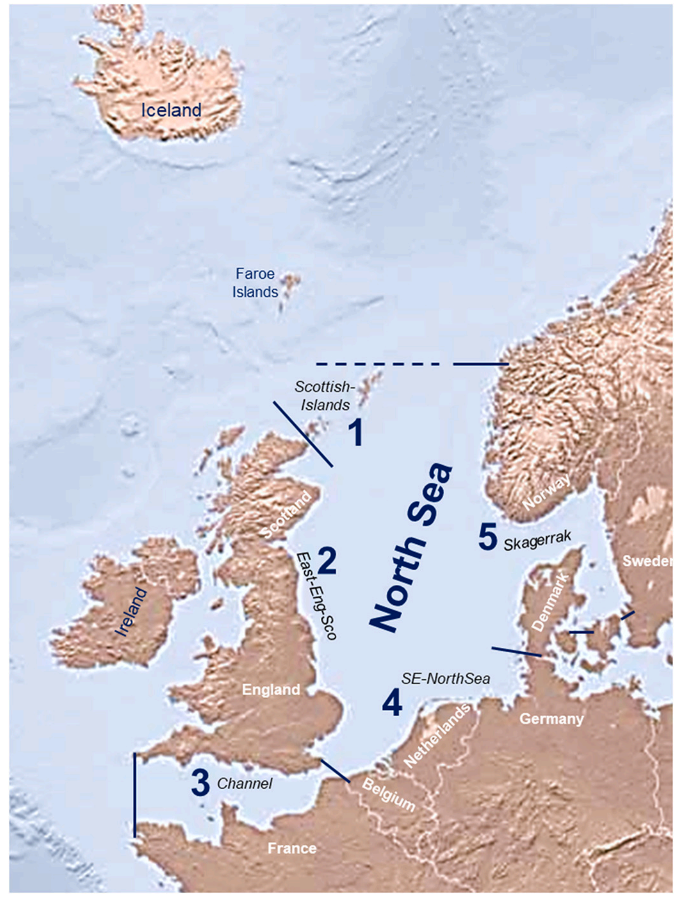

Fig. 1. Subregions in the Greater North Sea (OSPAR Region II) used in the OSPAR monitoring program of plastic particles in stomachs of beached fulmars.

bounded by southern England and northern France ('Channel'; n = 146); 4) the south-eastern North Sea coasts of Belgium, the Netherlands and Germany ('SE-NorthSea'; n = 1776); 5) the Skagerrak, combining Denmark, Sweden, and southwestern Norway ('Skagerrak'; n = 297). Full subregional sample details are provided in the Table S1 of the Supplementary material Section 3.

3. Results

3.1. *Establishment of the Fulmar Threshold Value*

For the dataset of 179 fulmars from the near pristine Canadian Arctic, the proportion of birds having more than 0.1 g of plastic in the stomach was 10.06%, almost identical to the arbitrarily chosen 10% in the OSPAR EcoQO definition (Tables 1 and 2). The 90th percentile value was 0.0992 g, very close to the arbitrarily chosen 0.1 g mass level used in the OSPAR EcoQO definition. The 0.1 g separator value from the OSPAR target definition or the 0.0992 g percentile value produced exactly the same output in terms of bird numbers: 18 of the 179 Canadian Arctic fulmars (10.06%) were above the separator value.

The overall calculation for the 179 Canadian birds conceals that the subsamples come from different locations and different seasons. Both variables may influence the results. When the data are split into southern and northern sampling locations (Table 1), it is clear that, as indicated earlier (Mallory, 2008; Van Franeker and Law, 2015), there is more ingested plastic in the southern locations (EcoQ% 15.79%) than the northern ones (EcoQ% 7.38%). The southern birds do not comply with the OSPAR EcoQO, whereas the northern ones are cleaner and do comply.

In addition to location, a seasonal gradient in the amount of plastics

Table 1
Plastic abundance in fulmars from the Canadian High Arctic in relation to regional variations and their potential use in an MSFD Fulmar-TV. The EcoQ% is given in high detail in order to document the subtle differences with the arbitrary OSPAR long term target (EcoQO 10%).

	All High Arctic Canada	South (Aug)	North
Number of stomachs	179	57	122
Average number n ± se *(max)*	2.47 ± 0.43 *(54)*	2.95 ± 0.64 *(21)*	2.25 ± 0.55 *(54)*
Average mass g ± se (max)	0.04 ± 0.01 *(1.35)*	0.05 ± 0.01 *(0.57)*	0.04 ± 0.01 *(1.35)*
%FO *(confidence limits)*	43% *(36%–50%)*	49% *(36%–62%)*	40% *(32%–49%)*
EcoQ% *(confidence limits)*	10.06% *(6%–15%)*	15.79% *(8%–27%)*	7.38% *(3%–13%)*
90th percentile (g)	0.0992	0.1425	0.0791

Table 2
Plastic abundance in fulmars from the northern Canadian High Arctic in relation to seasonal variation and their potential use in an MSFD Fulmar-TV. The EcoQ% is given in high detail in order to document the subtle differences with the arbitrary OSPAR long term target (EcoQO 10%).

	High Arctic North	May–June	July–August
Number of stomachs	122	37	85
Average number n ± se *(max)*	2.25 ± 0.55 *(54)*	3.92 ± 1.63 *(54)*	1.53 ± 0.35 *(22)*
Average mass g ± se *(max)*	0.04 ± 0.01 *(1.35)*	0.07 ± 0.04 *(1.35)*	0.03 ± 0.01 *(0.44)*
%FO *(confidence limits)*	40% *(32%–49%)*	35% *(21%–51%)*	42% *(33%–53%)*
EcoQ% *(confidence limits)*	7.38% *(3%–13%)*	10.81% *(4%–24%)*	5.88% *(2%–12%)*
90th percentile (g)	0.0791	0.1320	0.0791

in the Canadian fulmars' stomachs should be taken into account. Decreases of plastic over summer months have been observed (Mallory, 2008; Van Franeker and Law, 2015), possibly due to initial quantities of plastics being elevated from wintering in more polluted areas to the south such as the Newfoundland-Labrador area. These particles are only gradually eroded and fragmented in the gizzard (Van Franeker and Law, 2015), and during summer the stomach contents will gradually more reflect the local level of plastic pollution. Table 2 demonstrates this seasonal effect for the northern birds only (southern birds were only collected in August). Samples from May and June were combined and compared to those from July and August because samples sizes for May ($n = 8$) and August ($n = 22$) were too low to allow monthly analysis of the data. A seasonal reduction is strongly suggested by a c. 50% decrease in number and mass of plastics, as well as in the EcoQ% and 90th percentile value from May–June to July–August.

The 2-sample z-test comparing sample proportions in the EcoQ% between the southern Canadian Arctic birds ($n = 57$, proportion of 0.1597 above 0.1 g) and northern ones ($n = 122$, proportion of 0.0738 above 0.1 g) revealed that the difference suggested by Fig. 2A was not statistically significant ($p = 0.0814$). The difference between the 37 early, and 85 late season fulmars (Table 2) was insignificant in the 2-sample z-test ($p = 0.3382$), but also labelled as being inappropriate to the data used. The same applied to the most distant subsamples of 57 fulmars from the south and 85 fulmars from late in the season in the north. The calculated p value ($p = 0.0522$) was nearly significant, but labelled as an inappropriate test.

The above analyses did not consider year of collection which could be relevant because subsamples were collected over a considerable time period. Multivariate GLM analyses (VSN International, 2017) to include individual details on capture method, location or latitude, year, and month failed because terms in the models were strongly aliased. If data were pooled using the above split at 70°N, the northern and southern groups showed no significant difference in ingested plastic mass and year or month of collection made no significant contribution to the model. When using binomial proportions of birds above or below 0.1 g plastic, the difference between northern and southern birds was borderline significant ($p = 0.050$) but interannual (year $p = 0.189$) or seasonal (month $p = 0.241$) variations made no relevant contribution to the model.

3.2. Plastic ingestion by North Sea fulmars as formerly evaluated by OSPAR

Recent 5-year averages for the abundance of plastics in fulmar stomachs in the North Sea and its subregions (Table 3 and Fig. 3) indicate mostly relatively minor subregional differences but clearly elevated presence of plastics in the Channel subregion. Fig. 3 compares the EcoQ-Performance in the North Sea to more incidental observations in more northern locations in the Atlantic OSPAR area, showing reduced abundance of plastic when going further north. Data specifying industrial and user plastic details underlying Table 3 are provided in Table S2 in Supplementary material Section 4.

The linear trends in ingested plastic mass over the years 2009–2019 showed negative slopes in all subregions, indicating reduction, but significant trends of decrease were only seen in the south-eastern subregion and for the total North Sea (Table 4). Full details of linear regression results for all subregions and major plastic categories are provided in Tables S3 to S11 and Fig. S2 of Supplementary material Sections 5 to 6.

In addition to these mandatory elements from the OSPAR Guidelines, Dutch annual reports (e.g. Van Franeker and Kühn, 2019) and OSPAR Intermediate Assessments (OSPAR, 2017, 2019) often provided graphs of running 5-year averages plastic mass or EcoQO%, for illustration purposes of longer term changes and their background. For example, Fig. 4 shows the subregional EcoQ% data over the full period 2002–2018.

One issue that may complicate analyses of data on plastic ingestion in terms of the Fulmar-TV or trends over time, is that younger fulmars on average have more plastic in their stomachs than adults (Van Franeker and Meijboom, 2002; Van Franeker et al., 2011; Van Franeker and Law, 2015; Van Franeker and Kühn, 2019). When viewed by running 5-year averages, this age difference is clearly visible in the entire North Sea dataset (Fig. 5). Thus, changes in age composition in samples could influence trends observed in averaged results.

3.3. The MSFD approach to test for compliance with the Fulmar-TV

Using the epitools 2-sample z-test test to evaluate the most recent 2014–2018 North Sea data (393 birds, 51.15% over 0.1 g) for compliance with the Fulmar-TV (197 birds, 10.06% over 0.1 g), the difference is highly significant ($p < 0.0001$), and the same is true for all North Sea subregions. Also the incidental samples from other areas were all significantly different from (mostly far above) the Fulmar-TV (Faroe Islands $p < 0.0001$; Iceland $p = 0.0007$; North Norway $p < 0.0001$;

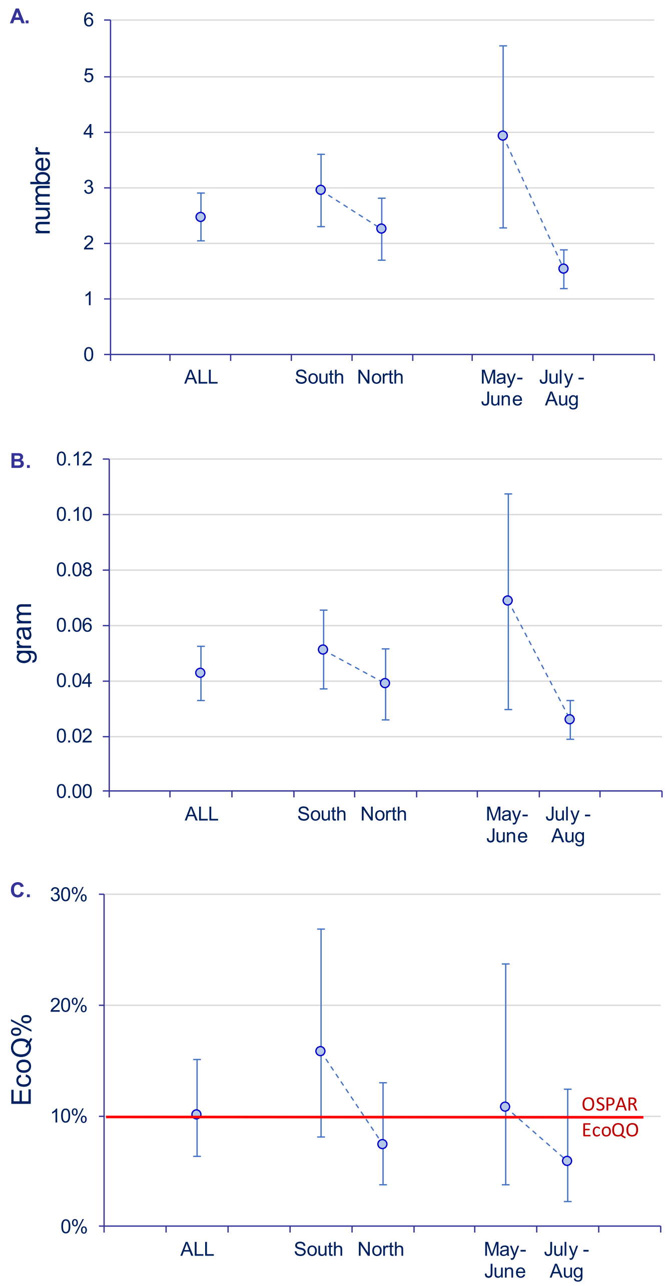

Fig. 2. The geographical and seasonal variations in averaged data (±se) occurring within the overall sample of all 179 fulmars from High Arctic Canada. For sample sizes and additional details see Tables 1 and 2. Panel A. average number of plastic particles, B. average mass of plastic, and C. EcoQ-Performance.

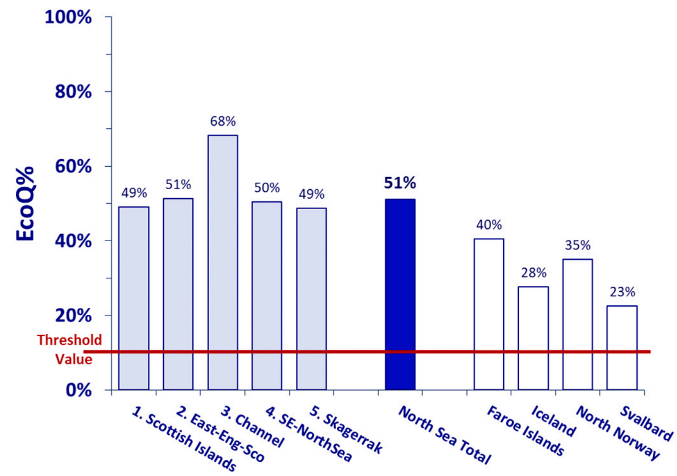

Fig. 3. EcoQ-Performance of fulmars in the North Sea monitored over the most recent 5-year period 2014 to 2018, compared to more incidental data obtained for Faroe Islands (Van Franeker et al., 2011), Iceland (Kühn and Van Franeker, 2012), North Norway (Herzke et al., 2016) and Svalbard (Trevail et al., 2015).

Table 4
Linear regression trends in ingested mass of plastic by fulmars in the North Sea and its subregions for the recent 2009–2018 10-year period. All slopes are negative, n.s. indicates a non-significant trend ($p > 0.05$), '-' indicates a significantly negative trend at $p \leq 0.05$.

10-Year trend 2009–2018	*n*	Constant	Slope	s.e.	t	p	
01 Scottish Islands	*128*	106	−0.054	0.053	−1.02	0.308	*n.s.*
02 East-Eng-Sco	*79*	154	−0.078	0.070	−1.12	0.268	*n.s.*
03 Channel	*31*	130	−0.067	0.168	−0.04	0.694	*n.s.*
04 SE NorthSea	*783*	97	−0.050	0.023	−2.12	0.034	–
05 Skagerrak	*96*	120	−0.061	0.067	−0.91	0.368	*n.s.*
North Sea total	*1117*	95	−0.048	0.019	−2.55	0.011	–

Svalbard $p = 0.0305$). All tests are evaluated as appropriate showing that nowhere in the OSPAR area the Fulmar-TV is being met. From Fig. 4 it is evident that the same applies to all North Sea data back to 2002. Further back, in the 1980s in the Netherlands (Van Franeker and Kühn, 2019), 67% of 70 birds had more than 0.1 g of plastic ($p < 0.0001$ for z-test difference with TV). Dutch data peaked in the 5-year period 1993–1997 with 76% of 41 fulmars in excess of 0.1 g plastic. For Iceland, contradictory EcoQ% data are reported: Fig. 3 and Fig. 4 use the value published in Kühn and Van Franeker (2012) but other incidental reports indicate substantial EcoQ% variations that range from a high 47.5% (Trevail et al., 2014) to a low 14.6% in the recent report by Snæþórsson (2019). Seasonal and unexpected sex or age differences may be involved here and necessitate a detailed and shared data analysis to explain

Table 3
Recent 5-year averaged data for plastics in stomachs of beached fulmars from the five North Sea subregions and the overall combined region.

2014–2018 (sub)region(s)	*Sample n*	EcoQ% (over 0.1 g)	%FO	Average number n ± se	Average mass g ± se	Geometric mean mass
1. Scottish Islands	*53*	49%	87%	21.7 ± 5.6	0.32 ± 0.10	0.07
2. East-Eng-Sco	*41*	51%	90%	25.1 ± 5.1	0.17 ± 0.05	0.06
3. Channel	*22*	68%	86%	24.4 ± 7.6	0.43 ± 0.14	0.10
4. SE-NorthSea	*240*	50%	93%	20.8 ± 3.0	0.27 ± 0.03	0.07
5. Skagerrak	*37*	49%	97%	19.1 ± 4.3	0.15 ± 0.03	0.07
North Sea total	*393*	51%	92%	21.4 ± 2.1	0.26 ± 0.03	0.07

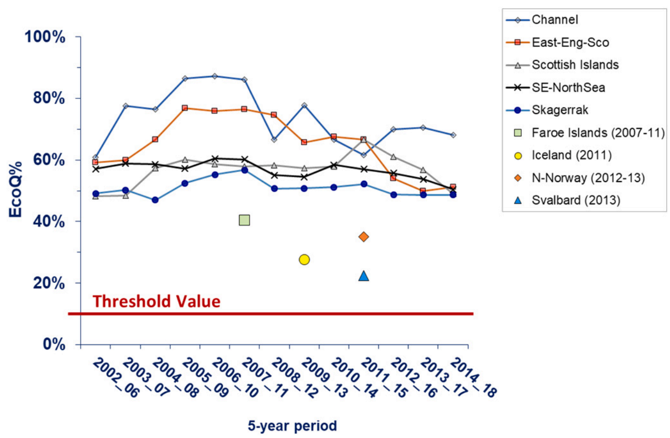

Fig. 4. EcoQ-Performance (the proportion of fulmars with more than 0.1 g of plastic in the stomach) in different subregions of the North Sea and the wider OSPAR area since 2002 visualized by running 5-year average datapoints, compared to point estimates further north in the OSPAR area. Subregional data are specified in Tables S3 to S7 in Supplementary material Section 5. Incidental data for Faroe Islands, Iceland, N. Norway and Svalbard were taken from resp. Van Franeker et al. (2011), Kühn and Van Franeker (2012), Herzke et al. (2016), and Trevail et al. (2015).

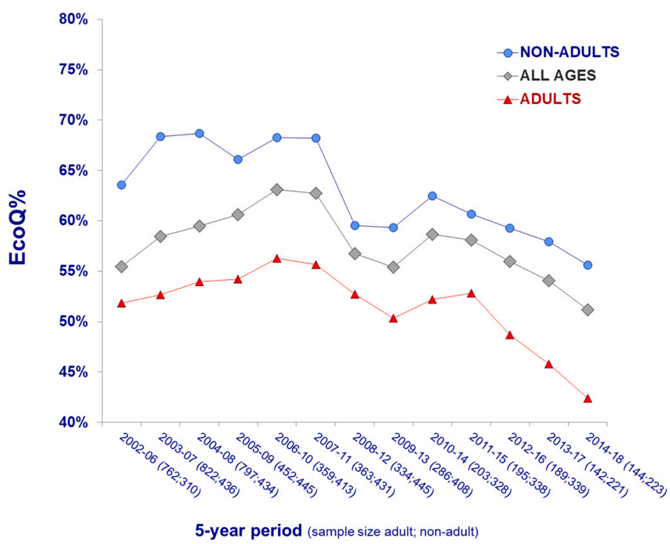

Fig. 5. EcoQ-Performance in the North Sea since 2002 visualized by running 5-year average datapoints, and the impact from changing age proportions in the samples. Younger birds (juveniles and immatures) consistently have more plastic in the stomach than adult birds.

sample differences.

3.4. *The MSFD approach to predict long term trends with reference to the Fulmar-TV*

With an increasing number of years of monitoring, it has become possible to test directly for trends in the annual figures of EcoQ% by logistic regression, thus making a direct link with the Fulmar-TV. Unfortunately the logistic trend on EcoQ% against year for all North Sea subregions combined is not significantly downward ($p = 0.055$), and thus should not be used to predict its future trajectory. Lower significance may be a consequence of bias from age and potentially sex, caused by an unusual and extremely large sample of adult females in 2004. If age (adult proportion) is included as a covariate in a more advanced logistic model, both year and age contribute significantly (both at $p < 0.001$) to a decreasing trend in the proportion of fulmars exceeding the 0.1 g level. This model (Fig. 6; details in Table S12 of Supplementary material Section 7) predicts that, if current rates of change persist, the Fulmar-TV may be reached by about the year 2054.

If also sex (male proportion) is added to the model it makes a non-significant contribution ($p = 0.081$) but predicts crossing of the Fulmar-TV about 5 years earlier, that is around 2049 (Fig. S3 in Supplementary material Section 7). The disturbing role of the exceptionally large 2004 sample dominated by adult females, can also be seen if only data for years 2005–2018 are considered (14 years of data; 1824 fulmars). In that calculation declines in three of the five subregions are significant in linear regressions and highly significant ($p < 0.001$) for total North Sea (Table S10 in Supplementary material Section 6). In the logistic regression of annual EcoQ% after 2005 the trend is significant downward ($p < 0.001$) with the trendline crossing the Fulmar-TV by the year 2067 (Fig. S4 in Supplementary material Section 7). Further attempted refinements to the logistic model, such as adding subregions or proportions of industrial plastics did not improve the overall model. When scaled down to separate subregional levels, most logistic regressions of EcoQ% against year over the 2002–2018 period do not reach significance. Only data for the southeastern North Sea indicate a significant downward trend ($p = 0.022$) as was suggested earlier by Dutch data (Van Franeker and Kühn, 2019). Also here, adding age as a covariate to the subregional analysis strengthens results ($p < 0.001$) but relations in the other subregions remain insignificant, probably due to smaller annual sample sizes at the subregional level.

4. Discussion

4.1. *MSFD Threshold Value*

In the assessment of the Fulmar-TV from the near-pristine Canadian Arctic, regional and seasonal variations were present in subsamples. In the strictest interpretation of the pristine area concept, data from only the most northern July–August sample ($n = 85$) could be used. In terms of proportions of birds accepted to exceed a 0.1 g plastic mass level, this would mean a considerably lower threshold of 5.88% between 95% confidence limits 2.3% to 12.4% (Table 2). Other subsamples used to construct the Canadian pristine Fulmar-TV show explainable differences but are not statistically significant or insufficiently different to allow statistical tests at available sample sizes. This illustrates that a 'data-derived' Fulmar-TV is not a simple arithmetic exercise, but will always involve arbitrary decisions over variable data sources. Here, we decided that the larger combined sample size of 179 fulmars with the inclusion of some known spatial and seasonal but potentially also other sources of variability, was preferred over smaller subsets of the samples. Complications with running the 2-sample test on smaller samples are discussed below. A practical advantage of using the combined High-Arctic Canadian Fulmar-TV is that it is extremely close to the long-term OSPAR EcoQO which had been originally formulated without reference to the 'pristine area' concept. It means that a new, data-based definition for the MSFD Fulmar-TV can be directly derived from the wording for the OSPAR EcoQO, as they are almost identical.

Recently, Baak et al. (2020) provided plastic ingestion data for 29 fulmars caught in 2018 in the same area as the southern Canadian subsample in Table 1. It was decided to not include these for recalculating the Fulmar-TV, but to consider them as a first sample for temporal changes in the Canadian Arctic. The reported proportion of birds exceeding 0.1 g of plastic in the stomach was very low (1 bird, 3.45%) which might suggest improved environmental conditions. However, the comparisons to the Fulmar-TV were labelled as inappropriate due to inadequate sample sizes. As also stated by the authors, statistically significant evidence for change will require further sampling in selected locations and months.

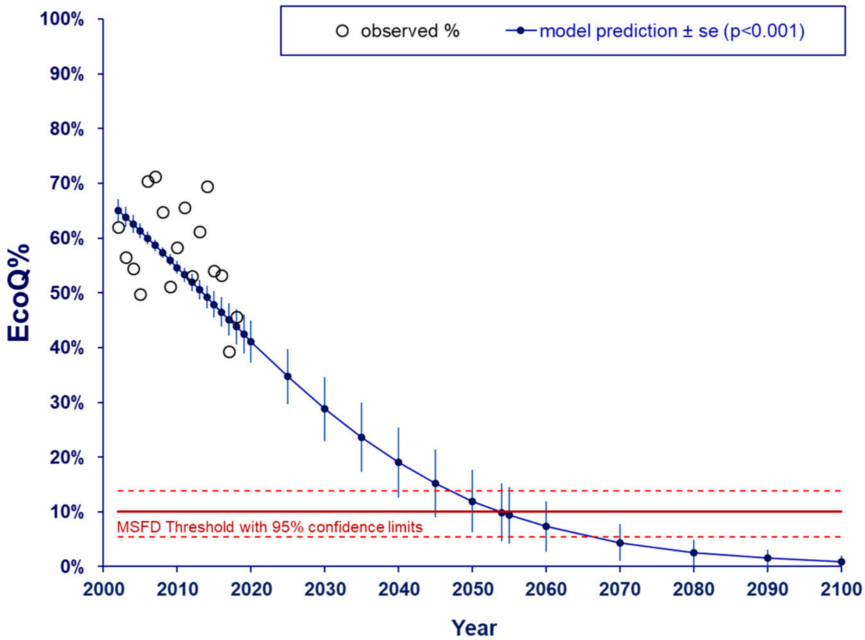

Fig. 6. Observed annual EcoQ-Performances (loose open circles) among fulmars in the North Sea 2002–2018 and the derived logistic regression model of annual EcoQ-Performances using age (proportion adults) as a covariate. The analysis combines observations for the whole North Sea region (2661 birds divided over 17 annual datapoints) and models the trajectory for reaching the Fulmar-TV if rates of change continue at the same strength as observed up to 2018. The small dots in the modelled curve represent annual estimates for EcoQ% with standard error. For data underlying the analysis and graph, see Table S12 in Supplementary material Section 7.

4.2. The OSPAR evaluation of plastic ingestion in North Sea fulmars

Results for the recent 2014–2018 period (Table 3) indicate that in the North Sea environment 51% of 393 fulmars exceeded the 0.1 g level (92% had plastic; on average 21 pieces and 0.26 g). For the earlier 2012–2016 period, OSPAR (2019) reported that 56% of 514 fulmars exceeded the level of 0.1 g of plastic in the stomach: 95% of all birds contained plastic, and average values were 31 particles and 0.28 g of plastic per bird. Thus, in terms of EcoQO performance and other figures the situation seems to have slightly improved. Compared to earlier analyses (OSPAR, 2017, 2019) subregional differences within the North Sea have weakened. The Channel area is still the most polluted, but going north along western and eastern coasts the decreases have become less pronounced than earlier reported (Table 3; Fig. 3). Fulmars from the North Sea area suffer from considerably higher pollution levels than those found in fulmars from more northern and Arctic study locations in the OSPAR area (Fig. 3), but also those did not meet the OSPAR EcoQO.

In the North Sea, linear regressions of ingested plastic mass over the most recent ten years of data confirmed a downward trend in all subregions (negative slopes in Table 4), but were only significant when sample sizes are large, as for the southeastern North Sea or overall regional data. Over longer time periods since 2002, EcoQ-Performances by 5-year averages in Fig. 4 do not directly reveal consistent trends (details in Supplementary material Sections 5 and 6). The graphs give a suggestion of some initial increases followed by later declines. In conclusion, mass of plastics in stomachs of fulmars from the North Sea is clearly declining in recent years, but over the full time frame of the SNS study the results are variable and sometimes even opposite.

As illustrated in Fig. 5 adult fulmars have less plastic in their stomach than younger birds. The proportions of different age groups in samples could thus influence the results. For example, around 2004 there was a highly unusual situation with a mass mortality in the North Sea of predominantly adult females (Van Franeker, 2004b; Van Franeker and the SNS Fulmar Study Group, 2011; see Table S1 in Supplementary material: nearly 80% of the exceptionally large 2004 sample were adult females). Consequently, in the early years the population average (grey diamond symbols in Fig. 5) starts closer to the adult line and gradually moves towards the non-adult line. This causes some age-related bias in the overall data, but in the early years, the adult and non-adult EcoQ% increased independently, indicating that age ratio was not the only cause of the observed pattern. Also, linear regressions for the recent 10-year period (Table 4) support the similar trends visualized in Fig. 5. Because the two age groups largely follow the same trend, their combined use in presenting and interpreting monitoring results can be continued.

Analyses as prescribed by the current OSPAR guidelines (OSPAR, 2015) could not go beyond the rather non-specific conclusion that in the North Sea, fulmars show a recent tendency of decreasing plastic ingestion, but that the OSPAR target in the North Sea as well as other OSPAR locations is still far off.

4.3. The MSFD approach: when is the Fulmar-TV reached?

For all known fulmar populations in the northeast Atlantic OSPAR area, the epitools 2-sample z-test assesses their EcoQ-Performance as significantly different from (higher than) the Fulmar-TV. Also fulmars from Svalbard, in which 9 out of 40 fulmars (22.5%) exceeded the 0.1 g level (Trevail et al., 2015) are assessed as significantly different ($p = 0.0305$) from the Fulmar-TV. Svalbard is a High Arctic environment in the northeast Atlantic, but differs from the Canadian sample locations in that the Canadian area mainly receives water from the Arctic Ocean, whereas waters around Svalbard mainly have an origin in the warm Gulf Stream from the south (AMAP, 1998; Fig. S1 in Supplementary material Section 2B), which actually may end in the Barents Sea in a gyre accumulating plastics (Van Sebille et al., 2012).

With current levels of plastic ingestion by fulmars in the northeast Atlantic, the statistical test is hardly needed to conclude that the situation is far off the EcoQO or Fulmar-TV. But in future, after intended marine litter reductions, interpretation of test results becomes critical to decide if a specific policy target has been met. In this, it is important to be aware that the statistical test only assesses whether two samples are statistically different: when the difference is not significant it provides no evidence that the samples are equal, i.e. that the target is actually met. How then do we interpret results?

In a strict statistical sense, the conclusion ‘Fulmar-TV reached’ demands that the tested sample is significantly lower than the Fulmar-TV. As an example, no more than three birds in a sample of 100 fulmars could exceed 0.1 g of plastic ($p = 0.03$) because already four birds in 100 ($p = 0.07$) do not differ statistically from the Fulmar-TV. Alternatively, when approaching the Fulmar-TV from above: already with 18 in 100

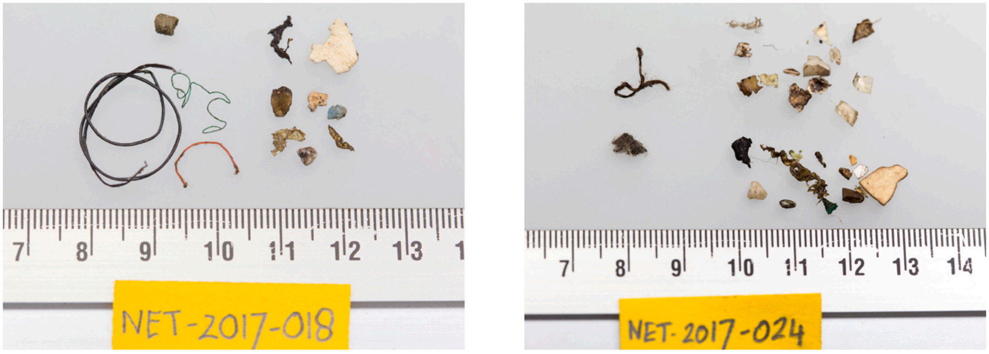

Fig. 7. Near threshold examples of plastics in fulmar stomachs. Fulmar NET-2017-018 contained a single industrial granule and 11 user plastic items, with a combined mass of 0.1174 g, so slightly above the mass level used in the OSPAR EcoQO and MSFD Fulmar-TV. The stomach of fulmar NET-2017-024 contained 28 user plastic particles, weighing 0.0954 g, so just under the 0.1 g level. The Fulmar-TV implies that no more than 10% of the birds may contain the amount of plastic or more as in the left photo. However, up to 90% of birds are still allowed to have a quantity of plastics up to that shown in the right photograph.

birds having more than 0.1 g of plastic the difference between sample and the Fulmar-TV is not significant ($p = 0.058$). In conclusion it appears that the z-test loses power when the Fulmar-TV is approached. In a test-sample of 100 birds the test thus indicates non-significant differences when between 4% to 18% of fulmars exceed 0.1 g of plastic in the stomach. A substantial increase in the tested sample size above 100 does not lead to serious improvement, whereas smaller sample sizes rapidly aggravate the problem. A policy decision when to decide to 'target reached' is thus complicated and may opt for significantly under the Fulmar-TV, the actual percentage, or no significant difference. In any of these a reasonable sample size is required, for which we propose 100 fulmars in the tested sample.

Annual EcoQ% data may be used to evaluate long-term trends which, if significant, could be used to predict when in future the Fulmar-TV might be reached. The simplest logistic model evaluating the EcoQ% against year over the 2002–2018 period in the total North Sea proved not significant. However, including age (the proportion of adults) as a covariate resulted in a highly significant model showing a downward trend and predicted that the Fulmar-TV may be reached around the year 2054. The addition of other covariates (sex, subregions, or proportions of plastic) did not improve to the model significantly.

Logistic regressions such as the one in Fig. 6 may assist policy makers in EU MSFD to decide on intermediate targets. It is clear that the Fulmar-TV will not have been reached by the original planned overall GES year of 2020. If the observed 2002–2018 trend is considered to represent an acceptable rate of improvement, its continuation may result in reaching the Fulmar-TV in about 35 years. In that scheme, intermediate North Sea threshold values could be set at model values for specific years, e.g. 41% in 2020, 29% in 2030, and 19% in 2040 (see Table S12 in Supplementary material Section 7). It must be emphasized that the modelled decrease of plastics in fulmars assumes continued new efforts by all stakeholders to further reduce the input of plastic debris into the environment. Without additional efforts, the predicted slope will not persist and will lead to delay in reaching the Fulmar-TV.

For both types of trend analyses (linear 10-year; logistic long-term) it is evident that at current rates of change, significance is not easily reached at the subregional level. Sharing data at the regional North Sea level is essential to obtain sample sizes that allow robust conclusions.

5. Conclusions

Results presented in this paper may be used to update guidelines for the monitoring program of plastic particles in fulmar stomachs in line with the threshold value approach required in EU MSFD. It is proposed that the MSFD Threshold Value for ingested plastics by fulmars (Fulmar-TV) is worded as:

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

This TV should be considered as fixed, and is only reconsidered if clear and extensive data on harm caused from plastic ingestion becomes available. This is not expected to happen in the near future.

It is recommended that future assessments of the fulmar monitoring program include:

1. the 'current' level of plastic ingestion as described by population averages with standard error for the number and mass of plastic particles and the EcoQ% for the most recent 5-year period.
2. a binomial proportion test (e.g. the 2-sample z-test in Sergeant (2019)) to evaluate compliance of the studied sample with the Fulmar-TV based on the Canadian Arctic dataset of 179 birds of which 10.06% had more than 0.1 g of plastic.
3. the recent trend in ingested mass of plastic as assessed by linear regression of normalized plastic mass data for all individual fulmars against year of death over the most recent 10-year period.
4. a test of the long-term trend and progress towards reaching the Fulmar-TV using logistic regression of annual proportions of the EcoQ% since the start of the monitoring program in 2002. Results of such models may be used to set intermediate targets until the required Fulmar-TV is reached.

In this format, the assessment of the fulmar monitoring program in the North Sea over the 2002–2018 period has resulted in:

1. The current level of plastic ingestion by North Sea fulmars (2014–2018; 393 birds) is that 51% exceed the 0.1 g level, and 92% of all birds contained some plastic with an average number of 21.4 ± 2.1 particles and plastic mass of 0.26 ± 0.03 g per bird.
2. The 2-sample z-test shows that this level is significantly above the Fulmar-TV ($p < 0.0001$).
3. Over the recent 10-year period (2009–2018; 1117 fulmars) linear regression showed that plastic mass in 1117 birds decreased significantly ($p = 0.011$).
4. Logistic regression of annual EcoQ% (17 years, 2661 fulmars) indicates a significant long-term decline ($p < 0.001$ if age included) and predicts reaching of the Fulmar-TV by the year 2054. If this trend persists, intermediate threshold values could aim for less than 41%, 29% and 19% of birds exceeding the 0.1 g level in respectively 2020, 2030 and 2040.

Threshold definitions like the above reluctantly accept that, in policy terms, it may be unrealistic to aim for a level of zero plastics, which would be the truly pristine reference level for plastic in the environment. All plastics are man-made, do not belong in the environment, and at the level of individual organisms any plastic item may represent some risk of harm. The photos in Fig. 7 illustrate the implications of the 10% target of 0.1 g of ingested plastic and may act as a reminder that when current policy targets are met, there is still very good reason to continue efforts towards further reduction.

CRediT authorship contribution statement

Jan A. van Franeker: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Supervision, Project administration. **Susanne Kühn:** Resources, Data curation, Writing – original draft. **Tycho Anker-Nilssen:** Resources, Investigation, Writing – review & editing. **Ewan W.J. Edwards:** Resources, Writing – review & editing. **Fabrice Gallien:** Resources, Writing – review & editing. **Nils Guse:** Resources, Investigation, Writing – review & editing. **Jenni E. Kakkonen:** Resources, Investigation, Writing – review & editing. **Mark L. Mallory:** Resources, Investigation, Writing – review & editing. **Will Miles:** Resources, Investigation, Writing – review & editing. **Kåre Olav Olsen:** Resources, Investigation. **John Pedersen:** Resources, Investigation. **Jennifer Provencher:** Resources, Investigation, Writing – review & editing. **Mervyn Roos:** Writing – review & editing, Funding acquisition. **Eric Stienen:** Resources, Investigation, Writing – review & editing. **Daniel M. Turner:** Resources, Investigation, Writing – review & editing. **Willem M.G.M. van Loon:** Writing – review & editing, Funding acquisition.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2021.112246.

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APPENDIX A
SUPPLEMENTARY MATERIAL
to
New tools to evaluate plastic ingestion by northern fulmars applied to North Sea monitoring data 2002-2018

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2. THRESHOLD VALUE

2.A. Threshold value for harm using a risk model?

For southern hemisphere procellariiform (= tubenosed) seabirds, Roman et al. (2019) produced a model to link plastic ingestion to mortality i.e. a direct predictor of harm at the population level. Unfortunately, we have no data to allow a species-specific recalculation for the northern fulmar *Fulmarus glacialis* (hereafter fulmar). However, the fulmar is a tubenosed seabird, related to and similar in size and ecology to various of the procellariiform species on which the southern hemisphere model is based. So, the question was raised about whether we can apply this southern hemisphere model to set a threshold level for harm to the population of northern fulmars?

The model predicts serious consequences from plastic ingestion. A single particle of ingested plastic is modelled to represent a 20% risk of mortality to tubenosed seabirds from the Southern Ocean. Procellariiforrm birds are very long-lived, and the annual survival for adults probably needs to be around 95% for a healthy and stable population. Dunnet and Ollason (1978) measured adult survival rates at over 97% in the long-term study population at Eynhallow, Orkney Islands, Scotland. In fulmars from Alaska a similar 97% survival rate was observed by Hatch (1987). At Jan Mayen, stable annual adult survival rates of 94% in the period from 2011-2019 were measured (Anker-Nilssen et al., 2020). All mortality factors combined should thus not lead to mortality of over a few percent. In this perspective, an additional mortality of 1-2% due to plastic ingestion could have devastating effects even if other factors for population stability are favourable. If one particle of plastic represents a 20% risk of mortality, then at most one of ten fulmars could contain one piece of plastic in the stomach in order to limit the plastic mortality risk to 2%.

In metrics for a potential threshold definition, this equates to a maximum frequency of occurrence (%FO) of any plastic at 10% i.e. a maximum average number of particles per bird of 0.1, or maximum average mass of 0.001 g per bird (average particle mass in fulmar stomachs is ± 0.01 gram). Therefore, for an OSPAR EcoQ% or Threshold Value, the acceptable proportion of fulmars containing more than 0.1 gram of plastic, would effectively be zero.

However, since the earliest studies in the 1980s, almost every fulmar from the North Sea contained plastics: recently, during 2012-2016 (OSPAR, 2019), 95% of fulmars in the North Sea had at least one piece of plastic in the stomach, and the average per bird was 31 particles at a total mass of 0.28 g. Although mostly derived from dead beached individuals, earlier work (Van Franeker & Meijboom, 2002) has demonstrated that these stomach contents are representative for all fulmars in the area. In terms of the Roman et al. (2019) model, these observed ingestion levels translate to a totally unsustainable impact and rapid extinction process for the North Sea population. Actually, such extinction would apply to the species as a whole since the average stomach content among fulmars even in the cleanest habitat exceeds one particle per fulmar.

In Europe, the population of fulmars is estimated to have declined by more than 40% since about the mid-1980s with IUCN Red-List status ‘Endangered’ (Birdlife International, 2015). Remarkably, the global status of the species is classified as of ‘Least Concern’ with an increasing population (Birdlife International, 2018). Unfortunately, that evaluation seems to be based on expansion in the previous two centuries in the temperate Atlantic, and assumed stability in the Arctic. However, strong declines have been reported for large fulmar populations in both the temperate and Arctic North Atlantic: a 35% decline over about 3 decades in Iceland (Garðarsson et al., 2011), 58% decline in about 25 years on Bear Island, Svalbard (Fauchald et al., 2015), and an alarming 87% in study colonies in the Canadian Arctic (Mallory et al., 2020). In spite of the current Red-List classification we therefore feel that the statement ‘the species is not doing well’ is fully justified.

Demographic analyses from the Eynhallow population by Grosbois & Thompson (2005) suggested that the 97% survival rate mentioned in Dunnet & Ollason (1978) had gradually declined to about 90%

possibly due to a combination of climate change and other factors. The recent study by Orzack et al. (2011) also gives these lower levels of survival.
However even if the 40% population decline in the European population over more than 30 years has been caused by plastics only (a highly unlikely explanation), the observed data are in total mismatch with the Roman et al. (2019) risk model. Therefore this model is not suitable to identify a 'no harm' MSFD threshold for plastic ingestion by fulmars in the northern hemisphere.

2.B. Threshold value derived from pristine area

Lacking direct harm models, the only option for an acceptable policy target seems a threshold reflecting a reduction in ingested plastics equal to the situation in the cleanest area for which we have fulmar ingestion data available, which is for High-Arctic Atlantic Canada.
In terms of plastic marine litter, the Canadian High-Arctic region may be viewed as near pristine as possible. It has a low level of human population of about 30,000 people in the whole of Nunavut. There are only a few industrial settlements. Much of the area is still ice-covered for most of the year, and water-currents flow in from the northern ice-covered Arctic basin, rather than from polluted Atlantic waters farther south (AMAP, 1998; Fig. S1).

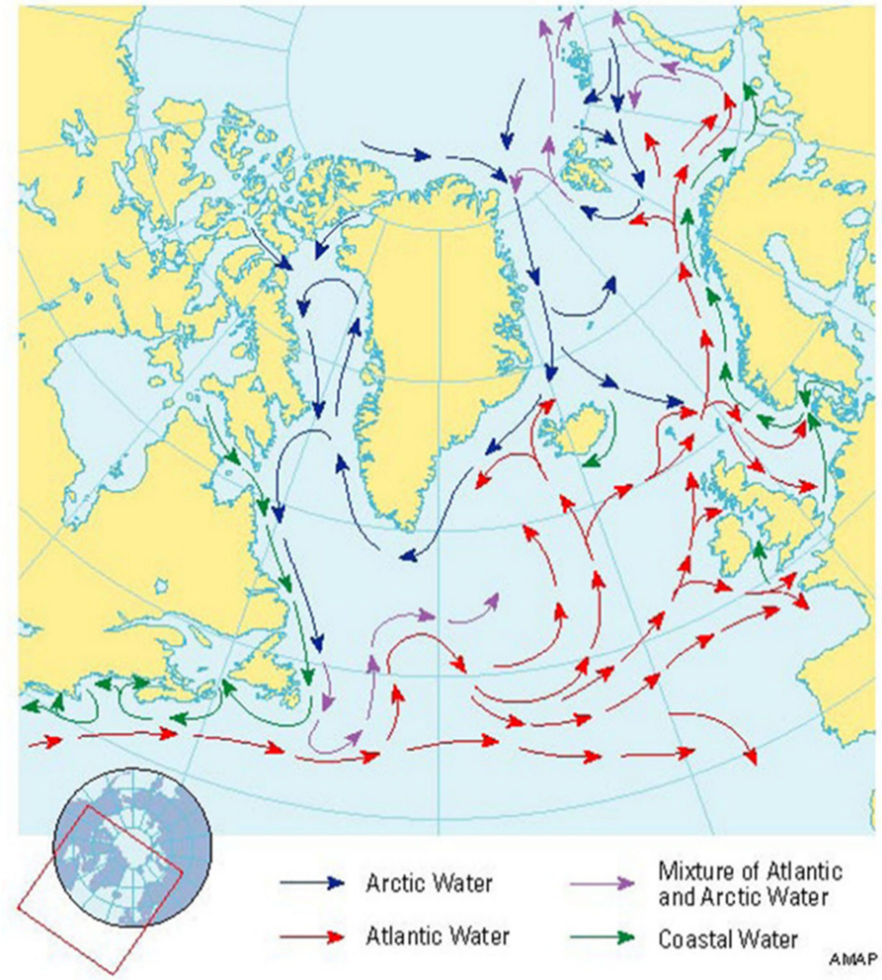

Fig. S1 Major surface currents in the North Atlantic Ocean show 'pristine' Arctic Ocean water flows to the Canadian High Arctic whereas waters near High Arctic Svalbard are mixed with water from the polluted warm Gulf Stream (Source: figure 3.33 in AMAP, 1998).

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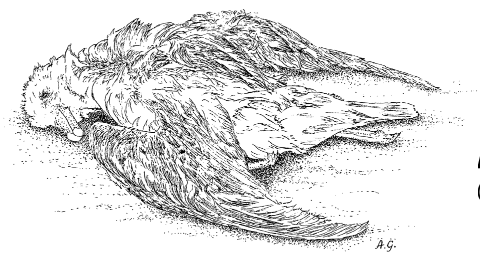

Beached fulmar
(line-drawing by Arnold Gronert)

3. SAMPLE DETAILS

Table S1 Annual sample numbers of fulmars included in the analysis*, specified for the five separate subregions and the North Sea as a whole.*

YEAR	Scottish Islands	East-Eng-Sco	Channel	SE North Sea	Skagerrak	SUM North Sea
2002	17	0	0	61	1	**79**
2003	24	1	0	93	68	**186**
2004	25	45	42	383	77	**572**
2005	7	6	4	165	17	**199**
2006	12	2	0	51	6	**71**
2007	27	6	61	161	23	**278**
2008	32	31	8	79	9	**159**
2009	35	7	1	159	25	**227**
2010	15	4	1	48	4	**72**
2011	12	3	1	60	20	**96**
2012	9	14	4	226	9	**262**
2013	4	10	2	50	1	**67**
2014	10	6	4	30	9	**59**
2015	7	0	2	58	7	**74**
2016	6	7	8	56	15	**92**
2017	10	3	1	70	5	**89**
2018	20	25	7	26	1	**79**
region total	**272**	**170**	**146**	**1776**	**297**	**2661**

4. INDUSTRIAL AND USER PLASTICS IN SUBREGIONS AND NORTH SEA

Table S2

Details for industrial and user plastic abundance in stomachs of fulmars for five subregions and overall North Sea over the 5-year period 2014-2018. This table complements total plastic data in Table 3 in the main paper.

Summarized test data (sign of slope and p value) for sequential 10-year linear trends and trend over the full SNS period 2002-2018 specified for major categories of plastic, illustrating that different categories of plastic have undergone different changes. A significant reduction in user plastics is a fairly recent phenomenon. This table complements total plastic data in Table 4 in the main paper.

A

(SUB)REGIONS		Industrial granules			User plastics		
2014_18	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
1. Scottish Islands	*53*	38%	1.3 ± 0.3	0.03 ± 0.01	87%	20.4 ± 5.5	0.29 ± 0.10
2. East-Eng-Sco	*41*	56%	1.9 ± 0.5	0.04 ± 0.01	90%	23.3 ± 4.7	0.13 ± 0.04
3. Channel	*22*	59%	3.0 ± 1.2	0.07 ± 0.03	86%	21.5 ± 7.1	0.36 ± 0.12
4. SE-NorthSea	*240*	51%	2.1 ± 0.3	0.05 ± 0.01	93%	18.7 ± 2.9	0.22 ± 0.03
5. Skagerrak	*37*	51%	1.8 ± 0.5	0.04 ± 0.01	95%	17.2 ± 3.9	0.11 ± 0.02
North Sea Total	***393***	**50%**	**2.0 ± 0.2**	**0.05 ± 0.01**	**91%**	**19.4 ± 2.0**	**0.22 ± 0.02**

B

North Sea - 10yr linear regressions since 2002

		Industrial plastic		User plastic		All plastics	
period	*n*	slope	p	slope	p	slope	p
2002-2011	*2120*	-	0.314	+	**0.003**	+	**0.042**
2003-2012	*2122*	-	0.356	+	**0.036**	+	0.190
2004-2013	*2003*	-	0.871	+	0.106	+	0.239
2005-2014	*1490*	-	0.359	-	0.919	-	0.677
2006-2015	*1365*	-	**0.003**	-	**0.002**	-	**0.003**
2007-2016	*1386*	-	**0.008**	-	**< 0.001**	-	**< 0.001**
2008-2017	*1197*	-	0.148	-	**< 0.001**	-	**0.002**
2009-2018	*1117*	-	0.618	-	**0.010**	-	**0.011**
Long term 2002-2018	*2661*	-	**<0.001**	-	0.537	-	0.106

5. FULL SUBREGIONAL DETAILS

Table S3 North Sea subregion 1 - The Scottish Islands.
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics, that is sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

Scottish Islands	Total plastics					
5-year period	*sample n*	EcoQ% (over 0.1g)	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*85*	**48%**	92%	20.8 ± 3.5	0.22 ± 0.04	0.06
2003_07	*95*	**48%**	92%	18.9 ± 3.0	0.20 ± 0.03	0.06
2004_08	*103*	**57%**	93%	22.8 ± 3.6	0.33 ± 0.07	0.09
2005_09	*113*	**60%**	90%	24.3 ± 3.5	0.36 ± 0.07	0.09
2006_10	*121*	**59%**	91%	23.3 ± 3.3	0.35 ± 0.06	0.09
2007_11	*121*	**58%**	90%	22.5 ± 3.0	0.35 ± 0.06	0.09
2008_12	*103*	**58%**	92%	24.6 ± 3.5	0.40 ± 0.08	0.11
2009_13	*75*	**57%**	92%	34.8 ± 12.9	0.33 ± 0.06	0.10
2010_14	*50*	**58%**	96%	35.9 ± 19.0	0.32 ± 0.06	0.11
2011_15	*42*	**67%**	98%	44.8 ± 22.6	0.47 ± 0.13	0.15
2012_16	*36*	**61%**	97%	44.5 ± 26.3	0.48 ± 0.15	0.14
2013_17	*37*	**57%**	92%	40.0 ± 25.7	0.39 ± 0.14	0.10
2014_18	*53*	**49%**	87%	21.7 ± 5.6	0.32 ± 0.10	0.07

B.

Scottish Islands		Industrial granules			User plastics		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*85*	41%	1.5 ± 0.4	0.04 ± 0.01	92%	19.3 ± 3.4	0.18 ± 0.03
2003_07	*95*	37%	1.3 ± 0.3	0.03 ± 0.01	92%	17.6 ± 3.0	0.17 ± 0.03
2004_08	*103*	42%	1.4 ± 0.3	0.03 ± 0.01	93%	21.4 ± 3.5	0.29 ± 0.07
2005_09	*113*	45%	1.3 ± 0.2	0.03 ± 0.00	90%	23.0 ± 3.4	0.33 ± 0.07
2006_10	*121*	46%	1.3 ± 0.2	0.03 ± 0.00	91%	22.0 ± 3.2	0.32 ± 0.06
2007_11	*121*	47%	1.3 ± 0.2	0.03 ± 0.00	90%	21.2 ± 3.0	0.32 ± 0.06
2008_12	*103*	49%	1.3 ± 0.2	0.03 ± 0.00	92%	23.3 ± 3.4	0.37 ± 0.08
2009_13	*75*	44%	1.1 ± 0.2	0.02 ± 0.00	92%	33.7 ± 12.9	0.31 ± 0.06
2010_14	*50*	44%	1.2 ± 0.3	0.03 ± 0.01	96%	34.8 ± 19.0	0.29 ± 0.06
2011_15	*42*	43%	1.2 ± 0.3	0.03 ± 0.01	98%	43.6 ± 22.6	0.45 ± 0.13
2012_16	*36*	39%	1.3 ± 0.4	0.03 ± 0.01	97%	43.2 ± 26.3	0.45 ± 0.15
2013_17	*37*	38%	1.2 ± 0.4	0.03 ± 0.01	92%	38.8 ± 25.7	0.36 ± 0.14
2014_18	*53*	38%	1.3 ± 0.3	0.03 ± 0.01	87%	20.4 ± 5.5	0.29 ± 0.10

Table S4 North Sea subregion 2 – East England and Scotland
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics: sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

East-Eng-Sco		Total plastics				
5-year period	*sample n*	EcoQ% (over 0.1g)	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*54*	**59%**	94%	28.5 ± 6.0	0.22 ± 0.03	0.11
2003_07	*60*	**60%**	95%	35.0 ± 6.9	0.23 ± 0.03	0.11
2004_08	*90*	**67%**	96%	39.1 ± 5.2	0.27 ± 0.03	0.13
2005_09	*52*	**77%**	98%	46.5 ± 6.4	0.36 ± 0.06	0.16
2006_10	*50*	**76%**	98%	46.2 ± 6.7	0.34 ± 0.07	0.15
2007_11	*51*	**76%**	98%	46.4 ± 6.7	0.35 ± 0.07	0.15
2008_12	*59*	**75%**	97%	39.7 ± 5.1	0.35 ± 0.06	0.13
2009_13	*38*	**66%**	95%	43.3 ± 12.3	0.36 ± 0.09	0.10
2010_14	*37*	**68%**	92%	43.4 ± 12.6	0.34 ± 0.08	0.11
2011_15	*33*	**67%**	91%	46.6 ± 14.1	0.36 ± 0.08	0.10
2012_16	*37*	**54%**	92%	39.3 ± 12.7	0.29 ± 0.07	0.08
2013_17	*26*	**50%**	92%	38.0 ± 16.8	0.25 ± 0.08	0.07
2014_18	*41*	**51%**	90%	25.1 ± 5.1	0.17 ± 0.05	0.06

B.

East-Eng-Sco		Industrial granules			User plastics		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*54*	54%	2.4 ± 0.5	0.06 ± 0.01	94%	26.1 ± 5.8	0.17 ± 0.02
2003_07	*60*	55%	2.7 ± 0.5	0.06 ± 0.01	95%	32.3 ± 6.6	0.17 ± 0.02
2004_08	*90*	62%	3.5 ± 0.6	0.08 ± 0.01	96%	35.5 ± 4.9	0.19 ± 0.02
2005_09	*52*	73%	4.7 ± 0.9	0.10 ± 0.02	98%	41.8 ± 6.0	0.25 ± 0.06
2006_10	*50*	76%	4.3 ± 0.9	0.10 ± 0.02	98%	41.9 ± 6.2	0.24 ± 0.06
2007_11	*51*	75%	4.2 ± 0.9	0.09 ± 0.02	98%	42.2 ± 6.2	0.26 ± 0.06
2008_12	*59*	73%	3.5 ± 0.7	0.08 ± 0.02	97%	36.2 ± 4.7	0.27 ± 0.06
2009_13	*38*	66%	2.1 ± 0.5	0.04 ± 0.01	95%	41.2 ± 11.9	0.32 ± 0.09
2010_14	*37*	65%	2.1 ± 0.5	0.04 ± 0.01	92%	41.3 ± 12.3	0.29 ± 0.07
2011_15	*33*	61%	2.2 ± 0.6	0.05 ± 0.01	91%	44.4 ± 13.7	0.31 ± 0.08
2012_16	*37*	59%	1.9 ± 0.5	0.04 ± 0.01	92%	37.4 ± 12.3	0.25 ± 0.07
2013_17	*26*	62%	2.0 ± 0.7	0.04 ± 0.01	92%	36.0 ± 16.3	0.21 ± 0.07
2014_18	*41*	56%	1.9 ± 0.5	0.04 ± 0.01	90%	23.3 ± 4.7	0.13 ± 0.04

Table S5 North Sea subregion 3 – The Channel area
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics: sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

Channel		**Total plastics**				
5-year period	*sample n*	**EcoQ%** *(over 0.1g)*	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*46*	**61%**	100%	56.4 ± 13.1	0.26 ± 0.04	0.14
2003_07	*107*	**78%**	100%	56.7 ± 8.3	0.44 ± 0.06	0.23
2004_08	*115*	**77%**	99%	54.4 ± 7.8	0.44 ± 0.05	0.21
2005_09	*74*	**86%**	99%	50.5 ± 9.1	0.53 ± 0.08	0.27
2006_10	*71*	**87%**	99%	52.3 ± 9.4	0.55 ± 0.08	0.29
2007_11	*72*	**86%**	99%	51.7 ± 9.3	0.54 ± 0.08	0.28
2008_12	*15*	**67%**	93%	22.8 ± 6.7	0.42 ± 0.11	0.16
2009_13	*9*	**78%**	100%	22.6 ± 6.8	0.38 ± 0.11	0.23
2010_14	*12*	**67%**	92%	18.2 ± 5.6	0.31 ± 0.09	0.13
2011_15	*13*	**62%**	85%	13.5 ± 4.5	0.23 ± 0.07	0.08
2012_16	*20*	**70%**	90%	17.7 ± 4.5	0.37 ± 0.14	0.11
2013_17	*17*	**71%**	88%	18.4 ± 5.2	0.38 ± 0.17	0.09
2014_18	*22*	**68%**	86%	24.4 ± 7.6	0.43 ± 0.14	0.10

B.

Channel		**Industrial granules**			**User plastics**		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*46*	65%	4.1 ± 1.1	0.06 ± 0.02	100%	52.3 ± 12.3	0.20 ± 0.03
2003_07	*107*	76%	6.0 ± 1.2	0.12 ± 0.02	100%	50.7 ± 7.5	0.32 ± 0.04
2004_08	*115*	77%	5.9 ± 1.1	0.12 ± 0.02	99%	48.4 ± 7.0	0.32 ± 0.04
2005_09	*74*	82%	6.9 ± 1.6	0.15 ± 0.03	99%	43.6 ± 7.9	0.38 ± 0.06
2006_10	*71*	83%	7.2 ± 1.7	0.15 ± 0.03	99%	45.1 ± 8.1	0.40 ± 0.06
2007_11	*72*	82%	7.1 ± 1.6	0.15 ± 0.03	99%	44.6 ± 8.0	0.39 ± 0.06
2008_12	*15*	73%	5.3 ± 1.8	0.13 ± 0.05	93%	17.5 ± 5.5	0.29 ± 0.07
2009_13	*9*	67%	4.6 ± 2.1	0.12 ± 0.06	100%	18.0 ± 5.1	0.26 ± 0.07
2010_14	*12*	67%	3.8 ± 1.6	0.10 ± 0.04	92%	14.4 ± 4.3	0.21 ± 0.06
2011_15	*13*	62%	2.8 ± 1.3	0.07 ± 0.03	85%	10.8 ± 3.5	0.15 ± 0.05
2012_16	*20*	70%	3.8 ± 1.4	0.10 ± 0.04	90%	13.9 ± 3.4	0.27 ± 0.11
2013_17	*17*	71%	3.6 ± 1.5	0.09 ± 0.04	88%	14.7 ± 4.0	0.28 ± 0.13
2014_18	*22*	59%	3.0 ± 1.2	0.07 ± 0.03	86%	21.5 ± 7.1	0.36 ± 0.12

Table S6 North Sea subregion 4 – South-eastern North Sea (Belgium, Netherlands, Germany)
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics: sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

SE-NorthSea		Total plastics				
5-year period	*sample n*	EcoQ% (over 0.1g)	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*753*	**57%**	94%	32.9 ± 3.5	0.30 ± 0.02	0.09
2003_07	*853*	**59%**	94%	31.1 ± 3.0	0.31 ± 0.02	0.09
2004_08	*839*	**59%**	94%	31.7 ± 3.1	0.32 ± 0.02	0.09
2005_09	*615*	**57%**	95%	24.9 ± 1.6	0.30 ± 0.03	0.10
2006_10	*498*	**60%**	95%	29.2 ± 2.2	0.33 ± 0.03	0.11
2007_11	*507*	**60%**	95%	27.8 ± 2.0	0.36 ± 0.04	0.11
2008_12	*572*	**55%**	95%	32.3 ± 5.3	0.31 ± 0.04	0.09
2009_13	*543*	**55%**	95%	32.1 ± 5.5	0.29 ± 0.04	0.09
2010_14	*414*	**58%**	94%	36.1 ± 7.1	0.33 ± 0.05	0.10
2011_15	*424*	**57%**	95%	32.0 ± 6.8	0.31 ± 0.04	0.09
2012_16	*420*	**56%**	95%	32.7 ± 6.9	0.28 ± 0.03	0.09
2013_17	*264*	**54%**	93%	23.4 ± 2.9	0.27 ± 0.03	0.08
2014_18	*240*	**50%**	93%	20.8 ± 3.0	0.27 ± 0.03	0.07

B.

SE-NorthSea		Industrial granules			User plastics		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*753*	59%	2.8 ± 0.2	0.06 ± 0.00	94%	30.1 ± 3.3	0.24 ± 0.02
2003_07	*853*	60%	2.8 ± 0.2	0.06 ± 0.00	93%	28.2 ± 2.9	0.25 ± 0.02
2004_08	*839*	59%	2.8 ± 0.2	0.06 ± 0.00	93%	28.9 ± 2.9	0.26 ± 0.02
2005_09	*615*	58%	2.4 ± 0.2	0.05 ± 0.00	95%	22.5 ± 1.5	0.25 ± 0.02
2006_10	*498*	58%	3.1 ± 0.6	0.07 ± 0.01	95%	26.1 ± 2.0	0.26 ± 0.03
2007_11	*507*	58%	3.1 ± 0.6	0.07 ± 0.01	94%	24.7 ± 1.8	0.29 ± 0.04
2008_12	*572*	55%	3.0 ± 0.5	0.06 ± 0.01	94%	29.3 ± 5.0	0.25 ± 0.03
2009_13	*543*	57%	3.0 ± 0.6	0.06 ± 0.01	94%	29.1 ± 5.3	0.23 ± 0.03
2010_14	*414*	63%	3.6 ± 0.7	0.07 ± 0.02	93%	32.6 ± 6.9	0.25 ± 0.04
2011_15	*424*	61%	2.8 ± 0.3	0.06 ± 0.01	93%	29.2 ± 6.6	0.25 ± 0.04
2012_16	*420*	60%	2.6 ± 0.3	0.05 ± 0.00	94%	30.1 ± 6.7	0.23 ± 0.02
2013_17	*264*	55%	2.1 ± 0.2	0.05 ± 0.00	92%	21.2 ± 2.8	0.22 ± 0.03
2014_18	*240*	51%	2.1 ± 0.3	0.05 ± 0.01	93%	18.7 ± 2.9	0.22 ± 0.03

Table S7 North Sea subregion 4 – Skagerrak (Denmark + Norway)
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics: sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

Skagerrak	Total plastics					
5-year period	*sample n*	EcoQ% (over 0.1g)	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*169*	**49%**	95%	40.3 ± 7.1	0.36 ± 0.12	0.07
2003_07	*191*	**50%**	95%	47.7 ± 8.6	0.36 ± 0.11	0.08
2004_08	*132*	**47%**	95%	58.4 ± 12.3	0.42 ± 0.16	0.08
2005_09	*80*	**53%**	98%	53.5 ± 15.4	0.31 ± 0.05	0.10
2006_10	*67*	**55%**	99%	58.7 ± 18.2	0.32 ± 0.06	0.12
2007_11	*81*	**57%**	94%	51.8 ± 15.2	0.32 ± 0.05	0.11
2008_12	*67*	**51%**	91%	30.6 ± 7.1	0.26 ± 0.05	0.08
2009_13	*59*	**51%**	90%	28.5 ± 7.1	0.25 ± 0.05	0.07
2010_14	*43*	**51%**	88%	16.4 ± 3.0	0.18 ± 0.03	0.06
2011_15	*46*	**52%**	87%	16.3 ± 2.9	0.17 ± 0.03	0.05
2012_16	*41*	**49%**	95%	20.1 ± 4.0	0.15 ± 0.02	0.07
2013_17	*37*	**49%**	97%	18.9 ± 4.3	0.15 ± 0.03	0.07
2014_18	*37*	**49%**	97%	19.1 ± 4.3	0.15 ± 0.03	0.07

B.

Skagerrak		Industrial granules			User plastics		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*169*	59%	3.6 ± 0.7	0.07 ± 0.02	95%	36.7 ± 6.8	0.29 ± 0.12
2003_07	*191*	61%	3.7 ± 0.7	0.07 ± 0.01	95%	44.0 ± 8.3	0.29 ± 0.11
2004_08	*132*	58%	3.5 ± 0.7	0.06 ± 0.01	95%	54.9 ± 11.9	0.36 ± 0.16
2005_09	*80*	54%	3.1 ± 0.7	0.06 ± 0.01	98%	50.3 ± 14.8	0.25 ± 0.04
2006_10	*67*	55%	3.5 ± 0.9	0.07 ± 0.02	99%	55.2 ± 17.5	0.25 ± 0.04
2007_11	*81*	53%	3.4 ± 0.8	0.07 ± 0.02	94%	48.5 ± 14.6	0.25 ± 0.04
2008_12	*67*	40%	2.4 ± 0.7	0.05 ± 0.02	91%	28.1 ± 6.5	0.21 ± 0.04
2009_13	*59*	36%	2.1 ± 0.7	0.05 ± 0.02	90%	26.4 ± 6.5	0.20 ± 0.04
2010_14	*43*	35%	1.4 ± 0.6	0.03 ± 0.01	88%	15.1 ± 2.7	0.15 ± 0.03
2011_15	*46*	39%	1.5 ± 0.5	0.03 ± 0.01	87%	14.8 ± 2.7	0.14 ± 0.02
2012_16	*41*	46%	1.7 ± 0.4	0.04 ± 0.01	93%	18.4 ± 3.7	0.11 ± 0.02
2013_17	*37*	51%	1.8 ± 0.5	0.04 ± 0.01	95%	17.1 ± 3.9	0.11 ± 0.02
2014_18	*37*	51%	1.8 ± 0.5	0.04 ± 0.01	95%	17.2 ± 3.9	0.11 ± 0.02

Table S8 North Sea all five subregions combined
Five-year averaged details on plastic ingestion by northern fulmars.
Table A provides the data for all plastics: sample size (n), the proportion of birds having more than 0.1 g of plastic in the stomach (EcoQ%), the Frequency of Occurrence of any plastic in the stomach (%FO), and averages ± standard errors for the number and mass of plastic particles. Geometric mean mass (back calculated from averaged ln-transformed mass data) is added to provide averages in which impact from exceptional outlying values is reduced.
Table B specifies the details for industrial and user plastic abundance.

A.

North Sea Total		Total plastics				
5-year period	*sample n*	EcoQ% (over 0.1g)	%FO	average number n ± se	average mass g ± se	Geometric mean mass
2002_06	*1107*	**55%**	94%	33.9 ± 2.7	0.30 ± 0.03	0.09
2003_07	*1306*	**58%**	95%	34.9 ± 2.5	0.32 ± 0.02	0.09
2004_08	*1279*	**59%**	95%	36.3 ± 2.5	0.34 ± 0.02	0.10
2005_09	*934*	**61%**	95%	30.5 ± 1.9	0.33 ± 0.02	0.11
2006_10	*807*	**63%**	95%	33.9 ± 2.3	0.35 ± 0.02	0.12
2007_11	*832*	**63%**	95%	32.6 ± 2.2	0.37 ± 0.03	0.12
2008_12	*816*	**57%**	95%	31.5 ± 3.8	0.32 ± 0.03	0.10
2009_13	*724*	**55%**	95%	32.5 ± 4.4	0.30 ± 0.03	0.09
2010_14	*556*	**59%**	94%	34.7 ± 5.7	0.31 ± 0.03	0.10
2011_15	*558*	**58%**	94%	32.1 ± 5.5	0.31 ± 0.03	0.09
2012_16	*554*	**56%**	94%	32.5 ± 5.6	0.29 ± 0.02	0.09
2013_17	*381*	**54%**	93%	25.3 ± 3.4	0.27 ± 0.03	0.08
2014_18	*393*	**51%**	92%	21.4 ± 2.1	0.26 ± 0.03	0.07

B.

North Sea Total		Industrial granules			User plastics		
5-year period	*sample n*	%FO	avg number n ± se	avg mass g ± se	%FO	avg number n ± se	avg mass g ± se
2002_06	*1107*	57%	2.9 ± 0.2	0.06 ± 0.00	94%	31.0 ± 2.6	0.24 ± 0.02
2003_07	*1306*	60%	3.1 ± 0.2	0.07 ± 0.00	94%	31.8 ± 2.3	0.25 ± 0.02
2004_08	*1279*	59%	3.1 ± 0.2	0.06 ± 0.00	94%	33.2 ± 2.4	0.27 ± 0.02
2005_09	*934*	59%	2.8 ± 0.2	0.06 ± 0.00	95%	27.7 ± 1.8	0.27 ± 0.02
2006_10	*807*	59%	3.3 ± 0.4	0.07 ± 0.01	95%	30.6 ± 2.2	0.28 ± 0.02
2007_11	*832*	59%	3.3 ± 0.4	0.07 ± 0.01	94%	29.3 ± 2.0	0.30 ± 0.03
2008_12	*816*	55%	2.8 ± 0.4	0.06 ± 0.01	94%	28.7 ± 3.6	0.26 ± 0.03
2009_13	*724*	54%	2.7 ± 0.4	0.06 ± 0.01	94%	29.8 ± 4.3	0.24 ± 0.03
2010_14	*556*	59%	3.1 ± 0.6	0.07 ± 0.01	93%	31.6 ± 5.5	0.25 ± 0.03
2011_15	*558*	58%	2.5 ± 0.3	0.05 ± 0.00	93%	29.6 ± 5.4	0.26 ± 0.03
2012_16	*554*	58%	2.5 ± 0.2	0.05 ± 0.00	94%	30.0 ± 5.5	0.24 ± 0.02
2013_17	*381*	54%	2.1 ± 0.2	0.05 ± 0.00	92%	23.2 ± 3.4	0.22 ± 0.02
2014_18	*393*	50%	2.0 ± 0.2	0.05 ± 0.01	91%	19.4 ± 2.0	0.22 ± 0.02

6. LINEAR REGRESSION FOR INGESTED PLASTIC MASS

Table S9 Linear regression analysis for normalized mass of ingested plastic against year of collection for the full 2002-2018 period for subregional and overall North Sea data. *Tests were conducted on data for total plastics in individuals, complemented with separate analyses for industrial plastics and user plastics. 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. Compare supplementary tables S9, S10 and S11to note the differences between periods 2002-2018, 2005-2018 and the standard 10-year period 2009-2018. In the longer-term analyses decreases in industrial plastics are important, but in the recent 10-year analysis a reduction in user plastics seems to have taken a dominant role.*

Long term trend 2002-2018		**linear regression results**					
Total plastic mass	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*272*	-42	0.020	0.027	0.74	0.459	*n.s.*
02 East England	*170*	94	-0.048	0.027	-1.79	0.076	*n.s.*↓
03 Channel	*146*	42	-0.023	0.044	-0.52	0.606	*n.s.*
04 SE NorthSea	*1776*	46	-0.025	0.012	-2.16	0.031	-
05 Skagerrak	*297*	25	-0.014	0.026	-0.53	0.593	*n.s.*
NORTH SEA total	***2661***	**24**	**-0.013**	**0.008**	**-1.61**	**0.106**	*n.s.*

Long term trend 2002-2018		**linear regression results**					
INDUSTRIAL plastics	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*272*	37	-0.021	0.026	-0.80	0.423	*n.s.*
02 East England	*170*	45	-0.025	0.033	-0.74	0.461	*n.s.*
03 Channel	*146*	42	-0.023	0.044	-0.52	0.606	*n.s.*
04 SE NorthSea	*1776*	9	-0.006	0.010	-0.57	0.571	*n.s.*
05 Skagerrak	*297*	153	-0.079	0.030	-2.61	0.009	- -
NORTH SEA total	***2661***	**57**	**-0.031**	**0.009**	**-3.27**	**0.001**	**- - -**

USER plastics	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*272*	-57	0.027	0.027	1.01	0.313	*n.s.*
02 East England	*170*	96	-0.049	0.027	-1.84	0.068	*n.s.*↓
03 Channel	*146*	49	-0.025	0.034	-0.75	0.455	*n.s.*
04 SE NorthSea	*1776*	27	-0.015	0.010	-1.45	0.148	*n.s.*
05 Skagerrak	*297*	-3	0.000	0.025	0.00	0.996	*n.s.*
NORTH SEA total	***2661***	**7**	**-0.005**	**0.008**	**-0.62**	**0.537**	***n.s.***

Table S10 Linear regression analysis for normalized mass of ingested plastic against year of collection during 2005-2018 for subregional and overall North Sea data (i.e. after the unusual wreck of birds in 2004). *For details see Table S9. Compare supplementary tables S9, S10 and S11 to note the differences between periods 2002-2018, 2005-2018 and the standard 10-year period 2009-2018. In the longer-term analyses decreases in industrial plastics are important, but in the recent 10-year analysis a reduction in user plastics seems to have taken a dominant role.*

Long term trend 2005-2018 **linear regression results**

Total plastic mass	*n*	constant	slope	s.e.	t	p	
01 Scottish Islands	*206*	49	-0.026	0.037	-0.70	0.484	*n.s.*
02 East England	*124*	216	-0.109	0.037	-2.94	0.004	- -
03 Channel	*104*	277	-0.140	0.053	-2.66	0.009	- -
04 SE NorthSea	*1239*	71	-0.038	0.016	-2.31	0.021	-
05 Skagerrak	*151*	78	-0.040	0.041	-0.98	0.331	*n.s.*
NORTH SEA total	***1824***	**75**	**-0.038**	**0.011**	**-3.37**	**<.001**	**- - -**

Long term trend 2005-2018 **linear regression results**

INDUSTRIAL plastics	*n*	constant	slope	s.e.	t	p	
01 Scottish Islands	*206*	32	-0.019	0.035	-0.52	0.601	*n.s.*
02 East England	*124*	245	-0.124	0.044	-2.81	0.006	- -
03 Channel	*104*	277	-0.140	0.053	-2.66	0.009	- -
04 SE NorthSea	*1239*	33	-0.018	0.014	-1.26	0.208	*n.s.*
05 Skagerrak	*151*	87	-0.046	0.049	-0.94	0.347	*n.s.*
NORTH SEA total	***1824***	**99**	**-0.051**	**0.013**	**-3.88**	**<.001**	**- - -**

USER plastics	*n*	constant	slope	s.e.	t	p	
01 Scottish Islands	*206*	48	-0.025	0.037	-0.68	0.496	*n.s.*
02 East England	*124*	188	-0.095	0.037	-2.53	0.013	-
03 Channel	*104*	132	-0.067	0.045	-1.50	0.137	*n.s.*
04 SE NorthSea	*1239*	49	-0.025	0.014	-1.82	0.070	*n.s.*↓
05 Skagerrak	*151*	76	-0.039	0.041	-0.97	0.334	*n.s.*
NORTH SEA total	***1824***	**60**	**-0.031**	**0.011**	**-2.73**	**0.006**	**- -**

Table S11 Linear regression analysis for normalized mass of ingested plastic against year of collection during 2009-2018 for subregional and overall North Sea data (the standard 10-year period used in OSPAR analyses to check for the presence of recent trends). For details see Table *S9*. *Compare supplementary tables S9, S10 and S11 to note the differences between periods 2002-2018, 2005-2018 and the standard 10-year period 2009-2018. In the longer-term analyses decreases in industrial plastics are important, but in the recent 10-year analysis a reduction in user plastics seems to have taken a dominant role.*

10-year trend 2009-2018 — **linear regression results**

all plastics	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*128*	106	-0.054	0.053	-1.02	0.308	*n.s.*
02 East-Eng-Sco	*79*	154	-0.078	0.070	-1.12	0.268	*n.s.*
03 Channel	*31*	130	-0.067	0.168	-0.40	0.694	*n.s.*
04 SE NorthSea	*783*	97	-0.050	0.023	-2.12	0.034	-
05 Skagerrak	*96*	120	-0.061	0.067	-0.91	0.368	*n.s.*
North Sea Total	***1117***	**95**	**-0.048**	**0.019**	**-2.55**	**0.011**	**-**

10-year trend 2009-2018 — **linear regression results**

industrial plastics	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*128*	103	-0.054	0.051	-1.05	0.294	*n.s.*
02 East-Eng-Sco	*79*	101	-0.053	0.072	-0.73	0.467	*n.s.*
03 Channel	*31*	130	-0.067	0.168	-0.40	0.694	*n.s.*
04 SE NorthSea	*783*	11	-0.008	0.028	-0.27	0.786	*n.s.*
05 Skagerrak	*96*	-44	0.020	0.078	0.25	0.804	*n.s.*
North Sea Total	***1117***	**17**	**-0.011**	**0.022**	**-0.50**	**0.618**	***n.s.***

user plastics	***n***	**constant**	**slope**	**s.e.**	**t**	**p**	
01 Scottish Islands	*128*	87	-0.045	0.053	-0.85	0.399	*n.s.*
02 East-Eng-Sco	*79*	189	-0.095	0.070	-1.36	0.178	*n.s.*
03 Channel	*31*	-89	0.043	0.161	0.27	0.791	*n.s.*
04 SE NorthSea	*783*	93	-0.048	0.023	-2.04	0.042	-
05 Skagerrak	*96*	171	-0.087	0.066	-1.31	0.192	*n.s.*
North Sea Total	***1117***	**96**	**-0.049**	**0.019**	**-2.59**	**0.010**	**- -**

Graphic example of the linear regression analyses

In the guidelines by OSPAR (2015) recent trends in ingestion of plastics are evaluated on the basis of linear regressions of individual ln-transformed data for mass of plastics in individual birds against the year of collection. The standard test-period uses data from all individual birds over the most recent 10 years in the dataset. Tests are conducted using Genstat 19th edition (VSN International, 2017).

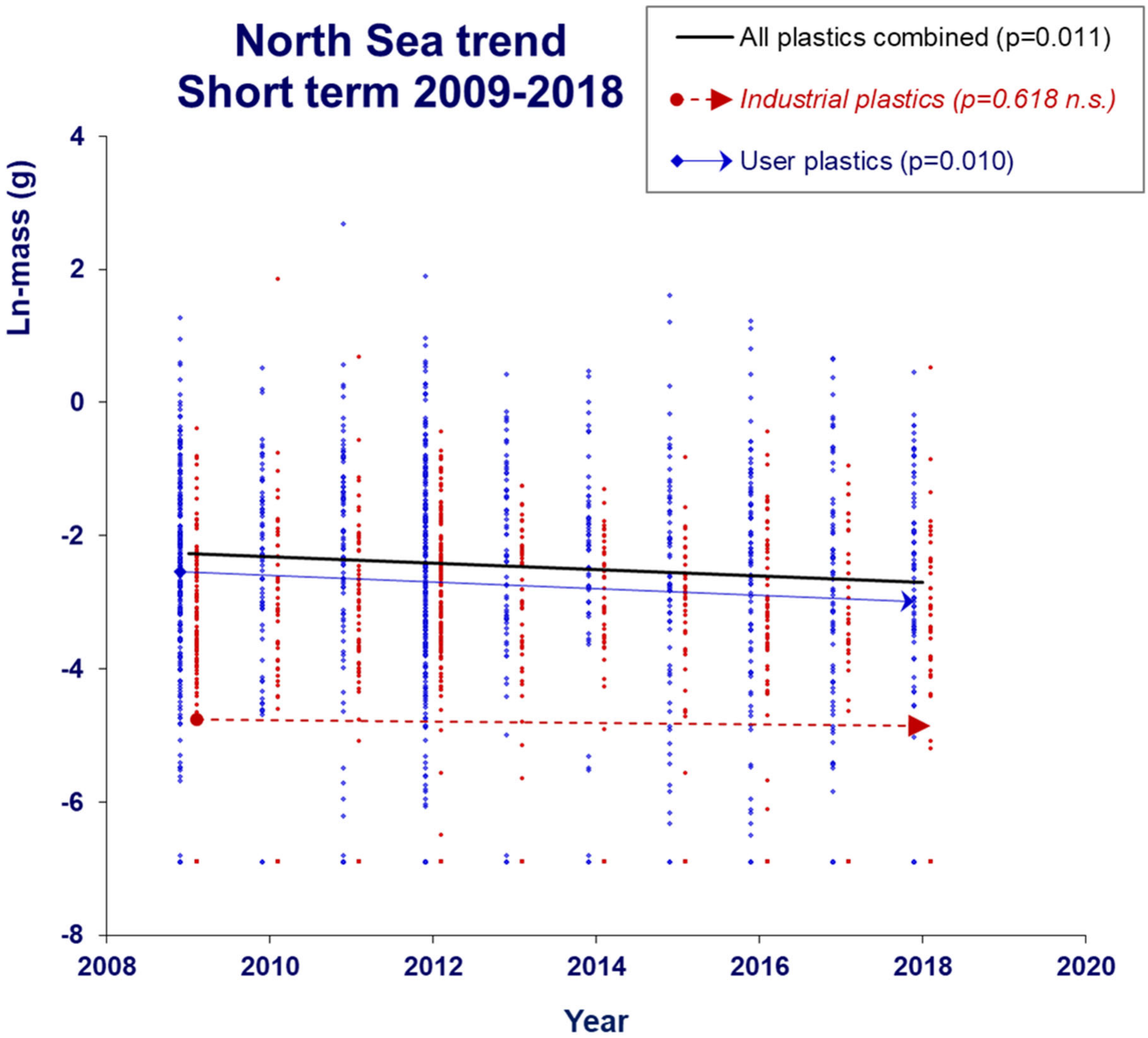

Fig. S2 Statistical trend in plastic mass in stomachs of fulmars from the North Sea over the 10-year period 2009-2018. *The graph, as an example of the existing statistical approach of linear regressions on ingested plastic mass, shows ln-transformed mass data for industrial plastic and user plastic 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 S11****. n.s. means that the test result is not significant. Trendlines are shown as solid line when significant, dashed when non-significant.*

7. ADDITIONAL DETAILS ON LOGISTIC TRENDS IN ECOQ-PERFORMANCE

Table S12 ***Data underlying main article Fig. 6*** *(Logistic model for all North Sea data 2005 to 2018; using the proportion of adult birds as covariate). The EcoQ% is expressed as a proportion because Genstat uses proportions in this model. Predicted means are given with standard errors. For predicted annual figures, 95% confidence intervals (approximately twice the se) might be appropriate. However, these model results may be used to set intermediate targets that can be compared to 5-year combined observation data. In that setting, standard errors is a more appropriate measure to indicate permitted band-width of the intermediate target.*

OBSERVED EcoQ Performance						Modelled EcoQ Performance	
YEAR	sample size	nr with over 0.1g plastic	EcoQ%	proportion adult birds	proportion male birds	Year	model prediction ± se (p<0.001)
2002	79	49	0.62	0.57	0.44	2002	**0.651** ± *0.02*
2003	186	105	0.56	0.57	0.51	2003	**0.638** ± *0.02*
2004	572	311	0.54	0.82	0.21	2004	**0.626** ± *0.02*
2005	199	99	0.50	0.65	0.46	2005	**0.613** ± *0.01*
2006	71	50	0.70	0.54	0.47	2006	**0.600** ± *0.01*
2007	278	198	0.71	0.40	0.51	2007	**0.587** ± *0.01*
2008	159	103	0.65	0.50	0.41	2008	**0.573** ± *0.01*
2009	227	116	0.51	0.49	0.57	2009	**0.560** ± *0.01*
2010	72	42	0.58	0.48	0.51	2010	**0.546** ± *0.01*
2011	96	63	0.66	0.46	0.57	2011	**0.533** ± *0.01*
2012	262	139	0.53	0.30	0.45	2012	**0.519** ± *0.02*
2013	67	41	0.61	0.42	0.39	2013	**0.506** ± *0.02*
2014	59	41	0.69	0.45	0.41	2014	**0.492** ± *0.02*
2015	74	40	0.54	0.35	0.54	2015	**0.478** ± *0.02*
2016	92	49	0.53	0.41	0.48	2016	**0.465** ± *0.03*
2017	89	35	0.39	0.34	0.54	2017	**0.451** ± *0.03*
2018	79	36	0.46	0.43	0.47	2018	**0.438** ± *0.03*
						2019	0.424 ± *0.04*
						2020	0.411 ± *0.04*
						2025	0.347 ± *0.05*
						2030	0.288 ± *0.06*
model output					antilog of	2035	0.236 ± *0.06*
Parameter	estimate	s.e.	t(*)	t pr.	estimate	2040	0.190 ± *0.06*
Constant	110.50	26.30	4.19	<.001	*	2045	0.152 ± *0.06*
YEAR	-0.05	0.01	-4.18	<.001	0.9469	2050	0.120 ± *0.06*
P_AD	-1.32	0.34	-3.92	<.001	0.2665	2055	**0.094 ± *0.05***
						2060	0.073 ± *0.05*
						2070	0.044 ± *0.03*
						2075	0.034 ± *0.03*
						2080	0.026 ± *0.02*
						2085	0.020 ± *0.02*
						2090	0.015 ± *0.02*
						2095	0.012 ± *0.01*
						2100	0.009 ± *0.01*
						2054	0.099 ± *0.05*

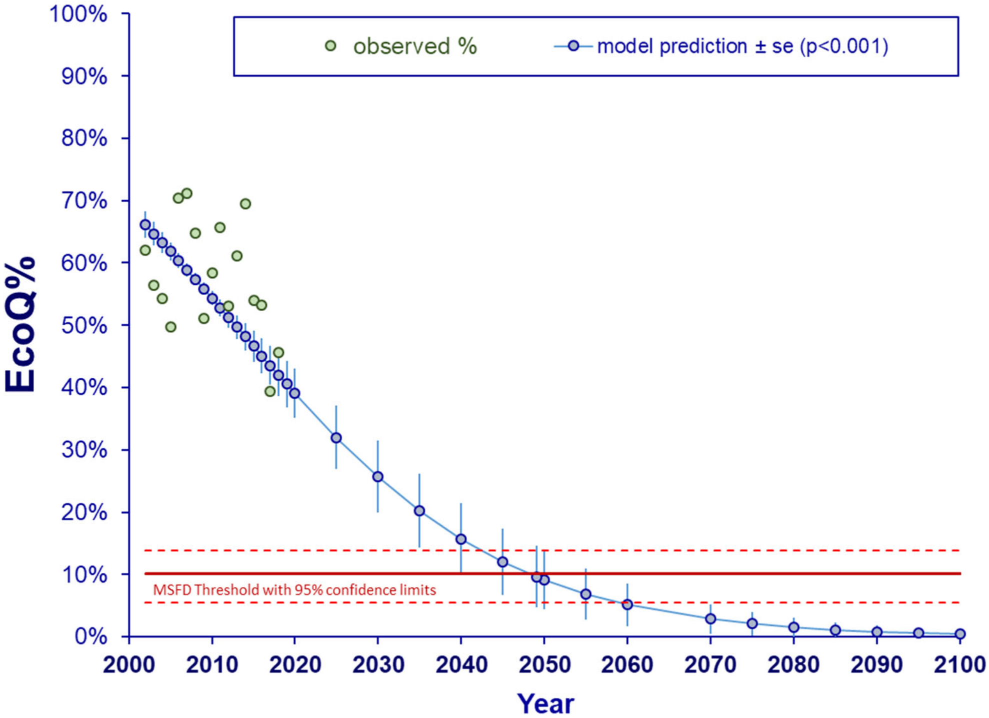

Fig. S3 Alternative model approach including both age and sex proportions as covariates to run the logistic model on EcoQ-Performance for all fulmars from the North Sea in 2002-2018. *Year and age contributed significantly to this model (both P<0.001), but not sex (p=0.08). This model predicts crossing of the Fulmar-TV by 2049, five years earlier than the model shown in the main article, which uses age as the only covariate.*

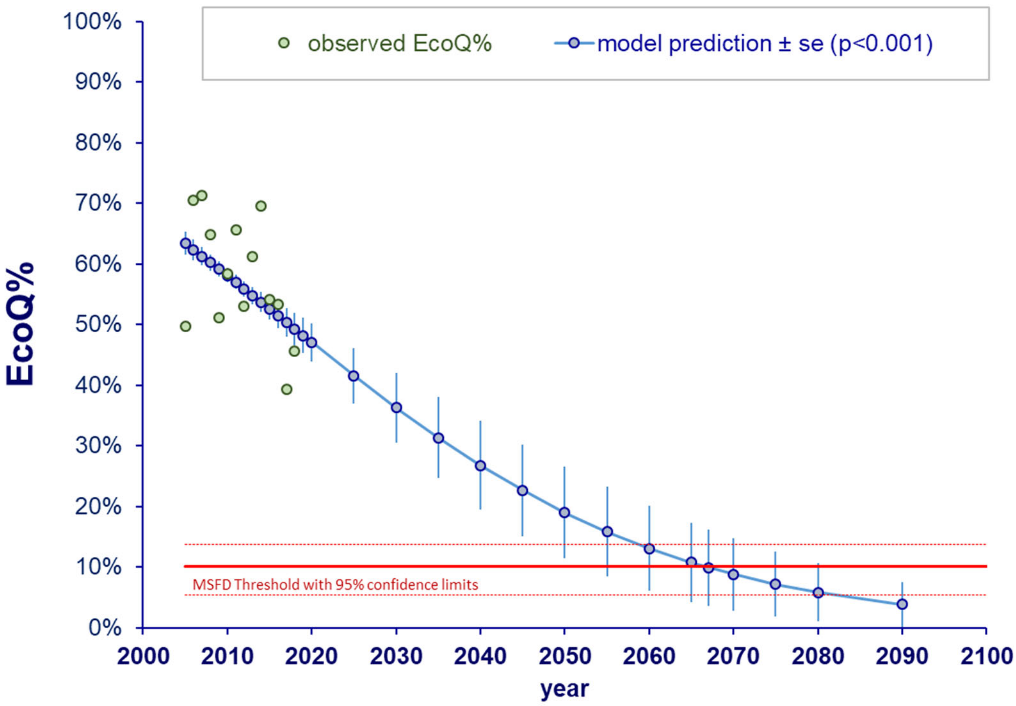

Fig. S4 Alternative approach of the logistic model without age and/or sex as covariates, but starting the analysis in 2005 *i.e. after the exceptionally large sample from 2004 which had an unusually high proportion of adult females. This logistic regression is significant and models that the Fulmar-TV may be reached by 2067.*

8. TERMINOLOGY

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, up-dated and extended by the 1992 OSPAR Convention.

EcoQO = Ecological Quality Objective (OSPAR) At the request of ministers of North Sea border states in 2002, OSPAR developed a system of measurable targets for environmental/ecological quality in the North Sea and the OSPAR area in general. There is a broad range of EcoQOs for various types of pollution (oil, fouling paints, mercury, organochlorines, litter), eutrophication, biodiversity, bycatch, fish stocks, seabird populations etc. Ingestion of plastic particles by northern fulmars is one of these. The OSPAR EcoQO for the fulmar has been set arbitrarily as a long term target in which the percentage of fulmars having more than 0.1 g of plastic in the stomach should be reduced to under 10%.

EcoQ% or EcoQ-Performance = the percentage (or proportion) of fulmars in a sample that exceed the level of 0.1 gram of plastic in the stomach

When software used proportions rather than percentages, associated texts and tables in the paper also use proportions (for example EcoQ% or EcoQ-Performance of 10% expressed as proportion 0.1).

EU MSFD = European Union Marine Strategy Framework Directive

The aim of the MSFD is to protect more effectively the marine environment across Europe. It was adopted on 17 June 2008. In 2010 the Commission 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.

GES = Good Environmental Status (MSFD)

GES represents the MSFD concept in which a broad combination of indicators with criteria (similar to EcoQOs) indicates a healthy state of the marine environment.

Fulmar-TV = MSFD Threshold Value for ingested plastics by fulmars

The situation in which less than 10.06% of fulmars in a sample are above the 0.1 g level of plastic in the stomach (value observed among 179 fulmars from the near-pristine environment of eastern Arctic Canada between 2002 and 2013). In Fulmar-TV assessments, the 2-sample Z-test for comparing sample proportions, is used to test the difference between the Fulmar-TV and the sample. When software used proportions rather than percentages, associated texts and tables also use proportions (for example EcoQ% or EcoQ-Performance of 10.06% expressed as proportion 0.1006).

9. CANADIAN SOURCE DATA FOR THE ASSESSMENT OF THE FULMAR THRESHOLD VALUE

The next pages provide the original data of 179 Canadian fulmars used to assess the Fulmar Threshold Value**.**

(original raw data for the 2661 North Sea fulmars will become available through national submissions to the OSPAR secretariat. With some delay these data become publicly available in OSPAR's Data & Information Management System https://odims.ospar.org/

DATA table plastics in stomachs of fulmars from the Canadian Arctic

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1	
1	High Arctic North	Mallory2008	2004051802	shot near or noosed at colony	18-May-2004	2004	5	18	Cape Vera	76.3	-89.3	UNK	AD	54	1	1.35	1.35	1	*a
2	High Arctic North	Mallory2008	JU04 (2003061001)	shot near or noosed at colony	10-Jun-2003	2003	6	10	Cape Vera	76.3	-89.3	UNK	AD	24	1	>0.1	0.474894	1	*b
3	High Arctic North	Mallory2008	03CV04 (2003070701)	shot near or noosed at colony	7-Jul-2003	2003	7	7	Cape Vera	76.3	-89.3	UNK	AD	22	1	>0.1	0.435319	1	*b
4	High Arctic North	Mallory2008	JU02 (2003061002)	shot near or noosed at colony	10-Jun-2003	2003	6	10	Cape Vera	76.3	-89.3	UNK	AD	14	1	>0.1	0.277021	1	*b
5	High Arctic North	Mallory2008	2004061703	shot near or noosed at colony	17-Jun-2004	2004	6	17	Cape Vera	76.3	-89.3	UNK	AD	10	1	0.24	0.24	1	*a
6	High Arctic North	Mallory2008	NOFU21 (2003071701)	shot near or noosed at colony	17-Jul-2003	2003	7	17	Cape Vera	76.3	-89.3	UNK	AD	8	1	>0.1	0.158298	1	*b
7	High Arctic North	Mallory2008	2004071601	shot near or noosed at colony	16-Jul-2004	2004	7	16	Cape Vera	76.3	-89.3	UNK	AD	6	1	0.14	0.14	1	*a
8	High Arctic North	Mallory2008	NOFU28 (2003072001)	shot near or noosed at colony	20-Jul-2003	2003	7	20	Cape Vera	76.3	-89.3	UNK	AD	4	1	>0.1	0.1001	1	*c
9	High Arctic North	Mallory2008	A1003 (2003081802)	shot near or noosed at colony	18-Aug-2003	2003	8	18	Cape Vera	76.3	-89.3	UNK	AD	5	1		0.098936	0	*b
10	High Arctic North	Mallory2008	CV14 (2003070704)	shot near or noosed at colony	4-Jul-2003	2003	7	4	Cape Vera	76.3	-89.3	UNK	AD	4	1		0.079149	0	*b
11	High Arctic North	Mallory2008	NOFU29 (2003072002)	shot near or noosed at colony	20-Jul-2003	2003	7	20	Cape Vera	76.3	-89.3	UNK	AD	4	1		0.079149	0	*b
12	High Arctic North	Mallory2008	NOFU96 (2003070401)	shot near or noosed at colony	4-Jul-2003	2003	7	4	Cape Vera	76.3	-89.3	UNK	AD	4	1		0.079149	0	*b
13	High Arctic North	Mallory2008	2004051808	shot near or noosed at colony	18-May-2004	2004	5	18	Cape Vera	76.3	-89.3	UNK	AD	14	1	0.06	0.06	0	*a
14	High Arctic North	Mallory2008	A0203 (2003081102)	shot near or noosed at colony	11-Aug-2003	2003	8	11	Cape Vera	76.3	-89.3	UNK	AD	2	1		0.039574	0	*b
15	High Arctic North	Mallory2008	NOFU23 (2003072005)	shot near or noosed at colony	20-Jul-2003	2003	7	20	Cape Vera	76.3	-89.3	UNK	AD	2	1		0.039574	0	*b
16	High Arctic North	Mallory2008	NOFU7 (2003071503)	shot near or noosed at colony	15-Jul-2003	2003	7	15	Cape Vera	76.3	-89.3	UNK	AD	2	1		0.039574	0	*b
17	High Arctic North	Mallory2008	NOFU19 (2003071703)	shot near or noosed at colony	17-Jul-2003	2003	7	17	Cape Vera	76.3	-89.3	UNK	AD	2	1		0.039574	0	*b
18	High Arctic North	Mallory2008	2004060903	shot near or noosed at colony	9-Jun-2004	2004	6	9	Cape Vera	76.3	-89.3	UNK	AD	6	1	0.04	0.04	0	*a
19	High Arctic North	Mallory2008	2004060907	shot near or noosed at colony	9-Jun-2004	2004	6	9	Cape Vera	76.3	-89.3	UNK	AD	4	1	0.03	0.03	0	*a
20	High Arctic North	Mallory2008	A0403 (2003081601)	shot near or noosed at colony	16-Aug-2003	2003	8	16	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
21	High Arctic North	Mallory2008	A1103 (2003081801)	shot near or noosed at colony	18-Aug-2003	2003	8	18	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
22	High Arctic North	Mallory2008	NOFU25 (2003072004)	shot near or noosed at colony	20-Jul-2003	2003	7	20	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
23	High Arctic North	Mallory2008	JU07 (2003061003)	shot near or noosed at colony	10-Jun-2003	2003	6	10	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
24	High Arctic North	Mallory2008	A0503 (2003081602)	shot near or noosed at colony	16-Aug-2003	2003	8	16	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
25	High Arctic North	Mallory2008	NOFU1 (2003071501)	shot near or noosed at colony	15-Jul-2003	2003	7	15	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
26	High Arctic North	Mallory2008	NOFU5 (2003071502)	shot near or noosed at colony	15-Jul-2003	2003	7	15	Cape Vera	76.3	-89.3	UNK	AD	1	1		0.019787	0	*b
27	High Arctic North	Mallory2008	2004060701	shot near or noosed at colony	7-Jun-2004	2004	6	7	Cape Vera	76.3	-89.3	UNK	AD	5	1	<0.01	0.0099	0	*d

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1	
28	High Arctic North	Mallory2008	2004061706	shot near or noosed at colony	17-Jun-2004	2004	6	17	Cape Vera	76.3	-89.3	UNK	AD	5	1	<0.01	0.0099	0	*d
29	High Arctic North	Mallory2008	2004061708	shot near or noosed at colony	17-Jun-2004	2004	6	17	Cape Vera	76.3	-89.3	UNK	AD	4	1	<0.01	0.0099	0	*d
30	High Arctic North	Mallory2008	2004060902	shot near or noosed at colony	9-Jun-2004	2004	6	9	Cape Vera	76.3	-89.3	UNK	AD	3	1	<0.01	0.0099	0	*d
31	High Arctic North	Mallory2008	2004051805	shot near or noosed at colony	18-May-2004	2004	5	18	Cape Vera	76.3	-89.3	UNK	AD	1	1	<0.01	0.0099	0	*d
32	High Arctic North	Mallory2008	2004071602	shot near or noosed at colony	16-Jul-2004	2004	7	16	Cape Vera	76.3	-89.3	UNK	AD	1	1	<0.01	0.0099	0	*d
33	High Arctic North	Mallory2008	1	shot near or noosed at colony	26May03-22Aug04	2004	5		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
34	High Arctic North	Mallory2008	2	shot near or noosed at colony	26May03-22Aug04	2004	5		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
35	High Arctic North	Mallory2008	3	shot near or noosed at colony	26May03-22Aug04	2004	5		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
36	High Arctic North	Mallory2008	4	shot near or noosed at colony	26May03-22Aug04	2004	5		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
37	High Arctic North	Mallory2008	5	shot near or noosed at colony	26May03-22Aug04	2004	5		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
38	High Arctic North	Mallory2008	6	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
39	High Arctic North	Mallory2008	7	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
40	High Arctic North	Mallory2008	8	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
41	High Arctic North	Mallory2008	9	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
42	High Arctic North	Mallory2008	10	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
43	High Arctic North	Mallory2008	11	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
44	High Arctic North	Mallory2008	12	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
45	High Arctic North	Mallory2008	13	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
46	High Arctic North	Mallory2008	14	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
47	High Arctic North	Mallory2008	15	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
48	High Arctic North	Mallory2008	16	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
49	High Arctic North	Mallory2008	17	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
50	High Arctic North	Mallory2008	18	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
51	High Arctic North	Mallory2008	19	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
52	High Arctic North	Mallory2008	20	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
53	High Arctic North	Mallory2008	21	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
54	High Arctic North	Mallory2008	22	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
55	High Arctic North	Mallory2008	23	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e
56	High Arctic North	Mallory2008	24	shot near or noosed at colony	26May03-22Aug04	2004	6		Cape Vera	76.3	-89.3	UNK	AD	0	0	0	0	0	*e

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	*inci-dence*	g_reported	**g_pla** (JAF)	*g>0.1*	
57	High Arctic North	Mallory2008	25	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
58	High Arctic North	Mallory2008	26	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
59	High Arctic North	Mallory2008	27	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
60	High Arctic North	Mallory2008	28	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
61	High Arctic North	Mallory2008	29	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
62	High Arctic North	Mallory2008	30	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
63	High Arctic North	Mallory2008	31	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
64	High Arctic North	Mallory2008	32	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
65	High Arctic North	Mallory2008	33	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
66	High Arctic North	Mallory2008	34	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
67	High Arctic North	Mallory2008	35	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
68	High Arctic North	Mallory2008	36	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
69	High Arctic North	Mallory2008	37	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
70	High Arctic North	Mallory2008	38	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
71	High Arctic North	Mallory2008	39	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
72	High Arctic North	Mallory2008	40	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
73	High Arctic North	Mallory2008	41	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
74	High Arctic North	Mallory2008	42	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
75	High Arctic North	Mallory2008	43	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
76	High Arctic North	Mallory2008	44	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
77	High Arctic North	Mallory2008	45	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
78	High Arctic North	Mallory2008	46	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
79	High Arctic North	Mallory2008	47	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
80	High Arctic North	Mallory2008	48	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
81	High Arctic North	Mallory2008	49	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
82	High Arctic North	Mallory2008	50	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
83	High Arctic North	Mallory2008	51	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
84	High Arctic North	Mallory2008	52	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
85	High Arctic North	Mallory2008	53	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1	
86	High Arctic North	Mallory2008	54	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
87	High Arctic North	Mallory2008	55	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
88	High Arctic North	Mallory2008	56	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
89	High Arctic North	Mallory2008	57	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
90	High Arctic North	Mallory2008	58	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
91	High Arctic North	Mallory2008	59	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
92	High Arctic North	Mallory2008	60	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
93	High Arctic North	Mallory2008	61	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
94	High Arctic North	Mallory2008	62	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
95	High Arctic North	Mallory2008	63	shot near or noosed at colony	26May03-22Aug04	2004	7		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
96	High Arctic North	Mallory2008	64	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
97	High Arctic North	Mallory2008	65	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
98	High Arctic North	Mallory2008	66	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
99	High Arctic North	Mallory2008	67	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
100	High Arctic North	Mallory2008	68	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
101	High Arctic North	Mallory2008	69	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
102	High Arctic North	Mallory2008	70	shot near or noosed at colony	26May03-22Aug04	2004	8		Cape Vera	76.3	-89.3	UNK	AD	0	*0*	0	**0**	*0*	*e
103	High Arctic North	Provencher2009	**21037**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**F**	AD	**12**	*1*	0.32208	**0.32208**	*1*	
104	High Arctic North	Provencher2009	**21038**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**F**	AD	**2**	*1*	0.08173	**0.08173**	*0*	
105	High Arctic North	Provencher2009	**21039**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**M**	AD	**1**	*1*	0.0245	**0.0245**	*0*	
106	High Arctic North	Provencher2009	**21040**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**M**	AD	**2**	*1*	0.024	**0.024**	*0*	
107	High Arctic North	Provencher2009	**21041**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**M**	AD	**2**	*1*	0.02343	**0.02343**	*0*	
108	High Arctic North	Provencher2009	**21042**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**F**	AD	**3**	*1*	0.01842	**0.01842**	*0*	
109	High Arctic North	Provencher2009	**21043**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**M**	AD	**1**	*1*	0.0053	**0.0053**	*0*	
110	High Arctic North	Provencher2009	**21044**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**M**	AD	**2**	*1*	0.00155	**0.00155**	*0*	
111	High Arctic North	Provencher2009	**21045**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**F**	AD	0	*0*	0	**0**	*0*	
112	High Arctic North	Provencher2009	**21046**	adult breeder noosed from nest	**1-Aug-2008**	**2008**	**8**	**1**	Prince Leopold Island	74	-90	**F**	AD	0	*0*	0	**0**	*0*	
113	High Arctic North	Poon2017	W132890	Adult bird - with egg NOFU-1	3-Jul-2013	2013	7	3	Prince Leopold Island	74	-90.1	F	AD	2	*1*	0.0077	**0.0077**	*0*	
114	High Arctic North	Poon2017	W132891	Adult bird - with egg NOFU-2	3-Jul-2013	2013	7	3	Prince Leopold Island	74	-90.1	M	AD	6	*1*	0.0222	**0.0222**	*0*	

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1	
115	High Arctic North	Poon2017	W132892	Adult bird - with egg NOFU-3	3-Jul-2013	2013	7	3	Prince Leopold Island	74	-90.1	M	AD	0	0	0	0	0	
116	High Arctic North	Poon2017	W132893	Adult bird - with egg NOFU-4	3-Jul-2013	2013	7	3	Prince Leopold Island	74	-90.1	F	AD	1	1	0.0076	0.0076	0	
117	High Arctic North	Poon2017	W132894	Adult bird - with egg NOFU-5	3-Jul-2013	2013	7	3	Prince Leopold Island	74	-90.1	F	AD	1	1	0.0077	0.0077	0	
118	High Arctic North	Poon2017	W132895	Adult bird - with egg NOFU-6	5-Jul-2013	2013	7	5	Prince Leopold Island	74	-90.1	M	AD	5	1	0.0264	0.0264	0	
119	High Arctic North	Poon2017	W132896	Adult bird - with egg NOFU-7	5-Jul-2013	2013	7	5	Prince Leopold Island	74	-90.1	F	AD	8	1	0.08	0.08	0	
120	High Arctic North	Poon2017	W132897	Adult bird - with egg NOFU-8	5-Jul-2013	2013	7	5	Prince Leopold Island	74	-90.1	M	AD	7	1	0.0434	0.0434	0	
121	High Arctic North	Poon2017	W132898	Adult bird - with egg NOFU-9	5-Jul-2013	2013	7	5	Prince Leopold Island	74	-90.1	F	AD	1	1	0.0048	0.0048	0	
122	High Arctic North	Poon2017	W132899	Adult bird - band & geolocator	5-Jul-2013	2013	7	5	Prince Leopold Island	74	-90.1	M	AD	2	1	0.0321	0.0321	0	*g
123	High Arctic South	Mallory2006	DS17	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	9	1	0.31	0.31	1	*a
124	High Arctic South	Mallory2006	DS1	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	10	1	0.23	0.23	1	*a
125	High Arctic South	Mallory2006	DS22	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	3	1	0.1	0.1001	1	*a
126	High Arctic South	Mallory2006	DS13	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	5	1	0.09	0.09	0	*a
127	High Arctic South	Mallory2006	DS16	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	5	1	0.07	0.07	0	*a
128	High Arctic South	Mallory2006	DS21	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	3	1	0.07	0.07	0	*a
129	High Arctic South	Mallory2006	DS10	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	3	1	0.04	0.04	0	*a
130	High Arctic South	Mallory2006	DS23	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	3	1	0.04	0.04	0	*a
131	High Arctic South	Mallory2006	DS19	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	2	1	0.03	0.03	0	*a
132	High Arctic South	Mallory2006	DS11	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	2	1	0.02	0.02	0	*a
133	High Arctic South	Mallory2006	DS12	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	2	1	0.02	0.02	0	*a
134	High Arctic South	Mallory2006	DS14	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	3	1	<0.01	0.0099	0	*f
135	High Arctic South	Mallory2006	DS20	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	2	1	<0.01	0.0099	0	*f
136	High Arctic South	Mallory2006	DS3	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	1	1	<0.01	0.0099	0	*f
137	High Arctic South	Mallory2006	DS18	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	1	1	<0.01	0.0099	0	*f
138	High Arctic South	Mallory2006	DS2	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	
139	High Arctic South	Mallory2006	DS15	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	
140	High Arctic South	Mallory2006	DS4	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	
141	High Arctic South	Mallory2006	DS5	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	
142	High Arctic South	Mallory2006	DS6	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	
143	High Arctic South	Mallory2006	DS7	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	0	0	

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1
144	High Arctic South	Mallory2006	DS8	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
145	High Arctic South	Mallory2006	DS9	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
146	High Arctic South	Mallory2006	DS24	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
147	High Arctic South	Mallory2006	DS25	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
148	High Arctic South	Mallory2006	DS26	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
149	High Arctic South	Mallory2006	DS27	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
150	High Arctic South	Mallory2006	DS28	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
151	High Arctic South	Mallory2006	DS29	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
152	High Arctic South	Mallory2006	DS30	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
153	High Arctic South	Mallory2006	DS31	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
154	High Arctic South	Mallory2006	DS32	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
155	High Arctic South	Mallory2006	DS33	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
156	High Arctic South	Mallory2006	DS34	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
157	High Arctic South	Mallory2006	DS35	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
158	High Arctic South	Mallory2006	DS36	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
159	High Arctic South	Mallory2006	DS37	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
160	High Arctic South	Mallory2006	DS38	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
161	High Arctic South	Mallory2006	DS39	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
162	High Arctic South	Mallory2006	DS40	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
163	High Arctic South	Mallory2006	DS41	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
164	High Arctic South	Mallory2006	DS42	caught longliner 15aug-10 sep		2002	8	28	at sea 67°-69°N	68	-62	UNK	UNK	0	0	0	**0**	0
165	High Arctic South	Provencher2009	21047	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**5**	1	0.01738	**0.01738**	0
166	High Arctic South	Provencher2009	21048	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**0**	0	0	**0**	0
167	High Arctic South	Provencher2009	21049	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**0**	0	0	**0**	0
168	High Arctic South	Provencher2009	21050	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**2**	1	0.00832	**0.00832**	0
169	High Arctic South	Provencher2009	21051	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**6**	1	0.09125	**0.09125**	0
170	High Arctic South	Provencher2009	21052	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**9**	1	0.13	**0.13**	1
171	High Arctic South	Provencher2009	21053	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**6**	1	0.0389	**0.0389**	0
172	High Arctic South	Provencher2009	21054	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**20**	1	0.1612	**0.1612**	1

record nr	region	source	birdnr	notescollection	Date	year	month	day	location	lat	lon	sex	age	n_pla	inci-dence	g_reported	g_pla (JAF)	g>0.1
173	High Arctic South	Provencher2009	21055	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**14**	*1*	0.28363	**0.28363**	*1*
174	High Arctic South	Provencher2009	21056	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**12**	*1*	0.10217	**0.10217**	*1*
175	High Arctic South	Provencher2009	21057	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**7**	*1*	0.35225	**0.35225**	*1*
176	High Arctic South	Provencher2009	21058	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**4**	*1*	0.00974	**0.00974**	*0*
177	High Arctic South	Provencher2009	21059	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	F	AD	**21**	*1*	0.57049	**0.57049**	*1*
178	High Arctic South	Provencher2009	21060	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	AD	**7**	*1*	0.08401	**0.08401**	*0*
179	High Arctic South	Provencher2009	21061	shot near colony	4-Aug-2008	2008	8	4	Cape Searle (Minarets)	67.3	-62.6	M	IM	**1**	*1*	0.00933	**0.00933**	*0*

notes

*a mass reported by Mallory pers inf

*b no mass reported; recalculated on basis particle mass =0.019787

*c mass reported >0.1; recalculated as =0.019787; estimated here 0.1001

*d recalculated value higher than 0.01; reported < 0.01; estimated at 0.0099

*e month derived from nr of dated birds above and total month data from Mallory2008 Fig2

*f actually less than 0.01g; taken as 0.0099

*g bird added in info provided by Provencher

data summary

n stomachs	*179*	number positive
n avg±se (max)	2.4749 ± 0.43 (54)	
g avg±se (max)	0.0427 ± 0.01 (1.35)	
%FO (confidence limits)	43.0% (39.1% - 46.0%)	77 g>0
EcoQO% (confidence limits)	10.1% (5.4% - 13.8%)	18 g>0.1
median (g)	0	
0.9 percentile (g)	0.0992	

http://epitools.ausvet.com.au/content.php?page=CIProportion
95% confidence limits calculated following
Brown, LD, Cat, TT and DasGupta, A (2001). Statistical Science 16:101-133: using Jeffreys interval
(following Provencher et al. (2017)